eled the effects of open windows, they found that it would not completely overcome the negative impact of the wall insulation unless ventilation was forced, as with a whole-house fan. Also, according to Parker, "many people in humid regions air condition their homes around the clock and never ventilate. Ventilation is possible, but only if interior humidity of 80% or even higher is acceptable."

Even in the hotter Phoenix climate, adding wall insulation may not be cost-effective. ORNL had modeled a prototypical house in Phoenix with a central gas, forced-air furnace and air conditioner to estimate the combined heating and cooling savings attained through additional insulation. For an average retrofit cost of $3,900, the simple payback was calculated to be 32 years at 9.4¢/kWh. Ternes explains, though, that "the simple payback is reduced to 12 years if the homeowners were planning to restucco the house anyway and only the insulation cost of $1,500–$1,900 is considered."

Parker cautions that "what is true of walls is not true of ceilings. Ceiling insulation in cooling climates is often exposed to very hot temperatures due to attic heat collection, often up to 130°F in the height of summer." Thus it is more universally desirable than wall insulation.

On the other hand, the retrofits all slowed daytime heat gain through walls, reducing peak cooling demand. This can be a major benefit, primarily to electric utilities but also to customers with time-of-day rates or those who have an opportunity to downsize their cooling equipment. The 15% demand reduction found by both studies is comparable to reductions achieved by replacing old air conditioners with high-efficiency units, which is often supported with utility subsidies.

Another benefit not captured in the analyses is the improved comfort resulting from lower interior wall temperatures after adding insulation. Lower radiant wall temperatures may allow residents to raise their setpoints comfortably, thereby saving energy. Ternes reports that "several occupants observed marked improvement in the comfort of rooms on the south and west sides of the house that once overheated unbearably."

Optimally, says Parker, we would have "dynamic walls where thermal resistance is adjustable throughout the daily cycle during the cooling season." Though some energy researchers have experimented with creative ideas, such as movable insulation and vacuum insulation, no practical system has as yet been developed.

In the absence of such a breakthrough, people who design and retrofit homes in hot climates will do well to examine the specifics of their situation in light of these studies.

—Doug Johnson

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Conditioned Attics Save Energy in Hot Climates

Do homes with vented attics use less cooling energy than homes with unvented, conditioned attics in hot climates? With little formal research available to answer the question, common wisdom and most building codes have favored venting. But a recent field study in Las Vegas challenges existing assumptions about the virtues of venting in hot, humid climates. The study shows that moving the thermal and air barrier from the plane of the ceiling to the sloped roof plane improves airtightness and can save cooling energy by eliminating heat gain to ducts located in the attic.

Curbing Condensation

Joseph Lstiburek of the Building Science Corporation (BSC) in Chestnut Hill, Massachusetts was the primary researcher for the Las Vegas study. He said that one goal of the study was to validate observations of energy savings at homes and schools that BSC had retrofitted in Florida and Hawaii to eliminate moisture problems. The buildings had leaky ducts and air handlers in vented attics that caused the buildings to be depressurized. In hot climates, negative pressures in the house cause infiltration of warm, moist air from outside. This led to mold growth throughout the house. Having given up on getting large builders to install tight ducts, Lstiburek decided to do the next best thing—put the ducts inside the conditioned space.

The retrofits (sealing the attic vents and insulating at the roof deck) solved the moisture problems because, with the ducts leaking only to the inside, the houses were no longer depressurized. They also showed reduced energy use. According to Lstiburek, having the duct system within the conditioned space saved more energy than was used to condition the attic.

To confirm these results, Lstiburek and Armin Rudd of the Florida Solar Energy Center designed a computer model to describe what was happening, which they then tested with real data from the Las Vegas study.

The Las Vegas Study

The field study was performed on three houses in a Las Vegas subdivision. Two of the houses had attics with roof air barriers of sheathing, along with R-30 fiberglass batt insulation under the plywood roof deck. The third house (the study control) had a conventional vented attic with insulation above the ceiling gypsum board. The three houses had the same floor plan, elevations, and orientation.

The researchers installed temperature sensors at several locations and elevations—from the roof tile top to the inside air space—to record temperatures throughout the day. They measured air conditioner energy use at the compressor units, and performed air leakage tests for each home. Lstiburek and Rudd then analyzed the monitoring data for two weekend days on which the outside temperature peaked at 92°F. The days also had similar solar radiation peaks.

Even though the maximum temperatures recorded at the bottom of the plywood roof deck were higher in some instances for the conditioned attics than for the vented attic, air leakage rates and energy consumption were significantly less in the conditioned attic homes. The duct systems for the sealed attic houses had no measurable air leakage via the attic to the outdoors. There was also reduced heat gain to the ducts, since the attic was now cooled along with the

