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Ventilating With Heat Recovery: The Challenge of a New Technology

by Peter duPont

Installer and homeowner experience with heat recovery ventilators has given rise to some hard questions.

For the past few years an experiment has been going on in parts of the northern U.S. and Canada, as mechanical ventilation systems with heat recovery have been installed in thousands of new and existing homes. The good news is that many experienced contractors have learned to install effective heat recovery ventilators (HRVs) that are seeing regular use, providing fresh air without drastically increasing heating bills. The bad news is that this learning process has taken place in real homes occupied by real people who in some cases, because of discomfort, noise, or other annoyance, switched off their HRVs.

The use of heat recovery ventilation systems—especially as retrofits—has not spread widely beyond a few utility- and industry-sponsored programs in northern climates. Indeed, the contractors who retrofitted over 1100 HRVs in the $20 million Hood River (Ore.) Conservation Project are no longer installing them now that the project is over. Participants in the project—program personnel, contractors, and homeowners—felt that the application of HRVs evolved too rapidly and preceded its understanding by the contractors installing them and the homeowners using them. After installing hundreds of HRVs some of the crews became expert at designing, locating, and installing the system and doing it in a way acceptable to the homeowner. As one contractor said, "Before us there weren't a lot of people who had retrofitted HRVs on a wide scale. We were writing the book as we installed them by the *hundreds.* If we came across a problem that wasn't in the project specifications, we had to figure it out ourselves." The lessons learned at Hood River tell an interesting story and shed light on an emerging but not-yet-accepted industry.[1]

> **What's In a Name?**
>
> Air-to-air heat exchanger or heat recovery ventilator (AAHX or HRV)? Initially, when the technology was developed in the late 1970s, the units were dubbed air-to-air heat exchangers because of their ability to transfer heat from one airstream to another. Several years ago, however, the industry groups began to champion the term "heat recovery ventilation" because it is a more accurate and desirable description: a device that brings in fresh air (ventilates) without wasting heat (heat recovery). "Most of us would agree that heat recovery ventilator is a better term," says Anne Patton of the Hood River Conservation Project.

Background

The use of heat recovery ventilation was pioneered in the severe climates of Canada and Sweden. As recently as the early 1980s, HRVs had never been extensively installed in the U.S. Then came the Bonneville Power Administration's $20 million Hood River Conservation Project, a test-bed for HRV retrofits.

The Hood River Project is a unique conservation effort in which an entire community of 2,900 homes was "super-retrofitted" to determine how much electrical demand could be displaced by an all-out conservation effort. (See articles in the Mar/Apr and Sep/Oct '85 issues of *EA&R*). Altogether, a total of 1,158 HRVs were installed in

1,050 homes. Initially, contractors installed HRVs in every home that received the Project's super-retrofit treatment. Later, because of the high per-unit cost and some consumer dissatisfaction with the units, the HRVs were installed only upon request of the homeowner. The Project also offered free radon testing to participants in the program and has tested 2,000 of the 2,900 weatherized homes using the three-month Track-Etch® radon test developed by Terradex of Walnut Creek, Calif. Sixty of the homes had radon levels above BPA's cutoff level of 5 pCi/l.[2]

Heat recovery ventilators were installed in 53 of these homes to mitigate radon levels. The Project also installed five heat pump HRVs manufactured by DEC International of Madison, Wisc. As with air-to-air HRVs, the DEC units provide mechanical ventilation and recover heat from the outgoing air. Unlike the air-to-air units, the DEC integrated appliances transfer the salvaged heat from stale exhaust air to the domestic hot water system. The DEC units operate with higher efficiencies than heat pump water heaters (they have a COP of 3 vs. 2 for HPWHs) by capitalizing on the latent heat released when moisture condenses in the exhaust air stream.

