Sensible and Latent Cooling Load Control Using Centrally-Ducted, Variable-Capacity Space Conditioning Systems in Low Sensible Load Environments

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The gist of my message

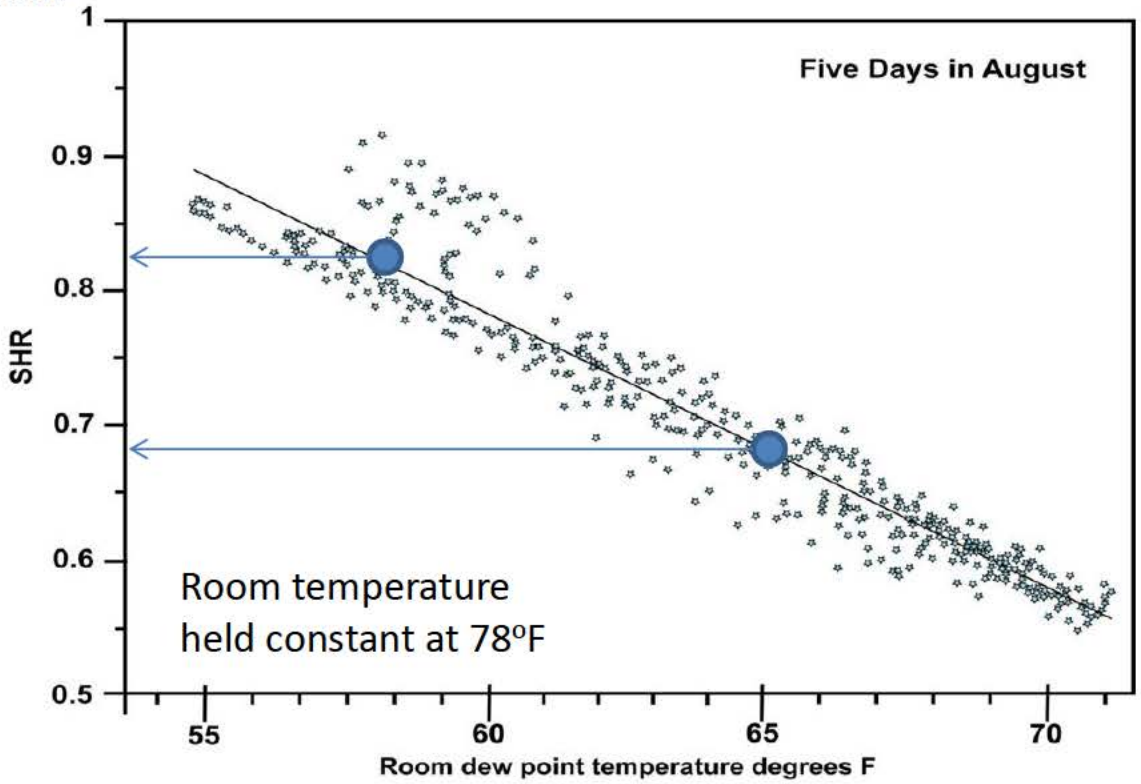
- Fixed capacity AC systems generally provide good RH control in typical residences.
- In low-load homes, they may be less effective in achieving good RH control.
- On the other hand, variable capacity AC systems have several characteristics which can provide improved RH control in homes.
  - Both Nordyne and Carrier have variable capacity units, varying from about 40% to 100% of nominal full capacity.
  - What is variable capacity? -- condenser fan, compressor speed, and AHU fan speed.

