HAZWRAP
HAZARDOUS WASTE REMEDIAL ACTIONS PROGRAM

Leading the Way to Environmental Stewardship

U.S. POSTAL SERVICE
RADON ASSESSMENT AND MITIGATION PROGRAM
PROGRESS REPORT FOR THE PERIOD
SEPTEMBER 1993 TO NOVEMBER 1994

December 31, 1994

HAZWRAP Program Manager, DOE Oak Ridge Operations Office: L. E. Velazquez
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U.S. Department of Energy
Oak Ridge Operations Office

HAZARDOUS WASTE REMEDIAL ACTIONS PROGRAM
Environmental Restoration and Waste Management Programs
Oak Ridge, Tennessee 37831-7606
managed by MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

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<td>ACH</td>
<td>air changes per hour</td>
</tr>
<tr>
<td>ASHRAE</td>
<td>American Society of Heating, Refrigerating, and Air Conditioning Engineers</td>
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<tr>
<td>BD</td>
<td>blower door</td>
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<tr>
<td>DMS</td>
<td>data tracking and management system</td>
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<td>CRM</td>
<td>continuous radon monitoring</td>
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<td>DOE</td>
<td>Department of Energy</td>
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<td>DP</td>
<td>differential pressure</td>
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<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>FH</td>
<td>flow hood</td>
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<tr>
<td>FVF</td>
<td>Flow per Volume Factor</td>
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<td>GSA</td>
<td>General Services Administration</td>
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<td>HAC</td>
<td>heating and air conditioning</td>
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<td>HAZWRAP</td>
<td>Hazardous Waste Remedial Actions Program</td>
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<td>HPLF</td>
<td>high pressure/low flow</td>
</tr>
<tr>
<td>HRV</td>
<td>heat recovery ventilation</td>
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<tr>
<td>HVAC</td>
<td>heating, ventilation, and air conditioning</td>
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<td>Interagency Agreement</td>
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<td>IRAA</td>
<td>Indoor Radon Abatement Act</td>
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<td>LPHF</td>
<td>low pressure/high flow</td>
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<td>ORNL</td>
<td>Oak Ridge National Laboratory</td>
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<td>pCi/L</td>
<td>picocurie per liter</td>
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<td>PFET</td>
<td>pressure field extension test</td>
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<td>POC</td>
<td>point of contact</td>
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<td>PVC</td>
<td>polyvinyl chloride</td>
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<td>QA</td>
<td>quality assurance</td>
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<td>QC</td>
<td>quality control</td>
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<td>radon entry pathway</td>
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<td>SMD</td>
<td>submembrane depressurization</td>
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<td>SP</td>
<td>shell pressurization</td>
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<td>USEPARTCs</td>
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EXECUTIVE SUMMARY

In 1992, the U.S. Postal Service (USPS) entered into an Interagency Agreement (No. 2055-E065-A1) with the Department of Energy (DOE) whereby DOE would provide technical assistance in support of the USPS Radon Assessment and Mitigation Program. To aid in this effort, DOE tasked the Hazardous Waste Remedial Actions Program (HAZWRAP), which is managed by Martin Marietta Energy Systems, Inc., for DOE under contract DE-AC05-84OR21400. Since that time, HAZWRAP has developed and finalized the sampling protocol, mitigation diagnostic protocol, and the quality assurance and quality control procedures. These procedures were validated during the Protocol Validation (1992–1993) and Pilot Study (1993–1994) phases of the program. To date, HAZWRAP has performed approximately 16,000 radon measurements in 250 USPS buildings. Mitigation diagnostics have been performed in 27 buildings. Thus far, 13% of the measurements have been above the Environmental Protection Agency action level of 4 pCi/L. This report summarizes the pilot program radon testing data and mitigation diagnostic data for 22 sites and contains recommendations for mitigation diagnostics.
1. INTRODUCTION

1.1 BACKGROUND OF THE U.S. POSTAL SERVICE RADON TESTING PROGRAM

In 1988 as a result of the Indoor Radon Abatement Act (IRAA), the General Services Administration (GSA) began conducting radon testing of all leased space under its control. Included in this study was space leased from the U.S. Postal Service (USPS). In 1991, GSA provided to USPS Headquarters several lists identifying 77 USPS buildings where a single reading greater than the Environmental Protection Agency (EPA)-recommended 4-pCi/L action guideline was measured. Concerned about possible radon exposure to USPS employees in the 36,000 USPS buildings nationwide, the USPS National Environmental Office reviewed existing EPA radon testing methodologies and procedures and found that EPA had not published any guidelines for large-building testing. To date, EPA has still not released a final protocol for the testing of radon in nonresidential buildings. The reason for the delay is that the development of a single testing protocol to cover all types of nonresidential buildings has proven to be extremely difficult. The tentative release date for the large-building testing protocol is still pending.

Aware of the Department of Energy (DOE) role in the U.S. Navy Radon Assessment and Mitigation Program, USPS contacted DOE in 1991 to inquire about potential assistance with a national USPS radon testing program. In 1992, DOE entered into an Interagency Agreement (IAG) (DOE No. 2055-E065-A1) with USPS whereby DOE would provide technical support to USPS on a task-order basis. As detailed in the IAG, this technical support would consist of radon surveys, assessments, cost-benefit analyses, mitigation design/specifications, data management and validation, training development, and technical writing. To aid in the fulfillment of its responsibilities to USPS, DOE selected the Hazardous Waste Remedial Actions Program (HAZWRAP), which is managed by Martin Marietta Energy Systems, Inc., for DOE under contract DE-AC05-84OR21400.

In April 1992, the USPS National Environmental Office requested assistance from HAZWRAP in the development of a prototypical USPS-specific radon testing and mitigation diagnostics protocol. The protocol emphasis was data interpretation and understanding of all aspects of the radon cycle: testing, diagnostics, mitigation, and postmitigation for USPS buildings. USPS requested that the protocol address the following topics in-depth: interpretation and limitation of radon test results, public relations aspects of a radon problem, mitigation diagnostics and data interpretation, mitigation consideration and design, postmitigation testing, maintenance of a mitigation system, and data and information management. For technical support in the development of the USPS protocol, HAZWRAP contacted the research staff at Oak Ridge National Laboratory (ORNL).

In May 1992, after a review of USPS needs and requirements, HAZWRAP provided to USPS a project outline for conducting a national radon testing program in USPS buildings. Briefly, the outline is as follows:

1. Conduct long-term radon testing of all ground-contact rooms in all USPS buildings over a 2- to 5-year period (Phase 1);

2. In buildings that have radon in excess of 4 pCi/L, perform mitigation diagnostics tests to identify the best method(s) for radon control (Phase 2);

3. Based on the data collected in Phase 2, install a radon mitigation system (Phase 3); and
4. After system installation, perform postmitigation radon testing and develop a building-specific management plan for maintaining radon control (Phase 4).

An evaluation of the proposed testing methods and procedures was performed at 38 USPS sites during 1992 and 1993 and reported in *Radon Levels and Diagnostics at 38 U.S. Postal Service Sites* (DOE/HWP-140), dated August 16, 1993. Based on the initial success of the development program, USPS requested that HAZWRAP conduct a pilot study using more sensitive electret devices.

1.2 OVERVIEW OF RADON

Radon is a naturally occurring, odorless, colorless, radioactive gas results from the decay of uranium in soil. For many years, radon was not considered to be a health problem in residential buildings. But in 1984, 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. Radon is not considered to be a human carcinogen; however, the short-lived, alpha-emitting progeny has been demonstrated to induce lung cancer. Excessive exposure to radon progeny is known to have resulted in more than the predicted number of deaths from lung cancer in mining populations (Bier et al. 1988). Nero (1986) estimated that about one million American homes have radon levels in excess of 8 pCi/L (1 pCi/L = 37 Bq/m³). Based on this and other information, EPA estimated that between 5,000 to 20,000 lung cancer deaths per year are attributed to radon exposure (*A Citizen's Guide To Radon*, OPA-86-004).

Radon migrates from surrounding soil into buildings through cracks in concrete slabs, basement cinder blocks, and air spaces around pipes. Radon can also collect in crawl spaces and then flow into living and work areas. The flow of radon into the living area of a building is caused by both natural diffusion and pressure-assisted flow. Natural diffusion usually contributes only a small amount of radon within a building. In most cases, elevated radon can be attributed to a process known as pressure-driven flow. This process can be both natural or man-made. Natural pressure-driven flow (or thermal stack effect) is due to the rising and exiting of warm air within a building. As warm air rises, "makeup" air is pulled into the building through slab and wall imperfections. If the imperfections are in contact with soil, the building radon concentration increases. Man-made means of enhancing radon entry are primarily caused by slight negative pressure caused by the operation of a furnace, ventilation fan, or clothes dryer. Certain weather conditions, such as wind and rain, can also induce transient increases in the building radon level.

In recognition of the public health hazard presented by indoor radon, the U.S. Congress passed and the President signed into law the 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 that manages a building will design a study to assess the extent of radon contamination in buildings within that agency's jurisdiction.

1.3 U.S. POSTAL SERVICE PILOT RADON TESTING AND MITIGATION PROGRAM

The primary goal of the USPS pilot program was to evaluate the USPS radon testing protocol over a wider cross section of buildings in different regions. In addition, further development of a data tracking and management system (DMS) capable of performing the entire program was to be
performed. For this study, approximately 12,000 measurements were to be made and reported. The duration of the tests were to be between 90 and 120 days each and be conducted during two climatic phases.

1.3.1 U.S. Postal Service Site Prioritization

Nationwide, USPS manages up to 36,000 buildings ranging in size from less than 200 to more than 1,000,000 ft². Using the existing protocol, between 300,000 to 400,000 radon measurements would be needed for both owned and leased USPS buildings. As currently planned, the testing of all USPS buildings would be completed within the next 5 years. Because some USPS sites could be more susceptible to elevated radon than others, USPS tasked HAZWRAP to develop a ranking system for site prioritization. To perform this task, HAZWRAP collected radon testing data from EPA and other federal and state agencies. Each state was assigned a radon availability score based on the projected percentage of buildings with radon in excess of 4 pCi/L. Using the building-size information provided by USPS, an estimate was made on the number of employees present at the site, and an employee score was assigned. A product of the two scores (radon availability score \times employee score) for each of the 36,000 sites was then calculated. To compensate for local (e.g., Guam, Reading Prong Area, and Clinton, New Jersey) historical data that indicated extremely high radon levels, a localized factor was added to certain product scores. All of the sites’ product scores were then ranked sequentially with testing priority given to the sites with the highest overall scores.

1.3.2 Site Selection

At the request of USPS, the pilot study only involved USPS-owned buildings. From the ranking score (Sect. 1.3.1), a list of the top 200 USPS-owned sites was generated. These sites were then grouped into specific target regions (e.g., Chicago, Minneapolis, Memphis). Smaller USPS-owned sites within a 30-mile radius of the main region site were then included in the target region list. All sites within the region were classified as primary (must be tested), secondary (alternate site), and tertiary (no testing at this time). Each of the target regions was then classified as a predominant heating and/or cooling region. The estimated number of detectors for all sites within a target region was then calculated. These sample density estimates were based on historical data collected during the 1992–1993 protocol evaluation study. Telephone contact was then established with the Postmaster of each of the primary sites in the target region, and a date was established for the ORNL project team to place the detectors. If the Postmaster at the primary site declined to participate in the study, an alternative region was selected. For a given region, a fixed number of detectors was assigned for deployment and a final list of regional sites was generated. Table 1 summarizes the primary target regions tested.

In addition to the primary sites (Table 1), single USPS sites requiring <200 detectors were selected for shipment of detectors to be placed by USPS personnel. The purpose of this study was to determine the responsiveness of USPS personnel in deploying the detectors and to evaluate the usefulness of the U.S. Postal Service Radon Testing Guidebook, which is an instructional handbook on how to place and retrieve radon detectors.
Table 1. Regional U.S. Postal Service sites selected for radon testing

<table>
<thead>
<tr>
<th>Regional site</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago, Illinois</td>
<td>Heating</td>
</tr>
<tr>
<td>Minneapolis, Minnesota</td>
<td>Heating</td>
</tr>
<tr>
<td>St. Paul, Minnesota</td>
<td>Heating</td>
</tr>
<tr>
<td>Cincinnati, Ohio</td>
<td>Heating and cooling</td>
</tr>
<tr>
<td>Dayton, Ohio</td>
<td>Heating and cooling</td>
</tr>
<tr>
<td>Memphis, Tennessee</td>
<td>Heating and cooling</td>
</tr>
<tr>
<td>Nashville, Tennessee</td>
<td>Heating and cooling</td>
</tr>
<tr>
<td>Chattanooga, Tennessee</td>
<td>Heating and cooling</td>
</tr>
<tr>
<td>Lehigh Valley, Pennsylvania</td>
<td>Heating</td>
</tr>
<tr>
<td>Knoxville, Tennessee</td>
<td>Heating and cooling</td>
</tr>
<tr>
<td>Denver, Colorado</td>
<td>Heating and cooling</td>
</tr>
<tr>
<td>Reading, Pennsylvania</td>
<td>Heating</td>
</tr>
<tr>
<td>Atlanta, Georgia</td>
<td>Cooling</td>
</tr>
<tr>
<td>Stanford, Connecticut</td>
<td>Heating</td>
</tr>
<tr>
<td>Dallas, Texas</td>
<td>Cooling</td>
</tr>
<tr>
<td>Central Oklahoma (Tulsa, Norman)</td>
<td>Cooling</td>
</tr>
</tbody>
</table>

1.3.3 Sample Plan

To ensure that no area of a USPS building contained elevated radon, each ground-contact room was tested for radon. Ground-contact areas tested included all stairwells, pipe chases, elevator shafts, and other interzonal conduits. In addition to testing ground-contact areas, main postal workrooms not in ground contact were sampled at an interval of one detector for every 5000 ft². To better understand radon transport within multistory USPS sites, certain sites (selected at random by the field teams) had upper-floor sampling performed.

1.4 DETECTOR SELECTION FOR THE PILOT PROGRAM

In 1992, USPS selected reusable, electret-based radon testing devices to monitor radon levels within USPS buildings. Electret-based radon detectors consist of two distinct parts, the ion chamber and the electret. The ion chamber is a specially designed holder for the electret, which is made of electrically conducting plastic. This feature allows for the uniform discharge of static energy generated by the decay of radon or radon daughters in the air inside the chamber.

1-4
Electrets consist of an electrically charged wafer of Teflon® that has been treated to hold a stable electrostatic potential. This potential attracts oppositely charged ions, which collect on the electret surface, neutralizing the surface charge and reducing the electrostatic potential. The surface potential is measured before and after exposure using a specially designed voltage reader. The decrease in surface potential during exposure is proportional to the concentration of radon integrated over time. When new, the voltage of an electret is between 700 to 750 V, and the electret can be reused until the voltage drops below 200.

The discharge rate, or volts per unit time per radon concentration, depends on the volume of the ion chamber and on the sensitivity of the electret. High-sensitivity electrets discharge at a rate 11 times that of low-sensitivity electrets. For short duration tests, such as 90-day tests, a higher discharge rate is needed for better accuracy. For example, a 90-day measurement conducted at 1 pCi/L of radon with a low-sensitivity electret would yield only a 6-V drop, while a high-sensitivity electret would yield 66 V. The higher voltage drop results in an increase in accuracy of about 50% in this example. Conversely, for longer exposures, such as 240 days, the drop in voltage for the high-sensitivity electret would be 176 V, or 35% of the usable voltage for the electret. The low-sensitivity electret would drop only 16 V, losing only 3% of its usable voltage.

1.4.1 Lessons Learned from the Evaluation Study

During the 1992–1993 USPS protocol evaluation study, USPS selected the model L-LT E-Perm manufactured by Radeld® (Fig. 1). Overall, the performance of the detector was good. However, the following problems were identified during the study that could have potentially complicated a nationwide radon survey.

- Special packaging and handling

  The design of the model L-LT radon detector is such that it cannot be turned off. Therefore, each detector required special packaging in airtight Mylar® bags with radon-absorbing material. Also, once retrieved, the detector would have to be repackaged in Mylar® bags by USPS site personnel before returning the detectors for analysis.

- Short shelf life

  Although the detector is enclosed within an airtight Mylar® bag, background gamma radiation will result in voltage discharge. Studies conducted at ORNL determined that the detectors had an approximate 30-day shelf life for a 1-year exposure period. Once exceeded, the detectors would have to be returned, reread, and repackaged before use. This limitation would require prompt deployment by USPS personnel at the sites. Conversely, once the detector had been retrieved, it must be returned and read within 14 days.

- Long exposure period

  For best results, Radeld® recommends that the model L-LT detector be deployed for a minimum of 120 days. However, significantly higher precision and accuracy are attained at testing periods approaching 1 year. The chief advantage of electret-based radon detectors is the ability to reuse them and lower the overall testing cost. A cost-benefit analysis performed
Fig. 1. The model L-LT E-Perm detector was used during the 1992–1993 U.S. Postal Service protocol evaluation study.
by HAZWRAP estimated that a 90- to 120-day exposure period offered the best performance per unit exposure cost. The analysis showed that a longer exposure period would increase the number of detectors needed for a full testing program geometrically. If the model L-LT were used for the full program, approximately 2.2 times as many detectors would be needed for a 1-year sample period vs a 90- to 120-day period.

1.4.2 Electret Chamber Selection

Based on the findings of the evaluation program, USPS requested that HAZWRAP evaluate the model S ion chamber (Fig. 2) for suitability during the pilot program. The advantages of using the S ion chamber are as follows:

- No special packaging

  By design, the model S ion chamber can be activated or deactivated by opening or closing the cap. This eliminates the need for Mylar® packaging for both placement and retrieval.

- Longer shelf life

  The model S ion chamber has a longer shelf life when compared to the L chamber because it can be deactivated when not in use. Studies conducted by ORNL found that the detectors have a 60-day storage life (longer duration studies are ongoing). The extended storage life would provide additional time for field deployment.

- Shorter testing period

  For best results, Radelec® recommends that the model S-LT detector be deployed for a minimum of 90 days. However, higher precision and accuracy are attained at testing periods approaching 120 days. Therefore, in theory, the S-LT detector falls within the optimal cost-benefit range.

1.4.3 Gamma Detectors

Although marketed as a radon gas detector, the E-Perm monitor is fundamentally a detector of ion-pairs generated inside the ion chamber by radiation sources. External gamma rays originating from natural external sources (e.g., building materials, soil) can and do cause a voltage decrease. If this is not corrected, the result could be a sizable increase in reported radon concentration. Thus, Radelec® publishes a gamma correction table that lists the contribution of the gamma background by state to the radon measurement. This gamma correction factor is simply subtracted from the calculated radon concentration.

During the 1992-1993 protocol evaluation study, the U.S. Post Office in Milledgeville, Georgia, was found to have a higher than expected gamma radiation background. Further investigation identified a certain type of building block as the reason. Concerned about the possibility that this problem may exist in other USPS buildings, HAZWRAP recommended to USPS that background gamma measurements be performed in other buildings during the pilot study. To perform the gamma background measurements, the L-LT detector sealed in a Mylar® bag was selected.
Fig. 2. The Hazardous Waste Remedial Actions Program evaluated the model S ion chamber for suitability during the pilot program.
During the pilot program, 170 gamma measurements were performed at 31 sites. Excluding the measurements in which tampering was suspected or bag failure was observed, none of the background measurements were significantly higher than the correction factors recommended by Radelco®. The recommendation is made to USPS personnel that the measurements should not be performed in the future unless high gamma background radiation is suspected.

1.5 RADON TESTING OVERVIEW

To date, 12,581 detectors have been allocated to perform radon measurements at 227 USPS sites. Project team members from ORNL and HAZWRAP placed and retrieved radon detectors at 100 USPS sites. Detectors were mailed to 127 sites for placement by USPS personnel. As of November 29, 1994, 28 sites had not placed or had not returned the detectors. The current status of radon testing at USPS sites is summarized in Appendix A. Charcoal testing data from the summer of 1992 are listed by site in Appendix B.

1.5.1 Shipment of Radon Detectors for U.S. Postal Service Deployment

Before shipping detectors to a USPS site, telephone contact was established with the Postmaster. During the initial contact, the program was explained, the level of effort was detailed, the time frame to complete the task was given, building information (e.g., address, size, number of rooms) was obtained, and a building point of contact (POC) was determined.

If the Postmaster agreed, then a package containing one radon detector for each ground-contact room, stairwell, pipe chase, elevator shaft, and other potential interfloor conduits in ground contact was shipped. Also included in the detector shipment was hardware for hanging the detectors (hooks, Velcro®, etc.), a building-specific data form for detector placement, USPS information brochures (1 per detector), and a single copy of the U.S. Postal Service Radon Testing Guidebook. For technical assistance, a Radon Hot Line (615-576-9343) was staffed from 8 a.m. to 5 p.m., Monday through Friday, Eastern Daylight Time.

After the detectors were placed by USPS personnel, the placement data forms were returned to HAZWRAP for data entry. If the forms were not returned within 21 working days of the date of shipment, a follow-up call was made to the site POC to determine the status of the detectors.

After receipt of the placement forms, each form was reviewed for completeness and compatibility with existing information. Any conflicts or questions were resolved by contacting the building POC.

Fourteen days before the scheduled retrieval date, a retrieval package consisting of detector retrieval data forms was mailed to the site. If the detectors were not returned within 21 days, a follow-up call was made to confirm that the detectors were removed and returned.

After the retrieval package was returned, the detectors were read and the average voltage recorded. Each retrieval form was reviewed for completeness and compatibility with existing information. Any conflicts or questions were resolved by contacting the building POC.

Along with the detectors, the U.S. Postal Service Radon Testing Guidebook was returned from the site once testing was completed. Each guidebook was checked for completeness, updated, and readied for future use.
1.5.2 Detector Tracking and Data Management

Based on lessons learned during the 1992–1993 protocol evaluation study, several hardware and software changes were made to the existing DMS. The following improvements reduced the detector handling cost approximately 45%:

- **Hardware improvements**
  - RS-232 E-Perm readers
    New E-Perm readers with RS-232 cables were procured and interfaced with the DMS, allowing automatic input of the voltages into the data file. This eliminated the need for manual transcription, data entry, and data entry verification of the electret voltages.
  - Bar code generator
    New bar code generators were procured, which allowed for faster generation at 10% of the previous cost.

- **Software enhancements**
  - Quality control enhancements
    With the introduction of the RS-232 E-Perm reader, data accuracy was improved. Each electret voltage is read three times. If the reading range exceeds 1 V, the software requires three new readings. Reference electret tracking alerts the user that the reader may be out of specifications.
  - On-line USPS site list
    An on-line data query system was developed to enable the user to search and obtain building and radon test results. This enables the user to answer any questions regarding radon testing for any USPS site.
  - Detector tracking
    During the validation phase, the needs for a DMS capable of tracking 400,000 radon measurement surveys were scoped. Because a radon survey of this magnitude using both reusable and consumable radon detectors has never been conducted, DMS was allowed to "grow" and adapt as needed to address specific problems. In November 1994, the lessons learned from the pilot program were incorporated into the existing DMS and are currently being evaluated. Currently, the DMS, in addition to data entry and reporting features, maintains detector chain of custody, tracks the location of each electret detector (e.g., in the field, in inventory, lost or disposed of), scheduling, tested vs nontested sites, site addresses and phone numbers, and site POCs.
  - Data query and reporting
    Based on numerous information requests made by regional USPS personnel for copies of earlier testing reports, the requirement for ad hoc radon reports was defined. Improvements were made to the reporting software that allow for the immediate generation of any site radon testing report. In addition, an on-line data query system was created that
allows the user to "navigate" to any USPS site and review the radon testing status or the data. Also, the DMS was expanded to enable all radon data to be maintained on-line for the duration of the program.

1.5.3 Quality Control

Before detector deployment began, in-depth discussions were conducted with Radelec® and others regarding potential problems with the E-Perm detectors. The objectives of these discussions were to identify potential problems and develop a quality control (QC) plan to address them. Based on these discussions, adjustments were made in the QC plan and in detector reading. For the pilot program, five types of QC radon detectors were utilized; their type and use are discussed in Sects. 1.5.3.1 through 1.5.3.5.

1.5.3.1 Laboratory Spikes

To verify detector calibration for the pilot program, 490 detector spikes (detectors exposed to a known concentration of radon) were performed at two concentrations within the ORNL Radon Calibration Facility. The first exposure was to verify the Radelec®-supplied voltage discharge curve. A total of 261 E-Perm detectors were exposed to a continuous concentration of radon (20.8 pCi/L) for 79 days. Temperature and humidity were maintained at 23°C and 50% RH for the duration of the study. The average concentration measured by the E-Perm detector was 22.3 pCi/L, with a range of 19.6 to 27.7 pCi/L and a standard deviation of 1.2 pCi/L. Figure 3 illustrates the range of the Round 1 results for the E-Perm chamber exposure.

The purpose of the second exposure was to determine the accuracy of electrets below the recommended 200-V threshold. In a large survey, a significant number of the detectors will be returned from the field under low voltage conditions. Determining the exact voltage limitations of the detectors will enable USPS to set minimum voltage requirements for electret reuse. Past studies conducted by ORNL have shown that the electret has a high error rate for final voltages below 20 V. However, some marginal success was observed for electrets in the range of 40 to 60 V. To perform this experiment, a total of 229 E-Perm detectors with an average of 348 V were exposed to a continuous concentration of radon (20.8 pCi/L) for 91 days. As before, the temperature and humidity were maintained at 23°C and 50% RH for the duration of the study. The detectors were removed after the average charge of the detectors had dropped to 44 V. The average concentration measured by the E-Perm detectors was 22.8 pCi/L, with a range of 19.5 to 26.0 pCi/L and a standard deviation of 0.9. Figure 4 illustrates the range of E-Perm results for the chamber exposure.

To verify chamber calibration, ORNL intercalibrated with the EPA Montgomery, Alabama, Radon Calibration Facility and participated in the International Chamber Exercise (ICE-1994). Results of the intercalibration are summarized in Table 2.

Table 2. Radon chamber intercomparisons

<table>
<thead>
<tr>
<th>Date</th>
<th>ORNL chamber (pCi/L)</th>
<th>EPA Montgomery (pCi/L)</th>
<th>International chamber exercise (pCi/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 8, 1994</td>
<td>22.9</td>
<td>N/A</td>
<td>23.9</td>
</tr>
<tr>
<td>September 19, 1994</td>
<td>17.2</td>
<td>18.5</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Fig. 3. E-Perm calibration distribution for Round 1.

Chamber mean concentration = 20.8 pCi/L
Detector mean concentration = 22.3 pCi/L
Chamber mean concentration = 20.8 pCi/L
Detector mean concentration = 22.8 pCi/L

Fig. 4. Low-voltage E-Perm distribution for Round 2.
1.5.3.2 Laboratory Blanks

Two hundred readings were performed on randomly selected detectors during the course of the testing. These data were used to determine electret reading errors and potential discharge in handling. The average voltage difference for all 200 electrets was found to be <0.1 V, with a reader failure rate of 0.5%.

1.5.3.3 Travel Blanks

For each shipment to a USPS site, travel blank detectors were included to monitor radon exposure that might have occurred during transit. Eighty-six travel blanks were used during the survey. The average transient radon exposure was found to be <0.1 pCi/L.

1.5.3.4 Duplicate Detectors

At each site, detectors were collocated to measure field precision. A key criterion for duplicate detectors was that they be located in an area or room where the likelihood of tampering would be slight. Unfortunately, well-meaning USPS personnel relocated or returned a total of 165 duplicate detectors, believing they were placed together in error or were forgotten. Therefore, the exact number of successful duplicate measurements per site varied. During the pilot program, 563 duplicate measurements were performed. The overall field variance was estimated to be 10%. Figure 5 illustrates the duplicate measurements.

1.5.3.5 Confirmation

Because mitigation is potentially an expensive option and to determine the percentage of false positive readings, it was decided during the planning stages of the pilot program that short-term (5-day) electret follow-up measurements (model S-ST) would be performed on all single long-term readings >4 pCi/L. Based on projections, it was estimated that of the 12,000 measurements performed, fewer than 500 readings would be over the 4-pCi/L threshold. Using that assumption and data collected during the protocol evaluation study, it was estimated that 100 short-term E-Perm detectors would be needed for follow-up measurements during the pilot program. This assumption was based on 14-day average turnaround per measurement. Unfortunately, the field turnaround for the short-term confirmation detectors has been significantly longer (30 days). As of November 28, 1994, only 136 of the 1,199 planned confirmation measurements had been performed.

With respect to the percentage of false positive readings, of the 136 confirmations measurements performed, 46 or 34% of the confirmed readings were identified as false positive readings. The reasons for the high percentage are discussed in detail in Sect. 1.6.1. A listing of the completed confirmation data is included in Appendix A.

1.6 RESULTS AND DISCUSSION

For the 199 sites in which data are available (9,595 measurements), 13% of the readings were found to be elevated (i.e., >4 pCi/L). This percentage is higher than the projected 5 to 7% for several reasons: (1) sites were selected based on the high probability of finding elevated radon;
(2) a previously unobserved problem with dust has given rise to a new source of false positive readings; and (3) detector tampering at some sites has resulted in false positive measurements.

1.6.1 Potential Measurement Problems

1.6.1.1 Dust Problems

During analysis of the first group of radon detectors, it was occasionally observed that the inside of the S chamber and the surface of the electret were coated with a fine layer of dust. It was further observed that detectors placed in the main mail-sort area had a higher frequency of dust inside the detector. Dust deposited on the surface of the electret can result in voltage discharge. This voltage discharge caused by dust would result in a higher reported radon concentration and potentially a false positive reading. During the 1992–1993 protocol evaluation study using the model GLT electret, this problem was not observed because the opening for radon diffusion into the chamber is located on the side of the detector, as opposed to the top of the S chamber. Dust is suspected to be the leading cause of the high percentage of false positive readings. Currently, discussions are under way with Radelec® to determine whether the existing filters in the S chambers can be replaced with a higher mesh filter or if procedural modifications can be made to reduce electret exposure to dust.

1.6.1.2 Detector Tampering

During the 1992–1993 protocol evaluation study, tamper tape was used on all detectors. Of all of the detectors that had damaged tape, <10% were suspected to be intrusive tampering. Apparently the tamper tape was the object of tampering, not the detector. Because installing tamper tape costs roughly $0.20/detector or potentially $80K for the full-scale program, it was decided to conduct the pilot study without the benefit of the tape to determine whether the percentage of actual tampering was significantly different. During the 1992–1993 survey with the tamper tape, the percentage of actual tampering was estimated to be 15%. The pilot study had a tampering percentage of 13%. Therefore, it appears that the percentage of detector tampering is constant with or without the tamper tape. If the current policy of 100% follow-up for all elevated readings is maintained, the conclusion is that no net benefit will result from using the tamper tape because all readings will be verified before corrective action is taken.

1.6.1.3 Attrition Rate

During the 1992–1993 protocol evaluation study, a majority of the detectors were secured to objects (e.g., pipes, walls) using wire, hooks, Velcro®, etc. Whenever possible, the detectors were located out of reach (e.g., 7 to 8 ft from the floor). This resulted in an average deployment rate of approximately 30 detectors per hour for a 2-person field team. For the pilot study, the detectors were mostly placed on out-of-the-way objects and not secured. Using this method of placement, the average time for detector deployment increased to 48 detectors/hour for a 2-person field team. The attrition rate using this method was comparable, 5.3% for unsecured detectors vs 8% for secured detectors. Therefore, securing a detector did not improve its "chance of survival." Table 3 provides the best method for detector placement in USPS building areas.
Table 3. Recommended radon placement per U.S. Postal Service building area

<table>
<thead>
<tr>
<th>Area</th>
<th>Location of placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mail lobby/high-traffic</td>
<td>Secure the detector to ceiling or wall a minimum of 8 ft from the floor</td>
</tr>
<tr>
<td>hallway</td>
<td></td>
</tr>
<tr>
<td>Workroom</td>
<td>Secure the detector to a support column a minimum of 8 ft from the floor</td>
</tr>
<tr>
<td>Vacant rooms</td>
<td>Place the detector unsecured on an object off of the floor</td>
</tr>
<tr>
<td>Occupied offices</td>
<td>Place the detector unsecured on an out-of-the-way object</td>
</tr>
<tr>
<td>Storage/mechanical rooms</td>
<td>Place the detector unsecured on an out-of-the-way object</td>
</tr>
<tr>
<td>Enclosed loading docks</td>
<td>Secure the detector to a support column or wall a minimum of 8 ft from the floor</td>
</tr>
<tr>
<td>Breakrooms</td>
<td>Place detector in an out-of-sight location</td>
</tr>
<tr>
<td>Locker rooms/bathrooms</td>
<td>Place detector in an out-of-sight location</td>
</tr>
</tbody>
</table>

1.6.1.4 Detector Reuse

To complete the USPS Radon Testing and Mitigation Program, HAZWRAP projects upward of 400,000 radon measurements. Detector procurement cost potentially would represent half or more of the entire program expenditures. If single-use detectors (such as alpha tracks) were used, the combined unit cost for the detector and analysis would be approximately $8. This would represent a total procurement cost of $3.2M. Using reusable detectors, such as the E-Perm, can possibly lower the per-measurement cost for the main program. Figure 6 illustrates the condition of the electret population after an average of two field exposures. Table 4 provides a summary of the data.

Table 4. Summary of electret population condition

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of electrets</td>
<td>5,054</td>
</tr>
<tr>
<td>Average voltage for new population</td>
<td>734 V</td>
</tr>
<tr>
<td>Number of field exposures</td>
<td>2 (average 93.4 days each)</td>
</tr>
<tr>
<td>Average total exposure</td>
<td>187 days</td>
</tr>
<tr>
<td>Average discharge per exposure</td>
<td>36 V</td>
</tr>
<tr>
<td>Number of consumed electrets</td>
<td>334</td>
</tr>
<tr>
<td>Total losses</td>
<td>666 (5.3%)</td>
</tr>
<tr>
<td>Projected number of readings remaining in electrets</td>
<td>15</td>
</tr>
</tbody>
</table>
Fig. 6. Status of electret voltage.
Based on the current consumption and loss rate, projections indicate that for the course of the program (e.g., 400,000 measurements), the average detector measurement cost would be $4.50/measurement. If the $1.50 analysis cost is included with the cost of the detector, the total cost per measurement using E-Perm detectors would be approximately $6/measurement. Currently, alpha track detectors in large quantity cost approximately $8/measurement. Therefore, using the E-Perm system may potentially save USPS $800K over the course of the program.

1.7 RECOMMENDATIONS

Although significant progress was made during the pilot program, several new problems have arisen that may impact the full program. The detector loss rate should be reduced. For every 0.5% reduction in detector losses, the cost per measurement would drop by $0.20. Also, the dust problem should be addressed. A 34% false positive rate (due in large part to dust) would result in an additional 20,000 follow-up measurements in the full program. The cost for material and labor alone would add approximately $300K to the overall program cost. Additional work is needed to identify a cost-effective method to prevent the detector’s exposure to dust. In addition, more work is needed in the area of tamper reduction. Fluorescent dyes (invisible in normal light) may help to verify whether a detector has been opened.
2. RADON MITIGATION DIAGNOSTIC PROTOCOL FOR U.S. POSTAL SERVICE FACILITIES

2.1 INTRODUCTION

During the past 10 years, considerable progress has been made in the field of residential radon mitigation. Six years ago, as required by IRAA, EPA established regional radon mitigation centers that train and certify private contractors in residential radon mitigation proficiency. As a result, the mystique of residential mitigation has diminished considerably along with mitigation cost ($2500 in 1983 vs $1200 in 1994).

Another change over the past 11 years has been the reduction in the amount of residential mitigation diagnostics. In the early 1980s, a typical mitigator would perform on average half a day of mitigation diagnostics in a typical home in order to select and design an effective mitigation system because the mitigation hardware technology (e.g., mitigation fans) was not very effective. This hardware limitation mandated that the mitigation system be placed in the optimum location (site optimization) to ensure success. By 1994, however, the power of available mitigation hardware increased significantly; therefore, the need for site optimization has been reduced. Also, in most areas of the country, sufficient historical mitigation data exist that suggest mitigation could be achieved without using extensive diagnostics. For example, during the past 2 years, a mitigation company in central Pennsylvania has been advertising guaranteed radon mitigation for any 1955 or newer house with a slab for $1200 using subslab depressurization as the mitigation method. This price is quoted and guaranteed without the benefit of mitigation diagnostics or preinspection. On the surface, it appears that the company is taking significant risk. However, success is ensured for this company because local building codes have required a standard size and amount for subslab aggregate, and hundreds of homes in this geographical area have been successfully mitigated using the advertised method. If the current trend continues in the advancement of mitigation hardware and as local mitigation methods become more standardized, the performance of residential mitigation diagnostics will substantially decrease within the next 10 years.

