VENTILATION STANDARDS AT WORK

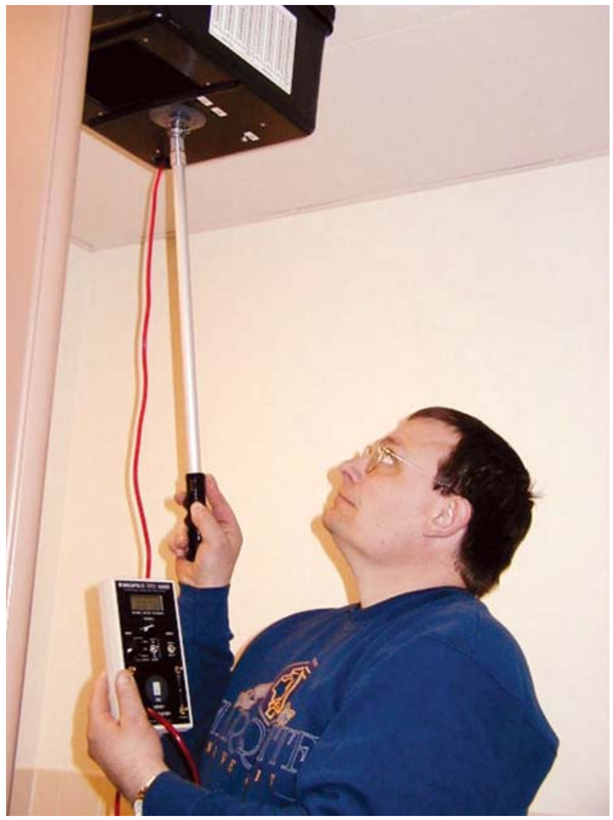
There was a time when it seemed unlikely that Wisconsin housing could be too tight, but times have changed.

by MARTHA BENEWICZ
AND ROBERT PARKHURST

After a full-scale review of our weatherization measures in 2004, Wisconsin decided to implement some changes. In July 2005, Wisconsin's Home Energy Plus Weatherization program began to move away from a building tightness guideline to a ventilation standard in evaluating its weatherization efforts. This change in our procedures has really been a change of mind-set. For almost 20 years, Wisconsin had used calculations based loosely on ASHRAE standards to set tightness limitations for weatherized homes.

In practical terms, these tightness limitations didn't give us enough flexibility to deal with the buildings and with our customers. Some houses that were below the guidelines before weatherization got virtually no sealing work—even when it was needed to maintain the intended air barrier between the house and the outside. Other houses with high occupancy rates needed help to ensure that there was enough fresh air to go around.

The weatherization program in Wisconsin had long recognized and addressed the problem of backdrafting appliances in tighter homes. But tight homes also pose other indoor air problems—primarily moisture and pollutants. These problems led the State of Wisconsin Home Energy Plus Weatherization program and its training and technical assistance subcontractor, the Wisconsin Energy Conservation Corporation (WECC), to consider incorporating proper ventilation in the package of weatherization services. We have made the change to a ventilation standard in two stages. In 2004, Wisconsin started to use ASHRAE Standard 62.1 to calculate building tightness and ventilation requirements. In 2005, Wisconsin adopted the ventilation standards outlined in the revised ASHRAE Standard 62.2, without building tightness requirements.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Robert Parkhurst measures exhaust ventilation. In July 2005, Wisconsin's Home Energy Plus Weatherization program began to move away from a building tightness guideline to a ventilation standard in evaluating its weatherization efforts.

Like many parts of the northern Midwest, Wisconsin has a mixed climate. Heating degree-days vary from more than 9,000 in the north to around 7,000 in the south. Summers can be hot and very humid. Our shoulder seasons—spring and fall—can combine the extreme conditions of both winter and summer.

Can Housing Be Too Tight?

Though significant temperature differentials between the inside and the outside intensify the stack effect on the buildings, our housing stock is generally tighter than buildings in more moderate climates. Wisconsin's average preweatherization building leakage measurement is around 2,400 CFM_{50}. Unfortunately, many of these leaks are unplanned exfiltration, typically through bypasses in the attic. Not only do these bypasses contribute to higher heating costs, but they can also cause severe ice dams on roof eaves.

There was a time when it seemed unlikely that low-income housing stock could ever be too tight. Things have changed—both air sealing technology and the housing stock. In many parts of Wisconsin, 1970s-era buildings now make up part of the low-income occupied-housing stock. These homes were built to tighter standards than older homes, but they were made with materials that have not held up as well as wood does to air movement and moisture. Particleboard, for example, doesn't allow for the natural migration of air and doesn't have the moisture-carrying capacity of wood. Many tight homes, built with these less-forgiving materials, are teetering on the edge of moisture overload and building failure. Most of these homes do have the potential to survive if the right steps are taken in time.

