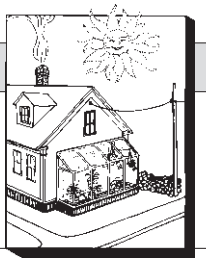

Ventilation Secrets From Sweden

by David Kaufman

Sweden adopted strict energy conservation measures after the first oil crisis in 1973 and has been strengthening them ever since. Features like R-33 walls and R-5 windows are now common.

Along with energy-efficiency standards, however, have come problems. Sweden experienced a spate of "sick building syndrome" claims in the late 1970s. Government sponsored researchers have responded by identifying toxins in building materials and alternative products. They have also found correlations between chemical sensitivity and humidity levels in buildings. But the majority of their work has centered on improving ventilation systems.

How Much Is Enough?

In this country, ASHRAE currently recommends ventilating homes at a rate of .35 air changes per hour (ACH). Based on their long experience grappling with air-quality concerns, however, the Swedes require more ventilation. Current regulations call for changing the air over completely about every two hours, or .5 ACH, in homes. Standards may soon rise. Already the required rate of ventilation in workplaces is .6 to .9 ACH, and a proposed standard for home ventilation of 1.25 ACH is pending.

All of these assume normal occupancy levels and no unusually heavy pollution problems. Heavily used areas require more air. One childcare center I visited in southern Stockholm was built with low-toxic materials, and the builders still opted to ventilate at a rate of 3 ACH.

Ironically, providing good central ventilation requires a very tight building. This goes for all systems, from a simple exhaust fan to sophisticated heat recovery ventilation systems. Swedish code requires a *maximum* leakiness of one air change an hour at 50 Pascals pressure for apartment buildings. (This means the blower door is cranked up to simulate a 20 mph wind blowing against the building.) This is virtually airtight.

Exhaust-Only Systems

Mechanical ventilation systems that rely on single-point exhaust fans are increasingly common in both Sweden and the U.S. These systems can be very cheap to install and operate — usually just one fan will do.

Exhaust-only systems have certain advantages. Because the exhaust fan is not directly tied to supply air, the building is under constant negative pressure, so the likelihood of moisture problems in outside walls is reduced. Also, complex duct runs aren't needed. Exhaust ports in the kitchen and bathrooms are usually sufficient. Typically in Sweden, bathrooms are equipped with an exhaust port that can be enlarged by pulling a string, like a light pull, which hastens the removal of odors. This damper is attached to a timer, which later returns the port to normal size. The Swedes have also learned to equip kitchen stoves with separate exhaust or carbon-filter hoods to avoid extensive grease buildup on the central ventilator filters.

One interesting alternative I found in Sweden is the "warm crawlspace," which is created by directing stale exhaust air into the crawlspace. There are several variations on this design. Some pressurize the crawlspace, with air leaving via vents in the sides. This seems the most radon-proof. Others seal the crawlspace completely and draw stale air down through the crawlspace through perimeter vents in the floor and then out a central exhaust. In this setup, the whole crawlspace serves as an exhaust plenum. Most insulate the ground or joists as well as the walls. Typical crawlspace headaches are reduced, and the savings on a small investment is substantial. If the average crawlspace temperature were raised from 32°F to 59°F, 23% of the heat in the exhaust air would be "recovered" without expensive exchangers. It would also raise the floor surface temperature nearly 2°F, adding to the comfort in the house.

All exhaust-only systems must have make-up air. Usually this is provided through "intentional holes" — plastic or metal diffusers — that duct fresh outdoor air directly into the living space.

Unfortunately, the cold, outside air can cause some discomfort, especially among the elderly. And there have been numerous cases in which people who didn't understand the system blocked the inlets, sometimes leading to severe indoor air problems.

Per Levin, a ventilation expert at Stockholm's Royal Institute of Technology, claims that the familiar plate (round) supply vents produce fewer discomfort complaints than the slot type. Both are typically located high on a wall. Recently, however, the Swedes have taken to locating inlets directly behind a hot radiator to warm incoming air. The radiators are almost always hot in cold weather because the hydronic heating systems in Sweden are usually equipped with an outdoor temperature sensor, which adjusts system water temperature to match outdoor conditions.

In this apartment building in Stockholm, slot-type fresh air inlets are located below the windows, so cold air is brought in behind the radiators. This warms the incoming air, reducing discomfort from cold drafts.

Heat Pump Ventilation

Exhaust-only systems can be adapted for heat recovery by adding a heat pump, which typically takes heat from the outgoing air stream to produce domestic hot water and hydronic heating. Heat pump ventilators are found in almost half of all new Swedish houses and have been popular since their introduction in the early 1980s. These systems are not to be confused with outdoor air heat pumps, which don't perform well in very cold climates.