The absence of mitigation diagnostics, however, will not be true for large buildings. To illustrate this point, a typical house is rather simple in design and construction (e.g., single substructure and mechanical system), and radon mitigation for a typical house is inexpensive. Large buildings, on the other hand, contain components that could potentially complicate mitigation reduction measures (e.g., multiple mechanical systems and substructures). In addition, the mitigation hardware currently available, although sufficiently powerful for residential applications, could potentially be overextended in large buildings. Other considerations in large buildings are the capital outlays for radon reduction. On a per-structure basis, radon reduction in large buildings costs considerably more than that in residential buildings. Currently, for active subslab mitigation measures, a working estimate is $1/ft² of ground-contact area. Therefore, a 100,000-ft² building would cost approximately $100K to mitigate using active subslab mitigation.

Another consideration for large-building mitigation is the long-term cost of mitigation. Most radon mitigation measures require energy (e.g., electricity) to operate or result in increased heating or cooling cost (energy penalty). Selection of the best mitigation method is essential for keeping energy costs under control. In addition, the mitigation measure for a large building must take into account the people who work within the space. If the mitigation measure results in a decrease in employee comfort, productivity may suffer. All of these considerations must be addressed to achieve radon reduction at a reasonable cost.
2.2 OVERVIEW OF RADON MITIGATION

The radon mitigation training offered by the U.S. Environmental Protection Agency Regional Training Centers (USEPARTCs) is designed for private mitigation contractors. The training provides participants with the knowledge to mitigate single, detached residential housing. For the USPS radon program, selected personnel will be responsible for the mitigation of thousands of postal facilities. Unfortunately, the existing training offered by USEPARTCs provides little information for the managers of large mitigation programs. In addition, with the exception of limited exposure to radon mitigation in schools, little information is available for large-building mitigation. USPS-wide, the potential cost for radon mitigation activities will be millions of dollars. If poor mitigation choices are made, maintenance and upkeep costs during the remaining lifetime of those buildings could also cost millions of dollars.

Radon mitigation is divided into two basic categories: passive and active. Passive mitigation is defined as a nonmechanical means of radon abatement or control. Examples of passive mitigation include sealing cracks, balancing an existing mechanical system, or increasing the natural ventilation rate of the building substructure (e.g., crawl space). For the remaining lifetime of the building, passive radon techniques are generally considered the most cost-effective means of radon control. Typically, installation costs for a passive system are less than half those of an active system, and a passive system has no maintenance and operation cost (i.e., energy for operation). Unfortunately, successful passive mitigation has proven difficult because all radon entry pathways within a structure must be identified and negated.

Active mitigation entails the use of mechanical means, such as a fan, to control radon entry into the living area. Generally speaking, all active mitigation methods can be grouped into two categories: preentry and postentry mitigation. Preentry mitigation is a technique that retards radon entry into the living area. Typical examples are shell pressurization (SP), subslab depressurization (SSD), and submembrane depressurization (SMD). SP, the oldest radon mitigation method, retards radon entry by mechanically introducing sufficient outdoor air to induce a positive pressure across the slab and into the soil. For buildings with slabs or basements, SSD is a common means of radon control. In this method, a pipe with a fan attached is inserted through the slab. When the fan is activated, the area beneath the slab (subslab) is depressurized. The resulting depressurization prevents radon entry into the living area by redirecting the subslab radon into the pipe for discharge into the atmosphere. For buildings with crawl spaces, SMD is usually employed. By placing a plastic sheet on the floor of the crawl space and depressurizing underneath the plastic sheet using a fan, radon can be collected and discharged into the atmosphere away from the building.

Postentry mitigation involves the treatment of the contaminated air inside the building. Charcoal absorption, for example, removes radon from the air by entrapment in an activated charcoal bed. Heat recovery ventilation (HRV) involves the exchange of contaminated indoor air with fresh uncontaminated outdoor air. Other active mitigation methods are described in Radon Reduction Techniques for Detached Housing (EPA/625/5-87/019).

2.2.1 Considerations in Large-Building Radon Mitigation

Current research has indicated that large buildings may contain construction features or mechanical systems that would inhibit the installation or operation of a residential-type mitigation system. Examples are return air ducts or supply ducts that are routed through the slab. These mechanical components have demonstrated sufficient subslab perturbation to overpower
traditional SSD systems. Also, highly segmented slabs were found to disrupt SSD fields (Wilson et al. 1991).

Other important issues for consideration during mitigation design are health, safety, and local building code requirements. For example, the best method for mitigation of a building might be SSD, but the presence of asbestos in building material might prevent the installation of the polyvinyl chloride (PVC) intake and exhaust piping. Local fire codes are a factor as well. To prevent the release of toxic fumes in the event of a fire, within certain areas of the country, PVC pipe cannot penetrate into occupied areas or through fire walls. Also, roof penetrations for radon exhaust may invalidate the contractor's warranty. All of these factors and more must be considered during the mitigation design.

2.2.2 Room Isolation and Relocation

By definition, radon mitigation is the measure taken to reduce human exposure to elevated levels of radon. As stated previously, elevated radon measurements within large buildings can be isolated in certain areas of a building. If these areas are occupied on a regular basis, then mitigation should be considered. But, before corrective action is taken, another option should be considered. The key part of the risk associated with radon exposure is that a person must be exposed to be considered at risk. Obviously, if no exposure occurs, no human health risk exists. Thus, by restricting or removing a worker from exposure, a more cost-effective mitigation may result. For example, by limiting or controlling access to a room (i.e., locking the door) or relocating occupants to safer areas within the building, the human health risks are eliminated and mitigation has occurred.

2.2.3 Cost Considerations

At the 1992 EPA Radon Conference in Minneapolis, Minnesota, the average mitigation cost for large buildings was estimated to be as high as $1 to $2 per ft². However, the installation cost of radon mitigation should not be the only consideration; future costs, such as the energy penalty and system upkeep, are factors as well. In private residences, the cost of operating and maintaining most mitigation systems has been estimated at less than $500/year for most areas of the United States. In large buildings, however, this cost could run as high as tens of thousands of dollars per year if mitigation entailed the use of unconditioned air for increased building ventilation. Because of the potential installation and lifetime operation costs involved, radon mitigation in large buildings can be a major investment. Matching the right system with the right building is essential to control both current and future costs.

2.2.4 Limitation of Existing Mechanical Systems

When dealing with radon in large buildings, the temptation exists to adjust and/or modify the existing mechanical system to increase the building ventilation rate. However, this type of corrective action must be performed with considerable caution. For example, the most typical response has been to increase the building ventilation rate by increasing the amount of fresh-air uptake. This approach has been successful, provided the existing system was designed to condition the extra volume of outside air. In cases where the system was not able to handle the increased air uptake, an overall decrease in the building comfort index resulted. Examples of the problems noted have been drastic changes in the building humidity, temperature variability, higher mold and spore counts (i.e., building flu), and substantially increased energy consumption. Also,
radon mitigation by performing minor mechanical balancing has been shown to be an ineffective means of long-term radon control. Studies by EPA indicate that the blockage of one supply duct could result in system imbalance. If mitigation is to be performed by this method, a qualified mechanical engineer should be consulted before action is taken.

2.2.5 Phase 2 Protocol Development

In June 1992, USPS requested HAZWRAP to begin the preliminary development of the Phase 2 interim radon mitigation diagnostics protocol. The final diagnostics protocol, according to USPS instructions, contained or addressed the following issues:

- To the best extent possible, the protocol must make use of existing methods and procedures found within the private sector or be of sufficient detail so that they can be readily transferred.
- The methods specified in protocol must be conducted in such a way as not to interfere with normal USPS operations or conflict or violate existing USPS health and safety rules or requirements.
- The protocol should provide clear mitigation choices.

After the acceptance of the Phase 2 scope by USPS, a sufficient number and types of USPS facilities with elevated radon were visited and the proposed protocol implemented. After each set of buildings, USPS and HAZWRAP reviewed the collected data and decided to continue, refine, or terminate the protocol development.

In response to the request by USPS, HAZWRAP submitted for USPS approval a two-step outline in July 1992. The letter detailed the methods and research requirements needed to develop a Phase 2 radon mitigation protocol. Briefly, the proposed USPS mitigation diagnostics protocol is as follows:

Step 1: Perform a radon test in all ground-contact rooms, stairwells, pipe chases, and other interfloor conduits. Record the results on the building floor plan and classify the radon data pattern as one of the following types:

- Random (no distinct pattern),
- Clustered (grouped together in a certain area of the building),
- Linear (results are in a row), and
- Uniform (all data are about the same).

With the radon room map, review the building construction plans, noting any building features, modifications, or additions that would enhance radon entry.

The building should then be divided into diagnostics zones of the following types: slab, interior, or mechanical. A slab diagnostics zone is area beneath the slab enclosed by footers or foundation. An interior diagnostics zone is area defined by rooms enclosed by fire walls or masonry construction. Consideration should be given to normal room door positions (open or closed) when defining this type of zone. A mechanical diagnostics zone is defined only if a forced-air system is present. For each forced-air mechanical system, locate the supply and return ducts. Identify the supply air zone(s) and return air zone(s). In a properly balanced system, the zones should overlap. Note any duct work that is in contact with the ground or that passes
through low ventilated or confined areas in contact with soil such as crawl spaces or storage rooms.

A visual walk-through inspection of the building should then be conducted to confirm the accuracy of the building plans and to collect information on individual room usage and occupancy patterns. If available, information on the building heating, ventilation, and air conditioning (HVAC) system and the duty cycle should be noted as well. After the walk-through inspection, an interview of the building maintenance staff should be conducted to review the collected information and discuss future diagnostics work. The Postmaster should also be interviewed to collect information on the future plans for the USPS building including renovations or expansions.

Step 2: From the data and information collected in the first step, active mitigation diagnostics are then performed within each of the identified zones, and a mitigation design is developed for each zone. Examples of active diagnostics are shell leakage, shell air-exchange rate, subslab permeability, SSD field extensions, and mechanical system balance determination. During the active diagnostics, all interzonal communications, such as subslab field extensions or interzonal mixing of different tracer gases, must be noted. If two zones communicate, then it may be advantageous to combine them into a single zone for corrective action. After completion of the diagnostics, a composite mitigation design for the building or zone is developed.

2.2.6 Radon Mitigation Diagnostics Utilized for Evaluation

In the 1992 proposed mitigation protocol, HAZWRAP proposed the use of four basic radon mitigation diagnostic techniques: episodic air change for HRV, blower door test for SP, subslab pressure field extension, and subslab permeability testing for SSD mitigation.

2.2.7 Episodic Air Change Diagnostics

Episodic air change is used to measure the turnover rate of air within a room or building. Tracer quantities of Freon-12 are injected into the building or room, and the rate of loss of the tracer is monitored as a function of time (hours). By calculating the inverse slope of the natural logarithm vs time in hours, the air change rate per hour (ACH) of the area sampled can be estimated.

A building or room's ventilation rate or ACH is very important from both economic and health standpoints. Ventilation is defined as the summation of the volume of infiltrating outside air and the volume of exhausting inside air across the building shell as a function of time. Ideally, to minimize energy cost, a building with a low ACH would be desirable. However, the breathing process of a building retards the buildup of moisture and indoor air pollutants that may cause health problems. To provide a healthy and comfortable indoor environment, the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommends various air turnover rates determined by the space's usage. For example, a minimum rate of 0.35 ACH is recommended (ASHRAE 62-1989, Tables 2.1-2.3) for single-family dwellings while rates for chemical laboratories can be as high as 18 ACH.

Low air change rates result in the buildup of high levels of radon, carbon monoxide, carbon dioxide, and nitrogen oxides from normal daily routines such as cooking, smoking, and working. In addition, because of the out-gassing of consumer products, unacceptably high levels of carcinogens, such as formaldehyde, chlorinated solvents, and hydrocarbons, may be present as well. Another problem with low ACH is the increase in humidity within the living or work area. The result is a "musty smell" usually caused by elevated mold and spore concentrations. Exposure
to these biogens has been linked to headaches and respiratory, sinus, and other health problems. Potentially, elevated radon may be the least of the health problems within certain USPS buildings.

The only practical way to solve an indoor air quality problem within a building is to increase the ventilation rate. One approach is to install an intake fan and import fresh air. Another is to install a whole-building fan to periodically remove the air from the building. Both approaches have some drawbacks. Importation of nonconditioned fresh air has a considerable energy and comfort penalty. Whole-building fans tend to depressurize the structure, which increases radon infiltration. The third possibility for increased ventilation is to install an HRV system, which is a packaged unit complete with blower fans, controls, and air-to-air heat exchanger. Filtered and desiccated fresh air is brought into the living area from outdoors, and stale air is removed. This swapping of air results in an increase in the building air change, thus lowering the concentration of indoor pollutants. In the process, heat energy is transferred from the warmer to the cooler air stream. This heat exchange or energy recovery results in saving heating costs in the winter and cooling costs in the summer. Energy recovery can be as high as 80% in some of the newer HRV units. For example, if the desired ventilation flow for better indoor air quality was 100 ft³/min, the energy penalty would be approximately that of 20 ft³/min of unconditioned fresh air.

Radon, like other indoor air pollutants, can be controlled by better ventilation. However, because of economical limits on the quantity of conditioned air that can exchanged, HRV has a very finite range of application in radon abatement. EPA has provided in Radon Reduction Techniques for Detached Housing (EPA/625/5-87/019) an algorithm to estimate the amount of air required for effective mitigation. The algorithm is as follows:

1. Calculate the volume of the building or room.
   
   \[ \text{Volume} = \text{square footage (ft}^2\text{)} \times \text{ceiling height (ft}^3\text{)} \]

2. Estimate or measure the existing air exchange rate and ventilation rate (if unknown).

   **Range of ACH**
   
   - Energy efficient: 0.3
   - Average: 0.50
   - Old wood frame: 0.80

   \[ \text{ACH} \times \text{cubic volume (ft}^3\text{)} \times 1 \text{ hour/(}60 \text{ minutes)} = \text{ft}^3/\text{min} \]

3. Calculate the required reduction factor.

   \[ \frac{\text{Current radon level (pCi/L)}}{\text{desired radon level (pCi/L)}} \]
   
   (Note: For most applications, assume 2 pCi/L to be the desired radon level.)

4. Calculate the total air input needed for mitigation.

   \[ \text{Reduction factor} \times \text{current ventilation rate (ft}^3/\text{min)} = \text{total air input (ft}^3/\text{min)} \]

5. Calculate the required air flow for HRV.

   \[ \text{Total air input (ft}^3/\text{min)} - \text{current ventilation rate (ft}^3/\text{min)} = \text{required HRV (ft}^3/\text{min)} \]

2-6
Blower door diagnostic tests measure the leakiness of a building or room's envelope or shell. The principle of the measurement is that as pressure across the shell increases, the air flowing through cracks and crevices will increase in an attempt to balance the induced pressure. Based on the flow and pressure data collected, one can calculate the average shell leakage under certain conditions. To perform the measurement, the blower door frame and fan are inserted into the door frame of a room or exterior door. By adjusting the speed of the fan, both fan and shell pressures at different settings can be measured. The fan pressure is proportional to the amount of air removed (ft³) from the building per minute (ft³/min). The shell pressure is proportional to the area of leakage present within the building.

One of the most common reasons for radon entry into a building is the slight positive pressure present beneath the slab relative to that in the living area. If the radon flux is great enough, this pressure differential pulls radon soil gas through the cracks and crevices, resulting in elevated radon. Radon infiltration and subsequent buildup have been observed with a pressure differential as small as 1 Pascal (250 Pa = 1 in. water). This imbalance can be reversed if sufficient air, typically 4 Pa, is introduced into the building or room, resulting in a positive pressure relative to the subslab pressure. However, wind and other environmental factors require nonstressed pressure of 8 Pa for effective long-term mitigation. Pressurization mitigation systems are also highly dependent on maintaining an airtight seal across the structural shell. Cracking a window or an outside door will result in the loss of pressure. In some cases, a loss of only 1 to 2 Pa will defeat the purpose of a pressurization radon mitigation system. Also, air exhaust systems within the building, such as bathroom or range fans and clothes dryers, would defeat a pressurization system.

### 2.2.9 Subslab Field Extension Test for Subslab Depressurization Mitigation

The pressure field extension test (PFET) is an integral part in the design of an SSD system. The test measures the lateral extent of a depressurization field at a given vacuum beneath the slab. In general, for an SSD system to be successful, the system pressure field, or more precisely the vacuum field, should cover at least 75% of the subslab surface area. To accomplish this, multiple penetrations in different areas of the slab are usually required. By performing PFET, a determination can be made for the number of SSD points and minimal vacuum requirements required for mitigation. To conduct PFET, a 1.5-in. diagnostic hole is drilled along the center line of the slab. Six to ten perimeter field extension holes (3/8 in.) are drilled at varying distances (1 to 20 ft) from the diagnostic hole. Using a small, variable-speed, industrial vacuum cleaner, a constant vacuum of 500 Pa (2-in. WC) is applied across the slab. The vacuum field extension is then determined by measuring the quantity of vacuum present in the 3/8-in. holes as a function of distance from the diagnostic hole. Ideally, the depressurization field extends radially beneath the slab around the diagnostic hole, with the fringe limits being defined as areas with less than 2 Pa of vacuum. By measuring the radius of extension and measuring a circle around the diagnostic hole, the extent of SSD is estimated.

A subslab permeability test is usually performed in conjunction with PFET. During the design of an SSD system, proper fan selection is critical for long-term continuous performance. A typical error most contractors make is the selection of a fan with too high a flow demand for a given pressure. For all mitigation fans, minimal air flows need to be maintained to keep the fan motor cool. Fan manufacturers provide fan performance curves (pressure vs flow) that indicate minimal flow requirements at a given pressure. A subslab permeability test measures the ease at which air
moves through the aggregate/soil beneath the slab (i.e., flow for a given vacuum). This property of porous materials is called permeability. To measure permeability beneath a slab, it is necessary to record the flows through a slab penetration at different degrees of depressurization. As in PFET, a 1.5-in. hole is drilled through the slab. A measurement stand, consisting of 1-in. pipe in a wooden flange, is inserted into the hole. A small, variable-speed, industrial vacuum cleaner evacuates the subslab air through the 1-in. pipe in which an anemometer (air velocity meter) and a micromanometer (pressure meter) are installed. By varying the speed of the small, variable-speed, industrial vacuum cleaner, the flow required to produce a given pressure can be measured. An xy-data plot of the data pairs can then be used to select the proper fan for the SSD system.

2.2.10 Building Flow and Pressure Mapping

Under ideal conditions, all zones in a large building with a forced-air system are under neutral or slightly positive pressure with respect to the outdoors. If all zones within the building have identical pressure with respect to the outdoors, the system is called balanced. If this is not true, the forced-air system is called imbalanced. An imbalanced forced-air system results in higher operating costs and may decrease occupant comfort. If the imbalance results in certain zones being depressurized with respect to the outdoors, increased radon entry into the zone is the result.

In theory, all forced-air systems are balanced when initially installed. Over time, however, the system may become imbalanced for a number of reasons: building modification, changes in the mechanical system, system performance degradation, occupant tampering, and lack of maintenance. To determine system balance, the flow of each room supply duct is measured using an instrument called a flow hood. A flow hood consists of a pressure sensor and a nylon hood placed over a register. The pressure measured by the meter is proportional to the exhaust flow measured in cubic feet per minute. If the combined flow into a zone in cubic feet per minute is divided by the cubic volume of the zone (ft^3), the zonal Flow per Volume Factor (FVF) is calculated.

However, if FVF is used as a means of forced-air system balancing, caution must be exercised. In a homogenous zonal building (e.g., all zones are identical), all zones should have similar FVF. However, in nonhomogeneous cases, some areas of the building may have a higher FVF as a result of its usage or the number of people occupying the area. Depending on the degree of occupancy and usage of the zone, ASHRAE recommends minimal zonal ventilation rates. In most cases, this is based on a fixed amount of flow (ft^3/min) per person under a specific working environment. For example, in a USPS facility, the main mail sort room should have a higher FVF than a small, private office because more people work within that area. Therefore, using FVF as a means of achieving system balancing may reduce the overall air quality in a work area.

Another way of determining system balance is to measure individual room pressure relative to the outdoors (differential pressure (DP)). This measurement is obtained by using an electronic micromanometer with <1 Pa sensitivity. To perform the measurement, a reference DP measurement is made from one area to the outside. All other areas are then measured sequentially relative to the last area measured. Once normalized to the outdoors, all room DP measurements should be neutral (e.g., DP = 0) or positive and should be within 1 to 2 Pa of each other.
2.2.11 Continuous Radon Measurements

Numerous studies have shown that indoor radon levels are rarely constant. Changing external environmental factors (such as external temperature, rain, wind, and barometric pressure) can change the indoor radon concentration by as much as an order of magnitude in a few hours. In large buildings, other factors, such as mechanical duty cycle and room usage, can also have an impact on the radon concentration. For example, to save energy cost, an HVAC system that maintains a high ACH rate in the building during normal work hours will reduce that ventilation rate by a factor of 4 or 5 during the night. If the daytime levels of radon are 2 pCi/L, then the night levels maybe as high as 10 pCi/L. Passive radon detectors, such as the E-Perm, average the concentration of radon over a period of time. Therefore, the average passive measurement for the building would be >4 pCi/L. If the building is unoccupied during this time of elevated radon, then no mitigation would be needed. Another example is a high radon measurement in a vault. During the day while the vault door is open, the room’s ACH rate and radon level are comparable to those in the room in which the door is open. However, during the night when the vault door is closed, the ACH rate could drop as much as 2 orders of magnitude, resulting in a similar increase in the radon level. Again, a passive detector would indicate a problem when personnel are not being exposed to elevated radon.

To diagnose these types of problems, an active radon measurement or continuous measurement is performed. The instrument used for these types of measurements must have good sensitivity (±0.2 pCi/L), be able to perform the measurement at an interval of 1 hour or less, and have the ability to record the measurement as a timed event. If a measurement is performed, the radon concentration (y-axis) is plotted vs time in hours (x-axis). A comparison of the duty or usage cycle is then performed. For best results, a minimum of 48 hours is required for this type of measurement.

2.2.12 Initial Evaluation of the Mitigation Diagnostics Protocol

In 1993, at the request of USPS, HAZWRAP performed an initial evaluation of the mitigation diagnostic protocol at four sites: Allentown, Pennsylvania; Pueblo, Colorado; Big Spring, Texas; and Okmulgee, Oklahoma. The initial study indicated that all of the mitigation diagnostics were needed to determine a cost-effective mitigation solution. Also, the recommendation was made that additional studies be performed on a more diverse population of buildings to determine any weaknesses in the protocol. A more detailed review of the findings are reported in Radon Levels and Diagnostics at 38 U.S. Postal Service Sites (DOE/HWP-140).

2.3 ADVANCED EVALUATION OF MITIGATION DIAGNOSTICS PROTOCOL

In June 1993, a meeting was held between the GSA and USPS to discuss elevated levels of radon in GSA out-leased space in USPS-owned buildings. GSA expressed an interest in the USPS performing radon mitigation in GSA out-leased buildings in which radon had been measured >4 pCi/L. USPS also committed to GSA that the mitigation would be performed based on the recommendations of an on-site mitigation evaluation. USPS also committed to GSA to perform mitigation diagnostics at 18 USPS sites with out-leased GSA tenants during 1994.

In January 1994, USPS tasked HAZWRAP to perform further evaluations of the proposed mitigation diagnostics protocol at 18 GSA out-leased sites and 4 USPS sites. In addition to the evaluation, HAZWRAP was to provide a draft protocol at the completion of the testing and
recommend the best mitigation diagnostic methods. The sites for the 1994 diagnostic study are listed in Table 5.

Table 5. Sites for 1994 radon mitigation diagnostics study

<table>
<thead>
<tr>
<th>Location</th>
<th>Mitigate</th>
<th>GSA out-leased site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abilene, Texas</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ada, Oklahoma</td>
<td>Retest</td>
<td>Yes</td>
</tr>
<tr>
<td>Clovis, New Mexico</td>
<td>Retest</td>
<td>Yes</td>
</tr>
<tr>
<td>Dallas, Texas</td>
<td>Retest after HVAC system installed</td>
<td>Yes</td>
</tr>
<tr>
<td>Eastport, Maine</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Eldora, Iowa</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Enid, Oklahoma</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Florissant, Missouri (leased)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Griffin, Georgia</td>
<td>Manage in place</td>
<td>Yes</td>
</tr>
<tr>
<td>Lancaster, Ohio</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Lowville, New York</td>
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<td>Yes</td>
</tr>
<tr>
<td>Machias, Maine</td>
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<tr>
<td>Marion, Indiana</td>
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<tr>
<td>Paris, Kentucky</td>
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<td>Yes</td>
</tr>
<tr>
<td>Raton, New Mexico</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Rockland, Maine</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Scott City, Kansas</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Talladega, Alabama</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Watertown, New York (163 Arsenal Road)</td>
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<td>No</td>
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<td>Waynesville, North Carolina</td>
<td>No</td>
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<tr>
<td>Willimantic, Connecticut (leased)</td>
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<td>No</td>
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<tr>
<td>Wrightsville, Georgia</td>
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</table>
2.4 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN ABILENE, TEXAS

The main post office in Abilene, Texas, located at 314 Pine Street, was constructed in 1936. The four-story building had one addition in 1964. The substructure consists of a one-level basement subdivided with concrete walls. The 154,560-ft² building has a total of 11 HVAC forced-air systems. Heating is provided by a hot water exchanger, while cooling is provided by chilled water. In August 1993, 156 short-term radon measurements were performed by USPS. A total of two measurements were >4 pCi/L.

Mitigation diagnostics were performed by the HAZWRAP team in May 1994. The diagnostics performed at the site are listed in Table 6.

<table>
<thead>
<tr>
<th>Diagnostic test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Air change</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>No suitable doorway</td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed</td>
<td>7 tests</td>
</tr>
<tr>
<td></td>
<td>Part 2 completed</td>
<td></td>
</tr>
<tr>
<td>Continuous radon</td>
<td>21 measurements</td>
<td>Elevated radon detected</td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>Safety (ceiling too high)</td>
</tr>
<tr>
<td>Radon entry measurements</td>
<td>9</td>
<td>0 to 6 counts per minute</td>
</tr>
<tr>
<td>Pressure mapping</td>
<td>107</td>
<td>Lower floors (negative)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper floors (positive)</td>
</tr>
</tbody>
</table>

During the continuous radon measurements, elevated radon was detected in two unoccupied storage rooms (B004 and B022). Both rooms have no windows or ventilation. However, radon concentration changes were a function of the HVAC day/night cycle: lower during the day and higher at night. All other rooms were found to be <4 pCi/L. Table 7 summarizes the continuous radon measurements for the site.
Table 7. Summary of continuous radon measurements for the U.S. Post Office in Abilene, Texas

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0.8</td>
<td>Room B006</td>
</tr>
<tr>
<td>02</td>
<td>1.0</td>
<td>Basement supply office</td>
</tr>
<tr>
<td>03</td>
<td>4.2</td>
<td>Room B022</td>
</tr>
<tr>
<td>04</td>
<td>4.3</td>
<td>Room B004</td>
</tr>
<tr>
<td>05</td>
<td>0.3</td>
<td>Postmaster’s office</td>
</tr>
<tr>
<td>06</td>
<td>0.4</td>
<td>Breakroom</td>
</tr>
<tr>
<td>07</td>
<td>0.5</td>
<td>Basement wood shop</td>
</tr>
<tr>
<td>08</td>
<td>0.8</td>
<td>Basement Room 001</td>
</tr>
<tr>
<td>09</td>
<td>0.9</td>
<td>Room 2109</td>
</tr>
<tr>
<td>10</td>
<td>0.7</td>
<td>Room 2317</td>
</tr>
<tr>
<td>11</td>
<td>0.4</td>
<td>Main room (front center)</td>
</tr>
<tr>
<td>12</td>
<td>0.6</td>
<td>Main room (center)</td>
</tr>
<tr>
<td>13</td>
<td>0.8</td>
<td>Boiler room</td>
</tr>
<tr>
<td>14</td>
<td>0.9</td>
<td>Basement shop</td>
</tr>
<tr>
<td>15</td>
<td>1.2</td>
<td>Room B003</td>
</tr>
<tr>
<td>16</td>
<td>0.7</td>
<td>Main room</td>
</tr>
<tr>
<td>17</td>
<td>0.4</td>
<td>Main room</td>
</tr>
<tr>
<td>18</td>
<td>0.2</td>
<td>Main room</td>
</tr>
<tr>
<td>19</td>
<td>0.9</td>
<td>Room B012</td>
</tr>
<tr>
<td>20</td>
<td>0.8</td>
<td>Room 001</td>
</tr>
<tr>
<td>21</td>
<td>0.7</td>
<td>Room 2202</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms in the building. The HVAC day/night duty cycle indicates significant differences between night and day ACH rates as a function of HVAC operation (Table 8).
Table 8. Air change measurements at the U.S. Post Office in Abilene, Texas

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>B001 south</td>
<td>1A/4855</td>
<td>0.21</td>
<td>No ventilation</td>
</tr>
<tr>
<td>B001 north</td>
<td>1A/9346</td>
<td>0.07</td>
<td>No ventilation</td>
</tr>
<tr>
<td>B102</td>
<td>101/2377</td>
<td>0.13</td>
<td>HVAC off</td>
</tr>
<tr>
<td>Main room north</td>
<td>1A/4855</td>
<td>0.04</td>
<td>HVAC off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.11</td>
<td>HVAC on</td>
</tr>
<tr>
<td>Main room south</td>
<td>1A/6346</td>
<td>0.29</td>
<td>HVAC on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.17</td>
<td>HVAC off</td>
</tr>
<tr>
<td>B102</td>
<td>101/2377</td>
<td>0.49</td>
<td>HVAC on</td>
</tr>
<tr>
<td>Main room north</td>
<td>1A/4855</td>
<td>0.32</td>
<td>HVAC on</td>
</tr>
<tr>
<td>Main room south</td>
<td>1A/9346</td>
<td>0.36</td>
<td>HVAC on</td>
</tr>
<tr>
<td>Postmaster's office</td>
<td>101/2377</td>
<td>0.05</td>
<td>HVAC off</td>
</tr>
<tr>
<td>2113</td>
<td>1A/4855</td>
<td>0.17</td>
<td>HVAC off</td>
</tr>
<tr>
<td>Postmaster's office</td>
<td>101/2377</td>
<td>0.26</td>
<td>HVAC on</td>
</tr>
<tr>
<td>2113</td>
<td>1A/4855</td>
<td>0.32</td>
<td>HVAC on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.04</td>
<td>HVAC off</td>
</tr>
<tr>
<td>2320</td>
<td>101/2377</td>
<td>0.12</td>
<td>HVAC off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.44</td>
<td>HVAC on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.26</td>
<td>HVAC on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.10</td>
<td>HVAC off</td>
</tr>
<tr>
<td>2320</td>
<td>101/2377</td>
<td>0.26</td>
<td>HVAC on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.14</td>
<td>HVAC off</td>
</tr>
</tbody>
</table>

Subslab diagnostics were performed at multiple locations throughout the basement. The data (Table 9) indicate good subslab field extension.
Radon entry pathway diagnostics identified no major entry pathways into the building. The results are listed in Table 10.

Table 10. Radon entry pathway diagnostics for the U.S. Post Office in Abilene, Texas

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall-to-floor joint</td>
<td>B102</td>
<td>6</td>
</tr>
<tr>
<td>Door joint</td>
<td>Basement freight elevator</td>
<td>3</td>
</tr>
<tr>
<td>Floor crack</td>
<td>Basement</td>
<td>4</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Basement</td>
<td>4</td>
</tr>
<tr>
<td>Floor joint</td>
<td>Basement supply area</td>
<td>4</td>
</tr>
<tr>
<td>Floor joint</td>
<td>Basement</td>
<td>3</td>
</tr>
<tr>
<td>Drain</td>
<td>Boiler room</td>
<td>1</td>
</tr>
<tr>
<td>False-floor joint</td>
<td>Boiler room</td>
<td>0</td>
</tr>
<tr>
<td>Door joint</td>
<td>Basement passenger elevator</td>
<td>2</td>
</tr>
</tbody>
</table>
During the diagnostic tests, a DP map of the building was performed. The data indicated that the basement and first floors are under negative pressure, while the second, third, fourth, and fifth floors were found to be under positive pressure. DP data are listed in Table 11.

Table 11. Differential pressure measurements for the U.S. Post Office in Abilene, Texas

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>Basement</td>
</tr>
<tr>
<td>Basement</td>
<td>-4</td>
</tr>
<tr>
<td>Breakroom</td>
<td>-6</td>
</tr>
<tr>
<td>Maintenance support room</td>
<td>-6</td>
</tr>
<tr>
<td>Hallway (basement)</td>
<td>-7</td>
</tr>
<tr>
<td>AH-1</td>
<td>-4</td>
</tr>
<tr>
<td>B003</td>
<td>-6</td>
</tr>
<tr>
<td>B006</td>
<td>-6</td>
</tr>
<tr>
<td>B008</td>
<td>-8</td>
</tr>
<tr>
<td>B012</td>
<td>-6</td>
</tr>
<tr>
<td>B014</td>
<td>-6</td>
</tr>
<tr>
<td>B016</td>
<td>-6</td>
</tr>
<tr>
<td>B020</td>
<td>-7</td>
</tr>
<tr>
<td>B024 (stairwell)</td>
<td>-6</td>
</tr>
<tr>
<td>First Floor</td>
<td>First Floor</td>
</tr>
<tr>
<td>Entry</td>
<td>0</td>
</tr>
<tr>
<td>Lobby</td>
<td>1</td>
</tr>
<tr>
<td>1001</td>
<td>1</td>
</tr>
<tr>
<td>1005</td>
<td>-1</td>
</tr>
<tr>
<td>1009</td>
<td>-1</td>
</tr>
<tr>
<td>Postmaster’s office</td>
<td>-1</td>
</tr>
<tr>
<td>Location</td>
<td>Differential pressure relative to outdoors (Pa)</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Manager of operations</td>
<td>3</td>
</tr>
<tr>
<td>Conference room</td>
<td>-1</td>
</tr>
<tr>
<td>Bathroom</td>
<td>-1</td>
</tr>
<tr>
<td>Customer relations</td>
<td>0</td>
</tr>
<tr>
<td>Workroom</td>
<td>2</td>
</tr>
<tr>
<td>Men's restroom</td>
<td>2</td>
</tr>
<tr>
<td>Women's restroom</td>
<td>3</td>
</tr>
<tr>
<td>Second Floor</td>
<td></td>
</tr>
<tr>
<td>Stairwell 1</td>
<td>0</td>
</tr>
<tr>
<td>Hallway</td>
<td>2</td>
</tr>
<tr>
<td>2000</td>
<td>3</td>
</tr>
<tr>
<td>2000A</td>
<td>2</td>
</tr>
<tr>
<td>2001 Stairwell 2</td>
<td>4</td>
</tr>
<tr>
<td>2002</td>
<td>2</td>
</tr>
<tr>
<td>2004</td>
<td>3</td>
</tr>
<tr>
<td>2005</td>
<td>2</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
</tr>
<tr>
<td>2007-8</td>
<td>4</td>
</tr>
<tr>
<td>2010</td>
<td>2</td>
</tr>
<tr>
<td>2012</td>
<td>2</td>
</tr>
<tr>
<td>2013</td>
<td>4</td>
</tr>
<tr>
<td>Bathroom</td>
<td>-1</td>
</tr>
<tr>
<td>2101</td>
<td>4</td>
</tr>
<tr>
<td>2102</td>
<td>4</td>
</tr>
</tbody>
</table>
Table 11 (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2103</td>
<td>3</td>
</tr>
<tr>
<td>2104</td>
<td>4</td>
</tr>
<tr>
<td>2105</td>
<td>3</td>
</tr>
<tr>
<td>2106</td>
<td>2</td>
</tr>
<tr>
<td>2107</td>
<td>2</td>
</tr>
<tr>
<td>2108</td>
<td>3</td>
</tr>
<tr>
<td>2109</td>
<td>0</td>
</tr>
<tr>
<td>2110</td>
<td>4</td>
</tr>
<tr>
<td>2111</td>
<td>-1</td>
</tr>
<tr>
<td>2112</td>
<td>3</td>
</tr>
<tr>
<td>2113</td>
<td>2</td>
</tr>
<tr>
<td>2201</td>
<td>2</td>
</tr>
<tr>
<td>2202</td>
<td>2</td>
</tr>
<tr>
<td>2203</td>
<td>3</td>
</tr>
<tr>
<td>2205</td>
<td>3</td>
</tr>
<tr>
<td>2207</td>
<td>2</td>
</tr>
<tr>
<td>2208</td>
<td>3</td>
</tr>
<tr>
<td>2209</td>
<td>4</td>
</tr>
<tr>
<td>2210</td>
<td>2</td>
</tr>
<tr>
<td>2211</td>
<td>1</td>
</tr>
<tr>
<td>2301</td>
<td>2</td>
</tr>
<tr>
<td>2302</td>
<td>3</td>
</tr>
<tr>
<td>2304</td>
<td>3</td>
</tr>
<tr>
<td>Location</td>
<td>Differential pressure relative to outdoors (Pa)</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>2305</td>
<td>3</td>
</tr>
<tr>
<td>2306</td>
<td>0</td>
</tr>
<tr>
<td>2308</td>
<td>0</td>
</tr>
<tr>
<td>2308-B</td>
<td>1</td>
</tr>
<tr>
<td>2310</td>
<td>0</td>
</tr>
<tr>
<td>2311</td>
<td>1</td>
</tr>
<tr>
<td>2312</td>
<td>0</td>
</tr>
<tr>
<td>2313</td>
<td>0</td>
</tr>
<tr>
<td>2314</td>
<td>0</td>
</tr>
<tr>
<td>2315</td>
<td>2</td>
</tr>
<tr>
<td>2317</td>
<td>4</td>
</tr>
<tr>
<td>2318</td>
<td>0</td>
</tr>
<tr>
<td>2319</td>
<td>2</td>
</tr>
<tr>
<td>2320</td>
<td>-2</td>
</tr>
<tr>
<td>2321</td>
<td>3</td>
</tr>
<tr>
<td>2324</td>
<td>-1</td>
</tr>
<tr>
<td>2326</td>
<td>2</td>
</tr>
<tr>
<td>2401</td>
<td>3</td>
</tr>
<tr>
<td>2402</td>
<td>2</td>
</tr>
<tr>
<td>2403</td>
<td>1</td>
</tr>
<tr>
<td>2404</td>
<td>4</td>
</tr>
<tr>
<td>Third Floor</td>
<td>Third Floor</td>
</tr>
<tr>
<td>Hallway</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 11 (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3002</td>
<td>8 (suspect)</td>
</tr>
<tr>
<td>3003</td>
<td>-1</td>
</tr>
<tr>
<td>3004</td>
<td>3</td>
</tr>
<tr>
<td>3006</td>
<td>10 (suspect)</td>
</tr>
<tr>
<td>3008</td>
<td>19 (suspect)</td>
</tr>
<tr>
<td>3009</td>
<td>4</td>
</tr>
<tr>
<td>3010</td>
<td>2</td>
</tr>
<tr>
<td>3011</td>
<td>4</td>
</tr>
<tr>
<td>3012</td>
<td>2</td>
</tr>
<tr>
<td>3014</td>
<td>4</td>
</tr>
<tr>
<td>3101</td>
<td>3</td>
</tr>
<tr>
<td>3103</td>
<td>4</td>
</tr>
</tbody>
</table>

Blower door measurements could not be performed because of the lack of a suitable exterior door. Flow hood measurements could not be performed because of the high ceiling and vent design.