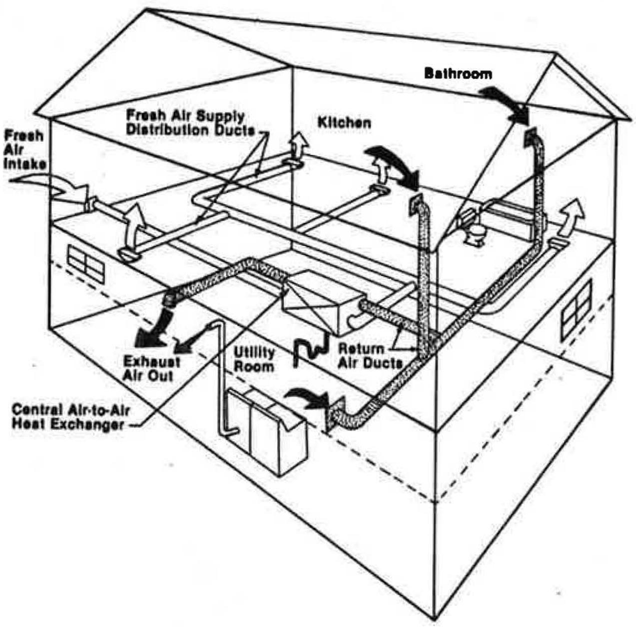
Table 1. Heat Recovery Ventilators installed through the Hood River Conservation Project.

Size of unit	Date	# of units	Average installed cost ($)
0 - 70 CFM	pre 1/85	117	957
	1/85 - 5/85	127	892
	after 5/85	570	700
> 70 CFM	pre 1/85	116	2189
	1/85 - 5/85	98	1718
	after 5/85	126	1497

Types of Installations

Table 1 shows the number of HRVs retrofitted in Hood River in two different size classes. The declining per-unit cost reflects a change in procedure from competitive bidding to a per-unit cost allowance in the Project's procedures. The HRVs installed in Hood River ranged from small, wall-mounted Mitsubishi systems (70 CFM or less) to fully-ducted systems that deliver between 100 and 300 CFM of air and serve most of the house. The types of installations are described below.

Through-the-wall, or unducted. As its name implies, this type of HRV is mounted through a hole in the wall and serves as large an area as possible, preferably from a central location.



Source: Department of Energy

Figure 1. A fully-ducted central heat recovery ventilator has the capability to distribute fresh air to and stale air from all areas of the house.

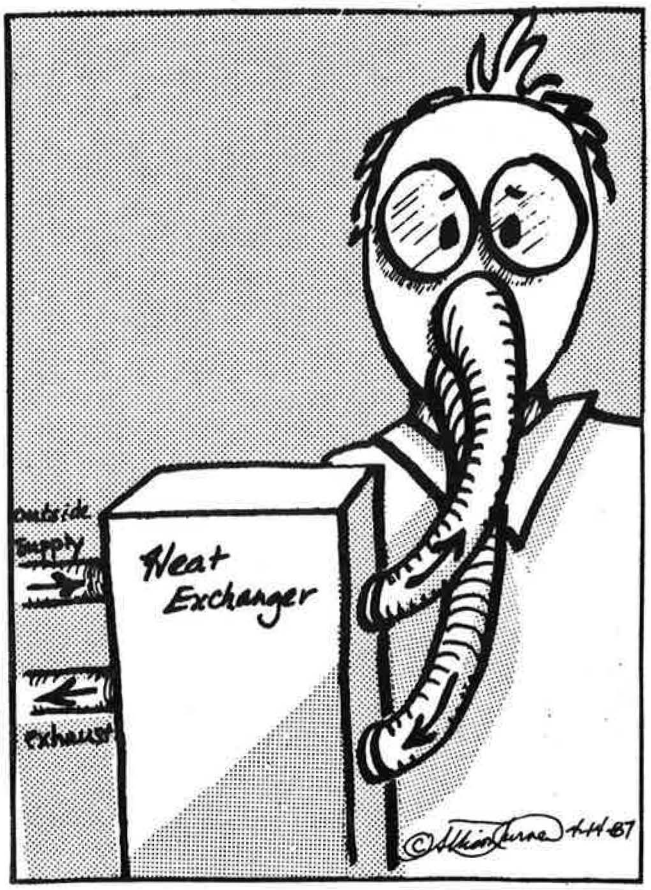
Window-mounted HRVs, similar to window-mounted air conditioners, are also available. Project contractors installed Mitsubishi, Star, and Nu-tone models that generally provided between 0 and 70 CFM of air.

Half-ducted. Ceiling-mounted Mitsubishi HRVs were installed in some houses. These work similarly to wall-mounted units and should be centrally located to serve as large an area as possible. Half-ducted units are connected to the outdoor air by flex ducts, which usually run through the attic.

Three-quarter ducted. This system requires ducts for the fresh air intake and stale air exhaust. Stale exhaust air is picked up at the machine itself, and fresh supply air is delivered through duct work to individual rooms of the house. This type of installation became a favorite at Hood River because it requires less duct work than fully-ducted units.

