Arizona (Arizona Public Service), Texas (City of Austin), Minnesota (Northern States Power), Wisconsin (Wisconsin Public Service), and Michigan (Detroit Edison).

WASHINGTON, DC — The US Department of Energy has produced a new CD-ROM titled *The Generator Absorber Heat Exchange Heat Pump*, which describes the history, technology, and energy-saving potential of Generator Absorber Heat Exchange (GAX) heat pumps (see *EDU*, July 1998). The DOE says that the GAX heat pump will be on the market by 2000, heating and cooling homes at an efficiency 50% better than today's gas furnace technology. A DOE market assessment projects that the manufacture, sale, and installation of GAX heat pumps will produce a $3.3 billion expansion of the domestic heating and cooling equipment market and create up to 42,000 jobs in the US. A free copy of the CD-ROM is available by contacting DOE's Office of Building Equipment, E-mail: james.freemont@ee.doe.gov; Fax: (202) 586-5557. Or contact Oak Ridge National Laboratory's Energy Division, Tel: (423) 574-2694; Fax: (423) 574-9331.

NEW YORK, NY — More than a dozen lighting manufacturers, publications, and organizations have joined to create The Lighting Design Forum on the Web, at www.qualitylight.com. The forum provides information about lighting projects, technique, technology, energy efficiency, aesthetics/color, and productivity research. The site also includes links to manufacturers, lighting professionals, and organizations.

WESTFIELD, MA — Home energy rating programs in Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont have formed a collaborative to develop a regional strategic plan that will allow shared resources, joint marketing efforts, strategic housing industry alliances, and rater training/certification reciprocity. "The participating states have united on a regional basis in the realization that by aggregating the states' markets, the housing industry will take more notice," says Richard Faesy of Energy Rated Homes of Vermont. The New England collaboration follows a similar move by Midwestern states last spring (see *EDU*, May 1998).

W. CONSHOHOCKEN, PA — The American Society for Testing and Materials (ASTM) is looking for speakers for a forthcoming workshop on "Investigation and Remediation of Water-Related Problems on EIFS-Clad Wood Framed Structures," sponsored by ASTM Committee E-6 on Performance of Buildings. The workshop will be held Sunday, April 18, 1999, in conjunction with the April 18-21 standards development meeting of Committee E-6. The intent of the workshop is to disseminate the latest information and discuss issues related to exterior insulation and finish systems (EIFS), especially means of investigating and repairing EIFS-clad buildings that have suffered water-related problems. Prospective speakers should contact workshop Chairman Robert Thomas, Jr., before November 15 at CMD Associates, Inc., 1800 Westlake Avenue North, Suite 203, Seattle, WA 98109. Tel: (206) 285-6811; Fax: (206) 285-0752; E-mail: rthomas@eifs.com.

BOSTON, MA — GMAC Mortgage Corp., one of the largest financial services companies in the US, announced it is offering special mortgage loans to borrowers who want to install solar energy systems. The company will offer regular mortgage financing at commercial rates for new and existing homes that include solar, though in some cases the loan rate may be one-eighth of a percentage point below commercial rates. GMAC will also offer equity lines of credit to homeowners who want to add solar systems.

RESEARCH AND IDEAS

Computer Simulations Look Good for "Cathedralized" Attics

Using computer modeling and analysis, Florida Solar Energy Center researcher Armin Rudd and building scientist Joe Lstiburek have confirmed that sealed attics can be used in hot climates — without any energy penalty — in houses that have ductwork located in the attic. Their research also finds that peak roof surface temperatures over unvented attics aren't much higher than over vented attics, which alleviates earlier worries about the longevity and durability of shingles and decking.

As we have reported earlier (see *EDU*, November and December 1997), sealed or "cathedralized" attics are insulated on the sloped plane of the roof rather than on the ceiling below. The roof decking, building paper, flashing, and shingles provide the air seal at the top of the house. With no vents to the outside, the attic becomes a conditioned space.