Based on data collected, the primary mitigation attempt should be the installation of passive vents in the doors for Rooms B004 and B022. The estimated mitigation cost would be approximately $200. If that attempt is unsuccessful, the addition of a small intake fan (75 to 150 ft³/min) above each door exhausting into the rooms should increase the ventilation sufficiently for mitigation. The estimated cost for the secondary mitigation attempt would be $450.

2.5 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN ADA, OKLAHOMA

The main post office in Ada, Oklahoma, located at 131 E. 13th Street, is a four-story building constructed in 1935. The substructure consists of a slab on grade (90%) and crawl space (10%). The approximately 40,000-ft² building has multiple HVAC forced-air systems. Heating is provided by electricity and a hot water exchanger, while cooling is provided by air compression. The fresh air intakes are located on the roof of the building.

In August 1992, 28 short-term radon measurements were performed at the site by USPS personnel. None of the results were found to be above the 4-pCi/L action level. In June 1994, the mitigation diagnostics were performed on the site by the HAZWRAP team. The diagnostics performed by the team are summarized in Table 12.
Table 12. Mitigation diagnostics summary for the U.S. Post Office in Ada, Oklahoma

<table>
<thead>
<tr>
<th>Diagnostic test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Part 2 completed</td>
<td></td>
</tr>
<tr>
<td>Continuous radon</td>
<td>16 measurements</td>
<td>No elevated radon detected</td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>Vents inaccessible</td>
</tr>
<tr>
<td>Radon entry</td>
<td>5</td>
<td>1 to 9 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>32</td>
<td>Basement neutral, 1st floor negative, 2nd floor positive</td>
</tr>
</tbody>
</table>

Sixteen continuous measurements were performed in various rooms in the building. No elevated radon was detected. The continuous radon measurements are summarized in Table 13.

Table 13. Summary of continuous radon measurements for the U.S. Post Office in Ada, Oklahoma

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0.9</td>
<td>Pump room</td>
</tr>
<tr>
<td>02</td>
<td>0.8</td>
<td>Storage room</td>
</tr>
<tr>
<td>04</td>
<td>1.3</td>
<td>Maintenance office</td>
</tr>
<tr>
<td>05</td>
<td>0.4</td>
<td>Postmaster's office</td>
</tr>
<tr>
<td>06</td>
<td>0.7</td>
<td>Office supply room</td>
</tr>
<tr>
<td>07</td>
<td>0.2</td>
<td>Breakroom</td>
</tr>
<tr>
<td>08</td>
<td>0.6</td>
<td>Boiler room</td>
</tr>
<tr>
<td>11</td>
<td>0.6</td>
<td>Room 232</td>
</tr>
<tr>
<td>13</td>
<td>0.7</td>
<td>Main room (front)</td>
</tr>
<tr>
<td>14</td>
<td>0.6</td>
<td>Main room (back left)</td>
</tr>
<tr>
<td>15</td>
<td>1.0</td>
<td>Room 204</td>
</tr>
<tr>
<td>16</td>
<td>0.6</td>
<td>Main room</td>
</tr>
</tbody>
</table>
Table 13 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>0.5</td>
<td>Main room</td>
</tr>
<tr>
<td>18</td>
<td>0.5</td>
<td>File room</td>
</tr>
<tr>
<td>19</td>
<td>0.6</td>
<td>Room 215</td>
</tr>
<tr>
<td>21</td>
<td>0.7</td>
<td>Main room</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms in the building. The data indicate significant differences between night and day ACH rates as a function of the HVAC cycle (Table 14).

Table 14. Summary of air change measurements for the U.S. Post Office in Ada, Oklahoma

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement storage</td>
<td>101/4855</td>
<td>0.40</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Breakroom</td>
<td>1A/9346</td>
<td>0.34</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Boiler room</td>
<td>1A/2377</td>
<td>0.48</td>
<td>No ventilation</td>
</tr>
<tr>
<td>Basement storage</td>
<td>101/4855</td>
<td>0.04 0.23</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Breakroom</td>
<td>1A/9346</td>
<td>0.19</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Boiler room</td>
<td>1A/2377</td>
<td>0.52</td>
<td>No ventilation</td>
</tr>
<tr>
<td>Postmaster's office</td>
<td>101/4855</td>
<td>0.49</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room west</td>
<td>1A/9346</td>
<td>0.37</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room east</td>
<td>1A/2377</td>
<td>0.64</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Postmaster's office</td>
<td>101/4855</td>
<td>0.09 0.40</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Main room west</td>
<td>1A/9346</td>
<td>0.07 0.27</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Main room east</td>
<td>1A/2377</td>
<td>0.12 0.50</td>
<td>Air conditioning off</td>
</tr>
</tbody>
</table>

2-21
A single subslab diagnostic was performed in the basement. The data (Table 15) indicate excellent communication beneath the slab.

Table 15. Subslab field extension data for the U.S. Post Office in Ada, Oklahoma

<table>
<thead>
<tr>
<th>Hole</th>
<th>Location</th>
<th>Field extension (ft)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material (in.)</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.45 (in.)</td>
<td>Basement</td>
<td>40+</td>
<td>5.5</td>
<td>0.125 to 0.5 gravel</td>
<td>4</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics did not identify any major entry pathways. The data are provided in Table 16.

Table 16. Radon entry pathway data for the U.S. Post Office in Ada, Oklahoma

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain</td>
<td>Basement boiler room</td>
<td>1</td>
</tr>
<tr>
<td>Wall</td>
<td>Basement pump room</td>
<td>1</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Basement boiler room</td>
<td>0</td>
</tr>
<tr>
<td>Open area</td>
<td>Crawl space</td>
<td>1</td>
</tr>
<tr>
<td>Gravel</td>
<td>Crawl space</td>
<td>9</td>
</tr>
</tbody>
</table>

DP measurements in the building found that the basement area was under negative pressure. The results are listed in Table 17.

Table 17. Differential pressure measurements for the U.S. Post Office in Ada, Oklahoma

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement storage</td>
<td>-3</td>
</tr>
<tr>
<td>Pump room</td>
<td>-4</td>
</tr>
<tr>
<td>Office storage</td>
<td>-5</td>
</tr>
<tr>
<td>Maintenance storage</td>
<td>-9 (suspect)</td>
</tr>
<tr>
<td>Maintenance office</td>
<td>-3</td>
</tr>
<tr>
<td>Back hallway</td>
<td>-4</td>
</tr>
<tr>
<td>Crawl space</td>
<td>-5</td>
</tr>
<tr>
<td>Front hallway</td>
<td>-5</td>
</tr>
</tbody>
</table>
Flow hood measurements could not be performed because of the design of the supply vent. Although the blower door test was performed, the data were inconclusive because of the large size of the building and the amount of customer traffic.

Since the last radon measurements were taken (1992), the HVAC system has been replaced with a new system. Because no elevated radon was detected during the mitigation diagnostics, it is suspected that the new HVAC system corrected the problem identified by GSA. The
recommendation is made that confirmatory long-term measurements be performed in the near future to confirm the absence of elevated radon.

2.6 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN CLOVIS, NEW MEXICO

The main post office in Clovis, New Mexico, is located at 405 Gidding Street. The two-story building was constructed in 1966 and has a slab-on-grade substructure. The 11,858-ft² building has one HVAC forced-air system. Heating is provided by a hot water exchanger, while cooling is provided by chilled water. The fresh air intakes are located on the roof of the building.

In August 1992, 34 short-term measurements were performed by USPS personnel. One measurement (7.0 pCi/L) was found to be above the action level. A follow-up 1-year electret measurement (1992–1993) conducted by USPS personnel confirmed the presence of elevated radon at the site.

In May 1994, the HAZWRAP team performed mitigation diagnostics at the site (Table 18).

Table 18. Mitigation diagnostics summary for the U.S. Post Office in Clovis, New Mexico

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>No suitable exterior doorway</td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed</td>
<td>Fractured sand base, not suitable for subslab mitigation</td>
</tr>
<tr>
<td></td>
<td>Part 2 not completed</td>
<td></td>
</tr>
<tr>
<td>Continuous radon measurements</td>
<td>19 instruments</td>
<td>No elevated levels of radon detected</td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>Height, size of vent</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>11</td>
<td>0 to 13 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>14</td>
<td>Positive pressure</td>
</tr>
</tbody>
</table>

During the diagnostics, 19 continuous radon measurements were collected in various areas of the building. None of the readings were >4 pCi/L. The continuous radon measurement data are summarized in Table 19.

Table 19. Summary of continuous radon measurements for the U.S. Post Office in Clovis, New Mexico

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0.5</td>
<td>CFS office</td>
</tr>
<tr>
<td>02</td>
<td>0.5</td>
<td>Supervisor's office</td>
</tr>
</tbody>
</table>
Table 19 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>03</td>
<td>0.2</td>
<td>Main room</td>
</tr>
<tr>
<td>04</td>
<td>0.4</td>
<td>Main room</td>
</tr>
<tr>
<td>05</td>
<td>0.8</td>
<td>Postmaster's office</td>
</tr>
<tr>
<td>06</td>
<td>0.4</td>
<td>Main room</td>
</tr>
<tr>
<td>07</td>
<td>0.4</td>
<td>Main room</td>
</tr>
<tr>
<td>08</td>
<td>0.3</td>
<td>Back sort room</td>
</tr>
<tr>
<td>09</td>
<td>1.1</td>
<td>Room 240</td>
</tr>
<tr>
<td>10</td>
<td>0.8</td>
<td>Room 216</td>
</tr>
<tr>
<td>11</td>
<td>0.9</td>
<td>Room 270</td>
</tr>
<tr>
<td>12</td>
<td>1.0</td>
<td>ACSC office</td>
</tr>
<tr>
<td>14</td>
<td>0.7</td>
<td>Shop</td>
</tr>
<tr>
<td>15</td>
<td>0.9</td>
<td>Room 207</td>
</tr>
<tr>
<td>16</td>
<td>1.0</td>
<td>Bulk mail office</td>
</tr>
<tr>
<td>17</td>
<td>0.5</td>
<td>Electrical and mechanical room</td>
</tr>
<tr>
<td>18</td>
<td>0.5</td>
<td>Room 252</td>
</tr>
<tr>
<td>19</td>
<td>0.9</td>
<td>Maintenance office</td>
</tr>
<tr>
<td>20</td>
<td>0.8</td>
<td>Side sort room</td>
</tr>
<tr>
<td>21</td>
<td>0.9</td>
<td>Room 260</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms in the building. The data indicate significant differences between night and day ACH rates as a function of the HVAC cycle (Table 20).

Table 20. Air change summary for the U.S. Post Office in Clovis, New Mexico

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>260</td>
<td>101/4855</td>
<td>0.19</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.37</td>
<td>Air conditioning on</td>
</tr>
</tbody>
</table>

2-25
Radon entry pathway diagnostics were also performed at the site. No significant entry pathways were identified. The entry pathway data are listed in Table 21.

Table 21. Radon entry pathway data for the U.S. Post Office in Clovis, New Mexico

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab joint</td>
<td>Side sort room</td>
<td>5</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Side sort room</td>
<td>5</td>
</tr>
<tr>
<td>Drain</td>
<td>Janitor’s closet (off main room)</td>
<td>2</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Back sort room</td>
<td>1</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Main room (front left)</td>
<td>4</td>
</tr>
<tr>
<td>Drain</td>
<td>Mechanical room</td>
<td>1</td>
</tr>
<tr>
<td>Drain</td>
<td>Boiler room</td>
<td>2</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Boiler room</td>
<td>2</td>
</tr>
<tr>
<td>Drain</td>
<td>Boiler room</td>
<td>0</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Maintenance office</td>
<td>3</td>
</tr>
<tr>
<td>Electrical outlet (floor)</td>
<td>Superintendent’s office</td>
<td>13</td>
</tr>
</tbody>
</table>
DP measurements were also performed at the site. However, no conclusive trends were noted. The DP data are listed in Table 22.

Table 22. Differential pressure measurements for the U.S. Post Office in Clovis, New Mexico

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Floor</td>
<td>First Floor</td>
</tr>
<tr>
<td>Front lobby</td>
<td>-2</td>
</tr>
<tr>
<td>Customer counter</td>
<td>1</td>
</tr>
<tr>
<td>Main room</td>
<td>-2</td>
</tr>
<tr>
<td>Side lobby</td>
<td>-7 (suspect)</td>
</tr>
<tr>
<td>Central forwarding</td>
<td>0</td>
</tr>
<tr>
<td>Second Floor</td>
<td>Second Floor</td>
</tr>
<tr>
<td>Hallway</td>
<td>0</td>
</tr>
<tr>
<td>204</td>
<td>2</td>
</tr>
<tr>
<td>207</td>
<td>8 (suspect)</td>
</tr>
<tr>
<td>214</td>
<td>4</td>
</tr>
<tr>
<td>235</td>
<td>0</td>
</tr>
<tr>
<td>260</td>
<td>-4</td>
</tr>
<tr>
<td>Back stairwell</td>
<td>-3</td>
</tr>
</tbody>
</table>

Inspection of the subslab diagnostic hole revealed a dry, compacted sand as the subslab material. Materials such as this have a tendency to dry out and crack. Over time, these subslab material cracks tend to network to the outside. A vacuum, when applied to this type of material in this state, will not flow radially but will flow the path of least resistance along the channels created by the cracks. The subslab diagnostics revealed substantial communication to the outside, meaning that the cracks have penetrated the foundation. Because SSD mitigation is dependent on radial field extension, not channeling, it was concluded that the subslab material was highly fractured and ill-suited for SSD mitigation.

The blower door test could not be performed because of the absence of a suitable exterior door. The flow hood measurements could not be performed because of height restrictions and supply vent design.

Because of the absence of the previously detected elevated radon and no plausible explanation, it is recommended that a heating season measurement be performed to determine whether the radon is a seasonal problem. If these measurements confirm a seasonal problem, then SP would be the primary mitigation method. This would require an upgrade of the building shell (e.g., sealing of windows and doors, addition of an airlock at the main and back entrances), and the installation of an additional HVAC 10,000-ft³/min unit. The additional HVAC unit

2-27
should be sufficient to maintain a pressure of 5 to 8 Pa in the lower floor of the building. The cost of the SP mitigation system is estimated to be $72.5K (includes other building modifications). Because of the type of subslab material and the already high ACH rate, there are no other conventional mitigation methods. However, a depressurized floor plenum system (an airtight subfloor installed on top of the existing slab) depressurized at 8 to 10 Pa could be installed in the effective areas at a cost of $15/ft².

2.7 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN DALLAS, TEXAS

The downtown post office in Dallas, Texas, located at Bryan and Ervey Street, is a five-story building constructed in 1929. The substructure consists of a one-level basement and is subdivided with concrete walls. The approximately 212,970-ft² building is serviced by multiple HVAC forced-air systems (exact number unavailable). Heating is provided by hot water exchange, while cooling is provided by chilled water. The fresh air intakes are located on the roof of the building. At the time of Phase 2 diagnostics, the old HVAC systems were being replaced. In August 1992, USPS personnel conducted a total of 165 short-term radon measurements in the building. Two measurements, both in the basement, were >4 pCi/L.

In May 1994, the HAZWRAP team conducted the Phase 2 mitigation diagnostics. Table 23 summarizes the mitigation diagnostics.

### Table 23. Summary of mitigation diagnostics performed at the U.S. Post Office in Dallas, Texas

<table>
<thead>
<tr>
<th>Diagnostic test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>No suitable exterior doorway</td>
</tr>
<tr>
<td>Subslab</td>
<td>1 test</td>
<td></td>
</tr>
<tr>
<td>Continuous radon measurements</td>
<td>21 measurements</td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>18</td>
<td>73 to 1001 ft³/min</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>13</td>
<td>0 to 11 counts per minute</td>
</tr>
<tr>
<td>Differential pressure mapping</td>
<td>15</td>
<td>All negative results (unit installation incomplete)</td>
</tr>
</tbody>
</table>

Twenty-one continuous radon measurements were performed in the building. None of the measurements were >4 pCi/L. The continuous radon readings are summarized in Table 24.
<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1.8</td>
<td>Room 17</td>
</tr>
<tr>
<td>02</td>
<td>0.6</td>
<td>Manager's office</td>
</tr>
<tr>
<td>03</td>
<td>0.7</td>
<td>Room 26 (August 1992 reading: 8.7 pCi/L)</td>
</tr>
<tr>
<td>04</td>
<td>1.4</td>
<td>Room 24A</td>
</tr>
<tr>
<td>05</td>
<td>1.5</td>
<td>Room 22A</td>
</tr>
<tr>
<td>06</td>
<td>1.8</td>
<td>Room 53</td>
</tr>
<tr>
<td>07</td>
<td>0.3</td>
<td>Breakroom</td>
</tr>
<tr>
<td>08</td>
<td>1.1</td>
<td>Room 28</td>
</tr>
<tr>
<td>09</td>
<td>0.8</td>
<td>Computer room</td>
</tr>
<tr>
<td>10</td>
<td>0.7</td>
<td>Main room (east center)</td>
</tr>
<tr>
<td>11</td>
<td>0.6</td>
<td>IRS storage room</td>
</tr>
<tr>
<td>12</td>
<td>0.8</td>
<td>Room 20</td>
</tr>
<tr>
<td>13</td>
<td>0.8</td>
<td>Room 45</td>
</tr>
<tr>
<td>14</td>
<td>0.7</td>
<td>Main room (west center)</td>
</tr>
<tr>
<td>15</td>
<td>1.3</td>
<td>Room B-31 (August 1992 reading: 4.0 pCi/L)</td>
</tr>
<tr>
<td>16</td>
<td>0.9</td>
<td>Main room (front center)</td>
</tr>
<tr>
<td>17</td>
<td>0.7</td>
<td>Main room (center)</td>
</tr>
<tr>
<td>18</td>
<td>0.5</td>
<td>Basement near chiller</td>
</tr>
<tr>
<td>19</td>
<td>0.7</td>
<td>Room 10A</td>
</tr>
<tr>
<td>20</td>
<td>1.1</td>
<td>Room 21A</td>
</tr>
<tr>
<td>21</td>
<td>0.9</td>
<td>Basement shop</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms in the building. The data indicate significant differences between night and day ACH rates as a function of the HVAC cycle (Table 25).
Subslab diagnostics were performed in the basement. The results (Table 26) indicate excellent communication beneath the slab.

Table 25. Air change summary for the U.S. Post Office in Dallas, Texas

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room</td>
<td>1A/2337</td>
<td>0.26</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.21</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>102</td>
<td>101/4855</td>
<td>0.21</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/2337</td>
<td>0.36</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.36</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>161</td>
<td>101/4855</td>
<td>0.32</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Basement shop</td>
<td>1A/9346</td>
<td>0.52</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Basement shop</td>
<td>1A/9346</td>
<td>0.58</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>230</td>
<td>101/4855</td>
<td>0.27</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>B-31</td>
<td>1A/9346</td>
<td>0.08</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>230</td>
<td>1A/9346</td>
<td>0.15</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>B-31</td>
<td>1A/9346</td>
<td>0.86</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>240</td>
<td>101/4855</td>
<td>0.35</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>240</td>
<td>101/4855</td>
<td>0.22</td>
<td>Air conditioning off</td>
</tr>
</tbody>
</table>

Subslab diagnostics were performed in the basement. The results (Table 26) indicate excellent communication beneath the slab.

Table 26. Subslab field extension data for the U.S. Post Office in Dallas, Texas

<table>
<thead>
<tr>
<th>Hole 1.45 (in.)</th>
<th>Location</th>
<th>Field extension (ft)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material (in.)</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Basement shop</td>
<td>30</td>
<td>3.5</td>
<td>0.5 to 2 river rock</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics measurements did not indicate any significant entry pathways. The data are listed in Table 27.

2-30
Table 27. Radon entry pathway data for the U.S. Post Office in Dallas, Texas

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain</td>
<td>Room 21-A</td>
<td>1</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 21-A</td>
<td>7</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 22-A</td>
<td>4</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 21-B</td>
<td>5</td>
</tr>
<tr>
<td>Elevator shaft</td>
<td>Basement freight elevator</td>
<td>2</td>
</tr>
<tr>
<td>Floor joint</td>
<td>Stairwell</td>
<td>1</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Room 28</td>
<td>4</td>
</tr>
<tr>
<td>Drain</td>
<td>Room 32</td>
<td>0</td>
</tr>
<tr>
<td>Drain</td>
<td>Boiler room</td>
<td>2</td>
</tr>
<tr>
<td>Wall</td>
<td>Boiler room</td>
<td>11</td>
</tr>
<tr>
<td>Drain</td>
<td>Boiler room</td>
<td>6</td>
</tr>
<tr>
<td>Wall</td>
<td>Maintenance office</td>
<td>4</td>
</tr>
<tr>
<td>Elevator shaft</td>
<td>Basement passenger elevator</td>
<td>7</td>
</tr>
</tbody>
</table>

Flow hood measurements indicate that the flow is balanced for most of the rooms tested. The data are listed in Table 28.

Table 28. Flow hood measurements for the U.S. Post Office in Dallas, Texas

<table>
<thead>
<tr>
<th>Location</th>
<th>Uncorrected flow (ft³/min)</th>
<th>Corrected flow (ft³/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 157-A</td>
<td>245</td>
<td>259</td>
</tr>
<tr>
<td>Room 161</td>
<td>281</td>
<td>286</td>
</tr>
<tr>
<td>Room 167-B</td>
<td>295</td>
<td>309</td>
</tr>
<tr>
<td>Room 167-B</td>
<td>247</td>
<td>261</td>
</tr>
<tr>
<td>Room 111</td>
<td>227</td>
<td>249</td>
</tr>
<tr>
<td>Postigue</td>
<td>73</td>
<td>67</td>
</tr>
<tr>
<td>Postigue</td>
<td>397</td>
<td>412</td>
</tr>
<tr>
<td>Room 230</td>
<td>269</td>
<td>282</td>
</tr>
</tbody>
</table>
The blower door mitigation diagnostics could not be completed because a suitable exterior door was not available.

Although the radon problem appears to be resolved, the problem may reoccur in the future. During the Phase I inspection, inadequate ventilation in certain areas of the basement was noted and substantiated during the Phase 2 ACH measurements (Table 25). Because the HVAC system is being replaced, the ventilation system should be expanded to include all basement rooms. The basement should be retested after the HVAC installation is complete.

### 2.8 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN EASTPORT, MAINE

The main post office in Eastport, Maine, is a three-story building constructed in 1890. The substructure consists of a one-level basement subdivided with mostly concrete walls. The approximately 8,500-ft² building has no HVAC or heating and air conditioning (HAC) forced-air systems. Heating is provided by hot water exchanger, while cooling is not provided. During 1992-1993, ten 1-year radon measurements were performed by USPS personnel. Six of the ten measurements were found to be >4 pCi/L.

In July 1994, the HAZWRAP radon mitigation diagnostic team performed radon mitigation diagnostics at the site. Table 29 summarizes the mitigation diagnostic data.

#### Table 29. Radon mitigation diagnostics at the U.S. Post Office in Eastport, Maine

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>3</td>
<td>Windows open during the day</td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>No suitable exterior door</td>
</tr>
</tbody>
</table>
Table 29 (continued)

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subslab</td>
<td>Not completed</td>
<td>No plans; subslab utilities and slab was more than 10 in. thick</td>
</tr>
<tr>
<td>Continuous radon</td>
<td>13 measurements</td>
<td>1 measurement &gt;4 pCi/L</td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>No forced-air system</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>8</td>
<td>Lowest reading: 2 counts per minute</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Highest reading: 11 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>10</td>
<td>Weather problems</td>
</tr>
</tbody>
</table>

During the diagnostics, 13 continuous radon measurements were performed. One measurement, boiler room, was found to be >4 pCi/L. The windows were open during the day of the test periods. Table 30 summarizes the data.

Table 30. Summary of continuous radon measurements for the U.S. Post Office in Eastport, Maine

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0.9</td>
<td>Postmaster’s office</td>
</tr>
<tr>
<td>02</td>
<td>3.0</td>
<td>Customs office (back)</td>
</tr>
<tr>
<td>04</td>
<td>2.5</td>
<td>Customs office (front)</td>
</tr>
<tr>
<td>05</td>
<td>0.4</td>
<td>Coast guard berthing 2</td>
</tr>
<tr>
<td>06</td>
<td>0.7</td>
<td>Main room (center)</td>
</tr>
<tr>
<td>07</td>
<td>0.5</td>
<td>Coast Guard operations room</td>
</tr>
<tr>
<td>08</td>
<td>1.6</td>
<td>Maintenance office</td>
</tr>
<tr>
<td>09</td>
<td>0.1</td>
<td>Coast Guard mess room</td>
</tr>
<tr>
<td>12</td>
<td>0.4</td>
<td>Coast Guard berthing 1</td>
</tr>
<tr>
<td>16</td>
<td>0.7</td>
<td>Main room (back)</td>
</tr>
<tr>
<td>18</td>
<td>1.5</td>
<td>Basement bathroom</td>
</tr>
</tbody>
</table>

2-33
Air change measurements were performed in various rooms in the building. The data indicate significant differences between night and day ACH rates as a function of windows being open or closed (Table 31).

Table 31. Air change summary for the U.S. Post Office in Eastport, Maine

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.87</td>
<td>Windows open</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.74</td>
<td>Windows open</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.16</td>
<td>Windows closed</td>
</tr>
<tr>
<td>Main room</td>
<td>101/2377</td>
<td>0.34</td>
<td>Windows open</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.07</td>
<td>Windows closed</td>
</tr>
</tbody>
</table>

No major entry pathways were identified during the radon entry pathway diagnostics. However, the testing was incomplete because of an instrument malfunction that occurred during the diagnostics. It is important to note that a large, ground-contact hole (approximately 3 × 3 ft) was discovered in the floor of the oil storage tank room after the instrument malfunction. Although no entry pathway data are available, it is suspected that this hole is a major radon entry pathway into the room. The data are listed in Table 32.

Table 32. Radon entry pathway measurements at the U.S. Post Office in Eastport, Maine

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall vent</td>
<td>Basement bathroom</td>
<td>8</td>
</tr>
<tr>
<td>Drain</td>
<td>Boiler room</td>
<td>6</td>
</tr>
<tr>
<td>Wall</td>
<td>Boiler room</td>
<td>2</td>
</tr>
<tr>
<td>Chimney</td>
<td>Boiler room</td>
<td>11</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Storage room</td>
<td>2</td>
</tr>
<tr>
<td>Floor</td>
<td>Customs back office</td>
<td>8</td>
</tr>
</tbody>
</table>
DP measurements were complicated by open windows and by variable wind speed and direction. The data listed in Table 33 are approximate averages. These significant negative DP measurements indicate that the building shell must be tight.

**Table 33. Differential pressure measurements for the U.S. Post Office in Eastport, Maine**

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry</td>
<td>-5</td>
</tr>
<tr>
<td>Customs office</td>
<td>-5 (variable)</td>
</tr>
<tr>
<td>Tank room</td>
<td>-5 (variable)</td>
</tr>
<tr>
<td>Boiler room</td>
<td>-6</td>
</tr>
<tr>
<td>Hallway</td>
<td>-6</td>
</tr>
<tr>
<td>Bathroom</td>
<td>-6</td>
</tr>
<tr>
<td>Maintenance</td>
<td>-4</td>
</tr>
<tr>
<td>Storage room</td>
<td>-5</td>
</tr>
<tr>
<td>Electrical room</td>
<td>-6</td>
</tr>
<tr>
<td>First Floor</td>
<td>First Floor</td>
</tr>
<tr>
<td>Lobby</td>
<td>-4</td>
</tr>
<tr>
<td>Main room</td>
<td>-4</td>
</tr>
<tr>
<td>Postmaster's office</td>
<td>-4</td>
</tr>
<tr>
<td>Second Floor</td>
<td>Second Floor</td>
</tr>
<tr>
<td>Stairway</td>
<td>-3</td>
</tr>
<tr>
<td>Hallway</td>
<td>-1</td>
</tr>
<tr>
<td>Berthing 2</td>
<td>-1</td>
</tr>
</tbody>
</table>
Three mitigation diagnostics could not be performed because of construction or design restrictions. The blower door measurement could not be performed because the windows were open at the site and a suitable exterior door was not available. Because the building did not have a forced-air system, the flow hood measurement could not be performed. Because of the presence of subslab utilities and the absence of building plans, diagnostics were not performed for safety reasons. It is important to note that even if the plans had been available, the thickness of the slab (10 in.) would have prevented successful drilling.

Radon mitigation of the U.S. Post Office in Eastport, Maine, is complicated by several factors that would prevent the installation of a traditional radon mitigation system. For example, the building is listed as a national historic site, which places severe restrictions on the number of modifications that can be made to the exterior. For example, the addition of an SSD exhaust pipe on the exterior wall would be prohibited. Also, because the roof is both decorative and pitched, it would be impossible to place a mechanical unit on it. Placing the mechanical units on the ground next to the building might detract from the building's architectural lines.

In the oil tank room, a 3- × 3-ft sewer access hole is in the slab. The hole is in direct contact with the soil and is an obvious entry pathway for radon into the room. The first mitigation attempt should be to fill in the hole with concrete. Once completed, radon testing should be performed to determine whether a reduction has occurred. The estimated cost for this type of mitigation would be $300. If the passive mitigation attempt is unsuccessful, then four HRV units with a 750-ft³/min capacity each should be installed in each quarter of the basement. Each unit should be set for 100% intake and 75% exhaust to ensure a positive reading. Supply and exhaust ducting will have to be added to each room in the basement to ensure adequate air circulation. Intake locations for all HRV units should be located on the grass knoll area to prevent intake of car exhaust. HRV exhaust should be at ground level at the most convenient location. The estimated cost for this mitigation is $30K.

2.9 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN ELDORA, IOWA

The main post office in Eldora, Iowa, is a two-story building constructed in 1939. The substructure consists of a one-level basement. The basement is subdivided with mostly concrete walls. The approximately 9,500-ft² building has one HAC forced-air system located on the roof that services the main floor only. On the main floor, heating is provided by a hot water
exchanger, while cooling is provided by a compressor. There is no forced-air system in the basement; cooling is provided by window air conditioning units.

During 1989, GSA personnel performed two 30-day radon measurements, which were both >10 pCi/L. In August 1992, USPS personnel performed a total of 13 short-term measurements. None of the measurements were >4 pCi/L.

In June 1994, radon mitigation diagnostics were conducted by the HAZWRAP team. The mitigation diagnostic data are summarized in Table 34.

Table 34. Mitigation diagnostics summary for the U.S. Post Office in Eldora, Iowa

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>4</td>
<td>Poor basement ventilation rate</td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>No suitable exterior doorway</td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed</td>
<td>Good field extension</td>
</tr>
<tr>
<td></td>
<td>Part 2 completed</td>
<td></td>
</tr>
<tr>
<td>Continuous radon measurements</td>
<td>14 measurements</td>
<td>No readings &gt;4 pCi/L</td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>Ceiling too high (safety)</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>6</td>
<td>5 to 19 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>Basement: 12</td>
<td>Negative pressure</td>
</tr>
<tr>
<td></td>
<td>First and second floors: 10</td>
<td>Negative pressure</td>
</tr>
</tbody>
</table>

During the mitigation diagnostics, 14 continuous radon measurements were performed. Although all of the data average <4 pCi/L, some of the single night readings were >10 pCi/L in some rooms. This increase in radon concentration is consistent with the cycle of the building air conditioning system. The continuous radon measurement data are summarized in Table 35.

Table 35. Summary of continuous radon measurements for the U.S. Post Office in Eldora, Iowa

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>2.9</td>
<td>Room 4</td>
</tr>
<tr>
<td>02</td>
<td>3.4</td>
<td>Copy room</td>
</tr>
<tr>
<td>03</td>
<td>2.3</td>
<td>Room 11</td>
</tr>
<tr>
<td>04</td>
<td>3.1</td>
<td>Room 5</td>
</tr>
<tr>
<td>05</td>
<td>2.5</td>
<td>Room 9</td>
</tr>
<tr>
<td>06</td>
<td>3.1</td>
<td>Room 1</td>
</tr>
</tbody>
</table>
Air change measurements were performed in various rooms in the building. The data indicate significant differences between night and day ACH rates as a function of the HVAC cycle. The data are summarized in Table 36.

**Table 36. Air change summary for the U.S. Post Office in Eldora, Iowa**

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement 3</td>
<td>101/9346</td>
<td>0.08</td>
<td>Window air conditioning unit on</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.24 0.08</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>112</td>
<td>1A/2377</td>
<td>0.02</td>
<td>No ventilation</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.22 0.10</td>
<td>Air conditioning on</td>
</tr>
</tbody>
</table>

Subslab diagnostic measurements were performed in the boiler room located in the basement. The data in Table 37 indicate good field extension beneath the slab.

**Table 37. Subslab field extension data for the U.S. Post Office in Eldora, Iowa**

<table>
<thead>
<tr>
<th>Hole</th>
<th>Location</th>
<th>Field extension (ft)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material (in.)</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.45 (in.)</td>
<td>Boiler room</td>
<td>20</td>
<td>8.5</td>
<td>0.5 gravel</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Radon entry pathway diagnostics did not locate any major pathways. The data are summarized in Table 38.

Table 38. Radon entry pathway diagnostics for the U.S. Post Office in Eldora, Iowa

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack in pipe</td>
<td>Storage under stairs</td>
<td>4</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Boiler Room 6</td>
<td>5</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Conference Room 9</td>
<td>9</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 5</td>
<td>5</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Conference Room 3-B</td>
<td>13</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 1 Iowa ext. office</td>
<td>19</td>
</tr>
</tbody>
</table>

DP measurements indicate that the building is under negative pressure. The room DP data are listed in Table 39.

Table 39. Differential pressure measurements for the U.S. Post Office in Eldora, Iowa

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>Basement</td>
</tr>
<tr>
<td>Stairwell</td>
<td>-4</td>
</tr>
<tr>
<td>Hallway</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>-2</td>
</tr>
<tr>
<td>4</td>
<td>-2</td>
</tr>
<tr>
<td>5</td>
<td>-3</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Storage room</td>
<td>-3</td>
</tr>
<tr>
<td>Stairwell</td>
<td>-3</td>
</tr>
</tbody>
</table>
Two planned diagnostics could not be performed: (1) the blower door diagnostic could not be performed because the exterior door was not suitable, and (2) the flow hood measurements could not be completed because of the ceiling height.

Because of the configuration of the air conditioning unit, it is possible that effective radon control is being maintained by the air conditioning unit during summer months. Once the air conditioning system is deactivated, it is likely that radon levels will increase. Short-term testing during the heating season is recommended. Also, the current ventilation system does not provide adequate ventilation to the basement offices currently occupied. The recommendation is made that the current system be removed and a new building-wide HVAC system be installed. The cost for the new HVAC system is estimated to be $65K for service to all areas of the building.

