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HUMIDITY

Efficiency versus Comfort with the New Air Conditioners

by Jeffrey S. Tiller, PE

The standard measurement for air conditioner efficiency, the Seasonal Energy Efficiency Ratio, tells how efficient the cooler is at reducing temperature, not humidity. In hot and humid climates, the latest "high-efficiency" models may not provide the desired comfort as efficiently as expected.

The problem may be imperceptible at first. At first, owners enjoy listening to their new energy-efficient air conditioners speedily deliver cool air and then shut off. They savor the silent savings as the machines patiently await the next opportunity to efficiently meet the demand for cool air. But over a period of days, new owners often notice, with some distress, that their homes are not as comfortable as when the old dinosaurs ran the show—those inefficient monsters they replaced with such good conscience. In retaliation, they set their thermostats lower, and to their chagrin, watch their cooling bills climb back up to the levels they were before the replacement, or even higher.

The truth is out. Energy-efficient air conditioners *can* present a dilemma in hot, humid climates. Some cool the air's temperature so quickly that they do not have the time to extract as much moisture. The result? "Cool" air that feels clammy or warm and sticky.

Humidity is not solely a concern because of discomfort, but also promotes health and nuisance problems. Bacteria, viruses, fungi, mites, and allergen molds all thrive at high humidities. The building itself can suffer the ill effects of moisture damage.

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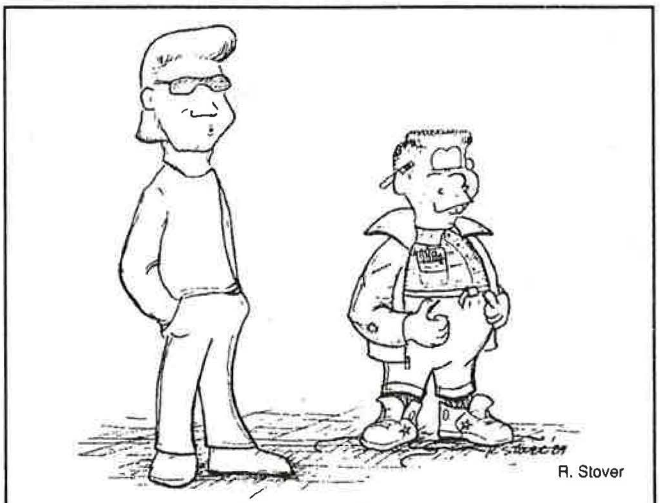
In examining the problems of humidity removal in air conditioners, let's look first at the basics. A central air conditioner (or heat pump in cooling mode) typically has two major components: an outdoor unit, which houses the compressor and the condensing coils; and an indoor unit, which contains the evaporator coils. The blower in the indoor unit propels air from the house over the evaporator coils, which contain a cold refrigerant. The house air is cooled by the coils and when the air reaches the dew point, water vapor in the air (what we know as humidity) condenses on the coils. Thus, the air is both cooled and dehumidified.

Reducing the temperature of indoor air is called **sensible cooling** (it is indeed the easiest to understand and makes the most sense). Dehumidifying the air is called **latent cooling**.



Meet Joe Cool's brothers, Sensible and Latent.

A given house in a given climate has a sensible cooling load, or estimated demand for summertime temperature reduction. It also has a latent cooling load, or demand for dehumidification. Of course, the load on the cooling system varies over time in response to outdoor and indoor conditions. Unfortunately, designers of some heating and cooling equipment have virtually ignored the latent load. After all, the thermostat that controls the cooling system senses only temperature. In climates with dryer summers, sensible cooling works fine to provide comfort. However, latent cooling is a major need in hot, humid climates, which occur in much of the eastern portion of the United States.

Inadequate dehumidification sometimes is exacerbated by energy-efficient building practices and weatherization. Increased insulation levels, efficient windows, more thorough infiltration control, and attention to window orientation and shading all reduce sensible cooling loads. While some of these measures cut the latent load as well, they can trap humidity inside the home. In the efficient building, air conditioners can satisfy the sensible load by operating only a few minutes per hour. However, the latent load often remains unmet.