The gist, continued

- As homes become more energy efficient, latent load (water vapor) can become a larger fraction of the total load, especially when higher ventilation rates are introduced.
- *CHALLENGE: how to meet both sensible and latent loads efficiently and effectively.*

Context

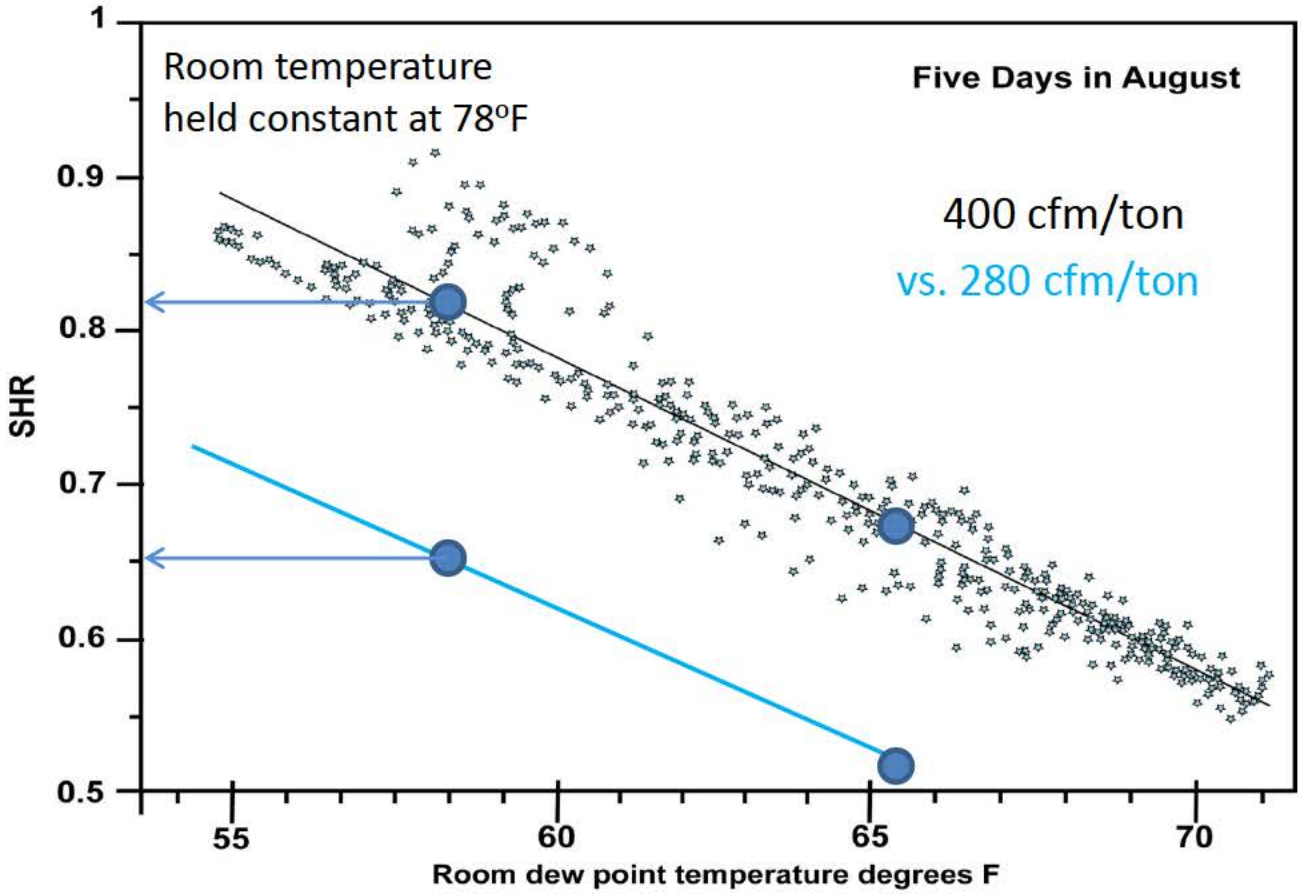
- For heating, load generally consists of just sensible heat.
- Cooling loads consist of two parts; sensible and latent.
  - AC systems service two loads; sensible and latent.
  - Typically, the AC system devotes 25% of its energy to removing moisture (SHR = 0.75). However, AC systems are self-adapting, removing more moisture as RH rises.