**2.10 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN ENID, OKLAHOMA**

The main post office in Enid, Oklahoma, located at 115 West Broadway, is a three-story building constructed in 1940. The substructure consists of a one-level basement subdivided with concrete and hollow-clay tile walls. The approximately 85,000-ft² building has two HVAC forced-air systems. Heating is provided by hot water exchange, while cooling is provided by chilled water. The fresh air intakes are located on the roof of the building.

In 1989, GSA personnel performed radon testing at the site; one reading of 23.1 pCi/L was reported on the third floor. In August 1992, USPS personnel performed 50 short-term radon measurements (including the area identified by GSA). All of the measurements were <4 pCi/L.

In June 1994, radon mitigation diagnostics were performed by the HAZWRAP team. The mitigation diagnostics performed at the site are summarized in Table 40.
Table 40. Mitigation diagnostics summary for the U.S. Post Office in Enid, Oklahoma

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>No suitable exterior door</td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Part 2 completed</td>
<td></td>
</tr>
<tr>
<td>Continuous radon</td>
<td>21 measurements</td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>No access to vents</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>11</td>
<td>1 to 23 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>22</td>
<td>Basement and second floor: positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>First floor: neutral</td>
</tr>
</tbody>
</table>

During the diagnostics, 21 continuous radon measurements were performed. All of the measurements were <4 pCi/L. No increase in radon concentration was observed during the night cycle of the HVAC system. The average data are listed in Table 41.

Table 41. Summary of continuous radon measurements for the U.S. Post Office in Enid, Oklahoma

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0.2</td>
<td>Postmaster's office</td>
</tr>
<tr>
<td>02</td>
<td>0.8</td>
<td>Room 16</td>
</tr>
<tr>
<td>03</td>
<td>0.6</td>
<td>Room 30</td>
</tr>
<tr>
<td>04</td>
<td>0.4</td>
<td>Room 10</td>
</tr>
<tr>
<td>05</td>
<td>0.3</td>
<td>Room 5</td>
</tr>
<tr>
<td>06</td>
<td>0.6</td>
<td>Room 40</td>
</tr>
<tr>
<td>07</td>
<td>0.4</td>
<td>Room 17</td>
</tr>
<tr>
<td>08</td>
<td>1.7</td>
<td>Room 33</td>
</tr>
<tr>
<td>09</td>
<td>0.5</td>
<td>Main room</td>
</tr>
<tr>
<td>10</td>
<td>0.7</td>
<td>Room 11</td>
</tr>
<tr>
<td>11</td>
<td>0.5</td>
<td>Main room</td>
</tr>
</tbody>
</table>

2-41
Air change measurements were performed in various rooms in the building. The data indicate significant differences between night and day ACH rates as a function of the HVAC cycle. The data are summarized in Table 42.

Table 42. Air change summary for the U.S. Post Office in Enid, Oklahoma

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement 11</td>
<td>101/4855</td>
<td>0.17</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.28</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>209</td>
<td>1A/2377</td>
<td>0.33</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Basement 11</td>
<td>101/4855</td>
<td>0.84</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.14</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.32</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>209</td>
<td>1A/2377</td>
<td>0.30</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Basement 30</td>
<td>101/4855</td>
<td>0.21</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Supervisor’s office</td>
<td>1A/9346</td>
<td>0.31</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>217</td>
<td>1A/2377</td>
<td>0.39</td>
<td>Air conditioning on</td>
</tr>
</tbody>
</table>
Subslab diagnostics were performed in the boiler room in the basement. The data indicate excellent field extension beneath the slab (Table 43).

Table 43. Subslab field extension data for the U.S. Post Office in Enid, Oklahoma

<table>
<thead>
<tr>
<th>Hole</th>
<th>Location</th>
<th>Field extension (ft)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Boiler room</td>
<td>45 (+)</td>
<td>7.5</td>
<td>Cinder settled</td>
<td>11 in.</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics were performed in various areas in the basement. None of the measurements identified any significant entry pathways. Table 44 lists the data.

Table 44. Radon entry pathway diagnostics for the U.S. Post Office in Enid, Oklahoma

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical outlet</td>
<td>Room 13</td>
<td>0</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room 17-19</td>
<td>3</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room 28</td>
<td>1</td>
</tr>
<tr>
<td>Sump</td>
<td>Room 36</td>
<td>10</td>
</tr>
<tr>
<td>Drain</td>
<td>Room 36</td>
<td>7</td>
</tr>
<tr>
<td>Drain</td>
<td>Room 41</td>
<td>23</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room 30</td>
<td>4</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room 29</td>
<td>5</td>
</tr>
<tr>
<td>Drain</td>
<td>Room 29</td>
<td>3</td>
</tr>
<tr>
<td>Drain</td>
<td>Room 10</td>
<td>4</td>
</tr>
<tr>
<td>Elevator</td>
<td>Elevator pit</td>
<td>1</td>
</tr>
</tbody>
</table>

DP measurements were performed in various rooms throughout the building. The building appears to be pressurized relative to the outdoors. Table 45 lists the DP data by room.
Table 45. Differential pressure measurements for the U.S. Post Office in Enid, Oklahoma

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td></td>
</tr>
<tr>
<td>Hallway</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>28</td>
<td>6</td>
</tr>
<tr>
<td>29</td>
<td>3</td>
</tr>
<tr>
<td>40</td>
<td>3</td>
</tr>
<tr>
<td>First Floor</td>
<td></td>
</tr>
<tr>
<td>Lobby</td>
<td>3</td>
</tr>
<tr>
<td>Main room</td>
<td>3</td>
</tr>
<tr>
<td>Back entry</td>
<td>2</td>
</tr>
<tr>
<td>Stairwell</td>
<td>7</td>
</tr>
<tr>
<td>Second Floor</td>
<td></td>
</tr>
<tr>
<td>Hallway</td>
<td>7</td>
</tr>
<tr>
<td>209</td>
<td>7</td>
</tr>
<tr>
<td>217</td>
<td>7</td>
</tr>
<tr>
<td>219</td>
<td>7</td>
</tr>
<tr>
<td>223</td>
<td>7</td>
</tr>
</tbody>
</table>

Two mitigation diagnostics could not be performed because of building design problems. The blower door tests could not be performed because a suitable exterior door was not available. The flow hood tests could not be performed because of the vent style.

Based on the data generated, no radon mitigation is required for this building. However, if a radon problem occurs, the HVAC system should be rebalanced to the parameters listed in Table 45.
2.11 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN FLORISSANT, MISSOURI

The main post office in Florissant, Missouri, is a leased, two-story, slab-on-grade building. The approximately 55,000-ft² building has multiple HVAC forced-air systems. Heating is provided by a hot water exchanger, while cooling is provided by air compression. The fresh air intakes are located on the roof of the building, and the system cycles down during nonpeak hours.

During 1992-1993, USPS personnel performed 70 1-year radon measurements. Three readings were found to be >4 pCi/L. Subsequent follow-up measurements failed to confirm the elevated readings. However, the building conditions during the confirmation measurements were in question.

In June 1994, the HAZWRAP radon mitigation diagnostics team conducted mitigation diagnostics at the site. The mitigation data are summarized in Table 46.

Table 46. Radon mitigation diagnostics summary for the U.S. Post Office in Florissant, Missouri

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>4</td>
<td>Poor</td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>No suitable exterior doorway</td>
</tr>
<tr>
<td>Subslab</td>
<td>Not completed</td>
<td>Underground utilities, no building plans</td>
</tr>
<tr>
<td>Continuous radon measurements</td>
<td>21 measurements</td>
<td>No elevated radon</td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>Could not reach supply ducts</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>6</td>
<td>2 to 12 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>32</td>
<td>15 positive and 17 negative measurements</td>
</tr>
</tbody>
</table>

During the mitigation diagnostics, 21 continuous radon measurements were performed. All of the average readings were <1 pCi/L. No increase in radon concentration was observed as a function of the HVAC cycle. Since the last radon measurements performed by USPS, the HVAC system has been replaced. The average data are summarized in Table 47.

Table 47. Summary of continuous radon measurements for the U.S. Post Office in Florissant, Missouri

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0.40</td>
<td>Customs office</td>
</tr>
<tr>
<td>02</td>
<td>0.6</td>
<td>Room 162</td>
</tr>
<tr>
<td>03</td>
<td>0.4</td>
<td>Postmaster's office</td>
</tr>
</tbody>
</table>
Air change measurements were performed in various rooms in the building. The data indicate significant differences between night and day ACH rates as a result of the HVAC system being off and on (Table 48). Even with the HVAC system on, the ACH was found to be substandard.

---

### Table 47 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>04</td>
<td>0.4</td>
<td>Room 2224</td>
</tr>
<tr>
<td>05</td>
<td>0.5</td>
<td>Room 132</td>
</tr>
<tr>
<td>06</td>
<td>0.4</td>
<td>Room 156</td>
</tr>
<tr>
<td>07</td>
<td>0.3</td>
<td>Room 167</td>
</tr>
<tr>
<td>08</td>
<td>0.4</td>
<td>IRS office</td>
</tr>
<tr>
<td>09</td>
<td>0.7</td>
<td>IRS office</td>
</tr>
<tr>
<td>10</td>
<td>0.8</td>
<td>Main room</td>
</tr>
<tr>
<td>11</td>
<td>0.7</td>
<td>Room 2222-C</td>
</tr>
<tr>
<td>12</td>
<td>0.7</td>
<td>Main room</td>
</tr>
<tr>
<td>13</td>
<td>0.9</td>
<td>IRS office</td>
</tr>
<tr>
<td>14</td>
<td>0.8</td>
<td>Custom's office</td>
</tr>
<tr>
<td>15</td>
<td>0.8</td>
<td>Storage across from Room 2220R</td>
</tr>
<tr>
<td>16</td>
<td>0.9</td>
<td>Room 2224</td>
</tr>
<tr>
<td>17</td>
<td>0.7</td>
<td>Room 117</td>
</tr>
<tr>
<td>18</td>
<td>0.6</td>
<td>Main room</td>
</tr>
<tr>
<td>19</td>
<td>0.8</td>
<td>Main room</td>
</tr>
<tr>
<td>20</td>
<td>0.5</td>
<td>Room 2222</td>
</tr>
<tr>
<td>21</td>
<td>0.6</td>
<td>IRS office</td>
</tr>
</tbody>
</table>
Table 48. Air change summary for the U.S. Post Office in Florissant, Missouri

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room (front left)</td>
<td>1A/2377</td>
<td>0.23 0.05 0.14</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room (back right)</td>
<td>101/4855</td>
<td>0.17 0.02</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Reception (front)</td>
<td>1A/9346</td>
<td>0.19 0.02 0.08</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>IRS office</td>
<td>1A/2377</td>
<td>0.28 0.08</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning off</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics failed to locate a major radon entry pathway at the site. The data are listed in Table 49.

Table 49. Radon entry pathway summary for the U.S. Post Office in Florissant, Missouri

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain</td>
<td>Hallway (GSA side)</td>
<td>8</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Boiler room</td>
<td>7</td>
</tr>
<tr>
<td>Floor joint</td>
<td>Room 132 storage</td>
<td>12</td>
</tr>
<tr>
<td>Drain</td>
<td>Air handler (Room 135)</td>
<td>4</td>
</tr>
<tr>
<td>Drain</td>
<td>Men's restroom (Room 153)</td>
<td>4</td>
</tr>
<tr>
<td>Drain</td>
<td>Breakroom</td>
<td>2</td>
</tr>
</tbody>
</table>

DP measurements were performed in various rooms at the site. The data are listed in Table 50.

Table 50. Differential pressure measurements for the U.S. Post Office in Florissant, Missouri

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Floor</td>
<td>First Floor</td>
</tr>
<tr>
<td>Entry</td>
<td>0</td>
</tr>
<tr>
<td>Breakroom</td>
<td>-3</td>
</tr>
</tbody>
</table>

2-47
Table 50 (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Door 150</td>
<td>-2</td>
</tr>
<tr>
<td>Hall</td>
<td>2</td>
</tr>
<tr>
<td>Men’s locker room</td>
<td>5</td>
</tr>
<tr>
<td>Men’s restroom</td>
<td>1</td>
</tr>
<tr>
<td>Hall/office</td>
<td>5</td>
</tr>
<tr>
<td>Door 159</td>
<td>3</td>
</tr>
<tr>
<td>Door 702</td>
<td>4</td>
</tr>
<tr>
<td>Assistant Postmaster’s office</td>
<td>2</td>
</tr>
<tr>
<td>Lobby</td>
<td>1</td>
</tr>
<tr>
<td>Main room</td>
<td>1</td>
</tr>
<tr>
<td>General office</td>
<td>0</td>
</tr>
<tr>
<td>Postmaster’s office</td>
<td>0</td>
</tr>
<tr>
<td>Door 156</td>
<td>-2</td>
</tr>
<tr>
<td>Door 145</td>
<td>14</td>
</tr>
<tr>
<td>Women’s locker room</td>
<td>-1</td>
</tr>
<tr>
<td>Postal supplies</td>
<td>0</td>
</tr>
<tr>
<td>Repair shop</td>
<td>3</td>
</tr>
<tr>
<td>Storage</td>
<td>1</td>
</tr>
<tr>
<td>Hall/government office</td>
<td>3</td>
</tr>
<tr>
<td><strong>Second Floor</strong></td>
<td></td>
</tr>
<tr>
<td>Entry</td>
<td>-4</td>
</tr>
<tr>
<td>Hallway</td>
<td>-6</td>
</tr>
<tr>
<td>2218</td>
<td>-6</td>
</tr>
<tr>
<td>2222</td>
<td>-4</td>
</tr>
<tr>
<td>2223</td>
<td>-8</td>
</tr>
<tr>
<td>2224</td>
<td>-5</td>
</tr>
</tbody>
</table>
Mitigation diagnostics could not be performed on the blower door (for lack of a suitable door) and the flow hood (because of the height of the supply vents); subslab tests could not be performed because of the lack of building plans and the presence of underground utilities.

Because the new HVAC system has apparently mitigated the radon problem, no further mitigation action is needed. However, because of the poor indoor air quality and ventilation rates, it is recommended that the amount of fresh air into the building be increased by 50%.

2.12 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN GRIFFIN, GEORGIA

The main post office in Griffin, Georgia, is a two-level, daylight basement building constructed approximately 21 years ago. The approximately 20,000-ft² building has four HVAC forced-air systems. Heating is provided by a hot water exchanger, while cooling is provided by chilled water. The fresh air intakes are located on the roof of the building. Since its original construction, the basement office area has undergone numerous modifications in the GSA office area.

During 1992–1993, USPS performed 43 1-year radon measurements. Eight radon measurements >4 pCi/L were found. Subsequent short-term follow-up readings failed to confirm the elevated 1-year measurements. However, information collected from the site (after the short-term measurements had been performed) indicated that HVAC supply duct modifications had occurred between the two radon measurements (Social Security and Department of Agriculture areas).

In April 1994, the HAZWRAP mitigation diagnostics team performed mitigation diagnostics at the site. The mitigation diagnostics data are summarized in Table 51.

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>1 measurement</td>
<td>Data inconclusive</td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed</td>
<td>Below average field extension</td>
</tr>
<tr>
<td></td>
<td>Part 2 completed</td>
<td></td>
</tr>
<tr>
<td>Continuous radon</td>
<td>20 measurements</td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>23</td>
<td>Inconclusive</td>
</tr>
</tbody>
</table>

Table 51. Radon mitigation diagnostics summary for the U.S. Post Office in Griffin, Georgia
Table 51 (continued)

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radon entry pathway</td>
<td>14</td>
<td>26 to 360 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>47</td>
<td></td>
</tr>
</tbody>
</table>

During the mitigation diagnostic measurements, 20 continuous radon measurements were performed (Table 52). Only one area, the boiler room tunnel, averaged above the action level. However, several rooms showed an increase in radon concentration as a function of the HVAC night cycle.

Table 52. Continuous radon measurements for the U.S. Post Office in Griffin, Georgia

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1.2</td>
<td>Room G-27</td>
</tr>
<tr>
<td>02</td>
<td>5.0</td>
<td>Boiler room tunnel</td>
</tr>
<tr>
<td>03</td>
<td>1.7</td>
<td>Social Security back office</td>
</tr>
<tr>
<td>04</td>
<td>1.9</td>
<td>Room G-40</td>
</tr>
<tr>
<td>05</td>
<td>1.3</td>
<td>Room G-9</td>
</tr>
<tr>
<td>06</td>
<td>2.2</td>
<td>Boiler room</td>
</tr>
<tr>
<td>08</td>
<td>1.6</td>
<td>Social Security breakroom</td>
</tr>
<tr>
<td>09</td>
<td>0.5</td>
<td>Main room</td>
</tr>
<tr>
<td>10</td>
<td>1.3</td>
<td>Elevator room</td>
</tr>
<tr>
<td>12</td>
<td>1.6</td>
<td>Room G-27</td>
</tr>
<tr>
<td>13</td>
<td>1.8</td>
<td>Room G-11</td>
</tr>
<tr>
<td>14</td>
<td>0.7</td>
<td>Room 111</td>
</tr>
<tr>
<td>16</td>
<td>0.8</td>
<td>Maintenance office</td>
</tr>
<tr>
<td>17</td>
<td>1.7</td>
<td>Lawn mower room</td>
</tr>
<tr>
<td>18</td>
<td>0.4</td>
<td>Breakroom</td>
</tr>
<tr>
<td>19</td>
<td>0.8</td>
<td>Postmaster's office</td>
</tr>
<tr>
<td>20</td>
<td>1.8</td>
<td>Room G-20</td>
</tr>
</tbody>
</table>
Air change measurements were performed in various rooms in the building. The data indicate significant differences between night and day ACH rates as a function of the HVAC cycle (Table 53). During normal HVAC operation, the ACH rate is within proper specifications for an office environment.

The HVAC system at the site is the original system installed in the building (i.e., the system is 21 years old). However, the system is in better operating condition than any of the HVAC systems (including new ones) observed by the mitigation team during the 25 on-site USPS facility investigations.

### Table 53. Air change summary for the U.S. Post Office in Griffin, Georgia

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.67</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Secondary sort room</td>
<td>101/2377</td>
<td>0.55</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.71 0.10</td>
<td>Air conditioning on Air conditioning off</td>
</tr>
<tr>
<td>Secondary sort room</td>
<td>101/2377</td>
<td>0.43 0.13</td>
<td>Air conditioning on Air conditioning off</td>
</tr>
<tr>
<td>G-9</td>
<td>1A/4855</td>
<td>0.92 0.35 0.02</td>
<td>Air conditioning on Air conditioning transition Air conditioning off</td>
</tr>
<tr>
<td>G-11</td>
<td>101/2377</td>
<td>0.53 0.23 0.06</td>
<td>Air conditioning on Air conditioning transition Air conditioning off</td>
</tr>
<tr>
<td>G-30</td>
<td>1A/9346</td>
<td>0.74 0.32 0.25</td>
<td>Air conditioning on Air conditioning transition Air conditioning off</td>
</tr>
<tr>
<td>G-9</td>
<td>1A/4855</td>
<td>0.93</td>
<td>Air conditioning on</td>
</tr>
</tbody>
</table>
Table 53 (continued)

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-11</td>
<td>101/2377</td>
<td>0.68</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>G-30</td>
<td>1A/9346</td>
<td>0.83</td>
<td>Air conditioning on</td>
</tr>
</tbody>
</table>

Subslab diagnostics performed in the basement indicate limited field extension beneath the slab. The data are summarized in Table 54.

Table 54. Subslab field extension data for the U.S. Post Office in Griffin, Georgia

<table>
<thead>
<tr>
<th>Hole 1.50 (in.)</th>
<th>Location</th>
<th>Field extension (ft)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material (in.)</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mechanical equipment room</td>
<td>&lt;10</td>
<td>5</td>
<td>0.5 gravel</td>
<td>9</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostic data indicated several potential entry pathways in the boiler room area. The recommendation was made to the site maintenance staff that the holes be sealed with a concrete patch or an elastomeric sealant. The data are listed in Table 55.

Table 55. Radon entry pathway diagnostic data for the U.S. Post Office in Griffin, Georgia

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Termite drill hole</td>
<td>Tunnel</td>
<td>37</td>
</tr>
<tr>
<td>Termite drill hole</td>
<td>Tunnel</td>
<td>225</td>
</tr>
<tr>
<td>Termite drill hole</td>
<td>Tunnel</td>
<td>183</td>
</tr>
<tr>
<td>Termite drill hole</td>
<td>Tunnel</td>
<td>40</td>
</tr>
<tr>
<td>Termite drill hole</td>
<td>Tunnel</td>
<td>42</td>
</tr>
<tr>
<td>Termite drill hole</td>
<td>Tunnel</td>
<td>145</td>
</tr>
<tr>
<td>Termite drill hole</td>
<td>Tunnel</td>
<td>53</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Mechanical room next to pumps</td>
<td>360</td>
</tr>
<tr>
<td>Termite drill hole</td>
<td>Mechanical room next to pumps</td>
<td>260</td>
</tr>
<tr>
<td>Termite drill hole</td>
<td>Mechanical room next to pumps</td>
<td>65</td>
</tr>
<tr>
<td>Floor drain</td>
<td>Water heater in mechanical room</td>
<td>55</td>
</tr>
</tbody>
</table>

2-52
The HVAC system at the site is both an autosensing and autoadjusting forced-air system. Hence, if a sensor in one of the four HVAC zones indicates too little or too much demand, the system automatically adjusts the air flow into the zone to compensate for the imbalance. This, in turn, increases the air flow demand on the other three zones. Consequently, the flow hood measurements performed in the building would be episodic to a particular condition. The data listed are listed in Table 56.

Table 55 (continued)

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Termite drill hole</td>
<td>Mechanical room near outside entrance</td>
<td>305</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room G-20</td>
<td>30</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room G-20</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 56. Flow hood measurement summary for the U.S. Post Office in Griffin, Georgia

<table>
<thead>
<tr>
<th>Location</th>
<th>Uncorrected flow (ft³/min)</th>
<th>Corrected flow (ft³/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hallway outside of room G-35</td>
<td>61</td>
<td>78</td>
</tr>
<tr>
<td>Room G-32</td>
<td>32</td>
<td>37</td>
</tr>
<tr>
<td>Room G-28</td>
<td>146</td>
<td>146</td>
</tr>
<tr>
<td>Room G-28</td>
<td>130</td>
<td>128</td>
</tr>
<tr>
<td>Room G-24</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>Room G-24</td>
<td>128</td>
<td>131</td>
</tr>
<tr>
<td>Lobby to GSA side</td>
<td>127</td>
<td>154</td>
</tr>
<tr>
<td>Lobby to GSA side</td>
<td>127</td>
<td>133</td>
</tr>
<tr>
<td>Lobby to GSA side</td>
<td>128</td>
<td>221</td>
</tr>
<tr>
<td>Lobby to GSA side</td>
<td>107</td>
<td>136</td>
</tr>
<tr>
<td>Room 118</td>
<td>54</td>
<td>78</td>
</tr>
<tr>
<td>Room 116</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Room 115</td>
<td>49</td>
<td>131</td>
</tr>
<tr>
<td>Men's restroom by G-18</td>
<td>35</td>
<td>36</td>
</tr>
<tr>
<td>Room G-17</td>
<td>39</td>
<td>54</td>
</tr>
</tbody>
</table>
DP measurements were performed in 47 rooms at the site. The data are listed in Table 57.

Table 57. Differential pressure measurements for the U.S. Post Office in Griffin, Georgia

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First Floor</td>
</tr>
<tr>
<td>Lobby</td>
<td>First Floor</td>
</tr>
<tr>
<td>G-7</td>
<td>1</td>
</tr>
<tr>
<td>G-4</td>
<td>5</td>
</tr>
<tr>
<td>Hallway</td>
<td>0</td>
</tr>
<tr>
<td>G-10</td>
<td>2</td>
</tr>
<tr>
<td>G-17</td>
<td>3</td>
</tr>
<tr>
<td>G-12-13</td>
<td>4</td>
</tr>
<tr>
<td>G-14</td>
<td>7</td>
</tr>
<tr>
<td>616-27</td>
<td>4</td>
</tr>
<tr>
<td>G-18</td>
<td>3</td>
</tr>
<tr>
<td>G-19</td>
<td>3</td>
</tr>
<tr>
<td>G-20</td>
<td>2</td>
</tr>
<tr>
<td>G-21</td>
<td>3</td>
</tr>
<tr>
<td>Location</td>
<td>Differential pressure relative to outdoors (Pa)</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>G-24</td>
<td>3</td>
</tr>
<tr>
<td>G-25</td>
<td>5</td>
</tr>
<tr>
<td>G-35</td>
<td>-5</td>
</tr>
<tr>
<td>G-34</td>
<td>-3</td>
</tr>
<tr>
<td>G-33</td>
<td>-8</td>
</tr>
<tr>
<td>G-28</td>
<td>4</td>
</tr>
<tr>
<td>G-32</td>
<td>1</td>
</tr>
<tr>
<td>G-31</td>
<td>2</td>
</tr>
<tr>
<td>Rear entry</td>
<td>6</td>
</tr>
<tr>
<td>Main room</td>
<td>7</td>
</tr>
<tr>
<td>129 (shop)</td>
<td>7</td>
</tr>
<tr>
<td>124</td>
<td>4</td>
</tr>
<tr>
<td>121</td>
<td>4</td>
</tr>
<tr>
<td>120</td>
<td>4</td>
</tr>
<tr>
<td>119</td>
<td>5</td>
</tr>
<tr>
<td>Main lobby</td>
<td>5</td>
</tr>
<tr>
<td>Envelope storage</td>
<td>7</td>
</tr>
<tr>
<td>Postal records</td>
<td>8</td>
</tr>
<tr>
<td>Elevator lobby</td>
<td>4</td>
</tr>
<tr>
<td>135 Men’s restroom</td>
<td>4</td>
</tr>
<tr>
<td>135 Women’s restroom</td>
<td>6</td>
</tr>
<tr>
<td>Stairway</td>
<td>3</td>
</tr>
<tr>
<td>Stairway</td>
<td>6</td>
</tr>
<tr>
<td>117</td>
<td>0</td>
</tr>
<tr>
<td>116</td>
<td>2</td>
</tr>
<tr>
<td>115</td>
<td>1</td>
</tr>
</tbody>
</table>
During the entry pathway diagnostics, numerous chlordane (termitecide) insertion holes (3/8 in.) were observed in the boiler tunnel. The data (Table 55) indicate a strong possibility that the holes were an entry pathway. The recommendation was made to the site that the holes be sealed and the building retested for radon. In May 1994, radon detectors were placed by USPS personnel for 90-day measurements but no improvement was observed.

Because the building has a cyclic HVAC system, it was theorized that the elevated radon might be limited solely to nonduty cycle hours. To test the theory, three Femto-Tech Model F-210 detectors were placed in the computer room, Rooms G13 and G30 (boiler room) for 27 continuous days (September–October 1994). The data, shown in Figs. 7, 8, and 9, show a strong correlation to the HVAC night cycle and an increase in radon concentration. A good example is Fig. 10, which shows that for a 10-day period, the radon begins increasing between 5 and 7 p.m., peaks between 12 p.m. and 3 a.m., and returns to low levels (e.g., <4 pCi/L) between 4 and 7 a.m.

Because the building has multiple, automatic, on-demand fresh air dampers, the blower door test was inconclusive. Within 1 minute of depressurizing the building, the automatic fresh air dampers would sense the pressure imbalance, engage, and override the blower door fan. To disable the system would have potentially taken several hours and might have resulted in permanent HVAC system damage. Therefore, it was elected not to complete the diagnostic test.

A closer examination of the radon data reveals that the only location within the building with consistent elevated radon levels is the boiler room tunnel. The need for mitigation in this area is in question because the area is an unoccupied crawl space. If mitigation is deemed necessary, then adequate reduction could be attained with the installation of a single 500-ft³/min HRV at the south end of the tunnel. To ensure good sweeping action, the HRV supply duct should exhaust near the middle of the tunnel. The estimated mitigation cost for the boiler room tunnel would be $4K.

With respect to the radon problem in occupied areas, it appears to only be a problem during the nonworking hours. The most cost-effective mitigation would be the implementation of the following radon management plan:

**Radon Management Plan for the U.S. Post Office in Griffin, Georgia**

1. Inform all tenants about the hazards of radon.

2. Describe the operation of the HVAC system and its impact on the radon concentration.
Fig. 7. Radon levels in the computer room at the U.S. Post Office in Griffin, Georgia.
Fig. 9. Radon levels in Room G-30 at the U.S. Post Office in Griffin, Georgia.
Fig. 10. Cyclic radon levels in the computer room at the U.S. Post Office in Griffin, Georgia.
3. Require all tenants to inform the building maintenance supervisor if they are planning to perform work in the basement from 9 p.m. to 4 a.m. so that the HVAC system may be left in full operation during that time.

If a management plan is unacceptable, then the blower of the HVAC system should be left in continuous operation with the air-exchangers taken off-line. This would allow for continued ventilation of the area while not increasing the energy consumption. If implemented, caution should be used during the heating season to avoid freezing of the unheated exchanger.

2.13 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN LANCASTER, OHIO

The main post office in Lancaster, Ohio, is a two-story building originally constructed in 1910 with additions in 1934 and 1964. The substructure consists of a one-level basement subdivided with hollow clay tile and concrete walls. The approximately 22,500-ft² building has multiple HVAC forced-air systems. Heating is provided by a hot water exchanger, while cooling is provided by chilled water. The fresh air intakes are located on the roof.

During 1992-1993, 35 1-year radon measurements were performed. All of the measurements were >4 pCi/L. Due to the high frequency of elevated readings, no confirmation tests were performed.

In July 1994, the HAZWRAP radon mitigation diagnostic team performed mitigation diagnostics at the site. The diagnostics performed are summarized in Table 58.

| Table 58. Radon mitigation diagnostics summary for the U.S. Post Office in Lancaster, Ohio |
|---------------------------------|----------------|-----------------|
| Diagnostics test              | Number of tests | Comments                  |
| Air changer                   | 4              |                             |
| Blower door                   | 2              | Inconclusive due to building size |
| Subslab                       | Part 1 completed Part 2 completed |
| Continuous radon measurements | 21 measurements |                             |
| Flow hood                     | 21             |                             |
| Radon entry pathway           | 8              | 0 to 8 counts per minute   |
| Differential pressure         | 32             |                             |

During the mitigation diagnostics, 21 continuous radon measurements were performed. Five average measurements were found to be >4 pCi/L. During the night, only the normal diurnal increase in radon was observed. The continuous radon data are summarized in Table 59.
Table 59. Summary of continuous radon measurements for the U.S. Post Office in Lancaster, Ohio

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3.5</td>
<td>Workshop</td>
</tr>
<tr>
<td>02</td>
<td>2.4</td>
<td>Chiller room</td>
</tr>
<tr>
<td>03</td>
<td>4.0</td>
<td>Room 41</td>
</tr>
<tr>
<td>04</td>
<td>1.6</td>
<td>Main room (back left)</td>
</tr>
<tr>
<td>05</td>
<td>1.6</td>
<td>Main room (front right)</td>
</tr>
<tr>
<td>06</td>
<td>2.7</td>
<td>Room M-108</td>
</tr>
<tr>
<td>07</td>
<td>1.3</td>
<td>Conference room</td>
</tr>
<tr>
<td>08</td>
<td>4.0</td>
<td>Room 43</td>
</tr>
<tr>
<td>09</td>
<td>2.6</td>
<td>Room M-110</td>
</tr>
<tr>
<td>10</td>
<td>2.8</td>
<td>Room M-112</td>
</tr>
<tr>
<td>11</td>
<td>1.8</td>
<td>Computer area</td>
</tr>
<tr>
<td>12</td>
<td>1.4</td>
<td>Main room (back right)</td>
</tr>
<tr>
<td>13</td>
<td>1.0</td>
<td>Room M-101</td>
</tr>
<tr>
<td>14</td>
<td>4.6</td>
<td>Room B-11</td>
</tr>
<tr>
<td>15</td>
<td>1.2</td>
<td>Main room (front left)</td>
</tr>
<tr>
<td>16</td>
<td>4.2</td>
<td>Room 36</td>
</tr>
<tr>
<td>17</td>
<td>2.2</td>
<td>Room 5</td>
</tr>
<tr>
<td>19</td>
<td>4.2</td>
<td>Room 20</td>
</tr>
<tr>
<td>20</td>
<td>3.7</td>
<td>Room 55</td>
</tr>
<tr>
<td>21</td>
<td>3.5</td>
<td>Room 31</td>
</tr>
</tbody>
</table>

The ACH measurements performed at the site were complicated by the seasonal operation of the HVAC system. For example, three HVAC systems operate 24 hours/day during the cooling season vs 3/4 of the day during heating season. Also, the percentage of fresh air is adjusted in the winter to bring in a higher percentage than in the summer (static electricity control). Based on this information, it is assumed that the ACH rates listed in Table 60 would be higher during the winter months. Because the measurement was taken in July, the air handler was on continuously and the team was unable to obtain an HVAC-off measurement. The ACH data are summarized in Table 60.

2-62
Subslab mitigation diagnostics were performed in the basement. The results, listed in Table 61, indicate marginal field extension beneath the slab.

Table 60. Air change measurement summary for the U.S. Post Office in Lancaster, Ohio

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postmaster’s office</td>
<td>1A/4855</td>
<td>0.35</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room (front)</td>
<td>1A/2377</td>
<td>0.42</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room (rear)</td>
<td>101/9346</td>
<td>0.31</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Postmaster’s office</td>
<td>1A/4855</td>
<td>0.31</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room (front)</td>
<td>1A/2377</td>
<td>0.40</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room (back)</td>
<td>101/9346</td>
<td>0.30</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>55</td>
<td>1A/4855</td>
<td>0.48</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>36</td>
<td>1A/2377</td>
<td>0.51</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Shop</td>
<td>101/9346</td>
<td>0.31</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>55</td>
<td>1A/4855</td>
<td>0.44</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>36</td>
<td>1A/2377</td>
<td>0.43</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Shop</td>
<td>101/9346</td>
<td>0.30</td>
<td>Air conditioning on</td>
</tr>
</tbody>
</table>

Subslab mitigation diagnostics were performed in the basement. The results, listed in Table 61, indicate marginal field extension beneath the slab.

Table 61. Subslab field extension data for the U.S. Post Office in Lancaster, Ohio

<table>
<thead>
<tr>
<th>Hole 1.45 (in.)</th>
<th>Location</th>
<th>Field extension (ft.)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Boiler room</td>
<td>10</td>
<td>5</td>
<td>Compacted earth</td>
<td>0</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics failed to locate a significant entry pathway into the building. The data are listed in Table 62.
The DP data for the site indicate that the HVAC system is exhausting more air than is being incorporated and that the system is unbalanced. The DP data for various rooms are listed in Table 63, and the flowhood measurements are listed in Table 64.

### Table 63. Differential pressure measurements for the U.S. Post Office in Lancaster, Ohio

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>Basement</td>
</tr>
<tr>
<td>Entry</td>
<td>-4</td>
</tr>
<tr>
<td>Hallway</td>
<td>-1</td>
</tr>
<tr>
<td>55</td>
<td>7</td>
</tr>
<tr>
<td>Next to 55</td>
<td>-4</td>
</tr>
<tr>
<td>29</td>
<td>-1</td>
</tr>
<tr>
<td>45</td>
<td>2</td>
</tr>
<tr>
<td>44</td>
<td>-2</td>
</tr>
<tr>
<td>25</td>
<td>-2</td>
</tr>
<tr>
<td>43</td>
<td>1</td>
</tr>
<tr>
<td>41</td>
<td>3</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Post Office lobby</td>
<td>-2</td>
</tr>
</tbody>
</table>
### Table 63 (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box lobby</td>
<td>1</td>
</tr>
<tr>
<td>Main room</td>
<td>-1</td>
</tr>
<tr>
<td>Women's restroom</td>
<td>-7</td>
</tr>
<tr>
<td>Men's restroom</td>
<td>-6</td>
</tr>
<tr>
<td>Mechanical room</td>
<td>-17</td>
</tr>
<tr>
<td>Work shop</td>
<td>-15</td>
</tr>
<tr>
<td>B-3</td>
<td>-14</td>
</tr>
<tr>
<td>B-4</td>
<td>-9</td>
</tr>
<tr>
<td>Next to 40</td>
<td>1</td>
</tr>
<tr>
<td>36</td>
<td>1</td>
</tr>
<tr>
<td>B-29</td>
<td>-1</td>
</tr>
<tr>
<td>B-30</td>
<td>0</td>
</tr>
<tr>
<td>B-28</td>
<td>-1</td>
</tr>
<tr>
<td>B-18</td>
<td>1</td>
</tr>
<tr>
<td>B-17</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>B-10</td>
<td>-8</td>
</tr>
</tbody>
</table>

### Table 64. Flow hood measurements for the U.S. Post Office in Lancaster, Ohio

<table>
<thead>
<tr>
<th>Location</th>
<th>Uncorrected flow (ft³/min)</th>
<th>Corrected flow (ft³/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 55 (front)</td>
<td>245</td>
<td>254</td>
</tr>
<tr>
<td>Room 55 (middle)</td>
<td>228</td>
<td>234</td>
</tr>
<tr>
<td>Room 55 (middle)</td>
<td>263</td>
<td>270</td>
</tr>
<tr>
<td>Room 55 (middle)</td>
<td>254</td>
<td>255</td>
</tr>
<tr>
<td>Room 55 (back room)</td>
<td>147</td>
<td>152</td>
</tr>
</tbody>
</table>

2-65
Although the blower door measurements were performed, the data were found to be inconclusive due to the building size and the power of the HVAC blower.