Cathedralized attics offer builders some powerful advantages. For example:

- HVAC equipment and ductwork can be located in the attic without suffering serious conductive and radiant heat losses. Even if the ducts leak, it's into conditioned space.
- In hot humid climates, cathedralized attics eliminate condensation problems inside the attic. Condensation occurs when hot, moisture-laden outdoor air

enters the attic through vents and comes in contact with a relatively cool surface, such as air conditioning supply ducts, ceiling drywall, pot lights, and plumbing vents. In humid southern climates, the dew point inside an attic may actually be higher than the outdoor air dew point because moisture stored in the wood framing at night is released during the day. This moisture absorption-desorption process is driven by the relative humidity gradient between surfaces and the air in contact with those surfaces.

- Generally speaking, it's easier to get a good air seal across the plane of the roof than across the ceiling. This is because the ceiling in most modern houses is not a single, horizontal plane, but a series of horizontal planes, vertical planes (knee walls), and sloped planes that intersect to create the ceiling. Thus, the continuity of the air barrier and thermal barrier is often compromised at knee walls, coffered ceilings, dropped ceilings, framed soffits or mechanical chases, recessed canister lights, fireplace flues or chimneys, and penetrations for plumbing, wiring, and space conditioning. Of course, there may also be changes in the plane of the roof, but these tend to be fewer and easier to reach.
- A sealed attic keeps dust out of the attic, providing cleaner living spaces below. (Dust can migrate from the attic into the house below via the HVAC system and through interstitial spaces.) This is one of the reasons that Pulte Homes of Las Vegas has switched to cathedralized attics.
- The technique can save money. While the insulation work may cost more, it's offset by eliminating the attic vents. Ductwork in the attic still needs to be sealed to make sure conditioned air gets where it's going and to avoid pressure imbalances.
- Since HVAC, electrical wiring, and plumbing placed in a sealed attic don't have to be covered with insulation, it's easily accessible for future service or remodeling.

On the other side of the ledger are some unanswered installation questions and institutional obstacles to building sealed attics, which we'll discuss below.

How the Modeling Was Done

To evaluate the effects of sealed attics in Orlando, Florida, and Las Vegas, Nevada, Rudd and Lstiburek selected a one-story, 1,500-ft² (139-m²) reference house that had been used in the past for many building energy modeling studies. The construction type (wood frame), foundation type (slab-on-grade), window area (224 ft² [20.8 m²]), roof geometry, and most other characteristics were held constant. Both reference houses were presumed to have ductwork located in the attic, with R-5 duct insulation and no duct leakage. A few characteristics were varied between the two houses to reflect local construction practices and to compare the performance of different configurations (see Table 2).

The researchers simulated hourly space conditioning energy use and roof and attic temperatures for peak cooling days and annual weather using a finite element computer program (FSEC 3.0). The program, which was empirically aligned with measured attic data from three roof research facilities in Florida and Illinois, calculates combined heat and mass transfer, including conductive, convective, and radiant heat transfer, and lumped moisture modeling.

The results show that a cathedralized attic would save 2% in annual energy use in Orlando and 4% in Las Vegas compared to the reference houses. This is because the extra energy required to condition the attic space is more than offset by the elimination of heat gain/loss to the attic air distribution system (see Tables 3 and 4).

When typical duct leakage was modeled in the Orlando house (10% return and 5% supply leakage), the peak cooling power increased by 42% and the sealed attic showed annual space conditioning savings of 18% (see Figure 3). When typical duct leakage was modeled in

