Sowing Conservation in Garden Apartments

BILL VAN DER MEER

by Steven McCarthy, Richard Taylor, and Bill Van der Meer

Low-rise attached apartments pose different challenges for energy auditors than either single-family or large multifamily buildings. One project for a Pennsylvania housing authority shows some of the situations auditors may find.

Auditing low-rise garden apartments is different from auditing single-family or high-rise multifamily buildings. While the apartments don't have the complex patterns of air movement found in high rises, they cannot simply be treated like single-family homes. Each unit is affected by another unit; they share walls and sometimes attic space. To treat each unit properly, auditors need to look at the construction of the entire building.

The Lycoming County Housing Authority (LCHA) pays the gas bills for tenants in its Penn Vale apartments. But if the tenants use more than a preset reasonable amount of gas, they must pay the difference to the authority. Last year, LCHA requested an analysis and recalculation of its "reasonable usage" for different types of apartment, along with an energy audit, from the Weatherization Training Center.

The Penn Vale subdivision consists of 250 apartments in 42 buildings, composed primarily of one-, two-, and three-bedroom units (plus four four-bedroom apartments). The apartments are all built on a slab foundation and are clustered with four to six units per building. All one-bedroom apartments are one story and are accessible to people with disabilities. There are also one-story, two-bedroom accessible apartments. The rest of the units have two stories.

All apartments have water heaters and forced-air furnaces located in a mechanical room that is attached to the apartment but is not accessible from inside. In the one-story apartments, most of the ducts are located in the ventilated attic. In the two-story apartments,

The photo above shows one of the 42 apartment buildings within the 250-unit Penn Vale Housing Complex, where auditors performed energy usage evaluation on ten different apartment types. Thirteen units also received a comprehensive energy audit.

ducts are located in the floor cavity between the first and second floor.

The complex was built in four phases, and there is some variation among the buildings. Buildings erected during phase one and two all have common, open attics above the apartments. Phase three and four buildings have individual attics above each apartment. Sixty units have instantaneous gas water heaters with added power vents, and 190 units have power-vented, gas-fired storage water heaters.

The quality of construction at Penn Vale is very good. All of the units inspected were well maintained. In general we found no serious problems, but we did see some worthwhile opportunities for energy savings.

Reasonable Expected Gas Usage

We determined expected gas usage for ten different types of apartment in the complex (see Table 1). To come up with reasonable numbers, we used historical gas usage for all the apartments, weather data, and meter readings from six unoccupied units during the month of March 1996. The unoccupied units had operating water heaters and heat set at 72°F. The results were estimates of reasonable usage by relatively energy-conscious tenants.

LCHA's previous estimates were not significantly different from ours, although we did add a few categories. We divided the two-bedroom inner and the three-bedroom end units into two categories when we discovered that the units in buildings with a common attic space use 10% less gas than the units with individual separate attic spaces. These two types of unit were built by different contractors in different years, and they lose heat at different rates. The separate attics had more attic vent area, which may cause cooler attic temperatures and more convection losses through building cavities open to the attic.

As expected, the smallest (one-bedroom) units use the least gas. The largest units use about 70% more gas than the smallest units. Also as expected, the inner units use less gas (3% to 14%) than the more-exposed end units.

The disabled-accessible units are the only single-story, two-bedroom apartments in the complex. We expect that gas usage in these units will vary greatly, depending on the nature of the tenant's disability. Therefore we told LCHA that each of these units should be considered on a case-by-case basis and paired with one of the other existing use categories based on anticipated needs for heat, hot water, and cooking.

The Audit

We chose a varied cross-section of units and tested for air leakage, did combustion analysis of the furnace, performed infrared scanning, and checked the pressure balance. We also looked at heating and baseload usage. During the inspection we took measurements and made observations pertaining to safety, indoor air quality, and client behavior as it relates to energy use.

Building Shell

We tested air leakage using a blower door. Apartment air leakage rates ranged from 1,000 cubic feet per minute at 50 Pascals (Pa) of house depressurization, or 1,000 CFM50, to 1,375 CFM50. This translated to estimated natural air exchange rates from 0.6 to 0.8 air changes per hour (ACH). While the blower door was running, we were able to feel air leaking into the apartment around doors, windows, and baseboards, and at electrical outlets. Air was also leaking from all supply and return registers and from many attic access hatches.