Based on the DP data (Table 63), it appears that the system is unbalanced and is exhausting more air than it is taking in. Generally, for a large building, 5 to 10% more fresh air should be imported than is being exhausted. However, this appears not to be the case for the building. The first mitigation step should be a complete inspection of the HVAC system by an ASHRAE-certified HVAC technician. A cost-benefit study of repairing the existing system vs replacing the system with a newer system should be performed. During the inspection, particular attention should be paid to the fresh air intakes and indoor exhaust and the forced-air system balance. The amount of fresh air should be increased to 5 to 10% more than the amount exhausted. If this is not possible, then a 5 to 10% reduction in flow exhaust should be performed. After these adjustments are made, two sets of radon measurements should be performed (heating and cooling season measurements). The estimated cost for inspection, adjustment, and replacement-benefit analysis of the existing HVAC system is $4K.

<table>
<thead>
<tr>
<th>Location</th>
<th>Uncorrected flow (ft³/min)</th>
<th>Corrected flow (ft³/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 55 (side room, front)</td>
<td>119</td>
<td>133</td>
</tr>
<tr>
<td>Room 55 (side room, middle)</td>
<td>109</td>
<td>112</td>
</tr>
<tr>
<td>Room 55 (side room, back)</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>Room 43 (front)</td>
<td>63</td>
<td>74</td>
</tr>
<tr>
<td>Room 43 (front)</td>
<td>98</td>
<td>101</td>
</tr>
<tr>
<td>Room 43 (side room)</td>
<td>76</td>
<td>91</td>
</tr>
<tr>
<td>Room 43 (side room)</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>Room 43 (back room)</td>
<td>295</td>
<td>300</td>
</tr>
<tr>
<td>Room 41 (front)</td>
<td>105</td>
<td>122</td>
</tr>
<tr>
<td>Room 41 (back)</td>
<td>76</td>
<td>79</td>
</tr>
<tr>
<td>Room 20 (front)</td>
<td>121</td>
<td>125</td>
</tr>
<tr>
<td>Room 20 (middle)</td>
<td>109</td>
<td>118</td>
</tr>
<tr>
<td>Room 20 (back)</td>
<td>116</td>
<td>119</td>
</tr>
<tr>
<td>Room 20-B</td>
<td>91</td>
<td>99</td>
</tr>
<tr>
<td>Room 17 (front)</td>
<td>136</td>
<td>136</td>
</tr>
<tr>
<td>Room 17 (back)</td>
<td>125</td>
<td>133</td>
</tr>
</tbody>
</table>
The main post office in Lowville, New York, is a two-story building constructed in 1939. The substructure consists of a one-level basement subdivided with concrete walls. The approximately 13,500-ft$^2$ building has no central HVAC or HAC forced-air systems. Heating is provided by a hot water exchanger, while cooling is provided by two window air conditioning units.

During 1992–1993, 15 1-year radon measurements were performed. Five results were found to be >4 pCi/L. No confirmation data were collected.

In July 1994, the HAZWRAP mitigation diagnostic team performed radon mitigation diagnostics at the site. Table 65 summarizes the diagnostics performed.

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>No suitable exterior doorway and open windows</td>
</tr>
<tr>
<td>Subslab</td>
<td>Attempted, not successful</td>
<td>High water table</td>
</tr>
<tr>
<td>Continuous radon measurements</td>
<td>17 measurements</td>
<td>Open windows</td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>No forced-air system</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>7</td>
<td>11 to 95 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

During the mitigation diagnostics, continuous radon measurements were performed (Table 66). As expected, with the windows open, the radon levels were found to be consistently <4 pCi/L during the day. However, radon levels increased at night after the windows were closed. The radon levels in the basement were >4 pCi/L during both nights in the small room.

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1.1</td>
<td>Records storage room</td>
</tr>
<tr>
<td>02</td>
<td>0.3</td>
<td>Main room (front right)</td>
</tr>
<tr>
<td>04</td>
<td>0.5</td>
<td>Main room (back left)</td>
</tr>
<tr>
<td>06</td>
<td>1.8</td>
<td>Old Army recruiting office</td>
</tr>
</tbody>
</table>
Air change measurements were performed in various rooms and floors in the building. As predicted, the ACH rate during the day (with windows open) was significantly higher than the night ACH rate under closed building conditions. The ACH data are summarized in Table 67.

Table 67. Air change summary for the U.S. Post Office in Lowville, New York

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postmaster’s office</td>
<td>1A/2377</td>
<td>1.35</td>
<td>Window air conditioning on, door open</td>
</tr>
<tr>
<td>Old recruiting office</td>
<td>101/9346</td>
<td>0.50</td>
<td>No air conditioning system (day)</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.09</td>
<td>No air conditioning system (night)</td>
</tr>
<tr>
<td>Old recruiting office</td>
<td>101/9346</td>
<td>0.03</td>
<td>No air conditioning system (night)</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.04, 0.46</td>
<td>Doors closed (night), Doors open (day)</td>
</tr>
<tr>
<td>Postmaster’s office</td>
<td>1A/2377</td>
<td>0.05, 0.43</td>
<td>Doors closed (night), Doors open (day)</td>
</tr>
</tbody>
</table>
Radon entry pathway diagnostics identified two marginal radon entry points in the basement boiler room (sump and wall hole). No other significant pathways were identified. The data are listed in Table 68.

Table 68. Radon entry pathway diagnostics at the U.S. Post Office in Lowville, New York

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain</td>
<td>Boiler room sump</td>
<td>95</td>
</tr>
<tr>
<td>Wall</td>
<td>Boiler room</td>
<td>35</td>
</tr>
<tr>
<td>Wall</td>
<td>Large basement room</td>
<td>16</td>
</tr>
<tr>
<td>Drain</td>
<td>Large basement room</td>
<td>15</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Large basement room</td>
<td>11</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Supply room</td>
<td>13</td>
</tr>
<tr>
<td>Drain in wall</td>
<td>Water fountain in hall</td>
<td>13</td>
</tr>
</tbody>
</table>

Because this is not a forced-air system building, under exterior dead-air conditions, the DP measurements should vary between -3 and +3 Pa. However, during the testing, a slight breeze was noted from the Northwest; therefore, some variation would be expected. The data are listed in Table 69.

Table 69. Differential pressure measurements for the U.S. Post Office in Lowville, New York

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>Basement</td>
</tr>
<tr>
<td>Back entry</td>
<td>3</td>
</tr>
<tr>
<td>Main room</td>
<td>4</td>
</tr>
<tr>
<td>Women's restroom</td>
<td>3</td>
</tr>
<tr>
<td>Postmaster's office (air conditioning on)</td>
<td>4</td>
</tr>
<tr>
<td>Men's restroom</td>
<td>2</td>
</tr>
<tr>
<td>Lobby</td>
<td>3</td>
</tr>
<tr>
<td>Upstairs breakroom</td>
<td>2</td>
</tr>
<tr>
<td>Men's upstairs restroom</td>
<td>0</td>
</tr>
<tr>
<td>Downstairs back hall</td>
<td>0</td>
</tr>
<tr>
<td>Front hall</td>
<td>0</td>
</tr>
</tbody>
</table>
Due to problems at the site, three mitigation diagnostics could not be performed. The blower door could not be performed due to the absence of a suitable exterior door and the presence of open windows. The flow hood measurement could not be taken because the building lacked a forced-air system. Subslab tests were not completed due to the presence of a high water table beneath the slab. After drilling the hole and applying suction, water (copious amounts) was observed being pulled from under the slab. Water continued flowing from the hole for several minutes after suction had been discontinued. Inspection inside the hole after the flow had subsided indicated that there was no damage to the subslab utilities pipe. The team elected to discontinue the diagnostic and seal the hole. Later, discussions with the maintenance staff confirmed that the pipe had not been damaged, but the team had found the natural water table (the Post Office is located directly over a swamp).

A major concern at the site is the condition of the existing ventilation. During the summer months, ventilation provided by open windows is more than adequate. However, if one equates summer night conditions with winter conditions (e.g., closed doors and windows), then the ACH during the winter months would be considerably substandard (see night ACH rates in Table 67). Consequently, if the ACH is a factor of ten lower during the winter, a similar increase in the radon levels would be expected.

The current mechanical conditions in the building are as follows. The building has no active means of ventilation. Opening windows is the only means of increasing the ventilation rate. Active cooling is limited to two small window air conditioning units; one in the postmaster's office and one in the main sort room. However, two large cooling units are present in the main sort room, but they not operational.

Based on the diagnostic data, only one mitigation solution, ventilation, is viable; however two options are available. Option 1 is the installation of 500-ft³/min HRV units in the basement (one per quarter basement area). From the units, duct work would have to be run to all rooms in the basement to allow for a good sweeping action. Option 2 is the installation of an energy-efficient, natural gas powered HVAC forced-air system. In both cases, the minimal basement ventilation rate should be maintained at 0.5 ACH.

From a cost standpoint, the HRV solution is more attractive: $20K vs $85K. However, one major consideration, the long-term usage of the building, enters into the mitigation equation. In other parts of the country, buildings of this vintage, size, and type are being replaced because of the excessive cost of upgrading the buildings to grant the physically challenged access to services offered on the lower floor. If a building is going to be replaced within the next 8 to 10 years, then the HRV solution is the most attractive. However, if no long-term plans exist to replace the facility, then the installation of the HVAC forced-air system is the best long-term solution.

2.15 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN MACHIAS, MAINE

The main post office in Machias, Maine, is a two-story building with a slab-on-grade substructure constructed in 1967. The approximately 15,000-ft² building has five HVAC forced-air systems, four of which are in a state of disrepair. Heating is provided by a hot water exchanger, while cooling is provided by compressor. The fresh air intakes are located on the roof of the building.

During 1992–1993, 14 1-year radon measurements were performed by USPS personnel. Eight readings were found to be >4 pCi/L. The diagnostics performed are summarized in Table 70.
Table 70. Mitigation diagnostics summary for the U.S. Post Office in Machias, Maine

<table>
<thead>
<tr>
<th>Diagnostic test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>No suitable exterior doorway</td>
</tr>
<tr>
<td>Subslab</td>
<td>Not completed</td>
<td>48-in.-thick slab, subslab utilities and no building plans</td>
</tr>
<tr>
<td>Continuous radon</td>
<td>20 measurements</td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>HVAC units broken and vents not accessible</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>3 completed</td>
<td>Very few areas accessible</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

During the mitigation diagnostics, 20 continuous radon measurements were performed. The data are listed in Table 71.

Table 71. Summary of continuous radon measurements for the U.S. Post Office in Machias, Maine

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3.9</td>
<td>Breakroom</td>
</tr>
<tr>
<td>02</td>
<td>0.9</td>
<td>Room 118</td>
</tr>
<tr>
<td>04</td>
<td>1.8</td>
<td>Main room (back right)</td>
</tr>
<tr>
<td>05</td>
<td>1.7</td>
<td>Main room (front right)</td>
</tr>
<tr>
<td>06</td>
<td>4.6</td>
<td>Maintenance shop</td>
</tr>
<tr>
<td>07</td>
<td>1.1</td>
<td>Room 119</td>
</tr>
<tr>
<td>08</td>
<td>3.2</td>
<td>Men's restroom off breakroom</td>
</tr>
<tr>
<td>09</td>
<td>1.5</td>
<td>Main room (front left)</td>
</tr>
<tr>
<td>11</td>
<td>1.3</td>
<td>Room 209</td>
</tr>
<tr>
<td>12</td>
<td>1.4</td>
<td>Room 212</td>
</tr>
<tr>
<td>13</td>
<td>1.1</td>
<td>Room 109</td>
</tr>
<tr>
<td>14</td>
<td>0.7</td>
<td>Room 205</td>
</tr>
</tbody>
</table>
Table 71 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>0.9</td>
<td>Soil Conservation Office</td>
</tr>
<tr>
<td>16</td>
<td>2.5</td>
<td>Women’s restroom off breakroom</td>
</tr>
<tr>
<td>17</td>
<td>1.0</td>
<td>Boiler room</td>
</tr>
<tr>
<td>18</td>
<td>0.5</td>
<td>Postmaster’s office</td>
</tr>
<tr>
<td>19</td>
<td>0.7</td>
<td>Room 110</td>
</tr>
<tr>
<td>20</td>
<td>0.8</td>
<td>Computer room (GSA side)</td>
</tr>
<tr>
<td>21</td>
<td>1.3</td>
<td>Room 118-A</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms and floors of the building. The data indicate significant differences between HVAC on and off cycles. The ACH data are summarized in Table 72.

Table 72. Air change summary for the U.S. Post Office in Machias, Maine

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.07</td>
<td>Air conditioning broken</td>
</tr>
<tr>
<td>118</td>
<td>1A/2377</td>
<td>0.66</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>109</td>
<td>101/4855</td>
<td>0.41</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>205</td>
<td>1A/9346</td>
<td>0.27</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>118</td>
<td>1A/2377</td>
<td>0.60</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>109</td>
<td>101/4855</td>
<td>0.33</td>
<td>Air conditioning on</td>
</tr>
</tbody>
</table>

Because most of the building was finished (e.g., tile or carpeted floor, finished walls, etc.), accessibility to logical entry pathways was limited. Of the three sites that were accessible, no major entry pathways were identified. The sites that were accessible and their results are listed in Table 73.

Table 73. Radon entry pathway diagnostics data for the U.S. Post Office in Machias, Maine

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain</td>
<td>Boiler room</td>
<td>4</td>
</tr>
<tr>
<td>Pipe from ground</td>
<td>Boiler room</td>
<td>10</td>
</tr>
<tr>
<td>Oil line hole</td>
<td>Boiler room</td>
<td>11</td>
</tr>
</tbody>
</table>

2-72
DP mapping was performed in various rooms within the building. The data are listed in Table 74.

Table 74. Differential pressure measurements for the U.S. Post Office in Machias, Maine

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>Basement</td>
</tr>
<tr>
<td>Entry</td>
<td>-5</td>
</tr>
<tr>
<td>Lobby/stairway</td>
<td>-4</td>
</tr>
<tr>
<td>Hallway</td>
<td>-3</td>
</tr>
<tr>
<td>110</td>
<td>-4</td>
</tr>
<tr>
<td>109</td>
<td>-3</td>
</tr>
<tr>
<td>118</td>
<td>-4</td>
</tr>
<tr>
<td>119</td>
<td>-4</td>
</tr>
<tr>
<td>Storage room</td>
<td>-2</td>
</tr>
<tr>
<td>Men's restroom</td>
<td>-1</td>
</tr>
<tr>
<td>Women's restroom</td>
<td>-2</td>
</tr>
<tr>
<td>Storage closet</td>
<td>-1</td>
</tr>
<tr>
<td>Upstairs entry</td>
<td>3</td>
</tr>
<tr>
<td>Upstairs hallway</td>
<td>-2</td>
</tr>
<tr>
<td>Soil office</td>
<td>0</td>
</tr>
<tr>
<td>205</td>
<td>2</td>
</tr>
<tr>
<td>207</td>
<td>12</td>
</tr>
<tr>
<td>209</td>
<td>17</td>
</tr>
<tr>
<td>Storage room</td>
<td>-9</td>
</tr>
<tr>
<td>Men's restroom</td>
<td>-6</td>
</tr>
<tr>
<td>Women's restroom</td>
<td>-3</td>
</tr>
<tr>
<td>212</td>
<td>-3</td>
</tr>
<tr>
<td>206</td>
<td>-3</td>
</tr>
</tbody>
</table>

Three diagnostic measurements could not be completed: the blower door (for lack of a suitable exterior door), flow hood (inaccessible supply vents and nonfunctional HVAC units) and
the subslab diagnostics [due to the reported thickness of the slab (48 in.) and the absence of building plans].

The style, condition, and vintage of this post office is identical to the U.S. Post Office in Waynesville, North Carolina (Sect. 2.24). In addition to the physical characteristics, the ventilation characteristics are similar as well. At the Waynesville site, mitigation was accomplished by replacing the nonoperational HAC forced-air system with a fresh air intake HAC forced-air system. Based on the success at that site, the recommendation is made that a similar system be installed at this particular site. According to USPS sources, the final cost for installation of the Waynesville system was $59K. Therefore, the estimated mitigation cost for the U.S. Post Office in Machias would be the same.

2.16 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN MARION, INDIANA

The main post office in Marion, Indiana, is a two-story building originally constructed in 1941. Additions to the building were made in 1955 and 1965. The substructure consists of a one-level basement subdivided with poured concrete, hollow clay tile, and hollow cement block walls. The approximately 63,000-ft² building has multiple HVAC forced-air systems. Heating is provided by a hot water exchanger, while cooling is provided by chilled water.

During 1992–1993, 38 1-year radon measurements were performed by USPS personnel. Eleven results were >4 pCi/L.

In April 1994, the HAZWRAP radon mitigation diagnostic team performed radon mitigation diagnostics at the site. The mitigation diagnostics are summarized in Table 75.

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed</td>
<td>Part 2 completed</td>
</tr>
<tr>
<td>Continuous radon measurements</td>
<td>17 measurements</td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>Vents inaccessible or wrong shape</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>11</td>
<td>3 to 257 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

As part of the mitigation diagnostics, 17 continuous radon measurements were taken. Nine measurements were found to be >4 pCi/L. The data are summarized in Table 76.
Table 76. Summary of continuous radon measurements for the U.S. Post Office in Marion, Indiana

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>1.7</td>
<td>Men’s restroom</td>
</tr>
<tr>
<td>03</td>
<td>7.6</td>
<td>Basement Room 16</td>
</tr>
<tr>
<td>04</td>
<td>2.7</td>
<td>Basement Room 15</td>
</tr>
<tr>
<td>05</td>
<td>2.1</td>
<td>Basement Room 13</td>
</tr>
<tr>
<td>06</td>
<td>12.4</td>
<td>Open storage area pole B-2</td>
</tr>
<tr>
<td>08</td>
<td>2.5</td>
<td>Room 8</td>
</tr>
<tr>
<td>09</td>
<td>4.9</td>
<td>Room 23</td>
</tr>
<tr>
<td>10</td>
<td>5.9</td>
<td>Basement ducting area near Door 16</td>
</tr>
<tr>
<td>12</td>
<td>2.0</td>
<td>Room 3</td>
</tr>
<tr>
<td>14</td>
<td>2.3</td>
<td>Records Room 12</td>
</tr>
<tr>
<td>15</td>
<td>2.3</td>
<td>Room 25</td>
</tr>
<tr>
<td>17</td>
<td>1.6</td>
<td>Basement near Door 11</td>
</tr>
<tr>
<td>18</td>
<td>5.9</td>
<td>Basement by Door 9</td>
</tr>
<tr>
<td>19</td>
<td>7.1</td>
<td>Room 21</td>
</tr>
<tr>
<td>20</td>
<td>7.3</td>
<td>Room 22</td>
</tr>
<tr>
<td>22</td>
<td>13.8</td>
<td>Room 18</td>
</tr>
<tr>
<td>23</td>
<td>13.2</td>
<td>Room 16</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms and floors in the building. The team was unable to collect a stable ACH measurement during the HVAC day cycle; the suspected reason is transport of tracer gas from other zones. In the GSA office area of the basement, there was not an operational HVAC system; therefore the ACH measurements were not affected. The ACH measurements are reported in Table 79.

Table 77. Air change summary for the U.S. Post Office in Marion, Indiana

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-A</td>
<td>1A/9086</td>
<td>0.59</td>
<td>Blower on</td>
</tr>
<tr>
<td>3</td>
<td>101/4855</td>
<td>0.66 0.27</td>
<td>HVAC on HVAC off</td>
</tr>
</tbody>
</table>
Table 77 (continued)

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour(^{-1}))</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>1A/2377</td>
<td>0.11</td>
<td>HVAC off</td>
</tr>
<tr>
<td>3</td>
<td>101/4855</td>
<td>0.15</td>
<td>HVAC off</td>
</tr>
<tr>
<td>14</td>
<td>1A/2377</td>
<td>0.29</td>
<td>HVAC off</td>
</tr>
<tr>
<td>3</td>
<td>101/4855</td>
<td>0.08</td>
<td>HVAC off</td>
</tr>
</tbody>
</table>

Subslab diagnostics were performed in two basement rooms. The results (Table 78) indicate no communication beneath the slab.

Table 78. Subslab field extension data for the U.S. Post Office in Marion, Indiana

<table>
<thead>
<tr>
<th>Hole 1.45 (inch)</th>
<th>Location</th>
<th>Field extension (ft)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material (in.)</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Room 16</td>
<td>0</td>
<td>4</td>
<td>0.25 gravel</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Boiler room</td>
<td>0</td>
<td>4.75</td>
<td>0.25 gravel</td>
<td>2</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics indicate that the drain in Room 16 is a potential entry pathway for radon. All other measurements were insignificant. The data are listed in Table 79.

Table 79. Radon entry pathway data for the U.S. Post Office in Marion, Indiana

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>Large ducting room</td>
<td>3</td>
</tr>
<tr>
<td>Wall</td>
<td>Boiler room</td>
<td>4</td>
</tr>
<tr>
<td>Door jam</td>
<td>Boiler room</td>
<td>11</td>
</tr>
<tr>
<td>Drain</td>
<td>Room 8</td>
<td>4</td>
</tr>
<tr>
<td>Drain</td>
<td>Boiler room</td>
<td>5</td>
</tr>
<tr>
<td>Drain</td>
<td>Room 16</td>
<td>46</td>
</tr>
<tr>
<td>Crack in wall</td>
<td>Room 16</td>
<td>257</td>
</tr>
<tr>
<td>Drain</td>
<td>Room 16</td>
<td>52</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 14</td>
<td>50</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 14</td>
<td>50</td>
</tr>
<tr>
<td>Pipe chase</td>
<td>Room 3</td>
<td>257</td>
</tr>
<tr>
<td>Man hole</td>
<td>Room 11</td>
<td>108</td>
</tr>
</tbody>
</table>
A blower door measurement was performed in the nonconditioned portion of the basement. Similar measurements performed in the conditioned areas were inconclusive. The blower door data are summarized in Table 80.

### Table 80. Blower door data for the U.S. Post Office in Marion, Indiana

<table>
<thead>
<tr>
<th>Location</th>
<th>Flow for 4 Pa (ft³/min)</th>
<th>Leakage area (in.²)</th>
<th>Room area (ft²)</th>
<th>Ceiling height (ft)</th>
<th>Room volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>4,444</td>
<td>1,266</td>
<td>9,000 (estimate)</td>
<td>8</td>
<td>72,000</td>
</tr>
</tbody>
</table>

DP measurements were performed in various rooms in the basement. The data indicate that the basement is under negative pressure. The data are listed in Table 81.

### Table 81. Differential pressure measurements for the U.S. Post Office in Marion, Indiana

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>Basement</td>
</tr>
<tr>
<td>16</td>
<td>-1</td>
</tr>
<tr>
<td>14</td>
<td>-2</td>
</tr>
<tr>
<td>11</td>
<td>-2</td>
</tr>
<tr>
<td>12</td>
<td>-4</td>
</tr>
<tr>
<td>13</td>
<td>-4</td>
</tr>
<tr>
<td>15</td>
<td>-4</td>
</tr>
<tr>
<td>Hallway</td>
<td>-4</td>
</tr>
<tr>
<td>10-A</td>
<td>-4</td>
</tr>
<tr>
<td>3</td>
<td>-4</td>
</tr>
<tr>
<td>R4-T</td>
<td>-4</td>
</tr>
<tr>
<td>7</td>
<td>-4</td>
</tr>
<tr>
<td>18</td>
<td>-4</td>
</tr>
<tr>
<td>Hallway</td>
<td>-7</td>
</tr>
<tr>
<td>21</td>
<td>-5</td>
</tr>
<tr>
<td>22</td>
<td>-7</td>
</tr>
<tr>
<td>Office</td>
<td>-5</td>
</tr>
</tbody>
</table>

2-77
The flow hood diagnostics measurement could not be performed because the forced-air system was not operational in the basement and the design of the vents was inconsistent with the flow hood templates.

Due to the poor subslab permeability, radon mitigation at this site is limited to only one solution, ventilation. A major factor in the mitigation recommendation for this site is the condition of the existing HVAC system. According to the site maintenance staff, the system is more than 20 years old and has never worked properly. For example, during the heating months, the air conditioning "make-up" air chiller must be removed from the intake hood or it will freeze. Also, none of the intake or outtake dampers work. Zonal mitigation using HRV units would potentially reduce the radon levels in the basement area. However, it would not solve the long-term mechanical problems in the building.

Estimating the cost for a new HVAC system for a building of this size is extremely difficult. For example, some of the supply duct in the basement was in need of replacement. It is suspected that a significant amount of the duct throughout the building is similar condition. In order for the proposed HVAC solution to work, the following features must be incorporated into the system:

1. An automatic pressure monitoring system must be installed in the basement to adjust fresh air intake and exhaust flow to maintain a constant pressure (3 Pa minimum).

2. Supply and return air ducting must be installed in all parts of the basement, and the system must be properly pressure balanced. Also, in each HVAC zone, the relationship for supply and return must be a piston-type flow to afford good area sweeping.

3. The basement area as a whole must receive 8,000 ft³/min more in air supply than what is being exhausted.

4. The air turnover rate for the basement and all other areas of the building must be at least 0.5 ACH.

Another cost consideration is the heating fuel. For this part of Indiana, it is uncertain whether oil or natural gas is the least expensive fuel. Depending on options and features, a new HVAC system with the features described previously could cost between $200K to $350K.
2.17 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN PARIS, KENTUCKY

The main post office in Paris, Kentucky, built in 1965, is a two-story, slab-on-grade building. The approximately 13,500-ft² building has multiple forced-air system heat pumps located on the roof. Supplemental heating is provided by hot water at an exterior temperature below 38°F. There are no fresh air intakes for the building.

During 1992–1993, USPS personnel performed 25 1-year radon measurements. Twenty-one measurements were >4 pCi/L.

In March 1994, the HAZWRAP radon mitigation diagnostic team performed radon mitigation diagnostics at the site. The mitigation diagnostic data are summarized in Table 82.

Table 82. Radon mitigation diagnostics summary for the U.S. Post Office in Paris, Kentucky

<table>
<thead>
<tr>
<th>Diagnostic test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Completed</td>
<td>GSA wing only</td>
</tr>
<tr>
<td>Subslab</td>
<td>Not completed</td>
<td>No building plans, asbestos floor tile, and subslab utilities</td>
</tr>
<tr>
<td>Continuous radon measurements</td>
<td>21 measurements</td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>Grills inaccessible</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>20</td>
<td>2 to 79 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

During the mitigation diagnostics, 21 continuous radon measurements were performed. Although all but one of the average measurements were <4 pCi/L, many of the time-interval measurements increased significantly above the action level during the night. The data are summarized in Table 83.

Table 83. Summary of continuous radon measurements for the U.S. Post Office in Paris, Kentucky

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>03</td>
<td>1.0</td>
<td>Upstairs conference room</td>
</tr>
<tr>
<td>04</td>
<td>2.5</td>
<td>Men's bathroom</td>
</tr>
<tr>
<td>05</td>
<td>2.4</td>
<td>Main room (front right)</td>
</tr>
<tr>
<td>06</td>
<td>2.1</td>
<td>Main room (back right)</td>
</tr>
</tbody>
</table>
Table 83 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>08</td>
<td>4.2</td>
<td>Room 128</td>
</tr>
<tr>
<td>09</td>
<td>0.7</td>
<td>Room 201</td>
</tr>
<tr>
<td>10</td>
<td>1.0</td>
<td>Room 209 A-B</td>
</tr>
<tr>
<td>13</td>
<td>3.7</td>
<td>Women's bathroom</td>
</tr>
<tr>
<td>14</td>
<td>3.2</td>
<td>Room 124</td>
</tr>
<tr>
<td>15</td>
<td>2.8</td>
<td>Room 126</td>
</tr>
<tr>
<td>17</td>
<td>3.3</td>
<td>Main room (P.O. Box area)</td>
</tr>
<tr>
<td>18</td>
<td>3.0</td>
<td>Room 118</td>
</tr>
<tr>
<td>19</td>
<td>2.5</td>
<td>Main room corner</td>
</tr>
<tr>
<td>20</td>
<td>3.2</td>
<td>Postmaster's office</td>
</tr>
<tr>
<td>21</td>
<td>1.1</td>
<td>Main room (front center)</td>
</tr>
<tr>
<td>22</td>
<td>3.5</td>
<td>Room 121 (men's bathroom)</td>
</tr>
<tr>
<td>23</td>
<td>2.8</td>
<td>Room 105</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms in the building. The data are summarized in Table 85.

Table 85. Air change summary for the U.S. Post Office in Paris, Kentucky

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>128A</td>
<td>1A/4855</td>
<td>0.65</td>
<td>Winter heat on</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.47</td>
<td>Winter heat on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.12</td>
<td>Heater off</td>
</tr>
<tr>
<td>Breakroom</td>
<td>101/2377</td>
<td>0.32</td>
<td>Winter heat on</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics failed to locate any significant entry pathways. The data are listed in Table 85.
Table 85. Radon entry pathway diagnostics for the U.S. Post Office in Paris, Kentucky

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall</td>
<td>Breakroom</td>
<td>4</td>
</tr>
<tr>
<td>Wall crack</td>
<td>Breakroom</td>
<td>4</td>
</tr>
<tr>
<td>Background</td>
<td>Breakroom</td>
<td>8</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Sort room</td>
<td>7</td>
</tr>
<tr>
<td>Drain</td>
<td>Room 105</td>
<td>13</td>
</tr>
<tr>
<td>Electrical outlet  (floor)</td>
<td>Sort room</td>
<td>3</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Room 113</td>
<td>10</td>
</tr>
<tr>
<td>Pipe chase</td>
<td>Sort room by vault</td>
<td>3</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 105</td>
<td>10</td>
</tr>
<tr>
<td>Wall crack</td>
<td>Room 105 closet</td>
<td>14</td>
</tr>
<tr>
<td>Floor joint</td>
<td>Box area (left wall)</td>
<td>18</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Sort room (left wall)</td>
<td>79</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Loading dock (left side)</td>
<td>10</td>
</tr>
<tr>
<td>Heater unit</td>
<td>Hallway across from Room 129</td>
<td>16</td>
</tr>
<tr>
<td>Pipe chase</td>
<td>Room 123</td>
<td>8</td>
</tr>
<tr>
<td>Wall</td>
<td>Front lobby</td>
<td>17</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Front lobby</td>
<td>12</td>
</tr>
<tr>
<td>Wall</td>
<td>Front lobby</td>
<td>12</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Room 124</td>
<td>9</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room 128-A</td>
<td>13</td>
</tr>
</tbody>
</table>

Blower door measurements were performed on the ground floor of the GSA wing. The data indicate that the GSA building is highly constructed. The data are listed in Table 86.

Table 86. Blower door data for the U.S. Post Office in Paris, Kentucky

<table>
<thead>
<tr>
<th>Location</th>
<th>Flow for 4 Pa (ft³/min)</th>
<th>Leakage area (in²)</th>
<th>Room area (ft²)</th>
<th>Ceiling height (ft)</th>
<th>Area volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office wing (ground floor)</td>
<td>733</td>
<td>207</td>
<td>3,700</td>
<td>8</td>
<td>29,600</td>
</tr>
</tbody>
</table>
DP measurements were performed in various rooms on the ground floor. The data indicate that the building is under significant negative pressure. Based on the blower door data (Table 86), the conclusion was that the building was tightly constructed. Therefore, the seemingly insignificant exhaust (such as bathroom fans (quantity 4), and leakage in the HAC blower box (located on roof)) would result in depressurization of the building. The data are listed in Table 87.

Table 87. Differential pressure measurements for the U.S. Post Office in Paris, Kentucky

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Floor</td>
<td>Ground Floor</td>
</tr>
<tr>
<td>Breakroom</td>
<td>-5</td>
</tr>
<tr>
<td>Men's restroom</td>
<td>-9</td>
</tr>
<tr>
<td>Service closet</td>
<td>-4</td>
</tr>
<tr>
<td>Women's restroom</td>
<td>-5</td>
</tr>
<tr>
<td>Loading dock</td>
<td>-5</td>
</tr>
<tr>
<td>Storage</td>
<td>-5</td>
</tr>
<tr>
<td>106</td>
<td>-6</td>
</tr>
<tr>
<td>Bathroom</td>
<td>-14 (suspect)</td>
</tr>
<tr>
<td>Lobby/counter</td>
<td>-5</td>
</tr>
<tr>
<td>Lobby door</td>
<td>-7</td>
</tr>
<tr>
<td>Front door</td>
<td>-9</td>
</tr>
<tr>
<td>Hole in wall</td>
<td>-8</td>
</tr>
<tr>
<td>Emergency door to outside</td>
<td>-4</td>
</tr>
<tr>
<td>Trash room</td>
<td>-4</td>
</tr>
<tr>
<td>Office</td>
<td>-5</td>
</tr>
<tr>
<td>Men's restroom</td>
<td>-5</td>
</tr>
<tr>
<td>Women's restroom</td>
<td>-4</td>
</tr>
<tr>
<td>Stairwell</td>
<td>-2</td>
</tr>
</tbody>
</table>

Two mitigation diagnostics could not be performed at the site. Subslab diagnostics could not be performed due to the presence of asbestos floor tile and subslab utilities and the absence of building plans. The flow hood test could not be performed due to the size and location of the forced-air system supply ducts.
The data in Table 87 indicated that the building was under negative pressure. Before active mitigation attempts are performed, it is strongly advised that all of the building mechanical systems be inspected (HAC and ventilation fans). The goal should be the attainment of neutral pressure throughout the building by means of mechanical balancing and incorporation of outside make-up air in the highly depressurized areas. If a neutral building can be attained, then retesting should be performed. The estimated cost for the passive attempt is $1K.

If the passive mitigation attempt fails, based on the mitigation diagnostic data collected, the best active mitigation method would be SP for this building. However, the selection of an exact means to accomplish this is another matter. According to the site maintenance staff, the existing HAC system is at least 20 years old. Due to its advanced age, units may have insufficient reserve capacity to both pressurize the building and maintain effective environmental control. If a qualified mechanical inspector finds sufficient life and capacity in the units, then the installation of one fresh air intake hood for each of the existing five roof HAC units on the roof would be the most cost-effective mitigation method. Assuming this is possible, the pressure of each room should be set to +5 Pa. The installation cost would be $4K.

However, if the units are too deteriorated or are scheduled for replacement within the next few years, then a modern HAC forced-air system equipped with fresh air intake hoods should be installed. Feedback pressure sensors should be installed in each room to ensure proper pressurization. As mentioned previously, each area should be pressurized to +5 Pa. The cost for complete mechanical replacement is estimated to be $59K.

2.18 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN RATON, NEW MEXICO

The main post office in Raton, New Mexico, is a 19,000-ft², two-story building constructed in 1966. The substructure is slab-on-grade. In June 1993, USPS personnel installed new, multiple HVAC, forced-air systems. Supplemental heating is provided by a hot water exchanger, while cooling is provided by gas. The fresh air intakes are located on the roof of the building.

In August 1992, USPS personnel performed 35 short-term radon measurements. None of the measurements were >4 pCi/L. However, previous radon data collected by GSA indicated elevated radon at the site.

In May 1994, the HAZWRAP radon mitigation diagnostic team performed radon mitigation diagnostics at the site. The diagnostic measurements performed at the site are summarized in Table 88.

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>1</td>
<td>Unsuccessful, too windy</td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed</td>
<td>Communication to outside</td>
</tr>
<tr>
<td></td>
<td>Part 2 completed</td>
<td></td>
</tr>
<tr>
<td>Continuous radon</td>
<td>19 measurements</td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
During the mitigation diagnostics, 19 continuous radon measurements were performed. Three areas were found to have radon in excess of the 4 pCi/L action level. The data are summarized in Table 89.