Table 2 — Summary of Annual Results for Orlando

Orlando, Florida Simulation Description	Annual Cooling kW-h	Diff. %	Annual Heating kW-h	Diff. %	Observations of Results
Reference case	4419		2193		*(R-19 ceiling, 1:300 vented attic, ducts in attic, no duct leakage, R-11 walls, single glazing)*
White tile, sealed R-28 sloped	3891	-12.0	1904	-13.2	Excellent for cooling and heating
Sealed R-28 sloped	4261	-3.6	1793	-18.2	Good for cooling, excel. for heating, excel. for balanced peak load reduction if using heat pump
White tile, sealed R-19 sloped	3948	-10.7	2142	-2.3	Excellent for cooling, good for heating
White tile	3971	-10.2	2270	3.5	Excellent for cooling, penalty for heating due to loss of solar gains, net positive benefit
Ducts in conditioned space	4324	-2.2	2103	-4.1	Always good
Sealed R-19 sloped	4467	1.1	2002	-8.7	Small penalty for cooling, good for heating, better overall than reference case
1:150 attic vent	4364	-1.3	2211	0.8	Very little net difference from 1:300 reference case
Sealed R-28 flat	4531	2.5	2120	-3.3	Penalty on cooling, saves on heating, nets essentially the same as reference case
Sealed R-19 flat	4713	6.6	2316	5.6	Energy use penalty – but excludes moisture-laden outside air
Duct leak 10% ret 5% sup	5058	14.4	2596	18.4	Never good
Duct leak 15% ret 10% sup	5428	22.8	2895	32.0	Never good

the Las Vegas house, peak cooling power increased by 23% and the cathedralized attic showed annual space conditioning savings of 13% (see Figure 4).

Note that sealing either of the attics without moving the insulation from the ceiling to the roof could increase the annual space conditioning cost by as much as 6%.

"Frankly, I don't think there'd be much interest in sealed attics in hot dry climates if we could convince builders to put ductwork inside conditioned space or to do a good job sealing and insulating ductwork in the attic," Rudd explains. "The problem is, in the real world, homebuilders don't want to sacrifice conditioned space for ductwork, and we can't get tight duct systems built on a production basis. By sealing the attic and moving the air and thermal barriers up on the sloped plane of the roof, you create a very forgiving system for hot climates."

Ventilation: Not as Cool as We Thought

One big worry connected with cathedralized attics is that peak roof temperatures over the unvented space would climb to the point where shingles and roof decking would decompose and fail prematurely. But Rudd and Lstiburek found that peak roof shingle temperatures in Orlando were within 9°F (5°C) for black shingles, peaking at 183°F (84°C), whether the attic was vented or sealed or whether the insulation was flat or cathedralized (see Figure 5). The same was true of Las Vegas, where the temperatures for black shingles were within 7°F (4°C), peaking at 198°F (92°C) (see Figure 6).

The difference in roof plywood temperatures between the vented and sealed attics was less than 13°F (7°C) in Orlando and less than 14°F (8°F) in Las Vegas.

When white roof tiles were used in the models instead of shingles, roof plywood temperatures fell 43°F (24°C) with respect to the 1:300 vented attic (Orlando) and 41°F (23°C) over the 1:150 vented attic (Las Vegas). In other words, the type and color of the roofing had a much more powerful influence on roof temperatures than attic ventilation.

Table 4 — While Most Characteristics of Two Reference Houses Were Held Constant, a Few Elements Differed.

	Orlando, Florida	Las Vegas, Nevada
Attic ventilation	1:300	1:150
Flat ceiling insulation	R-19	R-28
Wall insulation	R-11	R-19
Windows	Single glazing w/aluminum frame	Double glazing w/vinyl frame

"Roof tiles of all colors operate at significantly lower temperatures than asphalt shingles," Rudd notes. "Just using white roof tiles instead of black shingles could save 6% on annual space conditioning in Orlando and 2% in Las Vegas." (The annual savings in Las Vegas are less because white roof tiles become a liability in the winter, reflecting solar heat.)

The study found that combining white roof tiles and a sealed attic could save 12% on annual space conditioning in Orlando (versus black shingles and a vented attic) and 5% in Las Vegas. Again, the difference in annual savings was due to the tiles' wintertime performance.

One of the study's most interesting findings was how little influence attic ventilation had on roof temperatures and annual energy use. The simulation found that there was no difference at all in shingle temperatures between a 1:300 and a 1:150 vented attic and that the difference in roof plywood temperatures was only 4°F to 5°F (2°C to 3°C). What's more, increasing the net attic vent area from 1:300 to 1:150 would have less than a 1% net effect on annual space conditioning energy use in Orlando and no effect at all in Las Vegas, the study found.