Air conditioners are designed to deliver a certain Sensible Heating Fraction (SHF)—the fraction of the total cooling capacity that is expended to reduce the incoming air temperature. By subtracting the SHF from 1, you can compute the latent cooling fraction. In most cases, the SHF is greater than 0.75, meaning the latent cooling capacity is 0.25 or less; that is, at most 25% of the work the air conditioner expends goes into dehumidification. Yet latent loads are often 30% or greater. In fact, the Florida Solar Energy Center estimates that dehumidification in many energy-efficient homes in the Southeast comprises as much as 40% of the air conditioning load.

For a given air conditioner, the manufacturer's engineering data allow you to determine the SHF. As shown in Table 1, the SHF depends on the outdoor and indoor temperature conditions, (typically 95°F outdoor dry-bulb, 67° indoor wet-bulb, and 80° indoor dry-bulb).

(A wet-bulb thermometer, e.g., on a sling psychrometer, can determine the saturation temperature or dew point. The "wet bulb" refers to a thermometer bulb wrapped in a wet wick. Swing the bulb through the air and evaporation will cool it. Evaporation trades sensible for latent heat, so the temperature will lower until the air in the wick cannot absorb any more water vapor, that is, until it reaches saturation.)

At 95°F outdoor dry-bulb, 67°F indoor wet-bulb, and 80°F indoor dry-bulb, the SHF can be read directly off of Table 1 as 0.75. Some manufacturers present the engineering data in the format shown in Table 2. In this case, the SHF is the ratio of the sensible capacity at the entering dry-bulb temperature (17.3) to the total capacity (22.8), which is 17.3/22.8, or 0.76. The latent cooling capacities in these cases are 0.25 and 0.24, respectively.

It's not so much the heat as it is the humidity.

In order to increase the Seasonal Energy Efficiency Ratio (SEER) of air conditioners, some manufacturers have used a combination of measures such as speeding up the air flow across the evaporator or increasing the size of the evaporator coils to raise the SHF and lower the dehumidification capacity. Some HVAC contractors pay no attention to SHF when installing high-efficiency units, and now complaints are popping up.

We have received reports that utility companies, upon receiving complaints of clammy customers, have recommended lowering the thermostat. But the problem of inadequate dehumidification has not gone unnoticed. One Southeastern heating and air conditioning contractor, H.T. Davies, President of Associated Equipment Company, Inc., has complained about the inadequacies of the

Table 1. Sample Manufacturer's Engineering Data for Air Conditioners

for Lennox's HS14V-651V Model with C14-65 Evaporator, in high-speed compressor operation

Entering Wet Bulb (°F)	Total Air Vol. (cfm)	Outdoor Air Temperature Entering Condenser Coil (°F)									
		85					95				
		Total Cool Cap. (Btuh)	Comp. Motor Watts Input	Sensible to Total Ratio (S/T) Dry Bulb (°F)			Total Cool Cap. (Btuh)	Comp. Motor Watts Input	Sensible to Total Ratio (S/T) Dry Bulb (°F)		
				76	80	84			76	80	84
63	1500	62,200	5,480	.73	.83	.92	59,100	5,800	.74	.84	.95
	2,000	65,800	5,650	.79	.91	1.00	62,500	5,980	.81	.94	1.00
	2,500	68,200	5,770	.86	1.00	1.00	65,200	6,120	.89	1.00	1.00
67	1,500	66,900	5,710	.58	.67	.76	63,600	6,040	.58	.68	.78
	2,000	70,100	5,860	.62	.73	.85	66,600	6,180	.63	.75	.87
	2,500	72,300	5,950	.66	.80	.94	68,500	6,280	.68	.82	.96