Attic pressure testing indicated the existence of some minor air leakage connections between the house and the attic. These can most easily be treated from the attic. Except for the attic hatch and the ductwork, we did not recommend any further air sealing from the building interior.

We recommended that connections to the upper attic be eliminated by duct and air sealing treatments. Due to the difficulty and expense involved in gaining access to the small lower attics (above the mechanical room and above the front entrance area), we proposed no action for these areas.

Pressure Testing

With the furnace blower operating, we took pressure measurements to evaluate pressure imbalances both within the apartments and between the apartments and the outdoors. We also checked the cumulative effect of running all exhaust fans and the furnace fan together, and tested the flow on all exhaust fans.

Whenever furnace fans were operating, we found the apartments to be depressurized, suggesting supply duct leakage to the outside. The average amount of depressurization was about 5 Pa, and in the two worst cases, it was as high as 8 Pa.

Table 1. Reasonable Expected Gas Use for Ten Types of Apartment.

Unit Type	Number of Units	Expected Total Gas Use (Therms)	Expected Total Gas Use (Dollars*)
One-bedroom inner units	24	477	$206
One-bedroom end units	12	495	$317
Two-bedroom inner units with separate attics	97	587	$365
Two-bedroom inner units with common attics	39	514	$328
Two-bedroom end accessible units	2	613	$379
Three-bedroom inner units	4	642	$393
Three-bedroom end units with separate attics	48	748	$447
Three-bedroom end units with common attics	20	650	$398
Four-bedroom inner units	2	915	$527
Four-bedroom end units	2	946	$540
Penn Vale total	250		

*Gas costs are calculated based on utility charges: These include a customer charge of $8.45 (which includes the first 7.9 ccf of gas use), $0.5388/ccf for use up to 100 ccf, and $0.4115 for use over 100 ccf.

When the bedroom or bathroom doors were closed and the furnace fan was operating, the depressurization in the rest of the unit increased to about 7 Pa average, and in the worst apartment to 10 Pa. At the same time, the closed rooms were pressurized from 1 to 6 Pa, with the average room pressure being about 3 Pa.

The pressure imbalances that occurred whenever the furnace fans operated were causing increased air leakage above what we found in our blower door tests. Cold outside air is pulled into any area of the apartment that is depressurized and warm heated air is pushed out of spaces that are pressurized. This increase in the air leakage rate results in higher heating costs. The major cause of the pressure imbalances in these apartments is duct leakage.

Duct Leakage

Since the ducts run in the cavity between the first and second floors of two-story units, supply registers are located in the first-story ceiling to serve the downstairs, and in the second-story floor to serve the upstairs.

We found from pressure pan testing that the warm air distribution systems leak significantly to the outside. While there are many small leakage sites, the most significant "leak" was a supply register in each apartment's vented mechanical room.

The mechanical room is ventilated by required combustion air vents in the exterior door. However, the room is heated to keep pipes from freezing. Pipe freezing problems are common in vented mechanical rooms throughout North America, and the American Gas Association has recognized the problem.

Battelle Pacific Northwest National Laboratory has recently researched the issue of combustion air openings and pipe freezing. This research will be the basis for a modification of the next revision of the National Fuel Gas Code (NFPA 54), and we used it to form our recommendations for duct treatment.

A long-term solution for Penn Vale would be to replace existing furnaces and water heaters with sealed-combustion units. Sealed-combustion appliances draw air for combustion directly from the outside, so the vents on the door to the mechanical room could be sealed off completely.

In the short term, we made the following recommendations:

- Insulate all water piping in the mechanical room, including cold water supply pipes. Also verify that all elbows are insulated.
- Remove the supply plenum register and seal the opening.
- Install a reducer plate on existing furnace room door vents, modifying the combustion air openings to fulfill the requirements in the proposed National Fuel Gas Code.

We also recommended treatment of accessible sections of the distribution system. We suggested eliminating and sealing all filter slots that have been cut into the ducts, and installing the filter on the return grill or in the furnace cabinet instead.