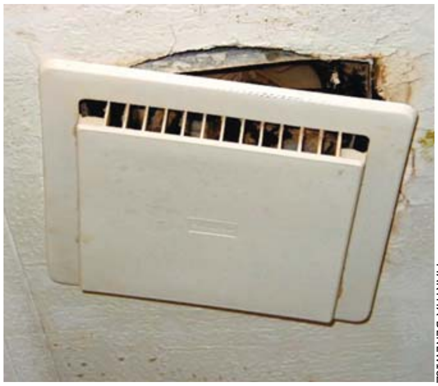
While Wisconsin's Weatherization program has funded the installation of exhaust ventilation as an allowable repair measure for about 20 years, fans were sized primarily by code requirements—a one size fits all approach. We had no system for conducting a field assessment or for properly sizing a building's ventilation needs. Even when a building has existing exhaust ventilation—about half of our housing stock has at least a bath exhaust fan—most of the fans our inspectors find are noisy and do not operate at their rated CFM air capacity. This prompted us to look for a more sophisticated approach to size ventilation.

We found that the same standard we used in part to determine building tightness—ASHRAE 62—might serve as a field tool to calculate the amount of ventilation needed in buildings. Our first step, taken in 2004, was to add the ventilation calculation to our building tightness assessment. At that time Wisconsin was using ZipTestPro software, available from WX Ware Diagnostics, to calculate building tightness (the BTL—building tightness limit—program). We moved to the slightly more sophisticated BTLa program (building tightness limit-advanced) to add the ventilation calculation. Based on ASHRAE 62.1, if a building comes in below the BTLa limit, the ventilation requirements are calculated in cubic feet per minute.

Investing in health and safety and the potential for increased building durability—but without direct energy savings—is a difficult step for a publicly funded weatherization program. But the problems of tight houses pose a risk to the health of the occupants, and the Home Energy Plus Weatherization program managers were unwilling to ignore the issue. It was a gutsy decision on the part of the program's senior managers—Steven Tyron, Susan Brown, and Carl Saueressig. But it signaled to all concerned that we cared as much about our customers' health as we did about the bottom line of energy savings.

Standard Diagnostic Procedures

Producing healthy weatherized homes requires more than added ventilation. It requires a standard package of diagnostic procedures. Using blower door-guided sealing and zone diagnostics has the potential to overtighten buildings. This is not a bad thing, unless weatherization fails to address the other systems at work in a building. To address the potential for overtightening the building, and to ensure combustion appliance safety and building integrity, Wisconsin put several diagnostic procedures in place in 2004. To assess building tightness and ventilation needs, we moved to ZipTest Pro BTLa (building tightness limits-advanced, as mentioned earlier). To make sure that buildings are not excessively depressurized—which might cause combustion, moisture, and other pollutant problems—we test every building for depressurization limits (DTL). We use this calculation to give our installers on-site guidelines. The depressurization limits let them know when the building needs pressure relief—a reduction in the existing exhaust ventilation or added makeup air, or, more likely, modifications to the existing mechanical equipment. Worst-case draft procedures are performed on every building with atmospheric combustion appliances.



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What is this fan ventilating? Even when a building has existing exhaust ventilation, most of the fans our inspectors find are noisy and do not operate at their rated CFM air capacity.

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Not all depressurization problems require a make-up air solution. This clean-out door in a basement obviously required some sealing.

While we have performed building tightness limits and worst-case draft procedures for years, integrating depressurization limits and ventilation requirements can be difficult. The building changes as it is weatherized. A leaky building with atmospheric combustion appliances could start out with an exhaust limit of over 300 CFM and drop to half of that when the building is sealed. The maximum depressurization limits for pressure differentials and CFM_{50} will also change when the building characteristics or the mechanical systems change. These moving targets force an inspector or installer to model for an end state condition for the building.

During weatherization, our crews are changing a building's design as they work. When the work is completed, they look at the new design and check to make sure that it is safe and energy efficient. If it is, that's great. But when final diagnostic testing indicates that additional work is necessary, this creates budgetary and scheduling problems. The job can't be closed until the additional work is done.