Table 2. Sensible Capacity Engineering Data

Compressor unit, evaporator unit, CFM rating

Outdoor Dry Bulb	Indoor Wet Bulb	Total Capacity	Sensible Capacity At Entering Dry Bulb Temp. 72	76	80
85	59	20.9	18.1	21.1	22.1
	63	22.5	14.9	18.1	21.3
	67	24.1	11.4	14.6	17.8
	71	25.8	7.8	11.1	14.3
95	59	19.7	17.6	20.1	21.1
	63	21.2	14.4	17.6	20.8
	67	22.8	10.9	14.1	17.3
	71	24.4	7.4	10.6	13.8
105	59	18.4	17.0	19.0	19.9
	63	19.8	13.8	17.0	19.9
	67	21.3	10.3	13.6	16.8
	71	22.8	6.8	10.0	13.2

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various efficiency rating systems for heating and cooling systems, in particular the SEER, the Coefficient of Performance (COP), and the Heating Season Performance Factor (for definition, see Mar/Apr '89, *HE*, p.12). He heaps the most abuse on the SEER, the standard by which most air conditioners are compared. He writes, "When operating costs are projected using SEER and COP values, it is assumed that the consumer will be comfortable at 75°F. If, in fact, he has a unit with an oversized coil and a high CFM requirement, then it is quite possible that he will have to operate his thermostat at 70°F (or lower) to be comfortable. Operating costs are going to escalate based on running time. When he moves the thermostat from 75°F to 70°, he increases the sensible load on the space by 25%, and that sensible load is going to make the unit run more. The sad fact is that a properly designed system can keep you comfortable at 80°F if you remove the latent load."[1] (*Ed. note:* Per ASHRAE data on comfort as a function of air temperature and relative humidity (rh), this 5° increase would be possible only if the 75° air was at 100% rh and 80° air was at 0%. Realistically, this isn't practical, so it wouldn't be possible to raise the temperature that much without sacrificing comfort.)

A study by the Air Conditioning and Refrigeration Institute (ARI) examined the dehumidification capacities of different air conditioning studies. Mike Woodford, assistant vice president of engineering at ARI, says the study showed that efficiency is not a major factor in the ability of an air conditioning unit to dehumidify. He says that they found good and "not-so-good" equipment at all efficiency levels. ARI is devising a new standard that will require all manufacturers to report their engineering data in a standard format from which it is easy to ascertain the SHF. In addition, the U.S. Department of Energy's pending Appliance Efficiency Standards Act will require that all air conditioning units with split systems (systems with an indoor and outdoor unit) have a SEER of 10 or more. The standard should become law in 1992. So soon the only choices available will be between "energy-efficient" cooling units, and the issue of latent vs. sensible cooling will become more prominent.