"The main message in this research is that it's not good building practice to vent attics in hot humid climates," Rudd says. "Also, builders who want to continue to

Table 3 — Summary of Annual Results for Las Vegas

Las Vegas, Nevada Simulation Description	Annual Cooling kW-h	Diff. %	Annual Heating kW-h	Diff. %	Observations of Results
Reference case	4062		6502		*(R-28 ceiling, 1:150 vented attic, ducts in altic, no duct leakage, R-19 walls, double glazing)*
Sealed R-40 sloped	3858	-5.0	5761	-11.4	Good for cooling, excellent for heating
White tile, sealed R-28 sloped	3611	-11.1	6455	-0.7	Excellent for cooling, no difference for heating
Ducts in conditioned space	3879	-4.5	6243	-4.0	Always good
Sealed R-28 sloped	4075	0.3	6107	-6.1	No difference for cooling, very good for heating
White tile	3697	-9.0	6669	2.6	Very good for cooling, penalty for heating due to reduced solar heat gain
1:300 attic vent	4096	0.8	6449	-0.8	Very little net difference from 1:150 reference case
Sealed R-40 flat	4261	4.9	6329	-2.7	Penalty on cooling, saves on heating, nets essentially the same as reference case
Sealed R-28 flat	4454	9.7	6689	2.9	Not recommended
Duct leak 10% ret 5% sup	4399	8.3	7169	10.2	Never good
Duct leak 15% ret 10% sup	4643	14.3	7649	17.6	Never good

build ventilated attics in hot dry climates should know that doubling the typical vent area (1:300) doesn't help much." To address existing moisture problems in vented attics, Rudd recommends sealing the attic and negating the energy penalty by adding insulation (R-11).

So What's the Building Inspector Going to Say?

Builders who want to use cathedralized attics will probably face stiff institutional barriers — at least for a while. For years building inspectors and home buyers have been inculcated with the idea that attics with ventilation are good and attics without ventilation are bad — end of story. (By the way, this may still hold true in mixed and cold climates where ventilation helps prevent ice damming.)

"Right now, the only way for a builder to go forward with this design is to convince the local code official on a one-to-one basis," Rudd says. He says he knows of several Orange County (Florida) builders who have persevered on the issue and won, but that the effort cost them project time. And of course, time is money. In Las Vegas, the approval process also started one-on-one, with Pulte Homes winning special permission to build two model homes with unvented attics. Now, Pulte and Watt Homes are building whole subdivisions using the design, and the approval process has become more or less routine.

One respected source that could help a builder make his case is the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Its 1997 *Handbook of Fundamentals* clearly supports the use

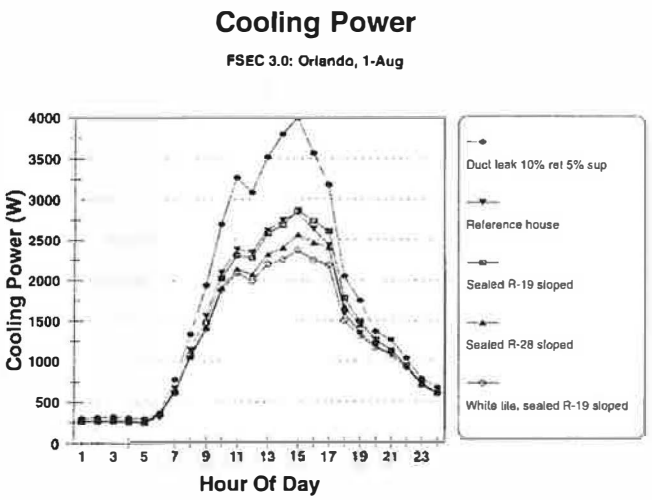

Figure 3 — Orlando peak day cooling load for a venting attic with duct leakage, the reference vented attic, and three variations of the sealed cathedral attic.