One approach to working around this issue is to model or estimate what the building's characteristics will be upon completion, or end state of weatherization work. Inspectors already routinely forecast how new insulation levels will affect a home, but an educated estimate of the final CFM_{50} and CFM of exhaust ventilation is also clearly needed. The required ventilation depends on this final CFM_{50} value. By estimating the final CFM_{50} leakage and ventilation requirements, inspectors can decide what work needs to be completed before the crews finish their work. For example, when a building in its modeled and projected end state will require ventilation, crews may opt not to insulate the attic until an exhaust fan is installed. Similarly, if the total CFM amount of exhaust appliances is likely to increase building depressurization, some atmospherically vented appliance may need to be changed out.

Wisconsin's program is no different from other publicly funded weatherization programs in that we want to weatherize as many homes as possible. Any new procedure that alters work flow will affect production. In 2004 we thought we were delivering a sensible protocol for adding ventilation, but we heard rumbling from our provider network almost immediately. Program management had to decide how to ensure proper pre- and posttesting while delivering adequate ventilation. Since weatherization crews must know the rate of initial building leakage (CFM_{50}) to determine what ventilation systems should be installed, management needed to decide who completes the initial blower door test, and at what point in the work flow. Similarly, the building pressure differentials and worse-case draft test results may drive decisions on distribution system work and mechanical system replacements. From a work flow perspective, either the inspector needs to run the tests and determine the measures or the decisions on installations will get shuffled to installers, which will delay closing out the job. Having a lot of in-progress buildings complicates life for both state and local program administrators.

We went back to the drawing board within a month of implementing ventilation protocols to streamline procedures with production issues in mind, and to provide more information on ventilation options. Given the feedback from the providers, we took a serious look at ventilation systems and controllers that can be easily modified when all other work is completed.

Ventilation is calculated based on building size and on number of occupants. In Wisconsin, we needed to decide not only how to measure a building correctly, but also, and more importantly, what parts of the building to include. ASHRAE 62.1 uses a minimum of 0.35 ACH to determine a building tightness limit before ventilation is required. The big debate in Wisconsin was whether or not to include basements in the volume calculations. In a single-story house, including the basement essentially doubles the volume and cuts the number of air changes in half. This choice also affects the blower door testing setup of the building by determining when a basement door should be open or closed.

The purpose of ventilation is to provide acceptable indoor air quality (IAQ) in residential buildings. ASHRAE defines habitable and occupiable spaces in a building to help us to decide how to measure a building. In addition, we are concerned with the exchange between conditioned air and outdoor air. In Wisconsin, the heating system is usually located in the basement. We expect to find air infiltration through the basement foundation, providing a path for fresh air to enter a building when an exhaust-only ventilation system is used. Finally, the basement can be a source of contaminants that affect IAQ and this air does enter the habitable section of the building.

All of these factors helped us to decide that even unintentionally conditioned basements should be included in the calculations for the building to determine air leakage rates that, in turn, affect ventilation.

Another key factor in determining ventilation rate is the proper measurement of a building. As part of our training on using the BTLa software, training participants measured houses as a group activity. If there were five groups, inevitably there were five different sets of measurements. This reinforced the need to take a consistent approach in measuring areas, volumes, and heights. To estimate the amount of insulation needed for walls and attics, auditors use the outside dimensions of a building and generally round up. The big change for auditors was to use the inside measurements of the building, as described by ASHRAE, to determine floor area and volume. Story heights must include floor cavities, and the building height should include only the pressure boundary of the building. These dimensions are used to measure the quantity of air inside the building that needs to be ventilated.

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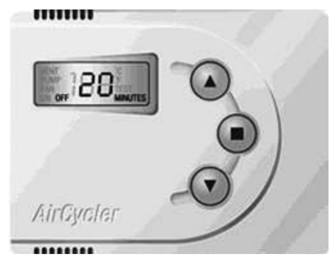

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Controllers such as these are a major part of a ventilation strategy. For example, sizing systems for intermittent operation allows installers to adjust the timers and flow rates to meet the end state required rate of ventilation.

Installing a ventilation systems can be a simple process—for example, installing a bathroom exhaust—or a highly complex process—for example, installing a balanced heat recovery ventilator (HRV) with its own distribution system. But even a simple exhaust fan installation can quickly become complicated. Key issues include sizing the fan, deciding where to install it, and deciding when in the work flow the fan should be installed. Our providers use a mix of their own installers and electricians for installation. Often the fan will be roughed in by the installers and connected by an electrician. It's important to consider whether an electrician needs to install a new circuit, or whether crews may already have insulated the attic. When the crews have already insulated the attic and a decision is made to install an exhaust fan for ventilation, all of the newly installed insulation must be moved out of the way. After the fan is installed, a crew will need to reinsulate the area around the new fan. This creates extra work and extra mess that can be avoided when decisions about ventilation are made before insulating. There may be other workflow obstacles based on local code.