Fully ducted. In a fully ducted system, fresh air is supplied through ducts into different rooms in the house. At the same time, stale air is drawn from other rooms such as the kitchen or bathroom, where there are likely to be odors and high levels of humidity or pollutants. Figure 1 shows a typical, fully-ducted HRV installation. (Some of the fully-ducted HRVs took on the appearance of octopi after all four sets of ducts were installed.)

In most of the Hood River installations with forced-air furnaces, contractors avoided using the existing furnace duct work. It is difficult to control the HRV air flow if it is incorporated into a



As the indoor air quality problem worsens, Joe takes matters into his own hands and plugs into his air-to-air heat exchanger to get a breath of fresh air.

furnace system with a much higher flow rate. In some cases installing the HRV near the return air intake of the furnace proved to be a successful strategy because it warmed the HRV supply air and eliminated the need to install duct work. The HRV can be wired independently from, or in conjunction with, the furnace. Hank Patton, a consultant to Pacific Power & Light at the Hood River Conservation Project, didn't like inspecting HRVs linked to furnace systems because "there were too many things that could go wrong and make the system not work properly." Table 2 lists some of the pros and cons for retrofitting an HRV on a forced-air furnace.

Controls

The most common type of HRV controls are humidistats, timers, and variable-speed controls. The main impetus for a control system is that without it, the occupants would not regularly ventilate the house (partially due to fear of high energy bills from continuously running the HRV fans). Many installations in new Minnesota housing are controlled by humidistats at the point of stale air intake (e.g., kitchen, bathroom) and a timer switch or manual override at a remote point (e.g., at the top of the stairs, or in a hallway).

Humidistat controls were not extensively used at Hood River. Indeed, Dave Harter, who has installed several thousand HRVs in Tacoma, Wash., discourages humidistats because he says it is impractical to have one humidistat setting for the whole year round. "The quality of the low-end humidistats is very poor," says Harter. "If you have condensation on your windows, you should use the unit more. You can come up with all the sophisticated controls you want, but they only make things more complicated and more expensive." Harter prefers a simple variable-speed control dial for the HRV fans.

Many of the three-quarter and fully ducted, ceiling-mounted HRVs installed at Hood River had no controls at all except a high/low/off switch at the unit itself. The most common type of control was a solid-state variable speed control wired to the heat exchanger fan, similar to the control favored by Harter. Running the fans at a lower speed uses less energy, creates less noise, and provides slightly better heat exchange, since the air is in contact with the heat exchanger core for a longer period of time. One common problem occurred when the solid-state variable-speed timer was incompatible with the HRV fan motor.

Installation Issues

The most common problems with HRV installations might be divided into two classes: (1) issues of detail, which can usually be fixed by thorough testing after completing the installation; and (2) structural or systemic problems that discouraged the occupants from using the unit by making them uncomfortable. It is in the second category that Hood River provides some useful examples of poor installations that violate the

Table 2. Retrofitting an HRV on a forced-air furnace.

Pros	Cons
• Air supplied to house by HRV is heated	• Operation of HRV is controlled by furnace; problem if furnace is over- or under-sized
• Less duct work to install	• Control is difficult; lose control of ventilation rate
• System easier to install	• Easier to design and size system independent of furnace
• Fewer materials	• Air flow is poor when furnace off
	• Leakiness in the furnace distribution system can dissipate HRV air flow.

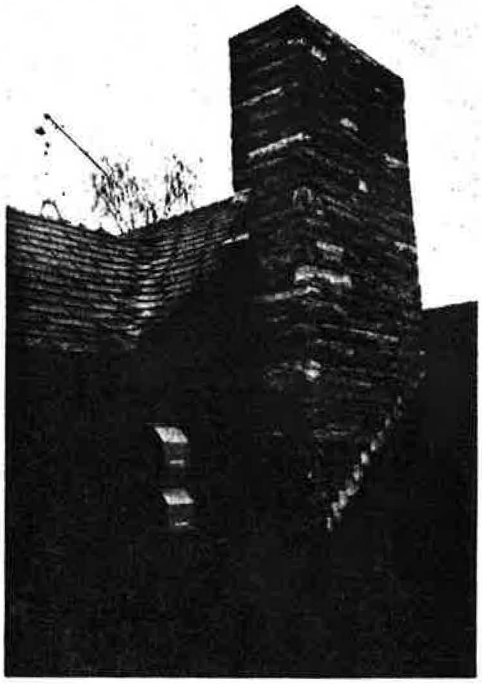


Figure 2. This wall-mounted unit is located too close to the chimney. The HRV drew in wood smoke.