Table 89. Summary of continuous radon measurements for the U.S. Post Office in Raton, New Mexico

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1.1</td>
<td>Room 206</td>
</tr>
<tr>
<td>02</td>
<td>0.6</td>
<td>Main room (front center)</td>
</tr>
<tr>
<td>03</td>
<td>3.4</td>
<td>Room 114</td>
</tr>
<tr>
<td>05</td>
<td>0.8</td>
<td>Main room (center)</td>
</tr>
<tr>
<td>06</td>
<td>1.3</td>
<td>Room 205</td>
</tr>
<tr>
<td>08</td>
<td>3.7</td>
<td>Room 110</td>
</tr>
<tr>
<td>09</td>
<td>1.5</td>
<td>Room 211</td>
</tr>
<tr>
<td>10</td>
<td>1.0</td>
<td>Room 115</td>
</tr>
<tr>
<td>11</td>
<td>3.2</td>
<td>Conference room</td>
</tr>
<tr>
<td>12</td>
<td>4.6</td>
<td>Room 111</td>
</tr>
<tr>
<td>13</td>
<td>6.3</td>
<td>Room 109</td>
</tr>
<tr>
<td>14</td>
<td>4.7</td>
<td>Room 103</td>
</tr>
<tr>
<td>16</td>
<td>3.0</td>
<td>Room 105</td>
</tr>
<tr>
<td>17</td>
<td>0.7</td>
<td>Room 127</td>
</tr>
<tr>
<td>18</td>
<td>0.8</td>
<td>Main room (back right)</td>
</tr>
<tr>
<td>19</td>
<td>0.7</td>
<td>P.O. Box hallway</td>
</tr>
</tbody>
</table>
Table 89 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.6</td>
<td>Main room (back left)</td>
</tr>
<tr>
<td>22</td>
<td>1.0</td>
<td>Postmaster's office</td>
</tr>
<tr>
<td>23</td>
<td>0.9</td>
<td>Main room (left center)</td>
</tr>
</tbody>
</table>

Air change measurements were preformed in various rooms in the building. During the testing, the blower was on continuously. The most significant finding of the ACH measurements is that very little fresh air is being incorporated into the building. Nominal ACH rate for the rooms tested should be 0.5 ACH or greater. The data are summarized in Table 90.

Table 90. Air change summary for the U.S. Post Office in Raton, New Mexico

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>1A/2377</td>
<td>0.16</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>111</td>
<td>101/9346</td>
<td>0.10</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>105</td>
<td>1A/2377</td>
<td>0.16</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.23</td>
<td>Air conditioning on</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics failed to locate any significant entry pathways. The data are summarized in Table 91.

Table 91. Radon entry pathway diagnostics for the U.S. Post Office in Raton, New Mexico

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone jack</td>
<td>Conference room</td>
<td>12</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 103</td>
<td>31</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 107</td>
<td>18</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 109</td>
<td>29</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 109</td>
<td>6</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 111</td>
<td>17</td>
</tr>
<tr>
<td>Wall crack</td>
<td>Room 111</td>
<td>6</td>
</tr>
</tbody>
</table>

2-85
Table 91 (continued)

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain</td>
<td>Hallway GSA side</td>
<td>4</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Equipment room</td>
<td>65</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Equipment room</td>
<td>185</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Equipment room</td>
<td>86</td>
</tr>
<tr>
<td>Drain</td>
<td>Breakroom</td>
<td>12</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Main sort room</td>
<td>5</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Assistant Postmaster’s office</td>
<td>7</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Postmaster’s office</td>
<td>8</td>
</tr>
</tbody>
</table>

DP measurements indicated the building is slightly negative overall. The data are summarized in Table 92.

**Table 92. Differential pressure measurements for the U.S. Post Office Raton, New Mexico**

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back entry</td>
<td>-1</td>
</tr>
<tr>
<td>Main room</td>
<td>-1</td>
</tr>
<tr>
<td>Supply room</td>
<td>-1</td>
</tr>
<tr>
<td>Women’s restroom</td>
<td>0</td>
</tr>
<tr>
<td>Swing room</td>
<td>0</td>
</tr>
<tr>
<td>Men’s restroom</td>
<td>-1</td>
</tr>
<tr>
<td>Office next to Postmaster’s office</td>
<td>-2</td>
</tr>
<tr>
<td>Postmaster’s office</td>
<td>-2</td>
</tr>
<tr>
<td>Maintenance office</td>
<td>-1</td>
</tr>
<tr>
<td>Hallway</td>
<td>-4</td>
</tr>
<tr>
<td>115</td>
<td>0</td>
</tr>
<tr>
<td>111</td>
<td>-2</td>
</tr>
<tr>
<td>116</td>
<td>-4</td>
</tr>
</tbody>
</table>
### Table 92 (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>109</td>
<td>-5</td>
</tr>
<tr>
<td>110</td>
<td>-3</td>
</tr>
<tr>
<td>Postal conference room</td>
<td>-4</td>
</tr>
<tr>
<td>105</td>
<td>-4</td>
</tr>
<tr>
<td>103</td>
<td>-4</td>
</tr>
<tr>
<td>Stairwell</td>
<td>-2</td>
</tr>
<tr>
<td>Main lobby</td>
<td>-2</td>
</tr>
<tr>
<td>Hallway</td>
<td>3</td>
</tr>
<tr>
<td>216-A</td>
<td>2</td>
</tr>
<tr>
<td>216</td>
<td>3</td>
</tr>
<tr>
<td>213</td>
<td>3</td>
</tr>
<tr>
<td>211</td>
<td>3</td>
</tr>
<tr>
<td>214</td>
<td>2</td>
</tr>
<tr>
<td>209</td>
<td>5</td>
</tr>
<tr>
<td>206</td>
<td>2</td>
</tr>
<tr>
<td>205</td>
<td>4</td>
</tr>
<tr>
<td>203</td>
<td>2</td>
</tr>
<tr>
<td>202</td>
<td>4</td>
</tr>
</tbody>
</table>

Subslab diagnostics measurements were performed in the boiler room. Part 1 of the measurement found that the slab was 3 in. thick with a 5.5-in. gravel base. Permeability testing determined that the subslab has a high flow/low pressure characteristic, with considerable communication to the outside. Field extension was estimated to be 18 ft at 1-in. static pressure. Although unable to quantify, the data do indicate that the building is tightly constructed.

Blower door diagnostics were performed, but the data were inconclusive due to wind. The current forced-air system has no duct work. The air from the units is forced into the suspended ceiling and is delivered into the areas by cutting holes or removing a ceiling tile. In the absence of a supply vent, the flow hood measurements could not be performed.

Radon mitigation should be a phased approach at this site. The first step should be the inspection of the fresh air intake vents on the roof. Based on the ACH data (Table 90), insufficient fresh air is being incorporated into the building. Adjustments should be made to
increase the overall air change to a minimal 0.75 hour\(^{-1}\), and then retesting should be performed. The estimated cost for this attempt is $700.

An alternative for increased air change is the installation of an HRV unit in the building. In the office wing, the installation of four 700-ft\(^3\)/min HRV units (one per quarter slab area) should provide sufficient increase in the air turnover rate to reduce the radon levels. Although not required for radon mitigation, it is recommended from an indoor air quality standpoint, that the USPS side of the building have three 700-ft\(^3\)/min HRV units installed as well. The estimated cost for installation of the HRV mitigation system (including ducting) is $28K.

If air change adjustments are unsuccessful, then the DP measurements should be repeated. If the DP measurements in the elevated area(s) are negative, then area and individual room flow adjustments should be made to compensate for this problem. One possibility is the installation of passive wall vents (6 in. \(\times\) 3 ft) connecting all of the office areas with the central hallway. Another suggestion is to reduce the amount of recycled air from an area. The target overall pressure for the office areas should be +5 Pa to ensure mitigation. The estimated cost for this mitigation attempt is $2K for vent installation and $700 for recycled damper adjustment and installation.

Subslab mitigation would be the next option (if all other ventilation attempts have failed). Installation of six 4-in. PVC suction pits in parallel rows (two rows of three pits each) alternating along the slab centerline within the office wing should be sufficient for reduction. No more than three pits should be connected to a single fan (2.5 in. at 500 ft\(^3\)/min). Five similar-size pits should be located on the USPS side of the building at equal distances from each other. All of the pits must be at least 20 ft from the slab edge. The exact locations of the pits should be determined by site personnel and the installation contractor to prevent work area obstruction. Although the negative pressure side of the PVC pipe may be located in the supply plenum, the exhaust fans must be located on the building exterior. Based on the estimated lengths of pipe runs and assuming mostly vertical exhaust stacks, the cost for installation of the SSD system is $17K.

2.19 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN ROCKLAND, MAINE

The main post office in Rockland, Maine, is a two-story, 19,000-ft\(^2\), slab-on-grade building constructed in 1967. The building has new multiple HVAC forced-air systems (installed July 1993). Heating is provided by both a hot water exchanger and compressor. Cooling is provided by compressor (electrical). The fresh air intakes are located on the roof of the building.

During 1992-1993, USPS personnel performed 25 1-year radon measurements. Ten measurements were >4 pCi/L.

In August 1994, the HAZWRAP radon mitigation diagnostic team performed radon mitigation diagnostics at the site. The mitigation diagnostics are summarized in Table 93.

Table 93. Radon mitigation diagnostics summary for the U.S. Post Office in Rockland, Maine

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Subslab</td>
<td>Not completed</td>
<td>No building plans and subslab utilities</td>
</tr>
</tbody>
</table>
During the mitigation diagnostics, 21 continuous radon measurements were performed. None of the measurements were $>4$ pCi/L. The data are summarized on Table 94.

Table 94. Summary of continuous radon measurements for the U.S. Post Office in Rockland, Maine

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0.2</td>
<td>Postmaster’s office</td>
</tr>
<tr>
<td>02</td>
<td>0.2</td>
<td>Room 148</td>
</tr>
<tr>
<td>03</td>
<td>0.7</td>
<td>Room 207</td>
</tr>
<tr>
<td>04</td>
<td>0.6</td>
<td>Supply room off main room</td>
</tr>
<tr>
<td>05</td>
<td>0.5</td>
<td>Main room (front left)</td>
</tr>
<tr>
<td>07</td>
<td>0.7</td>
<td>Conference room</td>
</tr>
<tr>
<td>08</td>
<td>0.4</td>
<td>Main room (front left)</td>
</tr>
<tr>
<td>09</td>
<td>0.2</td>
<td>Main room (back left)</td>
</tr>
<tr>
<td>10</td>
<td>0.7</td>
<td>Room 158</td>
</tr>
<tr>
<td>11</td>
<td>0.7</td>
<td>Main room (back right)</td>
</tr>
<tr>
<td>12</td>
<td>0.6</td>
<td>Breakroom</td>
</tr>
<tr>
<td>13</td>
<td>0.6</td>
<td>Room 200</td>
</tr>
<tr>
<td>14</td>
<td>0.3</td>
<td>Room 146</td>
</tr>
<tr>
<td>15</td>
<td>0.5</td>
<td>Room 143</td>
</tr>
<tr>
<td>16</td>
<td>0.6</td>
<td>Supply room off main room</td>
</tr>
</tbody>
</table>
Table 94 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>0.2</td>
<td>Room 147</td>
</tr>
<tr>
<td>18</td>
<td>0.1</td>
<td>Old smoke room</td>
</tr>
<tr>
<td>19</td>
<td>0.5</td>
<td>Room 149</td>
</tr>
<tr>
<td>20</td>
<td>0.5</td>
<td>Room 157</td>
</tr>
<tr>
<td>21</td>
<td>1.3</td>
<td>Room 155</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms in the building. The data are summarized in Table 95.

Table 95. Air change summary for the U.S. Post Office in Rockland, Maine

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.54</td>
<td>Air conditioning on 24 hours</td>
</tr>
<tr>
<td>FMHA office</td>
<td>1A/2377</td>
<td>0.26</td>
<td>Air conditioning on 24 hours</td>
</tr>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.40</td>
<td>Air conditioning on 24 hours</td>
</tr>
<tr>
<td>FMHA office</td>
<td>1A/2377</td>
<td>0.48</td>
<td>Air conditioning on 24 hours</td>
</tr>
<tr>
<td>Supervisor’s office</td>
<td>1A/4855</td>
<td>0.43</td>
<td>Air conditioning on 24 hours</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics failed to identify any major radon entry pathways. The data are summarized in Table 96.
Table 96. Radon entry pathway diagnostics for the U.S. Post Office in Rockland, Maine

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain</td>
<td>Boiler Room 157</td>
<td>1</td>
</tr>
<tr>
<td>Power conduit</td>
<td>Boiler Room 157</td>
<td>4</td>
</tr>
<tr>
<td>Floor crack</td>
<td>Boiler Room 157</td>
<td>0</td>
</tr>
<tr>
<td>Floor</td>
<td>Boiler Room 157</td>
<td>0</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Boiler Room 157</td>
<td>13</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 147</td>
<td>6</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 147</td>
<td>4</td>
</tr>
<tr>
<td>Pipe chase</td>
<td>Room 141</td>
<td>4</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Box area</td>
<td>14</td>
</tr>
</tbody>
</table>

DP measurements indicate that the forced-air system is unbalanced. The data are listed in Table 97.

Table 97. Differential pressure measurements for the U.S. Post Office in Rockland, Maine

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smokers’ room</td>
<td>0</td>
</tr>
<tr>
<td>Main room</td>
<td>0</td>
</tr>
<tr>
<td>Breakroom</td>
<td>-2</td>
</tr>
<tr>
<td>Maintenance room</td>
<td>1</td>
</tr>
<tr>
<td>Storage room</td>
<td>1</td>
</tr>
<tr>
<td>Office</td>
<td>-3</td>
</tr>
<tr>
<td>Supervisor’s office</td>
<td>-3</td>
</tr>
<tr>
<td>Postmaster’s office</td>
<td>0</td>
</tr>
<tr>
<td>Entry</td>
<td>-4</td>
</tr>
<tr>
<td>Box lobby</td>
<td>-5</td>
</tr>
<tr>
<td>Control lobby</td>
<td>-12 (suspect)</td>
</tr>
<tr>
<td>Hall</td>
<td>-5</td>
</tr>
</tbody>
</table>
Table 97 (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>141</td>
<td>-3</td>
</tr>
<tr>
<td>143</td>
<td>-6</td>
</tr>
<tr>
<td>144</td>
<td>-5</td>
</tr>
<tr>
<td>145</td>
<td>-9</td>
</tr>
<tr>
<td>147</td>
<td>-5</td>
</tr>
<tr>
<td>149</td>
<td>1</td>
</tr>
<tr>
<td>148-46</td>
<td>0</td>
</tr>
<tr>
<td>Hall</td>
<td>7</td>
</tr>
<tr>
<td>Men's restroom</td>
<td>8</td>
</tr>
<tr>
<td>217</td>
<td>14 (suspect)</td>
</tr>
<tr>
<td>Women's restroom</td>
<td>12 (suspect)</td>
</tr>
<tr>
<td>206</td>
<td>7</td>
</tr>
<tr>
<td>207</td>
<td>9</td>
</tr>
<tr>
<td>200</td>
<td>9</td>
</tr>
<tr>
<td>201</td>
<td>5</td>
</tr>
</tbody>
</table>

Flow hood measurements indicate sufficient flow in the areas tested. The data are summarized in Table 98.

Table 98. Flow hood diagnostics measurement data for the U.S. Post Office in Rockland, Maine

<table>
<thead>
<tr>
<th>Location</th>
<th>Uncorrected flow (ft³/min)</th>
<th>Corrected flow (ft³/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 148</td>
<td>141</td>
<td>174</td>
</tr>
<tr>
<td>Room 158</td>
<td>319</td>
<td>337</td>
</tr>
<tr>
<td>Room 151</td>
<td>274</td>
<td>318</td>
</tr>
<tr>
<td>Room 149</td>
<td>250</td>
<td>342</td>
</tr>
<tr>
<td>Room 147</td>
<td>236</td>
<td>278</td>
</tr>
<tr>
<td>Room 143</td>
<td>292</td>
<td>402</td>
</tr>
<tr>
<td>Room 200</td>
<td>480</td>
<td>584</td>
</tr>
<tr>
<td>Room 200-A</td>
<td>441</td>
<td>498</td>
</tr>
<tr>
<td>Room 207</td>
<td>511</td>
<td>638</td>
</tr>
</tbody>
</table>
Blower door measurements performed on the GSA wing of the site were inconclusive due to the constant opening and closing of the doors at the site. Although inconclusive, the data do indicate a tight building shell.

The subslab diagnostic measurement could not be performed due to the absence of building plans and the presence of subslab utilities.

Although the building tested negative for elevated radon levels during the on-site investigation (Table 94), the new HVAC system should be balanced. The pressure data (Table 97) indicate a system that needs some adjustment. In addition, it is recommended that long-term testing be performed during the heating season to confirm that radon has been reduced. If retesting shows elevated radon, then the building HVAC system should be adjusted to pressurize the building to +5 Pa. The estimated cost for this adjustment is $700.

2.20 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN SCOTT CITY, KANSAS

The main post office in Scott City, Kansas, is a two-story, 18,000-ft², slab-on-grade building constructed in 1965. The building has six new HVAC forced-air systems (installed in 1993). Heating and cooling is provided by gas, while supplemental heating is provided by a hot water exchanger. The HVAC fresh air intakes are located on the roof of the building.

During 1992-1993, USPS personnel performed 19 1-year radon measurements. Five were >4 pCi/L.

In May 1994, the HAZWRAP radon mitigation diagnostic team performed radon mitigation diagnostics at the site (Table 99).

Table 99. Mitigation diagnostics summary for the U.S. Post Office in Scott City, Kansas

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td>Subslab</td>
<td>Not completed</td>
<td>No building plans, and subslab utilities</td>
</tr>
<tr>
<td>Continuous radon</td>
<td>20 measurements</td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>25</td>
<td>0 to 6 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>First floor: 20</td>
<td>Negative pressure</td>
</tr>
<tr>
<td></td>
<td>Second floor: 5</td>
<td>Positive pressure</td>
</tr>
</tbody>
</table>

During the mitigation diagnostics, 20 continuous radon measurements were performed. None of the 24-hour average measurements were >4 pCi/L. However, during the night while the air conditioning system is operating at a reduced level, the radon concentration did increase to >4 pCi/L in several offices in the GSA wing. The data are summarized in Table 100.
Air change measurements were performed in various rooms in the building. Significant reduction in ACH was observed as a function of HVAC cycle. Although radon is under control, the ACH rate in the areas tested is substandard. Adjustments need to be made in the amount of fresh air for the building to increase the ACH to approximately 0.5 hour⁻¹. The data are summarized in Table 101.

Table 100. Summary of continuous radon measurements for the U.S. Post Office in Scott City, Kansas

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1.3</td>
<td>Room 116-B</td>
</tr>
<tr>
<td>02</td>
<td>1.7</td>
<td>Room 128</td>
</tr>
<tr>
<td>03</td>
<td>1.6</td>
<td>Room 116</td>
</tr>
<tr>
<td>05</td>
<td>1.4</td>
<td>Room 114</td>
</tr>
<tr>
<td>06</td>
<td>1.7</td>
<td>Main room (front right)</td>
</tr>
<tr>
<td>08</td>
<td>2.0</td>
<td>Room 107</td>
</tr>
<tr>
<td>09</td>
<td>1.8</td>
<td>Main room (back right)</td>
</tr>
<tr>
<td>10</td>
<td>1.9</td>
<td>Room 113</td>
</tr>
<tr>
<td>12</td>
<td>1.6</td>
<td>Room 108</td>
</tr>
<tr>
<td>13</td>
<td>1.6</td>
<td>Room 106</td>
</tr>
<tr>
<td>14</td>
<td>2.2</td>
<td>Main room (front left)</td>
</tr>
<tr>
<td>15</td>
<td>1.0</td>
<td>Room 210 (duplicate)</td>
</tr>
<tr>
<td>16</td>
<td>1.4</td>
<td>Room 118</td>
</tr>
<tr>
<td>17</td>
<td>0.7</td>
<td>Room 205</td>
</tr>
<tr>
<td>18</td>
<td>1.5</td>
<td>Postmaster's office</td>
</tr>
<tr>
<td>19</td>
<td>1.6</td>
<td>Swing room</td>
</tr>
<tr>
<td>20</td>
<td>1.0</td>
<td>Room 210</td>
</tr>
<tr>
<td>22</td>
<td>1.6</td>
<td>Room 216</td>
</tr>
<tr>
<td>23</td>
<td>0.8</td>
<td>Room 204</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms in the building. Significant reduction in ACH was observed as a function of HVAC cycle. Although radon is under control, the ACH rate in the areas tested is substandard. Adjustments need to be made in the amount of fresh air for the building to increase the ACH to approximately 0.5 hour⁻¹. The data are summarized in Table 101.
Flow hood measurements were performed in areas where the supply duct was accessible. Several of the areas tested had no measurable flow, although according to the maintenance staff the areas should. The data are listed in Table 102.

**Table 102. Flow hood measurements for the U.S. Post Office in Scott City, Kansas**

<table>
<thead>
<tr>
<th>Location</th>
<th>Uncorrected flow (ft³/min)</th>
<th>Corrected flow (ft³/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 204-206</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Room 205</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Room 205-A</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Room 210</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td>Room 210-B</td>
<td>27</td>
<td>25</td>
</tr>
<tr>
<td>Room 210-A</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>Main room - near 139</td>
<td>27</td>
<td>25</td>
</tr>
<tr>
<td>Main room</td>
<td>32</td>
<td>37</td>
</tr>
<tr>
<td>Main room - near 139</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>Main room - near 139</td>
<td>27</td>
<td>31</td>
</tr>
<tr>
<td>Breakroom</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Breakroom</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Blower door measurements were performed on the GSA office wing. The data indicate that the building shell is not particularly tight. The data are listed in Table 103.
Table 103. Blower door data for the U.S. Post Office in Scott City, Kansas

<table>
<thead>
<tr>
<th>Location</th>
<th>Flow for 4 Pa (ft³/min)</th>
<th>Leakage area (in.²)</th>
<th>Room area (ft²)</th>
<th>Ceiling height (ft)</th>
<th>Room volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal wing</td>
<td>5,058</td>
<td>1,433</td>
<td>3,800</td>
<td>8</td>
<td>30,400</td>
</tr>
</tbody>
</table>

DP measurements were performed in various rooms on the first and second floors of the building (Table 104).

Table 104. Differential pressure measurements for the U.S. Post Office in Scott City, Kansas

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hallway</td>
<td>-1</td>
</tr>
<tr>
<td>Storage room</td>
<td>-1</td>
</tr>
<tr>
<td>118</td>
<td>-4</td>
</tr>
<tr>
<td>114</td>
<td>-1</td>
</tr>
<tr>
<td>113</td>
<td>-2</td>
</tr>
<tr>
<td>111</td>
<td>-1</td>
</tr>
<tr>
<td>106</td>
<td>-1</td>
</tr>
<tr>
<td>Main sorting area</td>
<td>-2</td>
</tr>
<tr>
<td>134</td>
<td>-3</td>
</tr>
<tr>
<td>135</td>
<td>-4</td>
</tr>
<tr>
<td>136</td>
<td>-3</td>
</tr>
<tr>
<td>139</td>
<td>-3</td>
</tr>
<tr>
<td>128</td>
<td>0</td>
</tr>
<tr>
<td>128</td>
<td>-1</td>
</tr>
<tr>
<td>128B</td>
<td>-1</td>
</tr>
<tr>
<td>Stairwell</td>
<td>-2</td>
</tr>
<tr>
<td>Hallway, downstairs</td>
<td>-2</td>
</tr>
<tr>
<td>Hallway, upstairs</td>
<td>-1</td>
</tr>
<tr>
<td>Hallway, upstairs</td>
<td>-1</td>
</tr>
<tr>
<td>210</td>
<td>-1</td>
</tr>
</tbody>
</table>

2-96
Table 104 (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>211</td>
<td>0</td>
</tr>
<tr>
<td>207</td>
<td>-1</td>
</tr>
</tbody>
</table>

Subslab mitigation diagnostics could not be performed due to the absence of building plans and the presence of subslab utilities.

Based on the data collected, it appears that the new HVAC system has mitigated the radon problem at the site. However, limited continuous data have indicated a trend toward higher radon levels during the night while the HVAC is on limited cycle. The recommendation is made that a 30-day continuous radon measurement be performed at the site during the heating season to ensure radon reduction is permanent. If daytime measurements are elevated, then mitigation could be accomplished by increasing the air change rates in the affected areas. If nighttime measurements are elevated, then a radon management plan (Sect. 2.12) would be the most cost-effective means of controlling personnel exposure.

2.21 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN TALLADEGA, ALABAMA

The main post office in Talladega, Alabama, is a two-story, 18,000-ft², slab-on-grade building constructed in 1970. The building has six HAC forced-air systems. Heating is provided by gas furnace, while cooling is provided by compressor. The HAC systems, installed 3 years ago, have no fresh air intakes.

During 1992–1993, the USPS personnel performed 24 1-year radon measurements. Twenty-two measurements were determined to be >4 pCi/L.

In March 1994, the HAZWRAP radon mitigation diagnostic team performed radon mitigation diagnostics at the site (Table 105).

Table 105. Mitigation diagnostics summary for the U.S. Post Office in Talladega, Alabama

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>20</td>
<td>Some tests were invalidated due to open doors</td>
</tr>
<tr>
<td>Blower door</td>
<td>1</td>
<td>Inconclusive</td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed Part 2 completed</td>
<td></td>
</tr>
<tr>
<td>Continuous radon</td>
<td>21 measurements</td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>
During the mitigation diagnostics, 21 continuous radon measurements were performed. The data confirms the presence of elevated radon at the site. No significant increase in radon concentration was observed as a function of HAC night cycle. The data are listed in Table 106.

### Table 106. Summary of continuous radon measurements for the U.S. Post Office in Talladega, Alabama

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurements (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>6.4</td>
<td>Room 112</td>
</tr>
<tr>
<td>03</td>
<td>5.8</td>
<td>Room 217</td>
</tr>
<tr>
<td>04</td>
<td>6.2</td>
<td>Room 130-A</td>
</tr>
<tr>
<td>05</td>
<td>2.9</td>
<td>Main room (center)</td>
</tr>
<tr>
<td>06</td>
<td>3.1</td>
<td>Main room (P.O. Box area)</td>
</tr>
<tr>
<td>08</td>
<td>4.4</td>
<td>Room 204</td>
</tr>
<tr>
<td>09</td>
<td>5.1</td>
<td>Room 214</td>
</tr>
<tr>
<td>10</td>
<td>3.8</td>
<td>Main room (front right)</td>
</tr>
<tr>
<td>12</td>
<td>3.5</td>
<td>Room 122</td>
</tr>
<tr>
<td>13</td>
<td>5.0</td>
<td>Room 130</td>
</tr>
<tr>
<td>14</td>
<td>5.2</td>
<td>Room 205</td>
</tr>
<tr>
<td>15</td>
<td>3.1</td>
<td>Breakroom</td>
</tr>
<tr>
<td>16</td>
<td>10.3</td>
<td>Room 129</td>
</tr>
<tr>
<td>17</td>
<td>6.0</td>
<td>Room 108-C</td>
</tr>
<tr>
<td>18</td>
<td>3.3</td>
<td>Main room by Room 121</td>
</tr>
<tr>
<td>19</td>
<td>7.2</td>
<td>Room 104</td>
</tr>
</tbody>
</table>
Table 106 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurements (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>5.1</td>
<td>Room 103</td>
</tr>
<tr>
<td>21</td>
<td>2.4</td>
<td>Room 108-A</td>
</tr>
<tr>
<td>22</td>
<td>6.9</td>
<td>Room 108</td>
</tr>
<tr>
<td>23</td>
<td>9.7</td>
<td>Room 114</td>
</tr>
<tr>
<td>Fem-Tech-1</td>
<td>8.9</td>
<td>Room 108-C (17)</td>
</tr>
<tr>
<td>Fem-Tech-2</td>
<td>4.3</td>
<td>Room 103 (20)</td>
</tr>
<tr>
<td>Fem-Tech-3</td>
<td>1.3</td>
<td>Main room (center) (05)</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms in the building. The data indicate significant (factor of 2) increases in ACH as a function of the HAC cycle. Because this is not an HVAC system, the conclusion was made that a fresh air leak must exist somewhere in the return air system. Inspection of the blowers on the roof found significant gaps in the junction between the return air duct and the blower box. The maintenance staff concurred that water (e.g., rain) has been a problem since the system was installed. The air change data are listed in Table 107.

Table 107. Air change summary of for the U.S. Post Office in Talladega, Alabama

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room</td>
<td>1A/4855</td>
<td>0.10 0.20</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>214</td>
<td>101/9086</td>
<td>0.52 0.97</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning on</td>
</tr>
<tr>
<td>103</td>
<td>1A/2377</td>
<td>0.14 0.30</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning on</td>
</tr>
</tbody>
</table>

Subslab diagnostics were performed in two areas of the slab. The data indicate adequate subslab pressure field extension (Table 108).

Table 108. Subslab field extension data for the U.S. Post Office in Talladega, Alabama

<table>
<thead>
<tr>
<th>Hole 1.50 (in.)</th>
<th>Location</th>
<th>Field extension (ft)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Room 114</td>
<td>11(+)</td>
<td>5</td>
<td>0.5-0.75 gravel</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
<td>Breakroom</td>
<td>20(+)</td>
<td>5</td>
<td>0.5-0.75 gravel</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Flow hood measurements were performed in various rooms in the building. The data are listed in Table 109.

Table 109. Flow hood measurements at the U.S. Post Office in Talladega, Alabama

<table>
<thead>
<tr>
<th>Location</th>
<th>Uncorrected flow (ft³/min)</th>
<th>Corrected flow (ft³/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 204-B</td>
<td>111</td>
<td>107</td>
</tr>
<tr>
<td>Room 112</td>
<td>373</td>
<td>451</td>
</tr>
<tr>
<td>Room 108-A</td>
<td>249</td>
<td>281</td>
</tr>
<tr>
<td>Room 108-A</td>
<td>321</td>
<td>349</td>
</tr>
<tr>
<td>Room 108 (right)</td>
<td>415</td>
<td>589</td>
</tr>
<tr>
<td>Room 108 (left)</td>
<td>307</td>
<td>459</td>
</tr>
<tr>
<td>Room 108-C</td>
<td>283</td>
<td>342</td>
</tr>
<tr>
<td>Room 105</td>
<td>435</td>
<td>539</td>
</tr>
<tr>
<td>Room 204 (right)</td>
<td>492</td>
<td>580</td>
</tr>
<tr>
<td>Room 204 (left)</td>
<td>332</td>
<td>375</td>
</tr>
<tr>
<td>Room 217</td>
<td>453</td>
<td>534</td>
</tr>
<tr>
<td>Room 215</td>
<td>61</td>
<td>95</td>
</tr>
<tr>
<td>Room 213</td>
<td>458</td>
<td>490</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics failed to locate any significant entry pathways. The data are listed in Table 110.

Table 110. Radon entry pathway diagnostics data for the U.S. Post Office in Talladega, Alabama

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone jack</td>
<td>Room 103</td>
<td>16</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 103</td>
<td>27</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 103</td>
<td>20</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room 103</td>
<td>19</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 104</td>
<td>17</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Hallway near 108</td>
<td>28</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room 108-C</td>
<td>10</td>
</tr>
</tbody>
</table>

2-100
<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer cable outlet</td>
<td>Room 108</td>
<td>14</td>
</tr>
<tr>
<td>Power cable chase</td>
<td>Room 108-A</td>
<td>12</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 112</td>
<td>13</td>
</tr>
<tr>
<td>Drain</td>
<td>Hallway near water fountain</td>
<td>19</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Room 114</td>
<td>9</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Men’s restroom (first floor hallway)</td>
<td>15</td>
</tr>
<tr>
<td>Floor crack</td>
<td>Main lobby</td>
<td>22</td>
</tr>
<tr>
<td>Window frame crack</td>
<td>Main lobby</td>
<td>8</td>
</tr>
<tr>
<td>Door frame crack</td>
<td>Elevator</td>
<td>17</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 130-A</td>
<td>16</td>
</tr>
<tr>
<td>Wall crack</td>
<td>Room 129</td>
<td>8</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 128</td>
<td>8</td>
</tr>
<tr>
<td>Wall</td>
<td>Main room near safe</td>
<td>20</td>
</tr>
<tr>
<td>Floor crack</td>
<td>Room 125</td>
<td>10</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Main room</td>
<td>12</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Room 122</td>
<td>24</td>
</tr>
<tr>
<td>Wall</td>
<td>Main room near water fountain</td>
<td>12</td>
</tr>
<tr>
<td>Wall crack</td>
<td>Main room near box area</td>
<td>7</td>
</tr>
<tr>
<td>HVAC vent</td>
<td>Room 108-A</td>
<td>9</td>
</tr>
</tbody>
</table>

DP measurements indicated no significant room-to-room variations. The data are summarized in Table 111.
Table 111. Differential pressure measurements for the U.S. Post Office in Talladega, Alabama

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office hallway</td>
<td>0</td>
</tr>
<tr>
<td>113</td>
<td>0</td>
</tr>
<tr>
<td>109</td>
<td>-2</td>
</tr>
<tr>
<td>107</td>
<td>-2</td>
</tr>
<tr>
<td>111</td>
<td>-1</td>
</tr>
<tr>
<td>103</td>
<td>0</td>
</tr>
<tr>
<td>112 and 108</td>
<td>-4</td>
</tr>
<tr>
<td>108A and 108</td>
<td>-3</td>
</tr>
<tr>
<td>113</td>
<td>0</td>
</tr>
<tr>
<td>111</td>
<td>-1</td>
</tr>
<tr>
<td>107</td>
<td>-1</td>
</tr>
<tr>
<td>108</td>
<td>0</td>
</tr>
<tr>
<td>104</td>
<td>0</td>
</tr>
<tr>
<td>103</td>
<td>1</td>
</tr>
<tr>
<td>Lobby</td>
<td>0</td>
</tr>
</tbody>
</table>

Due to the frequent entrances and exits from the main entrance, a stable blow door depressurization curve could not be obtained. However, it was determined from the data that the building shell is not airtight (>2000 in²).

Around June 1994, GSA installed an SSD system in the GSA office portion of the building (Fig. 11). Follow-up testing by USPS personnel in August 1994 found that mitigation had not been achieved (Table 112.)

Table 112. Postmitigation testing at the U.S. Post Office in Talladega, Alabama

<table>
<thead>
<tr>
<th>Detector number</th>
<th>Location</th>
<th>Radon (pCi/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM2802</td>
<td>Room 112, file cabinet</td>
<td>5.8</td>
</tr>
<tr>
<td>SM2864</td>
<td>Room 108, book shelf</td>
<td>5.6</td>
</tr>
<tr>
<td>SM2842</td>
<td>Room 108, counter</td>
<td>2.4</td>
</tr>
<tr>
<td>SM2753</td>
<td>Room 108B, file cabinet</td>
<td>4.7</td>
</tr>
<tr>
<td>SF3976</td>
<td>Room 108A, file cabinet</td>
<td>2.5</td>
</tr>
<tr>
<td>SM2866</td>
<td>Room 114, shelf</td>
<td>4.6</td>
</tr>
</tbody>
</table>
Fig. 11. Ground-floor drawing for the U.S. Post Office in Talladega, Alabama (existing General Services Administration suction points).
SSD mitigation systems are classified as one of two types: high pressure/low flow (HPLF) or low pressure/high flow (LPHF). In an HPLF SSD system, mitigation is achieved by applying a significant vacuum under the slab (pit head pressure >3-in. WC). This subslab vacuum field essentially reverses the flow of air from the building into the subslab zone, thus retarding radon entry. Typical characteristics of HPLF systems are pipe of <3 in. in diameter and a high-pressure (>3-in. WC), low-flow fan (<100 ft³/min). An HPLF system is installed for slabs that have compacted subslab material (e.g., sand or clay) or for buildings with foundations that have very little communication to the outside. For an LPHF system, mitigation is achieved by the sweeping action of air beneath the slab. A typical LPHF system has pipe >3 in. in diameter and has a high-flow fan (>100 ft³/min) at low pressure (<3-in. WC). LPHF systems work best in permeable subslab material (e.g., noncompacted stone) or for foundations that communicate to the outside.

Selection of the proper SSD system is essential for proper radon reduction. For example, an HPLF system may not have the flow characteristics to sweep a subslab area. Conversely, an LPHF fan may stall in the absence of air flow. The only way to select the optimal SSD system is to perform the subslab mitigation diagnostics. Part 1 of the test generates a pressure vs flow curve, which enables the selection of the proper mitigation fan. Part 2 defines the extension and characteristics of the pressure field beneath the subslab. When the two diagnostic parts are combined, the type of SSD system is defined. For the U.S. Post Office in Talladega, the mitigation diagnostics data (Table 108) indicate that the subslab has LPHF characteristics. The SSD system installed by GSA is an HPLF system; thus the lack of radon reduction is suspected to be caused by incorrect system installation.