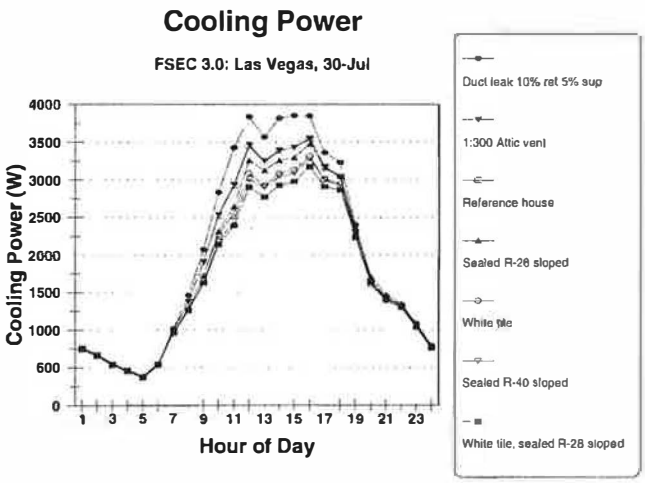

Figure 4 — Las Vegas peak day cooling load for a 1:150 vented attic with duct leakage, a 1:300 vented attic, the reference 1:150 vented attic, white tile roof, and three variations of the cathedralized attic.

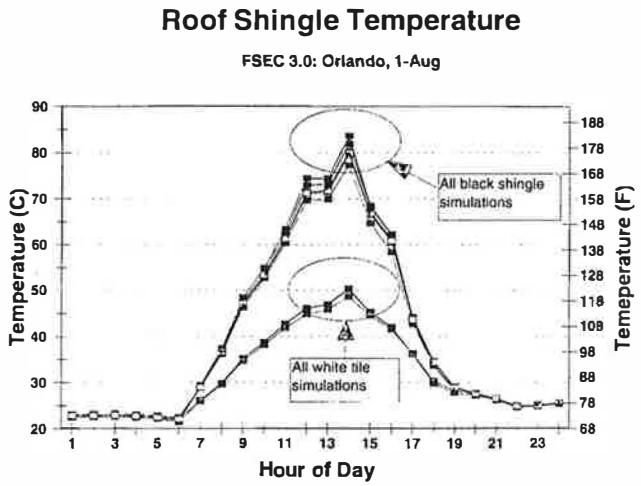

Figure 5 — Orlando peak cooling day temperatures from top-of-roof shingle or tile for all parametric simulations (south side of roof).

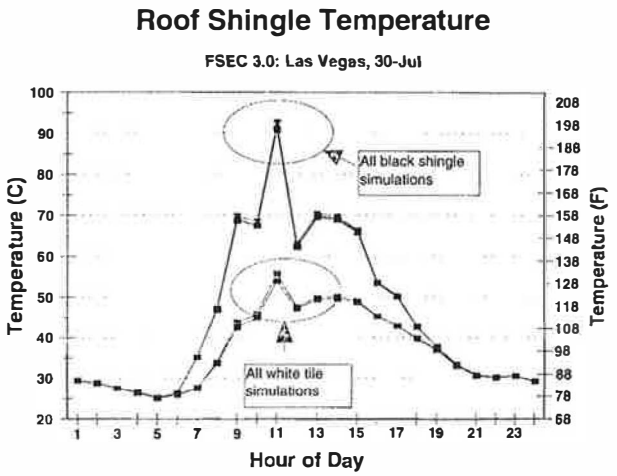

Figure 6 — Las Vegas peak cooling day top of roof shingle or roof tile temperature for all parametric simulations (south side of roof).

of unvented attics in hot humid climates (see *EDU*, October 1997).

Builders must also come to grips with the fact that the warranties on most asphalt shingles are voided if the shingles are installed over unvented roof assemblies. (At this juncture, only Certainteed and Elk Corp. warrant their shingles over unvented attics.)