Figure 3. The condensate line in this picture was "plumbed" into a five-gallon bucket filled with rocks and set in the attic. This caused the sheetrock underneath to sag. The condensate line should have been run to a permanent drain at a constant negative slope.

aesthetic or comfort needs of the occupants.

Since air supplied by an HRV is cooler than air supplied by a forced-air heating system, the favorite easy chair in the den is not the place to direct a fresh air supply. Contractors learned through experience to direct fresh supply air upwards so that the fresh air mixed and fell, rather than creating sensations of "blast and draft". Even though all other attributes of an HRV installation may be technically perfect, the sensation of drafts is all that it takes to prevent a ventilator from being used.

In a retrofit setting, the installation is especially challenging, because the installer's options are narrowed, tradeoffs must be weighed, and the home's occupants must be carefully involved in the design decision. For example, noise and vibrations cannot be eliminated, but their effects can be alleviated by careful placement. Although the laundry may seem crowded with the addition of an HRV, it would probably be a better location than hanging the unit from the joists directly under the master bedroom. Successful placement will consider and respect the lifestyle and needs of the home. This requires grace, diplomacy, and even some psychology by the installer; otherwise, the unit will be installed, but it may not be used.

Other technical issues may play a role in the installation. "Each house has its own microclimate," says Hank Patton, "and the contractor must be sensitive to the proximity of smoke from wood stoves, industrial and highway exhaust, and gas appliances. In cities with a lot of wood stoves, getting clean supply air can be a major problem."

The supply air intake should not be located near sources of pollutants and odors, including sources from neighboring buildings. For example, Patton recommends against installing wall-mounted units upstairs too close to a chimney. It is also possible that, if the house is surrounded by trees, wind currents can cause the supply air to be contaminated by smoke from a chimney on the opposite end of the rooftop. Another more obvious error to avoid is placement of the fresh air supply vent near a carport or a favorite barbecue spot. Figure 2 shows how HRV placement can result in contaminated supply air.

Anne Patton, wife of Hank and also a consultant to the Hood River Project, strongly recommends that air exhausted from rooms with high relative humidity pass strictly through heavily insulated ducts; otherwise, humidity being exhausted from the house can condense and accumulate in the ducts. In most cases, flex ducting has a nominal insulation of about R-4 to R-8 around it, but it should be further insulated if it passes through an unheated space. "I was checking a ceiling-mounted installation in a kitchen," says Anne Patton. "The duct work passed through an addition that was being built over an existing roof line and crossed 15 feet of non-insulated space, where humidity exhausted from the kitchen air was able to condense and collect. When I

Measuring Air Flows

Researchers agree on one point: that it is problematic to measure air flows in field situations, especially at the low flow rates found in HRV systems. Besides issues of where measurements should be taken (e.g, at the HRV core, or at the registers in each room) the velocity profile of air flow in ducts is extremely complex and variable, especially after elbows and twisting duct runs. Also, inserting a device in the air stream to measure the flow rate can affect the measurement by creating back pressure.

Bonneville Power guidelines for installation of HRVs call for a whole-house ventilation rate of 0.5 ach, 0.4 to be supplied by the heat exchanger and 0.1 to be supplied by natural ventilation.* All of the HRVs at Hood River were inspected to ensure that (1) the installed air flow met the 0.4 ACH specification and (2) that the incoming and outgoing air flows were balanced within roughly 10 percent. Some of the common field technologies for measuring air flow are described briefly below.

Pitot tubes with a magnehelic gauge. Pitot tubes are inserted into the duct and pressure readings are taken from a magnehelic gauge attached to the pitot tube. Several different measurements need to be taken across the diameter of the duct and the results averaged. The R-2000 Program in Canada requires a pitot tube array mounted in a short section of duct that is actually installed in the duct at the time the HRV is installed. R-2000 guidelines specify that all the supply and exhaust air is measured and that the device be located on the warm side of the HRV. The pitot tube array remains in the duct for the lifetime of the HRV; to make flow measurements, a pressure-sensitive gauge (micromanometer or magnehelic gauge) is attached to the pitot tube array.

