HOW QUIET ARE DRAFT-FREE, ENERGY EFFICIENT HOUSES?

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Sound is an important factor that affects the quality of the indoor environment. Basically, there are two possible sources of sound - that which is generated outside (traffic, aircraft, outdoor appliances) and that originated inside, created by the operation of the mechanical equipment in the house and by the residents.

Noise control is increasingly becoming a concern, as we use more mechanical equipment of all kinds (each generating noise) and build our communities more densely. As a result, ambient noise levels in the urban environment are increasing. High background noise can affect human health and well being.

We don't normally want to hear what our neighbours are doing. Commonly we think this is a problem only for apartment residents. But it is becoming more of a problem in single family dwellings as well, especially as lot sizes decrease.

A complicating factor is that not all noise sources are equal. What is music for one person may be noise for another, especially if its not wanted.

Development of energy conserving homes has focused on increased insulation levels and, more importantly, air sealing to produce tight building envelopes to control the amount of air infiltration/exfiltration. As it happens, air sealing the building envelope is a fundamental principle in acoustic insulation design. (A sound studio - recording, radio or TV isolates itself from exterior noise by sealing all air paths). It was soon discovered that a well sealed, draft-proof house also keeps out external noise sources, resulting in a quiet home.

The feature, once discovered, has been quickly exploited. But there has always been a nagging doubt on the part of some. What is the evidence that homes built to the R-2000 performance standard are quieter? and by how much? Residents state they enjoy the quiet of their new R-2000 home. Most of the evidence is anecdotal only, but it does suggest they are quieter.

Once, during a visit to an R-2000 home I asked the residents how they enjoyed their new home. Without prompting they replied they enjoyed the quiet. It was so quiet, in fact, that they were concerned about its safety. It seems one of the children was injured while playing outside, and the parents did not hear the screams until one of the other kids ran inside to raise the alert.

What are the sound levels in tight houses?

A recent study looked at five unoccupied, unfurnished houses (part of the Flair Enerdemo project in Winnipeg). Four of the houses were built to R-2000 standards, and the fifth was a 'conventional' house.

The objectives of the study were:
1. To measure the noise (sound pressure) levels generated by the heating and ventilating system in the houses, and to compare these to recommended indoor design goals for ventilation system sound control.
2. To measure the reduction of outdoor noise by the different building construction types used in these houses.

The houses tested were complete but unoccupied with no furnishings at the time of the test. Mechanical systems were in a contractor delivered state.

House #1 was built using the ADA (airtight drywall approach) envelope construction, with a vanEE heat recovery ventilator, using high sidewall supply registers and baseboard electric heating. It had wall-to-wall carpet on the main floor, an insulated but unfinished basement, and triple glazed windows.

House #2 used the Fiberglas Canada Low energy house system envelope construction, with a vanEE heat recovery ventilator, using high sidewall supply registers integrated through an indirect connection to a single speed belt drive electric forced air furnace (*standard practice where the furnace is part of the ventilation system is to equip the furnace with a 2 speed fan Ed.*). It had wall-to-wall carpet on the main floor, unfinished basement with no interior insulation, and triple glazed windows.