Occupant Survey and Behavior Observations

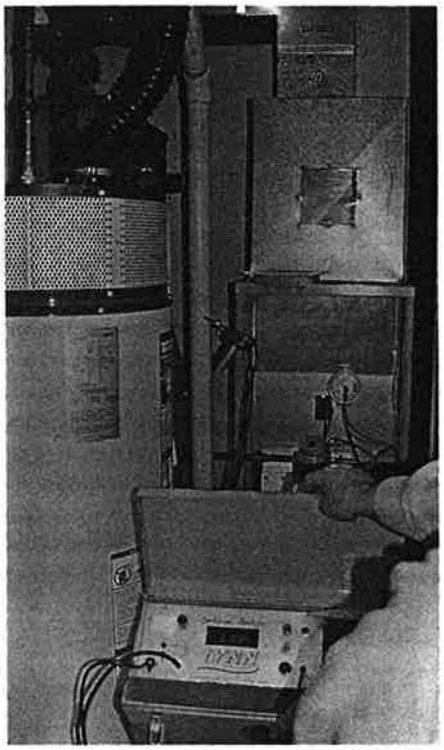
We informally asked residents in occupied apartments about energy bills, temperatures in the apartment, comfort, thermostat setting and use, and exhaust fan use.

Half of the occupied apartments we inspected or tested were being heated to between 75°F and 80°F. Recording thermometers placed in unoccupied apartments showed a temperature difference of 4°F between the first and second floor, with the upstairs always being overheated.

Occupants always said that the upstairs was the warmest part of the apartment, and some said it was uncomfortably hot. A surprising number of second floor windows were open on days when the outside temperature was between 40°F and 45°F.

Temperature stratification on the first floor, which is to some extent more extreme due to the placement of the supply registers in the ceiling, causes occupants to compensate with higher thermostat settings. (For example, to get a 72°F temperature while sitting in a chair on the first floor may require setting the thermostat to 75°F, which in turn will heat the upstairs to 78°F.)

In unoccupied units, when all upstairs bedroom registers were closed, there was no measurable temperature difference between the first and second floor. So we recommended closing or blocking off all second floor bedroom registers to deliver more heat downstairs and achieve better heat rise temperatures. (Note that it's very important to ensure sufficient air flow through the remaining ducts.) Since the ducts are located in conditioned space (between floors), any increased duct leakage caused by closing registers should be to the inside.

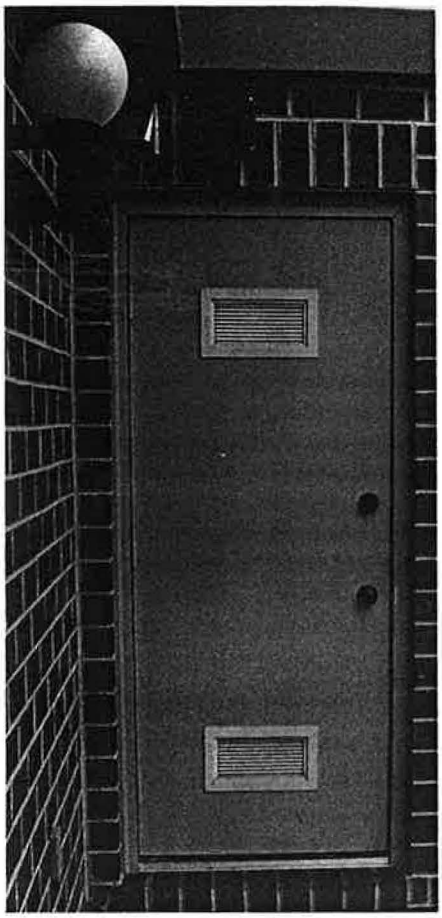


BILL VAN DER MEER

Combustion analysis is performed on a 90%+ efficient furnace inside the mechanical room of one unit. Note the register on the supply plenum (covered with tape for testing), which provided heat to prevent pipe freeze-ups.

Many occupants adjusted their thermostat continuously, sometimes setting it at 60°F when they were hot and adjusting it up to 80°F when they were cold. We recommended installing new thermostats that limit room temperature to 75°F maximum in any apartment that exceeds the reasonable usage. We also suggested installing inexpensive stick-on thermometers next to the thermostat in all apartments, with the 70°F point marked as "best room temperature."

The occupants should be educated concerning temperature setpoint and comfort, temperature setting and energy consumption, thermostat use, and exhaust fan use.