Hot wire anemometer. This device has a sensor tip at the end of a long probe that is inserted into the air stream. An electric current is supplied to the sensor to maintain a temperature higher than ambient temperature. The rate at which heat is lost is a direct measure of flow velocity. Hot wire anemometers need to be calibrated frequently.

Rotating vane anemometer. This is essentially a propeller (fan) blade that is placed in the air stream. The rotational speed of the vanes is proportional to air velocity. Lambert Engineering of Bend, Ore. has developed a flow measurement device that consists of a rotating vane anemometer mounted in a hood that fits over the grille or register and is connected to small battery-operated meter that displays the flow rate. The back pressure induced by the hood itself when placed into the air stream must be taken into account.

Hand-held velocity meter. These types of devices are low-cost (about $30) and not very accurate, but provide an estimate of air flow rate. They commonly display the wind velocity in feet per minute. The flow rate is then estimated by calculating the area of the grille or register.

* The ventilation guidelines set by different industry groups vary. ASHRAE is currently revising its recommended ventilation rate for residences. It is expected to be 0.35 ACH total or 15 CFM per person, whichever is greater. Also, ventilation capacities of 50 and 100 CFM are recommended for bathrooms and kitchens, respectively. Requirements of the R-2000 Program in Canada are a minimum of 10 CFM to each habitable room and 20 CFM to basement areas and utility rooms. Additional "boost" capacity is required to exhaust pollutants and odors at their source in the kitchen (100 CFM) and bathroom (50 CFM).

opened the access to the core filter, I got a half-gallon of water dumped onto my head!"

Russ Phillips, who installed HRVs during the Project for Sunwood Enterprises, stressed the importance of running the stale air exhaust ducts at a negative slope, with no dips, all the way from the HRV unit to the (lower) outside vent. "This is important with HRVs that don't have a condensation drain tube," said Phillips. "However, we didn't have any problems with the units that had a condensation drain and tube." Project inspectors came to recommend that flex duct be supported by 1" x 3" boards and be set at a constant negative slope in order to prevent the accumulation of water—"puddling" as this phenomenon came to be known. The condensate line should also have a continuous negative slope. Figure 3 shows an example of how *not* to install a condensation line.

The aesthetics of the HRV and its placement are also an important consideration that is often overlooked. The homeowner or occupant should be aware of what the unit will look like and where it will be placed. Often, a contractor will purchase and install a unit without spending enough time discussing with occupants where they would prefer to have fresh air supply registers located. If the occupants are disillusioned with the system from the start, they are even less likely to use it regularly.

The Start-Up Check

This procedure, as obvious as it sounds, can help satisfy the customer and eliminate the need for a call-back. As the retrofits at Hood River and

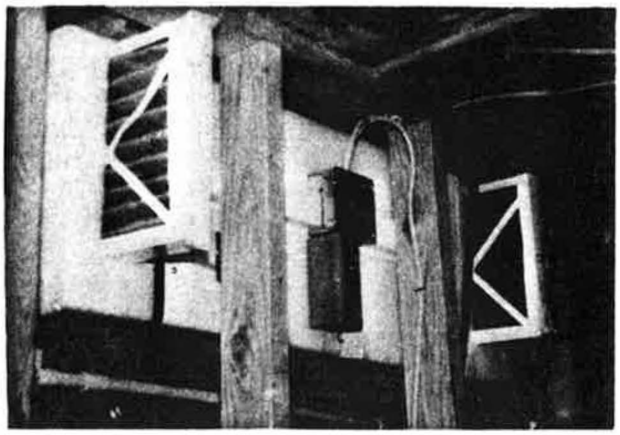


Figure 4. This unit is installed in an area slated to be finished later. Once the wall is sheet-rocked, the filters (pulled out part way in this picture) will no longer be accessible. Note the plastic condensate tube emerging from the lower left corner of the HRV.

the new HRV installations in the Pacific Northwest have shown (see box on the Northwest experience), there are a variety of steps that can ensure proper performance of the system:

- Make sure that once the unit is installed, it is possible to open the heat exchanger box to access and remove the filters. These have to be cleaned regularly to ensure adequate air flow through the core. (See Figure 4.)
- Check all duct work to ensure it is properly installed and attached to the HRV unit and outside vents. In one case, a duct was left unattached in the attic, exhausting air from and supplying air to the attic space. (The duct is supposed to be mechanically attached to the boot of the register. Relying on duct tape is not sufficient.)
- Insulation can be caught in the ducts of the heat exchanger core and/or blown into the indoor air. Since most ducts are drawn through the attic when they are installed, a start-up test to remove insulation and dirt trapped in the duct is recommended. After running the HRV for a day or so, the filter should be cleaned of the initial blast of dirt.
- Wall-mounted units need to be caulked very carefully on the outside, particularly on the top. The Mitsubishi wall-mounted units were installed in a pre-made plywood box. In some of the installations, water collected in puddles on top of the units and it ran into and through the wall.
- Check the air flow to ensure that the supply and exhaust air flows are within the range of normal values. Measuring low air flows (lower than 100 CFM) is extremely difficult, even in a laboratory setting, but inspection of the installed HRVs can avoid gross mistakes (see box on air flows).

Occupant Response

The energy and health effects of the HRVs at Hood River are not yet known. The key issue is whether homeowners actually use their systems regularly to maintain indoor air quality. Bonneville Power Association spent an enormous amount of money on ventilation systems at Hood River, yet they still don't know which homes use them and how often. Conversations with participants in the Project suggest that many occupants use their HRVs only intermittently. There are bright spots, though. "So far our interviews with homeowners who have radon levels above 5 pCi/l

Table 3. Occupant Experience with Air-to-Air Heat Exchangers.

Item	response	percent
Use	• never used	5
	• 1-4 hrs/day	42
	• 5-18 hrs/day	25
	• > 18 hrs/day	30
Maintenance (first year)	• changed filter	58
	• hadn't changed filter during first year	40
Freezing	• reported freezing of AAHX core	10
	• no freezing	90
Noise	• not noisy at all	20
	• slightly noisy	70
	• felt they were noisy	10
Drafts	• no drafts	51
	• drafts feel pleasant	6
	• drafts cause minor discomfort	29
	• unpleasant drafts	14
Overall problems	• reported problems with unpleasant drafts, repairs, or core freezing	50
	• reported no problems	50

Source: Vine, E., "Air-to-air heat exchangers and the indoor environment." Lawrence Berkeley Laboratory, report LBL-22908, February 1987.

The Northwest Experience

Builders and researchers in the Pacific Northwest have learned energy-efficient construction techniques in a series of pilot programs. In 1983, the Northwest Power Planning Council established a set of minimum energy-efficiency guidelines for new construction. These Model Conservation Standards (MCS) were introduced to builders and homeowners in the Northwest through a program called the Residential Standards Demonstration Program (RSDP), which has various goals and strategies: technology transfer, builder training, marketplace demonstration and research, and incentive payments.

EA&R spoke with several participants in the Demonstration Program about installation problems they discovered with air-to-air heat exchangers. Air-to-air heat exchangers (HRVs) were installed in 226 Demonstration Program houses in Washington state. Because these systems were a new technology for many of the contractors who installed them, there were a variety of problems, some of them minor but some preventing operation of the system. The need for proper training was emphasized by all of the researchers we contacted who were involved with the Demonstration program. Says Mike Lubliner of the Washington State Energy Office, "These types of installation problems are normal for *any* new technology. The government demonstration program here in the Northwest accelerated the rate of incorporation of air-to-air heat exchangers into new housing and aggravated the problem. The industry needs to work closely with the people they sell their products to in order to ensure that the installed HRVs are providing adequate ventilation and air balance. The manufacturers must be committed to training at this early stage in the industry."

In fact, Lubliner's comment may be an understatement, given the variety of problems that emerged from inspections of the air-to-air heat exchanger installations. Chris Dent, of Lambert Engineering in Bend, Ore., the firm that performed on-site testing of the systems, described few of the many cases of installer error:

- Air was blowing *out* of both the stale air exhaust and fresh air intake tubes in one HRV.
- The fresh air supply duct in one installation ended in the attic instead of going all the way outside; the result was that the HRV fan was sucking up bits of insulation from the attic.
- The backdraft damper in another HRV was installed on the inlet instead of the outlet pipe; the result was that no air could enter the HRV intake.
- Nu-Tone heat exchangers have a heat wheel, which acts as a core. The unit is packaged for transport with cardboard around the wheel. In one case, after no flow was measured through the heat exchanger, it was discovered that the cardboard had not been removed.

are showing remarkably high ventilator use levels," says Anne Patton.