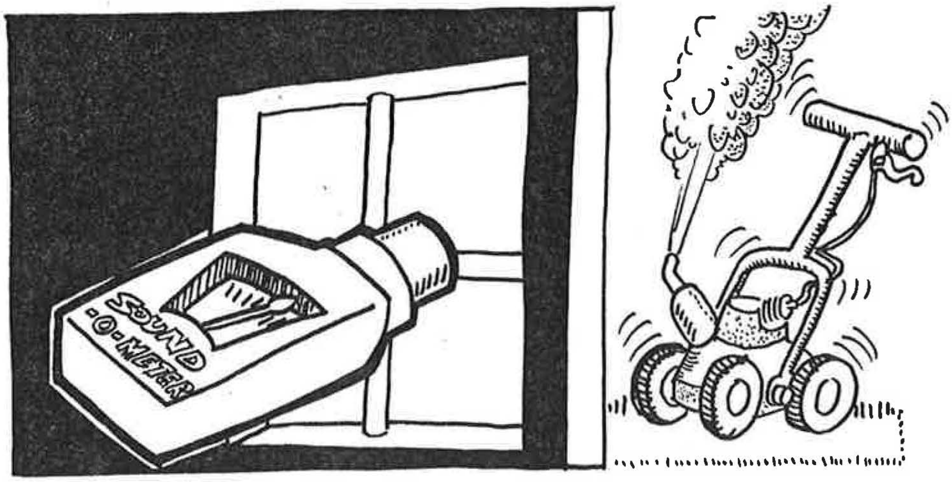
House #3 used double wall construction with a Nilan heat pump air-to-air heat recovery ventilator using high sidewall supply registers and baseboard electric heating. It had wall-to-wall carpet on the main floor, insulated but unfinished basement, and triple glazed windows.

House #4 used double wall construction with a Peach heat pump heating, cooling and ventilating system (forced air) using high sidewall supply and low wall return registers. Supplemental exhaust fans exhausted from the bathroom and kitchen and exhausted through the header. It had wall-to-wall carpet on the main floor, insulated but unfinished basement, and triple glazed windows.

House #5 was the "control" house with conventional 2x6 frame construction and a single speed belt drive natural gas forced air furnace using floor mounted supply registers. It had wall-to-wall carpet on the main floor, insulated but unfinished basement, and triple glazed windows.

No sound mufflers were installed on any of the mechanical systems. Canvas isolation boots were installed on the ductwork in house #4 to reduce vibration transfer from the mechanical system to the ductwork. None of the other houses were so equipped.

The houses were finished on the exterior with stucco on three sides. All windows were made by the same manufacturer and had 1/2" air spaces between glazing. Windows were judged to have relatively low air leakage based on airtightness performed on the four project houses.



What was measured?

To measure the noise generated by the ventilation and/or heating system, sound pressure levels were measured in the basement 3 feet from the equipment and in the bedroom directly above the mechanical equipment.

To measure outdoor noise reduction across the different building envelope systems, two tests were conducted. Outdoor noise was generated by a gas powered lawnmower.

In one test the mower was run in one spot in the back yard 13 feet from the master bedroom window. Sound levels were measured next to the bedroom wall on the outside and 7 feet from the bedroom window on the inside.

In the second test the mower was run 3 feet from the exterior wall of the bathroom. Sound levels were then measured at the wall on the outside and 3 feet from the wall on the inside (the bathroom did not have a window). The difference between outside and inside readings give the reduction of sound across the building envelope.

As air leakage paths are known to affect the noise reduction characteristics of building envelopes, airtightness tests were done on the four Enerdemo project houses. They tested between 0.71 and 1.33 ACH at 50 Pascals.

Unfortunately, no airtightness tests was performed on the "control" house. In Winnipeg most houses tend to be quite airtight, so the comparison of the results between the "standard" house and the airtight ones may be misleading.

What was found?

Sound reduction across the bedroom wall was found to be similar for all houses, suggesting that the windows were the major path of noise transmission and that the reduction of sound levels from the outside to the inside would be independent of the wall section type if the wall contained a window.

This suggests that airtight windows (low air leakage) should be chosen as a significant portion of airborne noise transmission can occur along the same pathways as air leakage. Measures should also be taken to reduce air leakage, and hence sound transmission, between the window frame and the rough opening. Where possible, windows should be located away from major sources of outdoor noise.

If the airtightness of the "control" house were known, it would have been easier to assess the significance of the tight building envelope.

TABLE 1
Sound Reduction (dBA)
(Lawnmower noise across the building envelope)

House	Bedroom	Bathroom
#1	34	45
#2	37	44
#3	37	50
#4	35	45
#5	37	

Sound levels generated by the heating and ventilation systems were measured, and compared to recommended goals for ventilation system sound control. The study found that sound levels generated by mechanical systems ranged greatly between houses, and on average, exceeded the acoustical design goal for the "worst case" room (the room located directly above the mechanical equipment).