Based on the data collected by the mitigation diagnostic team, the only practical mitigation option is SSD, specifically an LPHF system. To perform this mitigation, the existing GSA SSD system will first have to be removed and a new LPHF system installed in its place. For the new mitigation system, all pipe will need to be 4-in., SCH 40 PVC, and all fans will need to have at least 2.5-in. WC at 400 ft³/min. Each suction pit will need to be open style, excavated to bare soil (1 ft × 1 ft × 4.5 in.) For the office wing, a total of three SSD systems will be required. With respect to pipe runs, vertical penetration is not possible in the two-story office wing. However, two of the pipes can be run above the suspended ceiling in the hallway to exit the building above the back door. The other office wing pipe run could exit between the junction of the elevator lobby and the office wing (Fig. 12). For the postal part of the building, vertical penetration is possible and is highly recommended. The proposed system consists of nine vertical penetrations with a fan/pipe (Fig. 12). For all pit locations depicted, the option exists for movement within a 6-ft-diam circle to accommodate room functionality and existing obstructions. Networking pipes on the USPS side is not recommended because the cost of connecting the suction pits and the resulting larger fan would more than offset the expense of a single fan. Figure 13 illustrates the exterior view of the mitigation system. The cost for the proposed mitigation system is summarized in Table 113.

<table>
<thead>
<tr>
<th>Description</th>
<th>Estimated cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove and patch holes for existing GSA system</td>
<td>500</td>
</tr>
<tr>
<td>Install office wing system</td>
<td>9,000</td>
</tr>
<tr>
<td>Install 9 vertical systems in USPS side of building</td>
<td>9,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18,500</strong></td>
</tr>
</tbody>
</table>

Table 113. Radon mitigation cost estimate for the U.S. Post Office in Talladega, Alabama
Fig. 12. Ground-floor drawing for the U.S. Post Office in Talladega, Alabama (proposed suction locations).
Fig. 13. Exterior of the U.S. Post Office in Talladega, Alabama.
2.22 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN WILLIMANTIC, CONNECTICUT

The main post office in Willimantic, Connecticut, is a leased, one-story, slab-on-grade, 24,000-ft² building constructed in 1966. Cooling is provided by a forced-air system powered by an electric compressor located on the roof. Heating is provided by a boiler through hot water exchangers. There are no fresh air intakes for the building. Building renovations are currently under way to expand the loading dock.

During the 1992–1993 USPS radon survey, radon detectors were not placed at the site. Therefore, no USPS radon data are available for the site.

In August 1994, the HAZWRAP radon mitigation diagnostic team conducted radon mitigation diagnostics at the site. A summary of the mitigation diagnostics are listed in Table 114.

### Table 114. Mitigation diagnostics summary for the U.S. Post Office in Willimantic, Connecticut

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>4</td>
<td>Back dock wall missing</td>
</tr>
<tr>
<td>Blower door</td>
<td>Not completed</td>
<td>Renovation</td>
</tr>
<tr>
<td>Subslab</td>
<td>Not completed</td>
<td>No plans available, subslab utilities, and asbestos floor tile</td>
</tr>
<tr>
<td>Continuous radon measurements</td>
<td>16 measurements</td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>Ceiling was 12 ft high</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>8</td>
<td>5 to 22 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

During the mitigation diagnostics, 16 continuous radon measurements were performed (Table 115). None of the average measurements were >4 pCi/L. However, during the measurements, the loading dock was being reconstructed. Also, the main work room was open to the dock area except for a single plastic barrier. This may have reduced the radon levels in the main room. Additional postconstruction testing is recommended.
Table 115. Summary of continuous radon measurements for the U.S. Post Office in Willimantic, Connecticut

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>0.5</td>
<td>Postmaster’s office</td>
</tr>
<tr>
<td>02</td>
<td>0.7</td>
<td>Maintenance shop</td>
</tr>
<tr>
<td>03</td>
<td>0.7</td>
<td>Classroom</td>
</tr>
<tr>
<td>04</td>
<td>0.6</td>
<td>Main room (front right)</td>
</tr>
<tr>
<td>05</td>
<td>0.7</td>
<td>Locker room</td>
</tr>
<tr>
<td>08</td>
<td>0.6</td>
<td>Breakroom</td>
</tr>
<tr>
<td>09</td>
<td>0.6</td>
<td>Supply room</td>
</tr>
<tr>
<td>10</td>
<td>1.2</td>
<td>Boiler room</td>
</tr>
<tr>
<td>11</td>
<td>0.9</td>
<td>Supervisor’s office (annex)</td>
</tr>
<tr>
<td>12</td>
<td>0.7</td>
<td>Supervisor’s office</td>
</tr>
<tr>
<td>13</td>
<td>0.6</td>
<td>Main room (back left)</td>
</tr>
<tr>
<td>16</td>
<td>0.8</td>
<td>Top of P.O. Boxes</td>
</tr>
<tr>
<td>17</td>
<td>0.4</td>
<td>Probation office</td>
</tr>
<tr>
<td>19</td>
<td>0.3</td>
<td>Main room (back right)</td>
</tr>
<tr>
<td>20</td>
<td>0.4</td>
<td>Main room (center)</td>
</tr>
<tr>
<td>21</td>
<td>0.3</td>
<td>Computer room</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms. Even with the loading dock wall missing, the air change rates are below minimal ASHRAE standards (Table 116).

Table 116. Air change summary for the U.S. Post Office in Willimantic, Connecticut

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room (back)</td>
<td>1A/2377</td>
<td>0.34</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.31</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.23</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.23</td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Main room (front)</td>
<td>101/9346</td>
<td>0.15</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.09</td>
<td>Air conditioning off</td>
</tr>
</tbody>
</table>

2-108
Table 116 (continued)

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunch room</td>
<td>1A/2377</td>
<td>0.28 0.17</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Classroom</td>
<td>101/9346</td>
<td>0.18 0.15</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning off</td>
</tr>
<tr>
<td>Supervisor's office</td>
<td>1A/4855</td>
<td>0.32 0.17</td>
<td>Air conditioning on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Air conditioning off</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics failed to locate any significant entry pathways. The data are listed in Table 117.

Table 117. Radon entry pathway diagnostics for the U.S. Post Office in Willimantic, Connecticut

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical outlet</td>
<td>Classroom</td>
<td>6</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Training room</td>
<td>8</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Supply room</td>
<td>3</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Breakroom</td>
<td>22</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Locker room</td>
<td>5</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Boiler room</td>
<td>7</td>
</tr>
<tr>
<td>Drain</td>
<td>Boiler room</td>
<td>5</td>
</tr>
<tr>
<td>Wall</td>
<td>Boiler room</td>
<td>7</td>
</tr>
</tbody>
</table>

DP measurements were performed. However, the data are of limited value because the building was under renovation. The DP data are listed in Table 118.

Table 118. Differential pressure measurements for the U.S. Post Office in Willimantic, Connecticut

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box lobby</td>
<td>-4</td>
</tr>
<tr>
<td>Counter lobby</td>
<td>-4</td>
</tr>
</tbody>
</table>
## Table 118 (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. probation office</td>
<td>0</td>
</tr>
<tr>
<td>Civil service</td>
<td>-6</td>
</tr>
<tr>
<td>Postmaster's office</td>
<td>-6</td>
</tr>
<tr>
<td>Superintendent’s office</td>
<td>-4</td>
</tr>
<tr>
<td>Reception area</td>
<td>-5</td>
</tr>
<tr>
<td>Main room</td>
<td>-5</td>
</tr>
<tr>
<td>Front office</td>
<td>-1</td>
</tr>
<tr>
<td>Training office</td>
<td>-3</td>
</tr>
<tr>
<td>Women’s bathroom</td>
<td>-5</td>
</tr>
<tr>
<td>Men’s bathroom</td>
<td>-5</td>
</tr>
<tr>
<td>Supply room</td>
<td>-4</td>
</tr>
<tr>
<td>Stamped envelope room</td>
<td>-4</td>
</tr>
<tr>
<td>Lunch room</td>
<td>0</td>
</tr>
<tr>
<td>Locker room</td>
<td>-4</td>
</tr>
<tr>
<td>Men’s bathroom</td>
<td>-3</td>
</tr>
<tr>
<td>Postal storage</td>
<td>-4</td>
</tr>
<tr>
<td>Mechanical room</td>
<td>-5</td>
</tr>
</tbody>
</table>

Three planned mitigation diagnostics could not be performed. The blower door test was not performed because the back loading dock wall was missing. Flow hood measurements could not be performed because the supply vents were inaccessible (12-ft ceiling). Subslab diagnostics could not be performed due to the absence of building plans and presence of asbestos tile and subslab utilities.

Building renovations, such as those made at this site, can have a significant impact on the radon levels. The recommendation is made that after the renovations are complete, long-term radon testing be performed during a heating season to determine whether the radon levels are above the action level. If they are found to be above the action level, then the recommendation is made that a fresh-air, forced-air HAC system be installed at the site. Sufficient outside air should be incorporated to maintain a minimal 0.5 ACH. The cost for such a system (if needed) is estimated to be $55K.
2.23 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN WATERTOWN, NEW YORK

Radon mitigation diagnostics were not performed at the U.S. Post Office in Watertown, New York (located at 163 Arsenal) because the facility has closed since radon testing was performed in 1992–1993. Therefore, no recommendations are available.

2.24 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN WAYNESVILLE, NORTH CAROLINA

The main post office in Waynesville, North Carolina, is a two-story, slab-on-grade, 19,000-ft² building constructed in 1966. During the initial site investigation in April 1994, the building mechanical system consisted of six HAC units, four of which were nonfunctional. At that time, USPS was in the process of replacing the units with six forced-air heat pumps. This installation was completed in August 1994. However, in September 1994, the forced-air system was upgraded to include fresh air intakes.

On April 7, 1994, GSA notified USPS that elevated radon had been detected in the GSA portion of the building. Based on this information and direction from USPS Headquarters, the HAZWRAP radon mitigation diagnostic team performed radon mitigation diagnostics at the site on April 12, 1994. Due to the changes in the ventilation system, the team performed a total of three on-site investigations (April, August, and October 1994). Table 119 summarizes the initial mitigation diagnostics performed at the site in April 1994.

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed Part 2 completed</td>
<td></td>
</tr>
<tr>
<td>Continuous radon</td>
<td>20 measurements</td>
<td></td>
</tr>
<tr>
<td>measurements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>7</td>
<td>0 to 121 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>47</td>
<td></td>
</tr>
</tbody>
</table>

Continuous radon measurements were performed at the site during the four distinct phases of the HAC installation. Phase 1, preinstallation, was performed during the mitigation diagnostics (Table 120). Phase 2 monitoring spanned the shutdown of the HAC system (Figs. 14–17). Phase 3 monitored the radon levels after the HAC installation and before the installation of the fresh air intakes (Table 121). Phase 4 monitored the radon levels after the installation of the
Fig. 14. Radon levels in Room 1228 at the U.S. Post Office in Waynesville, North Carolina.

Radon (pCi/L)
Fig. 15. Radon levels in Room 125 at the U.S. Post Office in Waynesville, North Carolina.
Fig. 16. Radon levels in Room 124 at the U.S. Post Office in Waynesville, North Carolina.
Fig. 17. Radon levels in Postmaster's office at the U.S. Post Office in Waynesville, North Carolina.
fresh air vents (Table 122). Table 123 compares the radon levels for Phases 1, 3, and 4 of the HAC installation.

Table 120. Summary of continuous radon measurements for the U.S. Post Office in Waynesville, North Carolina (April 1994)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>03</td>
<td>3.1</td>
<td>Room 207</td>
</tr>
<tr>
<td>04</td>
<td>2.9</td>
<td>Room 205</td>
</tr>
<tr>
<td>05</td>
<td>2.0</td>
<td>Main room (front left)</td>
</tr>
<tr>
<td>06</td>
<td>3.0</td>
<td>Room 203</td>
</tr>
<tr>
<td>08</td>
<td>2.2</td>
<td>Main room (back right)</td>
</tr>
<tr>
<td>09</td>
<td>7.6</td>
<td>Postmaster's office</td>
</tr>
<tr>
<td>10</td>
<td>2.8</td>
<td>Main room (back left)</td>
</tr>
<tr>
<td>12</td>
<td>6.6</td>
<td>Room 122-B</td>
</tr>
<tr>
<td>13</td>
<td>2.5</td>
<td>Main room (center)</td>
</tr>
<tr>
<td>14</td>
<td>5.6</td>
<td>Room 120</td>
</tr>
<tr>
<td>15</td>
<td>2.6</td>
<td>Main room (front right)</td>
</tr>
<tr>
<td>16</td>
<td>5.7</td>
<td>Room 124</td>
</tr>
<tr>
<td>17</td>
<td>4.7</td>
<td>Room 129-B</td>
</tr>
<tr>
<td>18</td>
<td>5.8</td>
<td>Room 133</td>
</tr>
<tr>
<td>19</td>
<td>5.7</td>
<td>Room 117-A</td>
</tr>
<tr>
<td>20</td>
<td>6.3</td>
<td>Room 129</td>
</tr>
<tr>
<td>22</td>
<td>5.9</td>
<td>Room 117</td>
</tr>
<tr>
<td>23</td>
<td>6.3</td>
<td>Room 129</td>
</tr>
<tr>
<td>141</td>
<td>3.6</td>
<td>Computer room</td>
</tr>
<tr>
<td>151</td>
<td>6.3</td>
<td>Room 125</td>
</tr>
</tbody>
</table>
Table 121. Summary of continuous radon measurements for the U.S. Post Office in Waynesville, North Carolina (August 1994)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>6.5</td>
<td>Room 117-A</td>
</tr>
<tr>
<td>02</td>
<td>5.5</td>
<td>Room 129</td>
</tr>
<tr>
<td>04</td>
<td>4.3</td>
<td>Room 205</td>
</tr>
<tr>
<td>05</td>
<td>11.9</td>
<td>Room 122-B</td>
</tr>
<tr>
<td>08</td>
<td>2.9</td>
<td>Main room (back left)</td>
</tr>
<tr>
<td>09</td>
<td>9.2</td>
<td>Room 124</td>
</tr>
<tr>
<td>10</td>
<td>2.7</td>
<td>Main room (front left)</td>
</tr>
<tr>
<td>11</td>
<td>2.9</td>
<td>Main room (back right)</td>
</tr>
<tr>
<td>12</td>
<td>4.3</td>
<td>Room 203</td>
</tr>
<tr>
<td>14</td>
<td>2.3</td>
<td>Room 120</td>
</tr>
<tr>
<td>16</td>
<td>4.4</td>
<td>Room 207</td>
</tr>
<tr>
<td>17</td>
<td>3.5</td>
<td>Room 133</td>
</tr>
<tr>
<td>19</td>
<td>5.2</td>
<td>Room 129-B</td>
</tr>
<tr>
<td>20</td>
<td>6.8</td>
<td>Room 117</td>
</tr>
<tr>
<td>21</td>
<td>4.9</td>
<td>Room 125</td>
</tr>
</tbody>
</table>

Table 122. Summary of continuous radon measurements for the U.S. Post Office in Waynesville, North Carolina (October 1994)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>09</td>
<td>0.8</td>
<td>Room 207</td>
</tr>
<tr>
<td>10</td>
<td>1.0</td>
<td>Room 205</td>
</tr>
<tr>
<td>15</td>
<td>1.5</td>
<td>Room 203</td>
</tr>
<tr>
<td>13</td>
<td>0.5</td>
<td>Main room (back right)</td>
</tr>
</tbody>
</table>
Table 122 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>0.2</td>
<td>Postmaster’s office</td>
</tr>
<tr>
<td>01</td>
<td>0.2</td>
<td>Main room (back left)</td>
</tr>
<tr>
<td>16</td>
<td>1.4</td>
<td>Room 122-B</td>
</tr>
<tr>
<td>21</td>
<td>0.3</td>
<td>Room 120</td>
</tr>
<tr>
<td>18</td>
<td>0.4</td>
<td>Main room (front right)</td>
</tr>
<tr>
<td>05</td>
<td>1.2</td>
<td>Room 124</td>
</tr>
<tr>
<td>11</td>
<td>1.2</td>
<td>Room 129-B</td>
</tr>
<tr>
<td>07</td>
<td>1.8</td>
<td>Room 133</td>
</tr>
<tr>
<td>12</td>
<td>1.3</td>
<td>Room 117-A</td>
</tr>
<tr>
<td>08</td>
<td>1.1</td>
<td>Room 125</td>
</tr>
<tr>
<td>20</td>
<td>0.7</td>
<td>Room 117</td>
</tr>
<tr>
<td>14</td>
<td>1.2</td>
<td>Room 129</td>
</tr>
</tbody>
</table>

Table 123. Comparison summary of the continuous radon measurements for the U.S. Post Office in Waynesville, North Carolina

<table>
<thead>
<tr>
<th>Location</th>
<th>Average radon level in April 1994 (pCi/L)</th>
<th>Average radon level in August 1994 (pCi/L)</th>
<th>Average radon level in October 1994 (pCi/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 117</td>
<td>5.9</td>
<td>6.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Room 117A</td>
<td>5.7</td>
<td>6.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Room 122-B</td>
<td>5.7</td>
<td>9.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Room 124</td>
<td>6.6</td>
<td>11.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Room 125</td>
<td>6.3</td>
<td>4.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Room 129</td>
<td>5.5</td>
<td>5.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Room 129-B</td>
<td>4.7</td>
<td>5.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Room 133</td>
<td>5.8</td>
<td>3.5</td>
<td>1.8</td>
</tr>
</tbody>
</table>

2-118
### Table 123 (continued)

<table>
<thead>
<tr>
<th>Location</th>
<th>Average radon level in April 1994 (pCi/L)</th>
<th>Average radon level in August 1994 (pCi/L)</th>
<th>Average radon level in October 1994 (pCi/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakroom 120</td>
<td>5.6</td>
<td>2.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Main room (back left)</td>
<td>2.8</td>
<td>2.9</td>
<td>0.2</td>
</tr>
<tr>
<td>Main room (front left)</td>
<td>2.0</td>
<td>2.7</td>
<td>N/A</td>
</tr>
<tr>
<td>Main room (center)</td>
<td>2.5</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Main room (back right)</td>
<td>2.6</td>
<td>2.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Main room (front right)</td>
<td>2.8</td>
<td>N/A</td>
<td>0.2</td>
</tr>
<tr>
<td>Postmaster's office</td>
<td>7.6</td>
<td>N/A</td>
<td>0.2</td>
</tr>
<tr>
<td>Computer room</td>
<td>3.6</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Air change measurements were performed during Phases 1, 3, and 4 of the HAC installation cycle. Table 124 summarizes the air change measurements for Phases 1 and 3. Table 125 summarizes the air change data for Phase 4.

### Table 124. Air change summary for the U.S. Post Office in Waynesville, North Carolina (April and August 1994)

<table>
<thead>
<tr>
<th>Location</th>
<th>Air change April 1994 (hour⁻¹)</th>
<th>Air change August 1994 (hour⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room</td>
<td>0.20 (air conditioning on)</td>
<td>0.22 (air conditioning on)</td>
</tr>
<tr>
<td></td>
<td>0.19 (air conditioning on)</td>
<td>0.18 (air conditioning on)</td>
</tr>
<tr>
<td></td>
<td>0.06 (air conditioning off)</td>
<td></td>
</tr>
<tr>
<td>Computer room</td>
<td>No data</td>
<td>0.20 (air conditioning on)</td>
</tr>
<tr>
<td>GSA first floor</td>
<td>0.36 (air conditioning on)</td>
<td>0.06 (air conditioning off)</td>
</tr>
<tr>
<td></td>
<td>0.16 (air conditioning on)</td>
<td>0.04 (air conditioning off)</td>
</tr>
<tr>
<td></td>
<td>0.24 (air conditioning on)</td>
<td></td>
</tr>
</tbody>
</table>
Table 125. Air change summary for the U.S. Post Office in Waynesville, North Carolina (October 1994)

<table>
<thead>
<tr>
<th>Location</th>
<th>Air change October 1994 (hour⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room (back)</td>
<td>0.45 (air conditioning on)</td>
</tr>
<tr>
<td></td>
<td>0.47 (air conditioning on)</td>
</tr>
<tr>
<td>Main room (left)</td>
<td>0.47 (air conditioning on)</td>
</tr>
<tr>
<td></td>
<td>0.51 (air conditioning on)</td>
</tr>
<tr>
<td>Room 125</td>
<td>0.41 (air conditioning on)</td>
</tr>
</tbody>
</table>

Subslab mitigation diagnostics were performed in the mechanical room (Room 133). The data (Table 126) indicate good field extension beneath the slab.

Table 126. Subslab field extension data for the U.S. Post Office in Waynesville, North Carolina

<table>
<thead>
<tr>
<th>Hole 1.45 (in.)</th>
<th>Location</th>
<th>Field extension (ft)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material (in.)</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Room 133</td>
<td>18</td>
<td>5</td>
<td>2.0 (gravel)</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Blower door measurements were performed on the first-floor office wing of the building. The data indicate that the building shell is very tight (Table 127).

Table 127. Blower door data for the U.S. Post Office in Waynesville, North Carolina

<table>
<thead>
<tr>
<th>Location</th>
<th>Flow for 4 Pa (ft³/min)</th>
<th>Leakage area (in.²)</th>
<th>Size area tested (ft²)</th>
<th>Ceiling height (ft)</th>
<th>Room volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSA wing (first floor)</td>
<td>2,119</td>
<td>600</td>
<td>5,800</td>
<td>8</td>
<td>46,400</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics identified one marginal entry pathway in Room 118 (floor crack). The remaining measurements were insignificant (Table 128).

Table 128. Radon entry pathway diagnostics for the U.S. Post Office in Waynesville, North Carolina

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall crack</td>
<td>Room 122</td>
<td>11</td>
</tr>
<tr>
<td>Wall</td>
<td>Breakroom</td>
<td>6</td>
</tr>
<tr>
<td>Floor</td>
<td>Room 118</td>
<td>121</td>
</tr>
<tr>
<td>Hole type</td>
<td>Location</td>
<td>Counts per minute</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 116</td>
<td>10</td>
</tr>
<tr>
<td>Electrical outlet</td>
<td>Room 117-A</td>
<td>7</td>
</tr>
<tr>
<td>Wall-to-floor joint</td>
<td>Room 117</td>
<td>10</td>
</tr>
<tr>
<td>Wall</td>
<td>Room 123</td>
<td>0</td>
</tr>
</tbody>
</table>

Flow hood measurements were performed only during Phase 1 of the HAC installation. The data are summarized in Table 129.

**Table 129. Flow hood measurement data for the U.S. Post Office in Waynesville, North Carolina**

<table>
<thead>
<tr>
<th>Location</th>
<th>Uncorrected flow (ft³/min)</th>
<th>Corrected flow (ft³/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 117</td>
<td>133</td>
<td>162</td>
</tr>
<tr>
<td>Room 123</td>
<td>172</td>
<td>220</td>
</tr>
<tr>
<td>Room 123</td>
<td>107</td>
<td>125</td>
</tr>
<tr>
<td>Room 125</td>
<td>102</td>
<td>118</td>
</tr>
<tr>
<td>Room 129</td>
<td>203</td>
<td>233</td>
</tr>
<tr>
<td>Room 129-B</td>
<td>255</td>
<td>285</td>
</tr>
<tr>
<td>Room 203</td>
<td>209</td>
<td>236</td>
</tr>
<tr>
<td>Room 203-A</td>
<td>186</td>
<td>213</td>
</tr>
<tr>
<td>Room 206</td>
<td>236</td>
<td>290</td>
</tr>
<tr>
<td>Room 202</td>
<td>203</td>
<td>227</td>
</tr>
<tr>
<td>Room 207</td>
<td>225</td>
<td>297</td>
</tr>
<tr>
<td>Room 211</td>
<td>182</td>
<td>220</td>
</tr>
<tr>
<td>Room 211</td>
<td>190</td>
<td>281</td>
</tr>
<tr>
<td>Room 211-A</td>
<td>247</td>
<td>256</td>
</tr>
<tr>
<td>Room 213-A</td>
<td>194</td>
<td>207</td>
</tr>
</tbody>
</table>

DP measurements were performed in various rooms during Phases 1, 3, and 4 of the HAC installation cycle. The data are listed in Table 130.
Table 130. Differential pressure measurements for the U.S. Post Office in Waynesville, North Carolina

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stairwell</td>
<td>No data</td>
<td>-5</td>
<td>5</td>
</tr>
<tr>
<td>Main room</td>
<td>-2</td>
<td>-4</td>
<td>2</td>
</tr>
<tr>
<td>111</td>
<td>-1</td>
<td>No data</td>
<td>3</td>
</tr>
<tr>
<td>110</td>
<td>-2</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>114</td>
<td>0</td>
<td>No data</td>
<td>3</td>
</tr>
<tr>
<td>106</td>
<td>-2</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>108-B</td>
<td>-2</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Lobby</td>
<td>-3</td>
<td>-4</td>
<td>3</td>
</tr>
<tr>
<td>Assistant Postmaster's office</td>
<td>-2</td>
<td>No data</td>
<td>2</td>
</tr>
<tr>
<td>Postmaster's office</td>
<td>-1</td>
<td>-3</td>
<td>3</td>
</tr>
<tr>
<td>Hallway</td>
<td>-2</td>
<td>-6</td>
<td>3</td>
</tr>
<tr>
<td>133</td>
<td>-2</td>
<td>No data</td>
<td>0</td>
</tr>
<tr>
<td>131</td>
<td>-3</td>
<td>No data</td>
<td>1</td>
</tr>
<tr>
<td>129-B</td>
<td>-3</td>
<td>-4</td>
<td>7</td>
</tr>
<tr>
<td>129</td>
<td>-2</td>
<td>-3</td>
<td>No data</td>
</tr>
<tr>
<td>125</td>
<td>-3</td>
<td>-4</td>
<td>No data</td>
</tr>
<tr>
<td>123</td>
<td>-2</td>
<td>-8</td>
<td>No data</td>
</tr>
<tr>
<td>117</td>
<td>0</td>
<td>-1</td>
<td>6</td>
</tr>
<tr>
<td>116</td>
<td>-1</td>
<td>-7</td>
<td>7</td>
</tr>
<tr>
<td>118</td>
<td>-1</td>
<td>-9</td>
<td>1</td>
</tr>
<tr>
<td>120</td>
<td>-2</td>
<td>-8</td>
<td>0</td>
</tr>
<tr>
<td>122</td>
<td>-1</td>
<td>-9</td>
<td>2</td>
</tr>
<tr>
<td>124</td>
<td>-1</td>
<td>-11</td>
<td>2</td>
</tr>
<tr>
<td>130</td>
<td>-4</td>
<td>No data</td>
<td>1</td>
</tr>
</tbody>
</table>
Based on the most recent radon data (Table 122), the installation of fresh air intakes on the six HAC systems has appeared to have mitigated the elevated radon problem. Currently, long-term radon measurements are being performed to assess whether mitigation has been successful. If unsuccessful, the recommendation is made that the amount of fresh air being incorporated into the building be increased to yield an air change rate of 0.75 hour$^{-1}$. Another mitigation option is the installation of an LPHF SSD system. The installation of four suction pits in the office wing with an additional six single-pipe systems in the USPS wing would perform adequate reduction (Fig. 18). The SSD system should consist of 4-in., SCH 40 PVC and mitigation fans with 2.5-in.-WC pressure and 450-ft$^3$/min flow. Placement of the suction pits in the exact locations (as shown in Fig. 18) is not essential. The radius of variance for the installation can be up to 9 ft. The estimated cost for the SSD system would be $15K.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>132</td>
<td>-3</td>
<td>-4</td>
<td>2</td>
</tr>
<tr>
<td>134</td>
<td>-4</td>
<td>-8</td>
<td>3</td>
</tr>
<tr>
<td>Hallway</td>
<td>0</td>
<td>-6</td>
<td>3</td>
</tr>
<tr>
<td>212</td>
<td>3</td>
<td>No data</td>
<td>6</td>
</tr>
<tr>
<td>213</td>
<td>3</td>
<td>-5</td>
<td>3</td>
</tr>
<tr>
<td>211</td>
<td>2</td>
<td>-2</td>
<td>1</td>
</tr>
<tr>
<td>216</td>
<td>-3</td>
<td>-8</td>
<td>0</td>
</tr>
<tr>
<td>212</td>
<td>-1</td>
<td>No data</td>
<td>0</td>
</tr>
<tr>
<td>207</td>
<td>2</td>
<td>-8</td>
<td>5</td>
</tr>
<tr>
<td>210</td>
<td>1</td>
<td>-7</td>
<td>3</td>
</tr>
<tr>
<td>205</td>
<td>1</td>
<td>-7</td>
<td>1</td>
</tr>
<tr>
<td>208</td>
<td>-2</td>
<td>-7</td>
<td>3</td>
</tr>
<tr>
<td>206</td>
<td>-1</td>
<td>-6</td>
<td>3</td>
</tr>
<tr>
<td>202</td>
<td>-1</td>
<td>-9</td>
<td>5</td>
</tr>
<tr>
<td>203</td>
<td>1</td>
<td>-8</td>
<td>1</td>
</tr>
<tr>
<td>201</td>
<td>0</td>
<td>-8</td>
<td>6</td>
</tr>
</tbody>
</table>
Fig. 18. Schematic mitigation plan for the U.S. Post Office in Waynesville, North Carolina.
2.25 PHASE 2 DIAGNOSTICS AT THE U.S. POST OFFICE IN WRIGHTSVILLE, GEORGIA

The main post office in Wrightsville, Georgia, is a one-story basement building constructed in 1938. The basement is subdivided with mostly concrete and hollow-clay tile walls. The approximately 4,600-ft² building had a new HVAC forced-air system installed during the on-site investigation. Both heating and cooling are provided by an electric heat pump. The fresh air intake is located at the back of the building. By design, the basement area has a separate heating and cooling system with no ventilation.

During 1992–1993, USPS personnel performed nine 1-year radon measurements. One of the results was >4 pCi/L.

In March 1994, the HAZWRAP radon mitigation diagnostic team performed radon mitigation diagnostics at the site (Table 131).

Table 131. Radon mitigation diagnostics summary for the U.S. Post Office in Wrightsville, Georgia

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Number of tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Blower door</td>
<td>Completed</td>
<td></td>
</tr>
<tr>
<td>Subslab</td>
<td>Part 1 completed</td>
<td>Part 2 not completed</td>
</tr>
<tr>
<td>Continuous radon measures</td>
<td>15 measurements</td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Not completed</td>
<td>Supply vents to high</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>7</td>
<td>4 to 340 counts per minute</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

During the mitigation diagnostics, 15 continuous radon measurements were performed. One measurement performed in the mechanical room was found to be >4 pCi/L. The data are listed in Table 132.

Table 132. Summary of continuous radon measurements for the U.S. Post Office in Wrightsville, Georgia

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>04</td>
<td>1.1</td>
<td>Main room (center right)</td>
</tr>
<tr>
<td>05</td>
<td>1.2</td>
<td>Main room (back right)</td>
</tr>
<tr>
<td>08</td>
<td>1.3</td>
<td>Main room</td>
</tr>
<tr>
<td>09</td>
<td>1.3</td>
<td>Main room</td>
</tr>
</tbody>
</table>
Table 132 (continued)

<table>
<thead>
<tr>
<th>Instrument number</th>
<th>48-hour average radon measurement (pCi/L)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>0.9</td>
<td>Main room</td>
</tr>
<tr>
<td>14</td>
<td>1.1</td>
<td>Postmaster’s office</td>
</tr>
<tr>
<td>15</td>
<td>1.2</td>
<td>Postmaster’s bath</td>
</tr>
<tr>
<td>17</td>
<td>0.9</td>
<td>Room 3 (soil office)</td>
</tr>
<tr>
<td>18</td>
<td>2.2</td>
<td>Room 8 (storage)</td>
</tr>
<tr>
<td>19</td>
<td>1.2</td>
<td>Room 9 (storage)</td>
</tr>
<tr>
<td>20</td>
<td>1.5</td>
<td>Room 2 (vacant office)</td>
</tr>
<tr>
<td>21</td>
<td>1.7</td>
<td>Room 8 (duplicate)</td>
</tr>
<tr>
<td>22</td>
<td>1.2</td>
<td>Room 1 (vacant office)</td>
</tr>
<tr>
<td>23</td>
<td>3.9</td>
<td>Mechanical room storage</td>
</tr>
<tr>
<td>151</td>
<td>4.1</td>
<td>Mechanical room</td>
</tr>
</tbody>
</table>

Air change measurements were performed in various rooms in the building. Significant differences in air change were observed as a function of the HVAC cycle. To measure the impact on the basement air change rate, the amount of makeup air on the first floor was temporarily increased by approximately 100%. The air change in the basement did not increase. The data are summarized in Table 133.

Table 133. Air change summary for the U.S. Post Office in Wrightsville, Georgia

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
<th>100% added makeup air change (hour⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil office</td>
<td>101/4855</td>
<td>0.04</td>
<td>Blower off</td>
<td></td>
</tr>
<tr>
<td>Mechanical room</td>
<td>1A/2377</td>
<td>1.12</td>
<td>Blower on</td>
<td>1.14</td>
</tr>
<tr>
<td>Mechanical room</td>
<td>1A/2377</td>
<td>0.39</td>
<td>Blower off</td>
<td></td>
</tr>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.20</td>
<td>Blower off</td>
<td></td>
</tr>
<tr>
<td>Room 2</td>
<td>101/4855</td>
<td>0.31</td>
<td>Blower off</td>
<td></td>
</tr>
</tbody>
</table>
Table 133 (continued)

<table>
<thead>
<tr>
<th>Room number</th>
<th>Instrument number</th>
<th>Air change (hour⁻¹)</th>
<th>Comments</th>
<th>100% added makeup air change (hour⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.45</td>
<td>Blower off</td>
<td></td>
</tr>
<tr>
<td>Room 1</td>
<td>101/4855</td>
<td>0.14</td>
<td>Blower off</td>
<td></td>
</tr>
<tr>
<td>Main room</td>
<td>1A/9346</td>
<td>0.35</td>
<td>Blower on</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Radon entry pathway diagnostics identified one potential entry pathway in the mechanical room (sump pump). The data are listed in Table 134.

Table 134. Radon entry pathway diagnostics data for the U.S. Post Office in Wrightsville, Georgia

<table>
<thead>
<tr>
<th>Hole type</th>
<th>Location</th>
<th>Counts per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duct passage</td>
<td>Room 9</td>
<td>12</td>
</tr>
<tr>
<td>Pipe chase</td>
<td>Room 8</td>
<td>4</td>
</tr>
<tr>
<td>Electrical conduit</td>
<td>Mechanical room</td>
<td>12</td>
</tr>
<tr>
<td>Sump pump</td>
<td>Mechanical room</td>
<td>340</td>
</tr>
<tr>
<td>Door frame</td>
<td>Mechanical room</td>
<td>66</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 1 right AG. office</td>
<td>50</td>
</tr>
<tr>
<td>Phone jack</td>
<td>Room 1 left AG. office</td>
<td>44</td>
</tr>
</tbody>
</table>

The blower door data indicate that the building has a fairly tight shell (Table 135).

Table 135. Blower door data for the U.S. Post Office in Wrightsville, Georgia

<table>
<thead>
<tr>
<th>Location</th>
<th>Flow for 4 Pa (ft³/min)</th>
<th>Leakage area (in.²)</th>
<th>Room area (ft²)</th>
<th>Ceiling height (ft)</th>
<th>Room volume (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement (half)</td>
<td>2,399</td>
<td>680</td>
<td>1,449</td>
<td>8</td>
<td>11,592</td>
</tr>
<tr>
<td>Basement (full)</td>
<td>2,876</td>
<td>815</td>
<td>2,898</td>
<td>8</td>
<td>23,184</td>
</tr>
<tr>
<td>Upstairs</td>
<td>868</td>
<td>245</td>
<td>2,898</td>
<td>8</td>
<td>23,184</td>
</tr>
</tbody>
</table>

2-127
DP measurements were performed in various rooms of the building during normal HVAC-on cycles. The basement was found to be under negative pressure during the operation of the HVAC blower. The data are listed in Table 136.

Table 136. Differential pressure measurements for the U.S. Post Office in Wrightsville, Georgia

<table>
<thead>
<tr>
<th>Location</th>
<th>Differential pressure relative to outdoors (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stairwell (back)</td>
<td>7</td>
</tr>
<tr>
<td>Main room</td>
<td>6</td>
</tr>
<tr>
<td>Main room</td>
<td>8</td>
</tr>
<tr>
<td>Postmaster’s office</td>
<td>7</td>
</tr>
<tr>
<td>Postmaster’s bathroom</td>
<td>7</td>
</tr>
<tr>
<td>Lobby</td>
<td>7</td>
</tr>
<tr>
<td>Hallway</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Left door</td>
<td>5</td>
</tr>
<tr>
<td>Right door</td>
<td>3</td>
</tr>
<tr>
<td>Stairwell (right side)</td>
<td>1</td>
</tr>
<tr>
<td>Mechanical room</td>
<td>-4 (HVAC on), 0 (HVAC off)</td>
</tr>
<tr>
<td>Mechanical Room 2</td>
<td>-4 (HVAC on), 0 (HVAC off)</td>
</tr>
</tbody>
</table>

Subslab diagnostic measurements indicated excellent permeability beneath the slab. Field extension was estimated to be more than 24 ft at a pit-head pressure of 1.5-in. WC. A naphthalene-based tar barrier, approximately 0.5 in. thick, was found between the slab and the aggregate layer. The subslab diagnostic data are summarized in Table 137. Due to a high ceiling, the flow hood diagnostic measurement could not be performed.