An exhaust-air heat pump turns out 2.5 or more Kwh of heat for each Kwh used to operate it. The systems are particularly well-suited for those rare places where electricity is cheap and the climate is cold. However, heat pump ventilators are expensive to purchase and require very good maintenance to sustain this performance. They are most cost-effective where a large hot water demand is combined with high ventilation requirements, such as in a restaurant. In homes, they are usually cost-effective only when the heated water is used for hydronic heating.

Heat-Recovery Ventilators

The other half of new Swedish houses uses heat-recovery ventilators (HRVs). These systems use the exhaust stream to preheat incoming air. Air-to-air heat exchangers with a honeycomb core are by far the most common, followed by rotary and liquid-coupled systems. By law, the minimum recovery efficiency in Sweden is 60%, although some exceed 80% efficiency.

Originally used in industry, HRVs have been standard equipment in Swedish houses for more than a decade. They receive the highest ratings for occupant comfort and have better energy performance than heat-pump systems. Since an HRV forces fresh air through ducts to specific locations, these systems provide better ventilation than exhaust-only systems. Since fresh air is preheated and can be filtered easily, discomfort from drafts is minimized.

Nearly all residential HRV installations in Sweden are also used to distribute heat. Hydronic duct heaters are preferred to electric resistance ones, reportedly due to lower operating temperatures and fewer complaints about dry air. The HRV system relies on air recirculation to achieve adequate heat output and so mixes fresh and stale air together, a technique which is standard in commercial buildings, but frowned upon in air-quality circles. However, this technique provides enormous savings by eliminating the need for a separate heating system. Perfectionists may find a solution in systems employing one-way heating of ventilation air, which is possible only in very efficient buildings with slightly elevated ventilation rates and/or delivery temperatures.

Despite widespread use, HRVs continue to be dogged by certain problems. The biggest complaint is noise. Also, the heat-recovery efficiency is often not as good as predicted. Poorly insulated duct runs through attics or crawlspaces often produce up to 20% losses. Meticulous sealing and heavy insulation are absolutely required. Better still, keep all the duct runs inside the heated area. The building must be extremely airtight for good HRV performance.

In this experimental Swedish ventilation system, one wall is dedicated to the supply plenum and one to the exhaust. Here, air is exhausted through vents in a kick space on an exterior wall.

Cross-contamination of pollutants between air streams can also be a problem. In air-to-air systems with the common honeycomb core, which theoretically should have near zero cross-contamination, Swedish researchers frequently found contamination levels of 30%, and they have come to consider 10% a "good" result. The researchers found that cross-stream pollution can be dramatically reduced if the fans are rearranged, so the exhaust is "pulled" and the supply is "pushed."

Rotary (heat wheel) systems are rarely used in homes in Sweden, reportedly due to their higher potential for mixing between air streams. But new prototype rotary systems incorporating a "blow-out" phase before the fresh air stream show promise. Heat wheel systems recapture some of the moisture from the outgoing air, which can help avoid overdrying a house. Air/liquid/air systems, with zero cross-contamination but slightly lower efficiency, are useful in special "healthy" buildings, such as childcare centers.

Another problem with HRVs is that their electricity consumption can be uncomfortably high — up to five times higher than that of an exhaust fan alone. According to Eje Sandberg, an engineer who has studied the systems extensively for AIB, Sweden's huge consulting firm, energy consumption can be reduced by half with existing technology. He recommends sizing the fan system carefully, as fan efficiency declines steadily below 100% of designed capacity and plummets when turned down below 50%. A study of 110 Stockholm apartments found their fans averaging 20% efficiency!

Contrary to the usual ventilation rule of thumb is the new Swedish trend of supplying air low and exhausting it low — a so-called "displacement" system. This tests out superior in removing pollutants, and in commercial installations it sharply cuts air conditioning needs. The key to making these systems work is the newly developed low-velocity diffuser that delivers fresh air near the floor.

Finally, HRVs *must* have their filters cleaned or changed per spec. Though standard procedure is to set the exhaust fan at 10% over supply volume to depressurize the building slightly, if the filters clog the excess air will vanish. According to Levin, the major risk is causing an overpressure, which can lead to condensation problems in attics.

For More Information

The Swedish government graciously produces English-language periodicals detailing their latest work. Subscriptions to *Synopses* and *Newsletter of Swedish Building Research*, plus an annual list of their superb foreign language publications, are available free on request by writing to the Swedish Council for Building Research, St. Goransgatan 66, S-11233 Stockholm, Sweden. For persons free of math anxiety, *Classified Indoor Climate Systems* (50 pages) is an excellent literature review and simplified building ventilation guideline available from SCANVAC, WS Tekniska Foreningen, Hantverkargaten 8, S-11221 Stockholm, Sweden. ■

David Kaufman is an energy consultant in Brunswick, Maine.