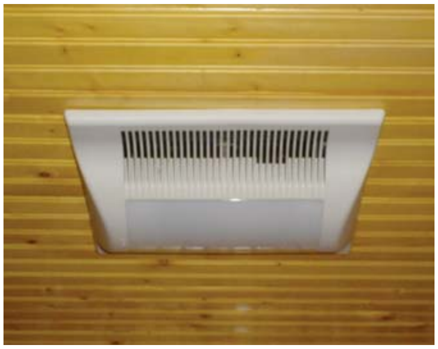
We brought in HVAC consultant Joe Nagan to give our 21 providers ideas and options on ventilation systems. Nagan has worked very effectively with Wisconsin's Focus on Energy program's private contractors, primarily on new construction projects. He explained how different systems can be installed, and how they can be performance-tested. Performance is important; we want the ventilation installed, and we also want it to perform as expected. Typically, based on Nagan's work, existing systems underperform at about 50% of the fan's rating, due to improperly sized ducting, poorly sealed ducts, and so on. Focusing on best practices in ducting equipment to the outside of the building helps to ensure an actual flow as high as 90%–95% of the fan's rating.

A larger obstacle to address was sizing systems to meet higher required ventilation rates. Thirty CFM is an easily attainable rate of ventilation with a single exhaust fan and the fan can be installed at the completion of weatherization with few complications. However the decision-making process at the end of weatherization becomes very complicated when, as a result of very good air sealing on a building, the required ventilation rate is above 100 CFM. Should the installation be multiple exhaust fans, or is a balanced HRV system the better choice? And maybe more importantly, who should make this determination? Crews in Wisconsin are very good at making decisions in the field about other measures, and about work that is accomplished in buildings that they have some control over, such as how to air seal cost effectively. But should these decisions about ventilation be left up to the crew to make? Adding ventilation requires the customer's input as well, because if the customer doesn't want it, or cannot complete routine maintenance, the ventilation system will fail.

With additional information and training, we found that our local providers were able to come up with their own action plans for incorporating ventilation into the weatherization mix. This included lots of experimentation with different products and installations. The people in the field who know how to treat buildings will always develop the best methods to accomplish the job. Our biggest task was to get everyone on the same page—and then get out of the way.

Piloting ASHRAE 62.2

Just as Wisconsin was developing the plans to implement ventilation procedures based on ASHRAE 62.1, the long-awaited, much-debated, 62.2 guidelines were adopted. There was good evidence that 62.2 would require lower ventilation rates, given the decrease in the CFM per person rate (15 CFM under natural conditions for 62.1 versus 7.5 CFM for 62.2). We wanted to determine the advantages, if any, of using 62.2 calculations. Given the steep learning curve on ventilation—toward consistent approaches to sizing and intermittent control strategies—we opted to pilot the new calculations in three provider areas, with diverse housing stock. The pilot was set up to test the 62.2 ventilation sizing requirements against the 62.1 calculations. We also wanted to know if providing ventilation would contribute to an unexpected combustion safety problem that could be created by depressurizing a building with exhaust ventilation.



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Installing a ventilation system can be a simple process—for example, installing a bathroom exhaust.

To calculate this data, we used Rick Karg's ZipTest Pro2 software (WX Ware Diagnostics) and a spreadsheet developed by Karg that compared the results automatically. Karg's software has evolved over the last couple of years. Depending on the edition, the 62.1 calculations use one of two methods—Quadrature or Ecotope. The methods generate slightly different figures. The pilot provider agencies were allowed to use any of the three methods to provide ventilation in their units.

The anecdotal feedback from the pilot agencies was unambiguous. The ASHRAE 62.2 method was the easiest to work with and allowed the most flexibility. The average cost of installing a single exhaust fan with a controller in the study was about $530.

The data we received early in the study from the three providers gave us information on two areas that have the biggest impact on production. When ventilation is called for by each standard, the results using 62.2 had, on average, lower flow rates of required ventilation. The percentage of buildings requiring ventilation is higher when using the 62.2 standard. The Quadrature method of calculating ventilation and the Ecotope method provide similar results.

Based on this early data, Wisconsin made the decision to move forward and begin using the ASHRAE 62.2 standard to determine ventilation rates. We believe that the 62.2 standard allows providers to plan production more effectively. In most cases, simple ventilation systems utilizing lower flow rates with an exhaust fan will meet the requirement. Sizing systems for intermittent operation allows installers to adjust the timers and flow rates to meet the end state required rate of ventilation. The number of buildings that will need ventilation does increase, but auditors are better able to determine maximum rates, and to determine them earlier in the weatherization process.