Table 137. Subslab mitigation diagnostics data for the U.S. Post Office in Wrightsville, Georgia

<table>
<thead>
<tr>
<th>Hole 1.45 (in.)</th>
<th>Location</th>
<th>Field extension (ft)</th>
<th>Slab thickness (in.)</th>
<th>Type subslab material (in.)</th>
<th>Subslab fill depth (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Boiler room storage</td>
<td>24+ (1.5-in. WC)</td>
<td>7</td>
<td>River rock, 0.5-1 (prewashed)</td>
<td>6</td>
</tr>
</tbody>
</table>

2-128
For this building, many mitigation options exist. Pressurization of the basement could be accomplished with the addition of 4,000 ft³/min of outside air. Use of the existing basement air handler with the addition of a fresh air intake would suffice. However, the basement system is 20+ years old and it would require a major overhaul or replacement before utilization as a pressurization system. A more attractive option would be to tap into the new first-floor mechanical system. Based on HVAC diagnostics performed by the team, the system is oversized and would have ample capacity to service the basement and first floor. To utilize this system, new supply and return ducts would have to be added to all rooms in the basement. Also, additional dampers need to be added to adjust the amount of fresh air intake for the basement and the upstairs. In addition, the vented exterior doors in the mechanical room would need to be replaced with solid doors. Because the existing mechanical blower air change is already high in the mechanical room (Table 133), increasing its ventilation rate would not be a feasible option. However, basement pressurization would be an option. According to the diagnostic data, 4,000 ft³/min of fresh air intake would pressurize the basement sufficiently for radon reduction.

Another, more attractive, option is the installation of a three-pit LPHF SSD system. Due to the subslab permeability characteristics, a 4-in. SCH 40 PVC attached to a single 2.5-in. WC, 450-ft³/min fan is recommended. The suction pits (Fig. 19) should be networked in the basement to a single exhaust pipe that exits the building through the old chimney. Exhaust should be approximately 1 ft above the existing chimney line. The estimated cost for the installation of the SSD system is $6K.
Fig. 19. Subslab mitigation plan for the U.S. Post Office in Wrightsville, Georgia.
3. SUMMARY

Over the past several years, HAZWRAP has generated a significant quantity of radon testing and mitigation diagnostic data for the USPS. These radon data sets represent one of the largest and finest data sets for large buildings anywhere in the world. An in-depth analysis of all of the information generated thus far would entail a considerable effort and is beyond the current project scope. This section deals with general conclusions, observations, and assessments that have been generated thus far in the program. As these studies progress, proposed amendments to the affected protocols will be forwarded to USPS Headquarters for consideration.

3.1 RADON TESTING

Based on the data collected thus far by USPS, no definable way exists to predict the presence or absence of elevated radon levels within a ground-contact room of a USPS structure without testing the room. Computer simulations performed on the collected data using a fixed 2,000-ft² sample density failed to identify 50% of the buildings with at least one reading above the 4-pCi/L action level. During the pilot program, upper-floor (non-ground-contact) radon testing was performed at certain sites. In the cases where elevated radon levels were detected on the upper floors in the building, elevated ground-contact levels were also measured. The testing of all ground-contact rooms, stairwells, and interfloor conduits for radon is recommended to be continued.

3.2 CONFIRMATION TESTING

Regardless of the level of quality assurance (QA)/QC, and because of the nature of the testing device, false positives will occur. Unexpected problems identified during the pilot program, such as dust, and expected problems, such as tampering, have resulted in a significant number of false positive measurements. Short-term, follow-up measurements have assisted greatly in the elimination of these erroneous measurements. From a conservative standpoint, all elevated readings (i.e., >4 pCi/L) should be confirmed. The disadvantage of this approach would be an increase in the number of measurements for the full-scale program (15,000 estimated). From the data collected thus far, buildings with multiple readings >4 pCi/L (e.g., three or more) have been confirmed repeatedly during the pilot program. Therefore, confirmation of all radon readings >4 pCi/L for buildings with three or fewer readings above the action level is recommended.

3.3 CONTINUOUS MONITORING

Even if radon above the action level is detected, the possibility may exist for certain types of buildings that the elevated radon may not be present during normal work hours, specifically in those buildings with a forced-air system that is reduced or shut down during the nonshift hours. A recent example of this type of problem was discovered in the U.S. Post Office in Griffin, Georgia (Fig. 20). During normal work hours, the HVAC system provides adequate radon mitigation. However, in the evening, use of the HVAC system is greatly reduced. In this case, passive testing indicated radon levels above the action level. But the continuous measurements
Fig. 20. Mechanical suppression of radon at the U.S. Post Office in Griffin, Georgia.
indicated a problem only during the nonshift hours. For radon to be considered a risk, people must be exposed to the radon; if no one is present, the risk is nonexistent.

In buildings containing annual forced-air systems with energy reduction cycles, before radon mitigation, continuous radon measurements are recommended in areas that have tested above the action level. Based on the data collected, the duration of the test should be at least 21 days. Integrated resolution of the instrument should be on the order of one measurement per 0.5 hour. In addition, the instrument should have a time and date stamp to document the time and date of the measurement.

3.4 RECOMMENDED ACTION LEVELS

Although no radon action levels for the workplace have been announced, EPA has stated that the risk associated with the residential action level (4 pCi/L) is still sufficient to warrant a similar response in the workplace. In the most recent A Citizens' Guide To Radon, Second Edition (ANR-464, May 1992), EPA discussed the risk associated with radon exposure but omitted discussions regarding the lead time during which corrective action should occur. The reason for the omission is that EPA considers any elevated radon exposure to be a concern requiring immediate corrective action (e.g., within a few months). This approach is practical for a homeowner who has a radon problem. In most parts of the United States, residential radon mitigation is only a phone call and $1,500 (average) away. Large buildings, on the other hand, pose problems that complicate radon mitigation. Multiple mechanical systems and complex substructures are just a few examples of the problems that could impede radon mitigation.

Another mitigation consideration for USPS is the number of buildings. Current projections indicate that USPS will have between 1,800 and 3,600 buildings requiring corrective action. Even assuming that infinite financial resources were available, it would still be impossible to mitigate all of these buildings within a few months. For example, the proposed mitigation solution for the U.S. Post Office in Marion, Indiana (Sect. 2.16) would require the installation of a new HVAC system. These mechanical systems are not "off-the-shelf" items and usually require several years from conception to completion (e.g., design, bidding, procurement, and installation steps). Clearly what is needed are internal USPS guidelines regarding radon mitigation. The proposed time line (Table 138) is based on recommendations made by EPA in the first version of A Citizen's Guide To Radon (OPA-86-004).

Table 138. Proposed U.S. Postal Service corrective action guidelines as a function of radon concentration

<table>
<thead>
<tr>
<th>Exposure radon level (pCi/L)</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 3.9</td>
<td>No further action</td>
</tr>
<tr>
<td>4 to 20</td>
<td>Corrective action within 5 years</td>
</tr>
<tr>
<td>20 to 199.9</td>
<td>Corrective action within 1 year</td>
</tr>
<tr>
<td>200</td>
<td>Corrective action within a few months</td>
</tr>
</tbody>
</table>
However, these proposed guidelines should not replace common sense. Radon exposure risk, like all radiological exposure, is based on dose [concentration × duration (hour)]. The dose should factor into the mitigation consideration and prioritization. A good example would be the radon problem in the vault at the U.S. Post Office in Okmulgee, Oklahoma (DOE/HWP-140). The vault (Vault 19), located in the basement of the building, has been used for surplus equipment storage for the past 10 years. Radon testing conducted by USPS personnel in 1993 yielded a 6.4-pCi/L reading in the vault. According to site personnel, the mitigation diagnostic team had been the only people in the vault over the past several years. Obviously, mitigation of the vault in its current utility is not a priority. A management-in-place plan controlling access would be the most cost-effective solution. The recommendation is made that over the long term, USPS develop mitigation response guidelines based on levels of exposure dose as opposed to integrated radon concentration.

3.5 TESTING CONSIDERATIONS

Over the past several years, many observations were noted during radon testing in USPS facilities. The largest concern is detector deployment. During both the protocol evaluation phase and pilot program, certain sites were mailed detectors. At some sites, delays in detector deployment were encountered. An important factor in cost containment using reusable radon detectors is prompt deployment and retrieval. For sites requiring less than 40 detectors, the recommendation is made that site personnel be responsible for deployment. For sites between 40 and 100 measurements, the site should be contacted and a decision made as to whether on-site placement is needed. For sites requiring more than 100 measurements, on-site placement is highly recommended.

3.6 MITIGATION DIAGNOSTIC MEASUREMENTS EVALUATION

During the mitigation diagnostic protocol study (Sect. 2), seven different diagnostics were performed. As required by USPS, the diagnostic measurements performed were similar to residential diagnostics, provided useful information about certain aspects of the buildings, and were nondisruptive to USPS activities. However, observed limitations for each of these tests have an impact on their usefulness. Table 139 lists the diagnostics performed, limitations, and recommendations.

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Limitations</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change</td>
<td>Measurements must be taken for both on and off cycles in forced-air locations</td>
<td>Perform at all sites</td>
</tr>
<tr>
<td>Blower door</td>
<td>Buildings or areas larger than 8,000 ft² yield inconclusive results</td>
<td>Limit to buildings of &lt;8,000 ft²</td>
</tr>
</tbody>
</table>

Table 139. Mitigation diagnostics measurement summary
Table 139 (continued)

<table>
<thead>
<tr>
<th>Diagnostics test</th>
<th>Limitations</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subslab</td>
<td>Multistory buildings hamper SSD systems</td>
<td>Limit only to buildings in which a subslab mitigation system can be installed</td>
</tr>
<tr>
<td>Continuous radon</td>
<td>Costs of continuous measurements are high compared with costs of passive</td>
<td>Perform in all buildings with forced-air systems</td>
</tr>
<tr>
<td>measurements</td>
<td>measurements</td>
<td></td>
</tr>
<tr>
<td>Flow hood</td>
<td>Accessibility to many supply vents complicates the measurements</td>
<td>Differential pressure measurement is a better imbalance indicator</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>In 26 on-site investigations, only one significant pathway was encountered</td>
<td>Perform only for obvious entry pathways</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>Cyclic and seasonal forced-air systems may not be operational during</td>
<td>If a seasonal or cyclic forced-air system is present, two measurements (on and off) must be performed</td>
</tr>
<tr>
<td></td>
<td>diagnostics</td>
<td></td>
</tr>
</tbody>
</table>

3.7 BUILDING CLASSIFICATION FOR MITIGATION DIAGNOSTICS

An essential part of contracting mitigation diagnostics in the future will be the ability to classify buildings into particular categories, with standardized mitigation diagnostics for each type. Based on the data collected thus far, two classifications exist for USPS buildings: mechanical system and structural.

3.7.1 Mechanical System Classification

The mechanical system category can be subdivided into eight different types, with the criterion being forced air. Table 140 summarizes the possible types of mechanical systems in USPS buildings.

Table 140. Types of forced-air systems in U.S. Postal Service buildings

<table>
<thead>
<tr>
<th>Type</th>
<th>Forced-air heating</th>
<th>Forced-air cooling</th>
<th>Forced-air ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table 140 (continued)

<table>
<thead>
<tr>
<th>Type</th>
<th>Forced-air heating</th>
<th>Forced-air cooling</th>
<th>Forced-air ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

After elevated radon levels have been confirmed (e.g., passive short-term measurements) in a USPS building, the first steps of the mitigation process should entail the inspection of the mechanical system. The inspection should be conducted by an ASHRAE-certified engineer with both diagnostic and estimator qualifications. Table 141 summarizes important questions that must be addressed during the inspection concerning mechanical type. In addition to these questions, the inspector should try to correlate elevated radon levels to areas of the building with poor ventilation (e.g., no forced-air supply). Also, as part of the mechanical inspection, 21-day continuous radon measurements should be recorded for Mechanical Types 4, 6, and 8 in all rooms (or representative subset) with elevated levels of radon. For seasonal forced-air systems (e.g., Mechanical Types 2, 3, 5, and 7), continuous radon measurements should be performed in both the on and off cycles, weather permitting.

Table 141. Questions for inspections of mechanical systems

<table>
<thead>
<tr>
<th>Question</th>
<th>Mechanical type*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the forced-air system continuous, seasonal, or intermittent?</td>
<td>2, 3, 4, 5, 6, 7, 8</td>
</tr>
<tr>
<td>Does the system operate within specifications?</td>
<td>2, 3, 4, 5, 6, 7, 8</td>
</tr>
<tr>
<td>Can the system be upgraded?</td>
<td>4, 6</td>
</tr>
<tr>
<td>Should the system be continuous?</td>
<td>4, 6, 8</td>
</tr>
<tr>
<td>Can the system be modified to provide year-round service?</td>
<td>2, 3, 5, 7</td>
</tr>
<tr>
<td>Is localized ventilation possible?</td>
<td>1, 2, 3, 4, 5, 6, 7, 8</td>
</tr>
<tr>
<td>Can the system be adjusted?</td>
<td>4, 6, 8</td>
</tr>
<tr>
<td>Should the system be replaced?</td>
<td>2, 3, 4, 5, 6, 7, 8</td>
</tr>
</tbody>
</table>

*See Table 140 for types.

The mitigation diagnostics listed in Table 138 can also be considered mechanical or structural (Table 142).
Table 142. Mitigation diagnostic classification

<table>
<thead>
<tr>
<th>Mitigation diagnostics</th>
<th>Abbreviation</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air change per hour</td>
<td>ACH</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Blower door</td>
<td>BD</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Subslab</td>
<td>SS</td>
<td>Structural</td>
</tr>
<tr>
<td>Continuous radon monitoring</td>
<td>CRM</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Flow hood</td>
<td>FH</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Radon entry pathway</td>
<td>REP</td>
<td>Structural</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>DP</td>
<td>Mechanical</td>
</tr>
</tbody>
</table>

Each mechanical type (Table 140) has mitigation diagnostics that would be recommended (Table 143).

Table 143. Recommended diagnostics for mechanical systems

<table>
<thead>
<tr>
<th>Mechanical Type</th>
<th>Air change</th>
<th>Blower door</th>
<th>Continuous radon measurements</th>
<th>Flow hood</th>
<th>Differential pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>2 (year-round)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No (Yes)</td>
<td>No (Yes)</td>
</tr>
<tr>
<td>3 (year-round)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No (Yes)</td>
<td>No (Yes)</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

See Tables 140 and 141 for descriptions.

3.7.2 Structural Classification

Over the past 3 years, the HAZWRAP mitigation diagnostic team has visited 26 USPS buildings. Information regarding building size, age, and substructure type has been taken into consideration, and the buildings have been classified into eight distinct categories (Table 144). For reference purposes, the sites visited by the HAZWRAP mitigation diagnostic team are listed in Table 145. The structural categories are far from being complete. Based on the observations made by the radon detector placement team, this list represents half of the USPS population observed thus far. Full diagnostic testing (Table 139) is recommended for each type of new building until a generalized list is completed for all types of USPS buildings.
Table 144. U.S. Postal Service structural types observed to date

<table>
<thead>
<tr>
<th>Type</th>
<th>Number observed</th>
<th>Description of structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>Large, Works Progress Administration style, multistory</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>Small, single story with basement</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Multistory, modern</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Extra large, many stories</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>1 story plus 2-story office wing</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>Pre-Works Progress Administration, multistory</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>Single story, modern</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>Large, multistory, multiaddition</td>
</tr>
</tbody>
</table>

Table 145. Structural classification of the study sites

<table>
<thead>
<tr>
<th>Location</th>
<th>Structural typea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abilene, Texas</td>
<td>4</td>
</tr>
<tr>
<td>Ada, Oklahoma</td>
<td>1</td>
</tr>
<tr>
<td>Allentown, Pennsylvania</td>
<td>1</td>
</tr>
<tr>
<td>Big Springs, Texas (mixed substructure)</td>
<td>3</td>
</tr>
<tr>
<td>Clovis, New Mexico</td>
<td>3</td>
</tr>
<tr>
<td>Dallas, Texas</td>
<td>4</td>
</tr>
<tr>
<td>Eastport, Maine</td>
<td>6</td>
</tr>
<tr>
<td>Eldora, Iowa</td>
<td>2</td>
</tr>
<tr>
<td>Enid, Oklahoma</td>
<td>1</td>
</tr>
<tr>
<td>Florissant, Missouri (leased)</td>
<td>7</td>
</tr>
<tr>
<td>Griffin, Georgia</td>
<td>3</td>
</tr>
<tr>
<td>Lancaster, Ohio</td>
<td>8</td>
</tr>
<tr>
<td>Lowville, New York</td>
<td>2</td>
</tr>
<tr>
<td>Machias, Maine</td>
<td>5</td>
</tr>
<tr>
<td>Marion, Indiana</td>
<td>1</td>
</tr>
<tr>
<td>Mercer, Pennsylvania</td>
<td>2</td>
</tr>
</tbody>
</table>
Although a mechanical classification may require that a particular diagnostic test be performed (Table 143), certain structural features (e.g., size) may limit the applicability of the data. These technological limitations will take precedence over certain mechanical diagnostics. Table 146 summarizes the recommendations for structural and mechanical diagnostics as a function of structural type.

**Table 145 (continued)**

<table>
<thead>
<tr>
<th>Location</th>
<th>Structural type&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okmulgee, Oklahoma</td>
<td>1</td>
</tr>
<tr>
<td>Paris, Kentucky</td>
<td>5</td>
</tr>
<tr>
<td>Pueblo, Colorado (mixed substructure)</td>
<td>1</td>
</tr>
<tr>
<td>Raton, New Mexico</td>
<td>5</td>
</tr>
<tr>
<td>Rockland, Maine</td>
<td>5</td>
</tr>
<tr>
<td>Scott City, Kansas</td>
<td>5</td>
</tr>
<tr>
<td>Talladega, Alabama</td>
<td>5</td>
</tr>
<tr>
<td>Willimantic, Connecticut (leased)</td>
<td>7</td>
</tr>
<tr>
<td>Waynesville, North Carolina</td>
<td>5</td>
</tr>
<tr>
<td>Wrightsville, Georgia</td>
<td>2</td>
</tr>
</tbody>
</table>

See Table 144.

**Table 146. Recommended structural mitigation diagnostics**

<table>
<thead>
<tr>
<th>Structural type</th>
<th>BD&lt;sup&gt;a&lt;/sup&gt;</th>
<th>SS&lt;sup&gt;a&lt;/sup&gt;</th>
<th>REP&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

See Table 142.
3.8 MITIGATION DIAGNOSTIC PROTOCOL

In a diverse population of buildings, such as those of USPS, no single radon mitigation protocol can predict with absolute certainty the best mitigation method. For this reason, the protocol has been developed in steps that allow the user to collect information and either implement the conclusions of that step or proceed to the next step. Also, the option to skip a step exists, based on building circumstances. In certain cases, contracting all or most of the mitigation diagnostics (Table 139) as a package may be more cost-efficient. Keeping accurate records and active data bases for the first few hundred radon mitigations will allow for adaptation and save money over the long term.

3.8.1 Step 1: Building and Mechanical Classification

Using Tables 140 and 144, classify the mechanical and building structures. Then select from Tables 143 and 146 the mitigation diagnostics to perform. If the building has a Type 1, 2, 3, 4, 5, or 7 mechanical system, then consideration may be given to skipping Step 2. However, ACH measurements are recommended as are BD measurements where size permits.

Note that, based on the studies at USPS Waynesville, North Carolina (Sect. 224), complete ground-contact testing should be performed after each mitigation attempt. In the case of the U.S. Post Office in Waynesville, the installation of a new HAC system resulted in mitigation in some areas but significant increases of radon in others. Short-term radon testing after a mitigation attempt would be sufficient to establish a baseline. However, only long-term testing results should be used as proof of mitigation.

3.8.2 Step 2: Mechanical Inspection, Assessment, and Diagnostics

During the 1994 mitigation diagnostic study (Sect. 2), the most common problem observed was localized poor ventilation. The poor ventilation problem, caused by improper forced-air system balance, malfunctioning mechanical systems, or no ventilation, was probably the most common reason for elevated radon levels in USPS buildings. The radon test data generated to date (Sect. 1) indicate that elevated radon level in USPS buildings tend to be localized within buildings. This information, coupled with the field air change measurements, clearly indicates that mechanical/ventilation inspection should be the first investigative step of the mitigation process. The objective of the mechanical/ventilation inspection should be to determine the best mechanical options (Table 141) for mitigation and estimate costs for the solution. To assist in this determination, mechanical mitigation diagnostics (Tables 143 and 146) are performed. The order in which the diagnostic tests are performed is not critical.

Once the data have been collected, the following general rules will assist in data interpretation:

- Areas in which the ACH is below 0.35 is considered substandard. By increasing an area's ACH, radon is comparably reduced (see Sect. 2).

- For pressurization, a BD measurement with a 4-Pa pressure ratio of 8 or greater [e.g., volume (of area)/ft³/min⁻¹ for 4 Pa] is considered suitable for SP.

- If no part of the mechanical system is in ground contact, DP measurements in areas with 3 Pa or greater of pressure (relative to the outdoors) can be ignored. In areas with measurements.
of <3 Pa, adjustments should be made to the area supply to provide, at a minimum, 3 Pa of pressure.

- If elevated radon levels are found only in a few areas (i.e., <4 areas) with low ACH (e.g., <0.35), then serious consideration should be given to increasing the localized ventilation rate first.

Concurrent with the mechanical inspection, a usage or occupancy pattern study should be conducted, because some areas with elevated levels of radon may not have usage sufficient to justify the cost of corrective action (see Sect. 3.4). Also, in certain cases, relocation from a "high radon" area to a "low radon" area within the building may be an option (see USPS Allentown, Pennsylvania, DOE/HWP-140).

3.8.3 Step 3: Structural Mitigation Diagnostics

During the 1994 mitigation diagnostic study, it became apparent that although subslab mitigation diagnostics could be performed, certain building characteristics made installation of a SSD system impractical. Therefore, the first step for subslab mitigation diagnostics should be an assessment of the practicality of an SSD system. Conditions that would potentially disqualify a building from SSD mitigation are as follows:

- Buildings with more than three stories (e.g., >40 ft from slab to roof).
- Historical buildings that cannot be modified on the exterior and for which vertical penetration is not practical.
- Building interiors without easy access to the roof (e.g., single fan pipe runs of more than 100 ft).
- Buildings constructed over shallow water tables (e.g., water table <4 ft from the slab).
- Buildings with extra thick (i.e., 1 ft) or steel-reinforced slabs (would increase installation cost greatly).

If one or more of the above statements are true, then performing subslab diagnostics is not recommended.

If the building is found suitable for potential SSD mitigation, then the building plans should be reviewed. During the review, all subslab utilities (e.g., water, sewer, and electrical) should be identified on the building plans. A walk-through of the building is then conducted to verify the accuracy of the drawings. Hazards, such as asbestos in floor tile, should be documented during the visual inspection. In addition to reviewing the building plans, the building maintenance staff should be consulted. Concurrent with the subslab utilities inspection, avenues for running SSD pipe should be documented as well.

After the walk-through inspection, subslab diagnostics can then be performed in areas where a potential suction pit could be installed. The exact number of subslab diagnostics to perform for a given building depends on many variables; size of the slab, subslab complexity, the measured field extension, details of the building plans, and the number of areas in which subslab diagnostics can be performed are just a few of the variables. For reference purposes, one subslab diagnostics should be performed for each foundation present. For example, a single perimeter, rectangular foundation with a monolithic slab could be characterized with only one subslab diagnostic test if the building plans indicate homogenous subslab fill. In cases where more than one foundation exists (e.g., multilevel basement or building additions) or where the foundation is composed of
nonhomogeneous subslab fill, then one subslab diagnostic test should be performed per section (provided elevated radon levels are present in those areas).

The second structural mitigation diagnostic, radon entry pathway measurements, should be performed in all buildings. The exact number of measurements will vary from building to building. All major ground-contact blemishes (or a representative sample) should be examined for radon entry pathways. Examples of blemishes are holes or breaks in the slab with visible subslab material, sumps, loose-fit slab penetrations, and expansion joints. Small slab and wall cracks (e.g., <3/8-in. cross section) can be ignored. The significance of the measurement depends on the volume of the room, room ACH, concentration of the soil gas, and estimated radon flux.

3.8.4 Mitigation Design

Once the diagnostic data have been collected, cost estimates should be prepared for each of the suitable mitigation options. Options such as whole building and localized mitigation should be considered as well. In addition to the installation cost, lifetime energy cost should be integrated into the bottom line. The following issues should also be addressed.

- Difficulty in installation
  - Is the lead time required for mitigation greater than the guidelines allow (Table 138)?
  - Are the chances for successful mitigation acceptable for the most cost-effective system?

- System upkeep
  - Will it be difficult to maintain the mitigation system once it is operational?
  - What are the costs associated with this upkeep?

- Remaining building lifetime
  - What is the remaining lifetime of the building?
  - Would it be more cost-effective to construct or lease a new facility?

- Short-term options
  - What are the exposure risks?
  - Can the space usage be modified to decrease the potential radon exposure?

- Scheduled mechanical replacements and upgrades
  - Is the building mechanical system scheduled for replacement within the mitigation time allotted?
- If yes, can the replacement system installation be accelerated and designed to mitigate the problem?

From these considerations, costs, and issues, a primary and secondary mitigation method is selected.
In summary, early indications, based on the buildings examined, are that increased ventilation will be the mitigation solution for well over half of the buildings. This should not be interpreted to mean that other mitigation means should be disqualified. As a general rule, SSD systems cost $800 per suction pit (HFLP) and less than $100 per year to operate. In buildings for which it is well suited, SSD is the most cost-effective long-term solution.

3.9 RECOMMENDATIONS FOR MITIGATION DIAGNOSTICS

Radon mitigation of large buildings will continue to be an evolutionary process for USPS in the foreseeable future. Based on the HAZWRAP diagnostic team’s knowledge of USPS buildings, approximately 30 additional buildings (different from the types listed in Table 144) will require study before a comprehensive matrix can be completed. The recommendation is made that mitigation diagnostics and mitigation be centrally managed in order to continue building a knowledge base.

3.10 POSTMITIGATION

The field of postmitigation testing is currently an unknown area because in order for concise recommendations to be made, long-duration studies must be performed to measure mitigation durability and reliability. Because of the lack of research funds during the past 5 years, EPA and DOE have been unable to conduct the in-depth studies needed to compile recommended guidelines. In lieu of this, ORNL has been collecting information from various sources (e.g., private contractors, fellow researchers, and state and federal agencies) and compiling a preliminary data base from which to develop a postmitigation protocol. This data base is not complete and deals only with residential mitigation. However, the existing data should provide a sufficient foundation on which to build an interim protocol. The recommendation is made that USPS maintain a centralized data base to track mitigation method and mitigation failure. If performed, sufficient information for long-term maintenance would be achieved within 5 to 7 years. From this information, a more comprehensive postmitigation plan could then be developed.

3.10.1 Postmitigation Interim Protocol

The postmitigation phase is divided into three distinct parts: verification, documentation, and maintenance. The first step, verification testing, is performed after the mitigation system has been installed and activated. These measurements are short term (2 to 5 days) and are performed solely to verify that mitigation has actually occurred. If mitigation has been achieved (e.g., radon <4 pCi/L), then a second, long-term (90 to 120 days) measurement is performed to verify long-term radon reduction. All testing should be in accordance with the procedures listed in Sect. 1.

If mitigation has been achieved (e.g., 90- to 120-day measurements of <4 pCi/L), then the following information must be collected for future reference:
• mitigation company name,
• specific type of mitigation system,
• specifications and design of system (e.g., drawings, flows, pressures),
• maintenance requirements (e.g., filter changes, damper adjustments),
• installation cost,
• pre- and postmitigation radon levels, and
• Phase II diagnostic data.

The next step, maintenance testing, is a short-term measurement performed at specific time intervals to verify that radon mitigation is still being achieved. The proper interval for the testing is based on the type of mitigation system and the premitigation radon levels. Table 147 lists the testing interval as a function of the mitigation system.

Table 147. Postmitigation testing interval as a function of mitigation system

<table>
<thead>
<tr>
<th>Mitigation system</th>
<th>Time between sampling (years)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive sealing</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Passive ventilation</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Pressurization</td>
<td>1 to 2</td>
</tr>
<tr>
<td>Heat recovery ventilation</td>
<td>2 to 3</td>
</tr>
<tr>
<td>Charcoal absorptionb</td>
<td>1 to 2</td>
</tr>
<tr>
<td>Subslab depressurization</td>
<td>3 to 5</td>
</tr>
<tr>
<td>Management in place</td>
<td>1 to 2</td>
</tr>
<tr>
<td>Mechanical system adjustment</td>
<td>1 to 2</td>
</tr>
</tbody>
</table>

*No independent, postmitigation data exist for this type of mitigation system. Estimates are based on conservative assumptions.

Interpretation of the maintenance testing data is as follows:

• If all measurements are <4 pCi/L, then retest at the next interval (Table 147).

• If the retest measurement is >4 pCi/L but <10 pCi/L, then an immediate confirmation test should be performed. If the follow-up measurement is confirmed or if the maintenance measurement is >10 pCi/L, then a mitigation system diagnostic test should be performed.

3.10.2 Mitigation Failure Diagnostics

All radon mitigation systems will eventually fail. Understanding the cause of the failure and tracking the solutions will provide insight for future mitigation system selection and design. Therefore, the need for established mitigation failure diagnostics is just as important as the Phase II diagnostics (Sect. 2).
The first step for mitigation failure diagnostics should be a review of the postmitigation documentation (Sect. 3.10.1). The mitigation system should then be inspected, performance diagnostics performed, and comparisons made to the original documentation and system specifications. During the data review, the key questions to ask are as follows:

- Is the system performing within the original documented parameters?
- Is this a new radon problem or a general system failure?
- Can the existing system be repaired or modified?

Based upon this inspection, one of following events will occur:

- The system will be repaired or modified.
- The system will be replaced.
- An additional system will be installed to supplement the existing system.

After this step, the steps outlined in Sect. 3.10.1 are repeated.

3.10.3 Major Renovation

After any mechanical or structural renovation, radon retesting should be performed. This is particularly important if mitigation was achieved by ventilation. Ideally, for buildings with a history of elevated radon, the testing should be performed as soon as possible after the renovation has been completed. If testing determines that mitigation failure has occurred, then the procedures outlined in Sect. 3.10.2 should be followed. For buildings that have been tested, but were found to be <4 pCi/L, the buildings should be retested in accordance with the potential for elevated radon in that geographic area. The recommended retest due to renovation schedule is outlined in Table 148.

<table>
<thead>
<tr>
<th>Radon zone (% &gt;4 pCi/L)</th>
<th>Recommended testing interval (months)b</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>12</td>
</tr>
<tr>
<td>1 to 5</td>
<td>8</td>
</tr>
<tr>
<td>5 to 10</td>
<td>6</td>
</tr>
<tr>
<td>10 to 20</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>2</td>
</tr>
<tr>
<td>Mitigated building</td>
<td>1</td>
</tr>
</tbody>
</table>

a All retesting due to renovation should be short term and conducted in accordance with the procedures outlined in Sect. 1.
b Months after renovation has been completed.
REFERENCES


APPENDIX A

RADON TESTING DATA
FOR THE U.S. POSTAL SERVICE SITES
<table>
<thead>
<tr>
<th>USP0ID</th>
<th>City/State</th>
<th>Location</th>
<th>Room</th>
<th>Detector</th>
<th>Confirm</th>
<th>Conf</th>
<th>Detector</th>
<th>Confirm</th>
<th>Result</th>
<th>Conclusion</th>
<th>Report Date: 12/13/94</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO0523</td>
<td>DENVER, CO</td>
<td>ROOM OFF OF COMPUTER ROOM</td>
<td>D-16</td>
<td>LE7770</td>
<td>SE2434</td>
<td>0</td>
<td>10.1</td>
<td>4.6</td>
<td>Confirmed Mitigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO0523</td>
<td>DENVER, CO</td>
<td>WALL 3</td>
<td>C-14</td>
<td>LF0042</td>
<td>SE5527</td>
<td>0</td>
<td>13.1</td>
<td>1.1</td>
<td>False Pos</td>
<td>No Further Testing</td>
<td></td>
</tr>
<tr>
<td>CO0523</td>
<td>DENVER, CO</td>
<td>UNDER THROUGHFARE ACROSS FROM J-6</td>
<td>180</td>
<td>LF1931</td>
<td>SF9785</td>
<td>0</td>
<td>6.2</td>
<td>5.1</td>
<td>Confirmed Mitigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO0526</td>
<td>DENVER, CO</td>
<td>WALL 3 FILE CABINET</td>
<td>271</td>
<td>LE3306</td>
<td>SE5545</td>
<td>0</td>
<td>5.8</td>
<td>2.9</td>
<td>False Pos</td>
<td>No Further Testing</td>
<td></td>
</tr>
<tr>
<td>CO0526</td>
<td>DENVER, CO</td>
<td>ON N-12</td>
<td>159</td>
<td>LE7426</td>
<td>SF0164</td>
<td>0</td>
<td>7.3</td>
<td>5.7</td>
<td>Confirmed Mitigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO0526</td>
<td>DENVER, CO</td>
<td>SUPPLY ROOM WALL 1</td>
<td>237</td>
<td>LF1879</td>
<td>SM3244</td>
<td>0</td>
<td>28.7</td>
<td>0.5</td>
<td>False Pos</td>
<td>No Further Testing</td>
<td></td>
</tr>
<tr>
<td>CO0526</td>
<td>DENVER, CO</td>
<td>H- 17 ON MF</td>
<td>242</td>
<td>LE9166</td>
<td>SD2580</td>
<td>0</td>
<td>5.3</td>
<td>1.3</td>
<td>False Pos</td>
<td>No Further Testing</td>
<td></td>
</tr>
<tr>
<td>CT0381</td>
<td>STAMFORD, CT</td>
<td>MAINT. SUPPLY RN TOP OF METAL CABINET</td>
<td>176</td>
<td>LD6063</td>
<td>SE2311</td>
<td>0</td>
<td>4.7</td>
<td>0.1</td>
<td>False Pos</td>
<td>No Further Testing</td>
<td></td>
</tr>
<tr>
<td>CT0381</td>
<td>STAMFORD, CT</td>
<td>COLUMN P6</td>
<td>129</td>
<td>LF0049</td>
<td>SF0169</td>
<td>0</td>
<td>6.5</td>
<td>0.0</td>
<td>False Pos</td>
<td>No Further Testing</td>
<td></td>
</tr>
<tr>
<td>CT0381</td>
<td>STAMFORD, CT</td>
<td>TOP OF STAMP MACHINE MAIN LOBBY</td>
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<td>LF0555</td>
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**Martin Marietta Energy Systems**
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### United States Postal Service

**Radon Confirmation Summary**

**Martin Marietta Energy Systems**

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### United States Postal Service

**Conclusions by Site**

**Martin Marietta Energy Systems**

**Report Date:** 12/13/94

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**Totals:** 14201 939 87 154
### United States Postal Service

**Radon Testing Summary to Date**

**Martin Marietta Energy Systems**

**Report Date: 12/13/94**

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### United States Postal Service

**Radon Testing Summary to Date**

**Martin Marletta Energy Systems**

**Report Date: 12/13/94**

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United States Postal Service  
Radon Testing Summary to Date  
Martin Marietta Energy Systems  
Report Date: 12/13/94

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<th>Number Lost</th>
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Total Post Offices Tested: 243  
Total Detectors Shipped: 14201  
Total Detectors Lost: 662  

Total Detectors with PCIL Values:  

- 0 to 4: 8409  
- 4 to 20: 1158  
- >>20: 72  
- >>4: 1230  

Average PCIL Value: 1.5  
Highest PCIL Value: 87.4
APPENDIX B

U.S. POSTAL SERVICE CHARCOAL TESTING DATA (1992)
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### USPS Charcoal Testing Data (1992)

**Martin Marietta Energy Systems**
**USPS ABILENE, TX**
**3RD & PINE STREETS**

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USPS Charcoal Testing Data (1992)
Martin Marietta Energy Systems
USPS ADA, OK
TWELFTH & RENNIE STREETS

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<tr>
<td>1365094</td>
<td>MAIL RM</td>
<td>LIGHT SWITCH COLUMN 145</td>
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<tr>
<td>1365092</td>
<td>MAIL RM</td>
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<td>1365072</td>
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<tr>
<td>1365074</td>
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<td>1365034</td>
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<td>LOCKER #285 BTW COL 160-161</td>
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<td>OVER PIGEON HOLE #214001/FRAZE</td>
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<td>1365657</td>
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<td>Location</td>
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<td>1365581</td>
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### USPS Charcoal Testing Data (1992)
Martin Marietta Energy Systems
USPS HOPE, AR
3RD & LAUREL STREETS

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### USPS Charcoal Testing Data (1992)

**Martin Marietta Energy Systems**  
**USPS SCOTT CITY, KS**  
**211 WEST MAIN STREET**

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**USPS Charcoal Testing Data (1992)**
Martin Marietta Energy Systems
**USPS WACO, TX**
800 FRANKLIN
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