Noise is probably the single largest cause of inadequate use of ventilation systems in homes. If the noise is excessive, homeowners shut off the system as a means of controlling noise generated inside the house. (Which is

TABLE 2
Measured Sound Levels
(noise due to mechanical system)

House	Test Condition	Sound Level (dBA) Basement	Bedroom	Background Noise(dB) Basement (Calculated Noise Criteria)	Bedroom
#1					
vanEE 2000 baseboard heat	HRV "on"	41	33	37	27
#2					
forced air vanEE 2000	furnace on HRV "on"	49	37	45	29
	furnace off HRV "on"	44	26	41	17
#3					
Nilan heat pump baseboards	low speed compressor off	46	34	43	27
#4					
Peach heat pump	low speed compressor off	50	35	44	35
#5					
control house		54	40	54	34

Other readings were also done at high speed ventilation rates. Performance at low speed is important as in most situations that is how the system is going to work. Peak air flows are of short duration, and a slightly higher noise level (if not excessive) can be tolerated. The maximum level for high speed operation was 36 dB in the bedroom.

ASHRAE recommends a noise level of 25-30 as a design goal for noise levels generated by mechanical systems in single family dwellings.

why most bathroom and kitchen fans are not used as often as they should be).

When run at the recommended continuous low speed condition, the noise levels generated by the mechanical equipment was variable. On average the systems exceeded noise criteria (NC) goals. Only one of the five mechanical installations met the goal of a NC level less than 30 under normal operating conditions in the "worst case" room. Of the two furnaces tested (without the ventilation system operating) only one met the NC goal. At high speed operation, the noise levels were higher.

Ductwork which runs through exterior walls also creates acoustic weak spots through which sound is readily transmitted. To control the transmission of outdoor noise, it is best to minimize duct penetrations on walls which face major sources of noise such as major arterial streets or adjacent commercial zones.

All the houses are simple 1100 sq.ft. bungalows with full basement, a common design in the Winnipeg area. As the basement is unfinished, mechanical systems can be laid out easily. The findings in this study underscore the importance of careful design and attention to installation detail. It is evident that research and training initiatives must continue to emphasize the importance of mechanical system noise control.

For example, the same HRV was used in two of the houses. In one house it produced the lowest sound levels, in another it was the worst.

Equipment Manufacturer's Responsibility

Ventilation equipment generates noise several ways. Vibration (especially if the equipment is out of balance) is transmitted to ducts and the building structure through direct contact between different elements. Motor noise and whine can be transmitted through the air or the structure. Improperly sized or laid out ductwork can magnify such noise (this is especially the case if the ducts are too small for the air flows, at which point the ducts start to act as a giant whistle).

Motor noise can be transmitted to the structure by being mounted directly to the structure, without any acoustic isolation.

A major source of irritation to homeowners is flanking noise, where noise travels between rooms through short circuits in the ducting.

A good installer will take into account many of these factors in laying out and installing equipment. However, to be fair, the quality of the system installation and the noise level it generates is also a problem for the manufacturers. Manufacturers should be making an effort to improve their products. A qualified installer can only do as good a job as the tools and equipment he has to work with.

This study looked at mechanical systems as delivered by the installers. The small sample of houses may not represent a good statistical study, but it does give us some concrete evidence of what is really happening in the field. It shows that all kinds of equipment can have problems.

Material for this story has been taken from:

Flair Homes Project, Report No. 4: A Survey of Sound Levels in Five Unoccupied Houses. (A part of the Flair Homes Energy Demo/CHBA Flair Mark XIV Project.) It was prepared by G. Proskiw and J. Beckman of Unies Ltd and D. Fisher of K.P. Engineering & Design.
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