But in Washington state, where more than 200 air-to-air heat exchangers were installed in new homes over the past two years (see box on the Northwest experience), many homeowners "mothballed" the systems. According to Mike Lubliner of the Washington State Energy Office, nearly 70 percent of the homeowners surveyed reported that they seldom or never used their HRV. Table 3 shows the results of a survey of over 300 households in Oregon, Washington, Idaho, and Montana in which a heat exchanger was installed during construction. The results support Lubliner's findings about lack of use of the HRVs and reveal, to a lesser extent, some problems with maintenance, freezing, noise, and drafts. Fully 50 percent of those queried reported problems with unpleasant drafts, repairs, or core freezing.

"When I return to a house after an HRV installation, I find that many people don't turn it on, they just don't see the need," says Russ Phillips. "They don't want to pay for the electricity to run it except for the during the coldest few months of the year. The rest of the time they can get fresh air by opening a door or window."

Performance, Certification, and Training

There are currently 11 Canadian and at least 10 U.S. manufacturers of HRVs. The Canadian government has pioneered efforts to test and standardize air-to-air heat exchanger equipment, through the guidelines that the Ontario Research Foundation (ORF) has developed for the R-2000 Energy-Efficient Housing Program. The Canadian Standards Association has developed a preliminary standard (CSA C439-M1985) that is now in active use. Testing to this standard by the Ontario Research Foundation and publication of these test results is required for all HRVs used in R-2000 homes. The results for each model tested are available as "design specification sheets." In the

ORF tests and tests conducted by other laboratories, HRVs typically recover between 50 and 80 percent of the sensible heat from the outgoing air stream.[3]

The Home Ventilating Institute (HVI) in the U.S. currently has nine members who manufacture HRVs. HVI is developing testing and certification procedures based on those developed for the R-2000 program. HVI uses the Canadian standard for performance testing. All HVI members are required to submit one of their HRV models for testing in 1987, and eventually all of their models must be certified. HVI soon will be publishing a certified products directory that will include all performance testing data for HVI-member air-to-air heat exchangers that have been tested. According to Dale Rammien of HVI, the directory will be available free of charge (see box on resources).

The Heating, Refrigerating, and Air-Conditioning Institute (HRAI) in Canada has a training program for installers of heat recovery ventilation equipment. By early 1987, 1,500 individuals had successfully completed the program. HRAI is also educating builders and authorities—people involved in the regulatory aspects of HRV installation.

Recommendations

No one yet knows the future of the HRV industry. Certainly it has not caught on as a significant factor in the residential retrofit market. Most of the units sold today are installed in new construction. But at this early stage, the lessons from Hood River (as well as from other demonstration programs in Canada and the Northwest) can benefit future installers of HRVs.

HRVs are not the sole answer to indoor air quality problems; however, they can reduce levels of pollutants and increase comfort in houses in cold climates that have strong pollutant and moisture sources. The systems must be installed carefully and conscientiously, and the occupants should be consulted so that they are a part of the installation process. They should understand how the system works, help decide where to locate supply air registers, and know how to maintain and operate the HRV.

Inspection of the HRVs installed at Hood River provided critical (and sometimes painful) feedback to the contractors, who initially were unfamiliar with the design and installation of HRVs. But the inspection process ensured, for the most part, that the occupants were satisfied with the installation and that the systems were operating properly. As for the future of the HRV industry in the private sector ... stay tuned.

Notes

1. An article in the Mar/Apr '85 issue of *EA&R* discussed how HRVs work. A good reference for installers is the article by Richard Karg in the October '84 issue of *Solar Age*: "Tips and Cautions About Heat Exchangers."

2. A picoCurie is a measure of radiation activity, specifically 2.2 decay events or nuclear transformations per minute. Radon levels are commonly expressed as picoCuries/liter (pCi/l). Bonneville Power Administration has set 5 pCi/L as its action level for indoor radon levels in existing homes being weatherized.

3. Sensible heat is the heat in air that we feel. It does not include latent heat, which is the heat needed to evaporate a liquid at a constant temperature. Sensible heat recovery thus refers to how much the outgoing air increases the temperature of the incoming air.

Resources

Canadian Standards Association
Attn: Richard Cohen
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Rexdale, Ontario
Canada M9W 1R3

Heating Refrigerating and Air-Conditioning Institute of Canada (HRAI)
Attn: Sam Cryer
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