One major contributor to the dehumidification problem

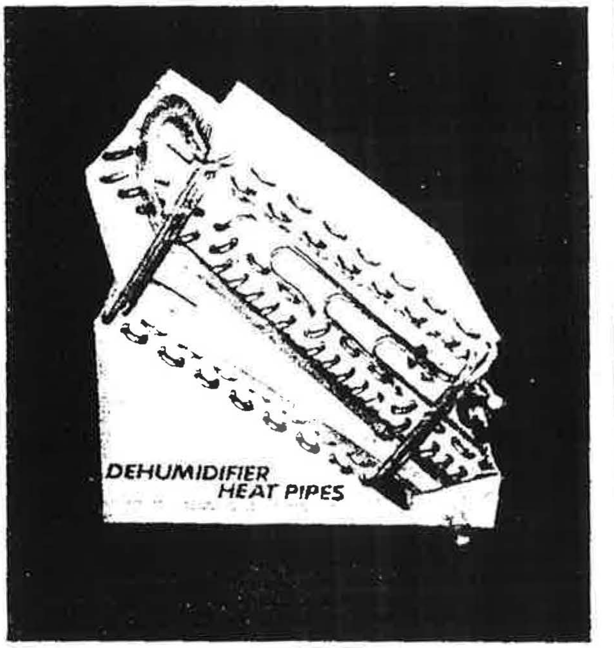
Space Age Technology: the Heat Pipe

The heat pipe is a technology developed for the United States space program that has been adapted for use in home cooling. As described in the main article, if the temperature of the indoor air entering the air handling unit is decreased, then the latent cooling capacity will increase. The company most noted for its residential work with heat pipes is the Dinh Corporation (P.O. Box 999, Alachua, FL 32615; 904/462-3464). The Dinh Z-coil evaporator unit uses heat pipes to pre-cool the air entering the air handler. Independent tests on the unit reveal a 91% increase in condensate removal and dehumidification. There is about a 4% decrease in efficiency and cooling capacity; however, this reduction will be compensated for by the ability of the homeowner to elevate thermostat settings in the summer and still maintain comfort. You can save up to 3–5% on air conditioning costs for every degree above 78°F you adjust your thermostat.

The concept of heat pipe operation is simple. As shown in Figure 1, unlike a standard evaporator in the air handling unit of a cooling system, the Z-coil has two additional heat-pipe coils that are connected and charged with a refrigerant (R-22) at a pressure that results in a low boiling temperature. Incoming room air first contacts the pre-cooling side of the heat-pipe coil, where it is cooled by about 10°F as the refrigerant "boils." Then the pre-cooled air contacts the air conditioner's evaporator coil. The evaporator is able to remove substantially more humidity from the pre-cooled air than a standard unit, because the air is cooled to a lower-than-normal temperature. On the way out of the unit, the air flows across the other end of the heat pipe, the reheater, where it is heated to typical exit temperatures. The refrigerant in the reheating section of the heat pipe condenses and returns to the pre-cooling section as a liquid.

The Dinh unit has been featured in the national, technology-oriented press, but thus far the heat pipe has not been embraced by major cooling equipment manufacturers.

William Beckwith of Dinh claims that the engineering departments of the larger heating and cooling equipment manufacturers have been favorably impressed by the Z-coil. He suggests that the large companies have not used the coil in their units in hot and humid areas because they do not want to develop a regionalized design that is not appropriate across the country.



The Dinh Z-coil can retrofit high-efficiency air conditioners to decrease latent heat.

As the manufacturer, Dinh is reluctant to quote retail prices for their units. Other sources estimate a range of $350 to $500 for the 3-ton unit, which would not cost substantially more than a standard evaporator.

Dinh offers several other products that use heat pipe technology. The DHP is a flat heat pipe intended for the retrofit market. By orienting the main supply and return ducts side-by-side, the DHP can be installed in a position so as to transfer heat between the two air streams. The company also sells a water-to-air heat pump with heat pipe technology, called the Rotocom.

happens when a heat pump is used for both heating and cooling and the heating load is greater than the cooling load. In such a case, the heat pump is oversized in the cooling mode. It cools the temperature quickly, but fails to dehumidify enough.

There are ways to increase the latent capacity of cooling equipment. In Table 1, note that if the temperature of the incoming air is reduced to 76°F, the sensible fraction will drop to 0.63, thus raising the latent fraction to 0.37. A device known as the Dinh heat pipe operates this way to increase the dehumidification capacity (see box).

Multispeed and Variable-Speed Compressors

Alternatively, the air flow can be adjusted. If the total air volume across the evaporator coils is decreased from 2,000 to 1,500 cubic feet per minute (cfm), the SHF declines from 0.75 to 0.68, thus increasing the latent cooling capacity from 0.25 to 0.32. Some experts suggest using a multispeed blower on the air handling unit of the air conditioner to lower the total air volume. High-speed operation yields the greatest efficiency and most sensible cooling, but lower speeds yield more dehumidification. The Florida Solar Energy Center suggests operating the air conditioner at low speeds during humid evenings and nights. It reports that at least one manufacturer offers a multispeed blower controlled by a humidistat that automatically switches the unit to low speed. If you are considering retrofitting your air conditioner with a multispeed blower, be careful—at too low a speed frosting may occur on the coil. Consult with a heating and cooling contractor if you don't have HVAC expertise. When purchasing a new unit, check to see whether an integrated multispeed blower is an option. The Florida Solar Energy Center has a fact sheet, which includes a description of a kit to alter your existing air conditioner into three-speed mode.[2]