But the Association of Asphalt Roofing Manufacturers (AARM) is in the process of reexamining its position to see whether its blanket support of vented roof assemblies makes sense in light of ASHRAE's revised position and new research on the subject.

On August 13, AARM's ventilation task group, which includes all of the big asphalt shingle manufacturers, met at the University of Illinois' Building Research Council (BRC) to discuss the subject.

"The industry realizes that its warranties, with regard to vented and unvented roof assemblies, are based on decades of tradition rather than real test data," says BRC's Bill Rose, who attended the meeting. "What we need is a good model of how shingles fail that would incorporate the effects of temperature, exposure, roof geometry, and wind."

Armin Rudd agrees. "Rather than making blanket statements about vented or unvented roof assemblies, we need to establish real temperature limitations for asphalt shingles," he says.

Rose tells *EDU* that he supports the roofing industry's conservatism when it comes to making changes. "They're quite willing to challenge their own assumptions," he says. "But they want to make sure that in opening the door to unvented attic assemblies, they don't also open the door to slipshod work."

More research work also needs to be done defining the temperature limitations of plywood, which can vary with the types of adhesive and lamina used in manufacturing. "We don't know what the real limits of plywood are," Rudd says. "The peak bottom-of-roof plywood temperatures on our simulations came in well below the 180°F threshold that people sometimes use. But there are no published test data." Nonetheless, Rudd and Lstiburek both prefer roofing tiles for cathedralized attics because they deliver superior energy savings and keep the roof decking substantially cooler.

Perhaps the biggest unanswered question with regard to cathedralized attics is how best to insulate a sloped plane. Pulte Homes experimented with unfaced fiberglass batts (R-30) held in place by rows of wire fastened to the top chords of the roof trusses. The method proved to be considerably slower and more costly than laying batt on the attic floor. Pulte has since changed to netted cellulose insulation.

"With cathedralized attics, you have to pay attention to air sealing certain places that didn't require it before," Rudd says. "For example, around plumbing stacks. And where roof trusses go into the garage. In some cases it may be necessary to have the framer help out by building in a little wall."

Rudd tells *EDU* that some Florida builders are using Icynene on their upscale jobs because it provides a good air barrier and insulation in one application. One such project is the Cocoa Beach Country Club, which is being "cathedralized" to address moisture problems in the attic. To avoid having to cover the Icynene with a fire barrier to meet the local interpretation of fire codes, the builder persuaded the local code official to treat the sealed attic space as a mechanical closet.

Another key question that has yet to be answered is how far north cathedralized attics can be used. "The issue is how much potential there is for condensation in the roof sheathing," Rudd says. "We're confident recommending this design for hot climates, but don't know yet about mixed and cold climates."

As reported in *EDU* (see January 1998), a Building America house in chilly Pittsburgh was built with a cathedralized attic to see if any moisture or ice damming problems result. The test is still under way.

Until those results are in, the use of cathedralized attics should be limited to hot dry and hot humid climates. Hot, Joe Lstiburek says, is defined as a climate where average monthly temperatures exceed 45°F. A humid climate is characterized by more than 20 inches (50 cm) of annual precipitation.

Rudd and Lstiburek are continuing their research by monitoring the performance of cathedralized attics in occupied homes in Florida and Nevada. Should sealed attics become a mainstream building technique across the South, it could mean increased sales for some product manufacturers (roofing tiles, Icynene) and lost sales for others (passive attic vents, wind turbines, power attic ventilators, and radiant barriers).

More details on this research are available in the paper "Vented and Sealed Attics in Hot Climates" (TO-98-20-3), which can be obtained by writing to the American Society of Heating, Refrigerating and Air-Conditioning Engineers at 1791 Tullie Circle NE, Atlanta, GA 30329, or by calling its publication office at (800) 527-4723 or (404) 636-8400. Enclose $4 per copy. Web site: www.ashrae.org.

Heard on the Job:

Pascal \pas-'kal\ 1: the weight a housefly exerts on 1 square centimeter.