Given the greater number of units needing ventilation, we wondered what effect ventilation would have on depressurization. To find out, we tracked final CFM_{50} blower door tests and compared them to the depressurization tightness limits. In early results, we found that ventilation as required by the 62.2 standard had no significant effect on depressurization in the building. In the buildings where we found excessive depressurization, the required ventilation by itself was not causing problems. In the buildings where we found potential excessive depressurization, the combined effect of all exhaust appliances caused that depressurization, and would have done so even had the required ventilation not been included. As mentioned earlier, the depressurization problems are most often solved by modifications to the existing mechanical equipment, including distribution sealing.

Final results of the Wisconsin study looked at 173 units of varying types (see Table 1). If the properties of all of the buildings in the study were averaged, this average building would have 1,900 ft² of floor area with a volume of 14,900 cubic feet and would have 4.13 occupants.

The occurrence rate for required ventilation using 62.2 was 79% at an average rate of 30 CFM. There were no ventilation rates above 100 CFM for 62.2, but there were 19% above 100 CFM for 62.1. This is a considerable difference. It is much easier to site and design low flow systems than to site and design systems over 100 CFM. Lower ventilation rates also mean lower costs for the customer, both for electrical consumption and for heating the replacement air coming into the home as a result of exhaust ventilation.

Wisconsin's migration from a building tightness guideline to a ventilation standard has been gradual. When building tightness guidelines are based on ASHRAE 62.1, some houses may be tightened below 800 CFM_{50}. Other houses will remain leakier based on their profile—the vertical area above grade—rather than on their footprint—the horizontal area at grade, which is utilized by 62.2. As mentioned earlier, the 62.1 guideline requires at least 15 CFM per occupant under natural conditions and 0.35 ACH. When the building falls below the building tightness level, and when the unventilated flow rate of the building is lower than acceptable, the solution is to add ventilation.

Table 1. Occurrence Rates of Required Ventilation

	All Units (173)		
	Count	%	Average Rate of Ventilation
Quadrature	80	46	71 CFM
Ecotope	79	46	65 CFM
62.2	136	79	30 CFM

	Greater Than 10 CFM			Greater Than 30 CFM		
	Count	% of All Units	% of Units With Ventilation	Count	% of All Units	% of Units With Ventilation
Quadrature	79	46	99	71	41	89
Ecotope	74	43	94	61	35	77
62.2	109	63	80	64	37	47

	Greater Than 50 CFM			Greater Than 100 CFM		
	Count	% of All Units	% of Units With Ventilation	Count	% of All Units	% of Units With Ventilation
Quadrature	59	34	74	15	9	19
Ecotope	47	27	59	15	9	19
62.2	18	10	13	0	0	0

Using the 62.1 requirements, our average postweatherization ventilation rate was 71 CFM under winter conditions, with ventilation required in 46% of the buildings. The 62.2 guideline requires at least 7.5 CFM per occupant under natural conditions and 1 CFM/100 ft² of floor area. When an inspector can run a blower test and properly measure the building, 62.2 allows an infiltration credit when it calculates ventilation. This credit applies when the natural ventilation rate is above 2 CFM/100 ft² of floor area. Our average rate of ventilation in the 62.2 study was 30 CFM. The average final leakage rate of units in the study was 1,820 CFM_{50}.

The newer standard allows weatherization agencies and crews to use either continuous or intermittent controls. When they have decided which type of control to use, they must next choose the proper control to operate the system. Different models of timer will provide options ranging from 5-minute cycles to 30-minute cycles. Other controls allow the flow rate of the exhaust fan to be adjusted to various levels. Other controls, such as dehumidistats, work well as a moisture source control, but do not guarantee the correct amount of run time to meet ventilation requirements. These controls give crews a lot of flexibility to set up ventilation systems properly, using an exhaust fan that is installed early in the production schedule.

Ventilation costs money to operate, and it does not save energy overall. In fact, the air moved by the ventilation system has to be conditioned, and that requires energy. Wisconsin is installing ventilation as a health and safety measure, not as an energy-saving measure. It's important for our customers, as well as our provider agency staff, to understand that. We also need to look at the entire building and the energy savings generated by the weatherization process, some of which cannot be achieved if we do not ventilate to ensure our customers' safety.

Martha Benewicz has worked in the weatherization and housing field for many years. She currently works for the Wisconsin Division of Energy, Home Energy Plus program as the weatherization technical coordinator. Robert Parkhurst is a seasoned veteran in the weatherization field. He currently works as the quality assurance and training coordinator for the Wisconsin Energy Conservation Corporation (WECC).

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