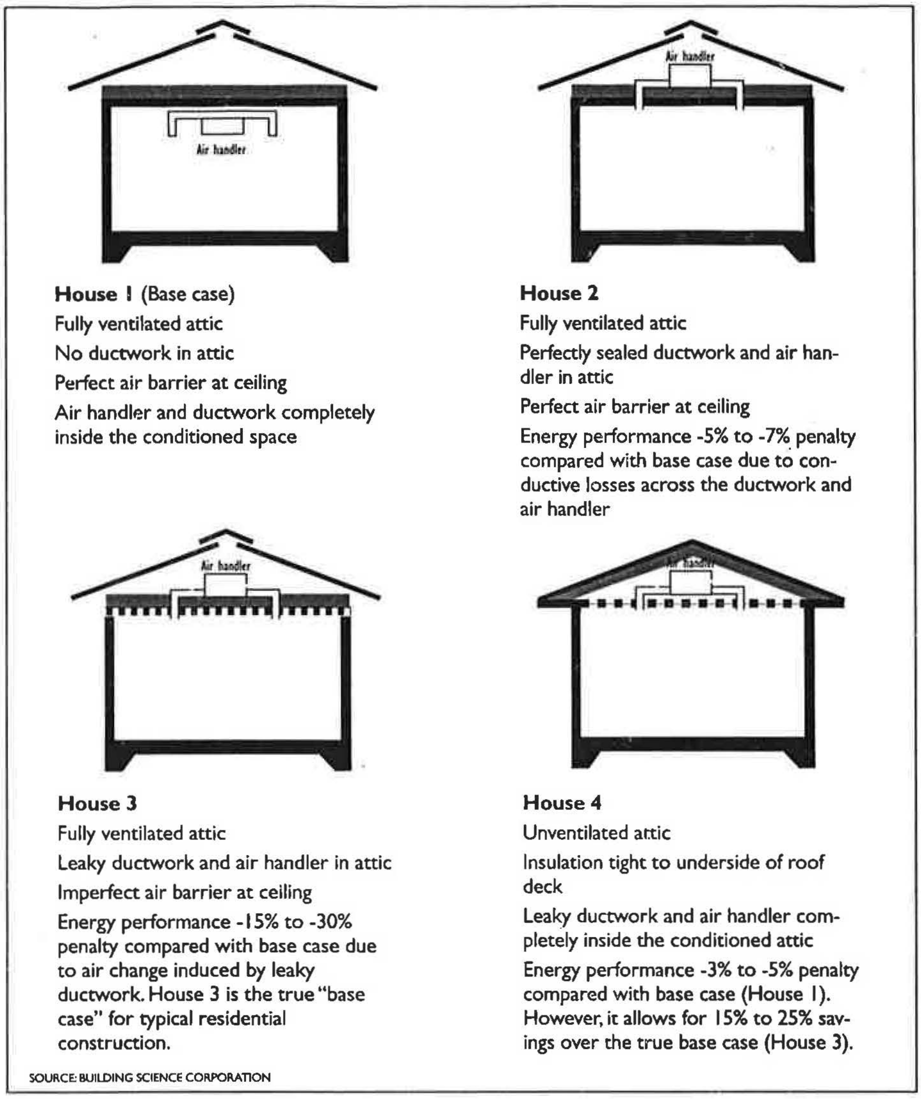

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Figure 1. Energy comparison of different options for attic sealing and ventilation.

house. The two conditioned-attic houses used an average of 19% less cooling energy than the vented-attic house.

Lstiburek and Rudd used these data to calibrate their computer model, which compares space-conditioning energy use and roof temperatures in hot climates for homes with vented attics and conditioned attics (see Figure 1). The model also incorporated extensive laboratory test data on the ways in which conditioned attic space and venting affect temperatures in the attic, roof, and roof deck. These test data were provided by William Rose of the Building Research Council at the University of Illinois.

Annual simulation results for Las Vegas showed that, compared to a vented attic, an unvented, conditioned attic could save 4% on space-conditioning energy assuming no duct leakage. However, when modeled with typical duct leakage (10% return leak and 5% supply leak), the conditioned attic could save 10% on space-conditioning energy.

In addition to energy savings, Lstiburek noted that conditioned attics also reduce pressurization and depressurization problems associated with opening and closing doors to interior rooms. The attic acts as a pressurization equalization system for the house. Much of the air leakage in houses built in the South is between the house and the attic, and this leakage is eliminated by conditioning the attic. Thus, if a bedroom has a supply register in it and the door is closed, the air can travel through the attic to the rest of the house, instead of pressurizing the bedroom. The balanced pressure eliminates uncontrolled air leakage, backdrafting of gas appliances, and soil gas infiltration.

Contending with Codes

Traditionally, building codes in most locations require vented attics in houses. Lstiburek has been battling the general assumption among building officials that homes with vented attics use less cooling energy than those with unvented, conditioned attics. For instance, the Florida code now allows the option of a conditioned attic; however, it requires a higher level of insulation in the conditioned attic.

Lstiburek expects that "building codes will eventually be rewritten to reflect [the Las Vegas] findings." He says that the building department in Las Vegas waived their venting requirement when he showed them the results of the study. The builder of the 100-home Las Vegas subdivision where the study was performed is using unvented conditioned attics for the entire development.

When to Vent

The benefits of having ducts in conditioned space also apply to cold and mixed climates. But in these climates attics must be vented. In 1995, Rose tested attic construction in which the insulation was placed along the underside of the roof sheathing with various venting configurations. With a conditioned attic space, Rose found that "energy transfer through the ductwork, both convective and conductive, is no longer a loss to the exterior," while "airtightness requirements for the ceiling plane are reduced or eliminated." However, for moisture control, Rose concluded that having an air chute to maintain an air gap between the sheathing and the top of the insulation is critical for keeping the sheathing dry.

Lstiburek recommends completely unvented attic assemblies only for hot climates with mild winters. These areas include Florida; the southern parts of Louisiana, Alabama, Mississippi, and Texas; and the southern tips of California and Arizona. Homes in areas with cool or cold winters should vent the roof to avoid moisture problems and prevent the formation of ice dams (see "Out, Out, Dammed Ice," *HE* Nov/Dec '96, p. 21).

—Ted Rieger

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