A previous edition of *Home Energy* (Mar/Apr '89) discussed variable-speed heat pumps in detail. They can help dehumidify by operating for extended periods of time at low speeds.

A variable-speed heat pump controls the operation of the compressor and fan at varying speeds, depending on the demand. Variable-speed units differ from standard or two-speed units in several ways. One major difference is that the variable-speed unit operates for a much greater portion of the hours during the heating and cooling seasons. Much of the time, it is running at low speeds, which results in very high efficiency.

The Trane distributor in Atlanta claims that the SEERs for their unit varies from 12 to 21, depending on the speed and conditions. The average SEER for their 3-ton unit is 15. It costs about 40% more than standard energy-efficient models, which have SEERs of around 10.

Carrier's variable-speed machine operates at an average SEER of approximately 11. Their distributor estimates an average cost about 30% higher than a comparable high-efficiency standard unit. Some units, such as the Trane machine, have a special dehumidification cycle that turns on when the relative humidity makes a home uncomfortable. Both the Trane and Carrier distributors claim that the biggest selling point of the variable-speed units is the increased comfort due to better dehumidification.

Recommendations

Proper selection, installation, and maintenance of air conditioners can help the unit provide the desired reduction of latent heat.

- Select a high-efficiency unit (SEER greater than 10) that can meet your latent load (the new Manual J method for residences considers humidity for sizing air conditioners). In humid climates, make sure the SHF is less than 0.80. In addition, look for a unit with a multispeed blower. If the desired SHF cannot be obtained, investigate one of the new technologies, or buy a slightly less-efficient model.
- Size the unit properly—save on installation costs and avoid the reduced dehumidification that an oversized unit provides.
- Identify all indoor sources of moisture—e.g. clothes dryers, washing machines, showers—and try to vent them directly outdoors.
- Retrofit existing air conditioners with multispeed blowers or heat pipes as explained earlier.
- Don't use a dehumidifier. Dehumidifiers extract water from the air, producing water and dryer (but warmer) air. They don't save any energy, but, in fact, increase the overall cooling load—the waste heat from fan and compressor are added to the indoor air.

Reduce both sensible and latent loads through standard measures:

- Reduce infiltration of hot, humid air.
- Locate the outside (compressor/condensing) unit in the shade. The higher the condenser's temperature, the lower the efficiency.
- Locate the evaporator coils and blower in a conditioned space, if possible.
- Seal all of the ductwork and insulate those portions that run through unconditioned areas.
- Use ceiling fans and other internal forced ventilators to increase air speed across your body, optimize your biological evaporating and cooling system, and make you feel cooler.

Also, take care when initially charging the air conditioner or recharging it later. Under-charging a system by 10% can reduce efficiency by 20%; over-charging a system can lead to overheating, slugging, and a reduced system life. Also, since the refrigerants used in residential systems are a source of chlorofluorocarbons (CFCs) that have been linked to the depletion of the earth's ozone layer, they should be handled carefully and not spilled or otherwise leaked to the environment. They can be recycled. ■

Endnotes

1. Air Conditioning Contractors of America (ACCA) Technical Reference Bulletin (Bulletin #21) ACCA, 1513 16th Street NW, Washington, DC 20036.
2. The fact sheet is entitled "Air Conditioner Fan Speed Controller for Comfort and Dehumidification" (FSEC-FS-31-85) FSEC, Public Information Office, 300 State Road 401, Cape Canaveral, FL 32920. Tel: (407) 783-0300.