BILL VAN DER MEER

Combustion air inlets in the door to the mechanical room. The existence of these intentional openings and a supply duct on the furnace plenum combined to produce significant house depressurization during the blower cycle.

Building Thermal Flaws

We used infrared scanning to assess the performance and completeness of wall and ceiling insulation. We did the infrared scan while depressurizing the building with the blower door, in order to locate air leakage pathways within the building shell.

We found some evidence of poorly installed or missing insulation, and of air flow through the building framework, especially in second-floor sloped ceilings. However, we didn't recommend any treatment, because insulation repair in this area would be too difficult and expensive to be cost-effective.

Attics were already insulated with 12 to 13 inches of loose fill fiberglass or R-30 rated fiberglass batts. Loose-fill insulation was somewhat compressed around the attic hatch and along walkways. Only two attic hatches were insulated. No moisture problems were visible in the attic. All attics were ventilated.

Open wiring penetrations in the top plate were leaking air. This problem was most severe above the wall that separates the bathroom from the adjacent bedroom. This wall also contains a plumbing stack that was leaking a significant amount of air.

Appliances

The temperature of the hot water at kitchen faucets ranged from 105°F to 149°F. Considering the capacity of the water tank and that the apartments do not have dishwashers, maintaining the water temperature above 120°F is unnecessary.

We measured furnace flue gas with a combustion analyzer to determine oxygen and carbon monoxide (CO) content and to assess the integrity of the heat exchanger. Fan on/off temperatures and heat rise were measured with a digital thermometer. Finally, we checked the thermostat heat anticipator setting. (The heat anticipator fools the thermostat into turning off the gas early. This lets the space coast up to the desired temperature from residual heat in the furnace.)

Furnace testing did not reveal any problems in need of immediate attention. We did suggest verifying the gas manifold pressure on all furnaces to be 3.5 inches of water column and adjusting it if necessary; changing all air filters two times during the heating season; and setting all thermostat anticipators to 0.15 amps, an appropriate setting for these furnaces.

We tested the gas range for burner operation and CO production, and the gas line for gas leaks. All accessible gas lines in the mechanical room were checked for leaks.

Most ranges and ovens were found to be in good operating condition. Carbon monoxide testing showed that CO concentrations at start-up varied from 115 to 200 parts per million (ppm). After a period of warm-up, they dropped to less than 50 ppm. One stovetop burner out of 12 stoves would not light, and we found one gas leak between the flexible connector and the gas piping.

We recommended using a combustible gas leak detector or a leak detection solution each time gas piping is changed or modified or whenever the gas cock is closed and opened.

The Housing Authority's Response

LCHA has chosen one building as a pilot and has begun implementing several of the suggestions we made. These are the actions they've taken so far:

- Thermostat anticipators checked and reset.
- Second-floor bedroom supply registers sealed closed.
- Mechanical room combustion air grille reduced by 50%.
- Supply register in the mechanical room replaced with a dampered 3-inch duct to the pipe area.
- Attic hatch weatherstripped and insulated with 3 inches of extruded polystyrene board.
- Plumbing stack caulked.

In addition, they have checked for gas leaks in all units, and set all water heaters to 120°F.

BILL VAN DER MEER

Pressure pan testing revealed significant leakage to the outside. Since the ducts were contained within the building envelope, most of the leakage was attributed to a register supplying heated air to the mechanical room.

BILL VAN DER MEER

Even though the main emphasis of this study was on gas consumption, auditors also monitored refrigerator electrical consumption and temperatures using a digital thermometer and a watt meter. Most of the refrigerators were deemed to be operating fairly efficiently, although auditors recommended that one guzzler be replaced.

Lessons Learned

Garden apartments are unlike high-rises because the units should be audited individually. However, one doesn't need to audit every apartment in a complex. Most of the problems we identified at Penn Vale were common to all apartments of the same construction type. By identifying the various categories of apartment—by number of stories, number of bedrooms, location, phase of construction, energy bills, and short-term monitoring results—we were able to choose a cross-section of apartment types to inspect. The inspection turned up some significant recurring problems in all the units, such as the supply register in the mechanical room, and temperature stratification in the two-story apartments. We were then able to make recommendations for all the units in the complex.

Steven McCarthy, Richard Taylor, and Bill Van der Meer are teachers at the Weatherization Training Center at the Pennsylvania College of Technology.