Context

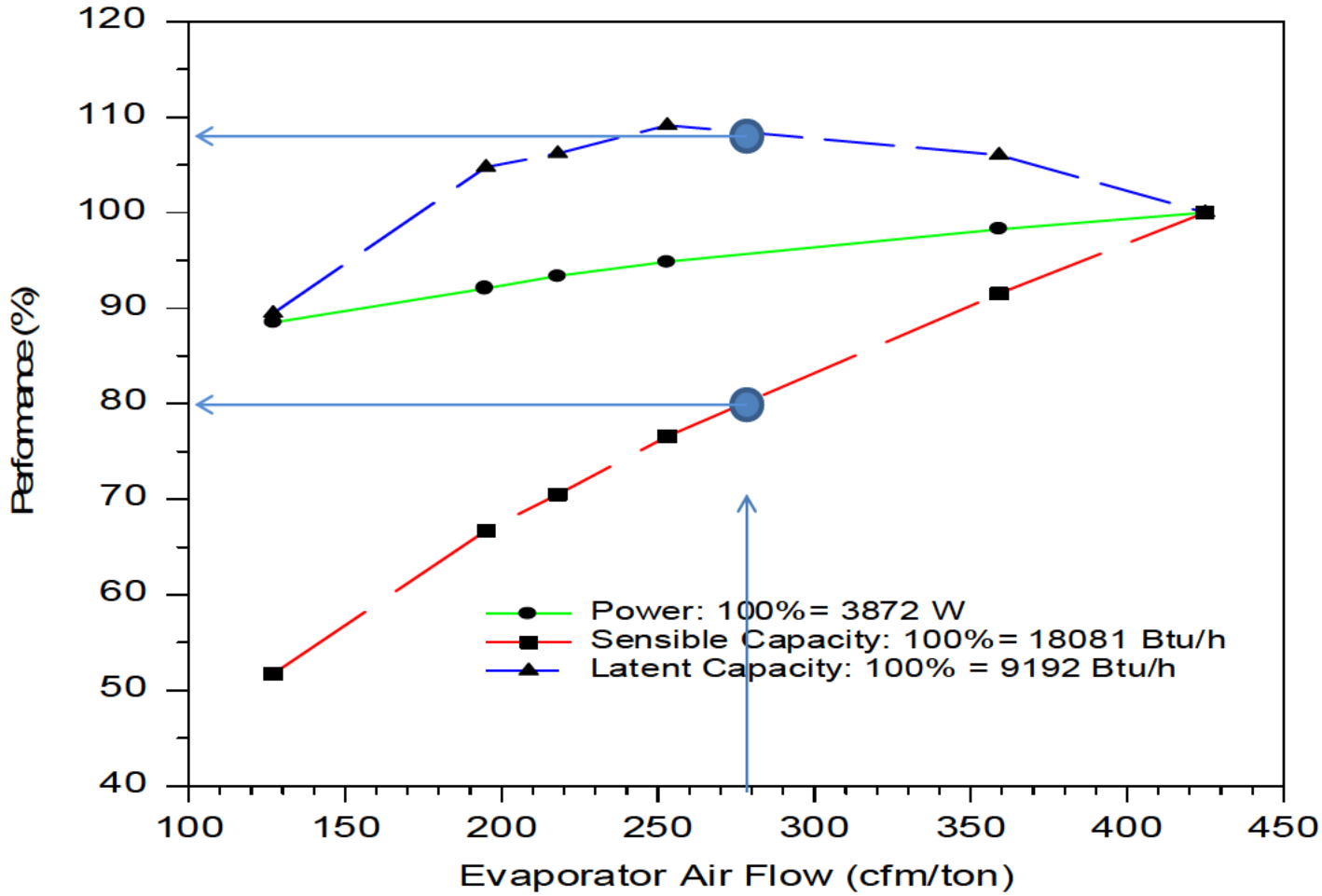
- Space cooling is typically controlled based solely on sensible load (temperature set-point).
  - The resulting RH is just what you get.
  - Some systems allow an RH set point.
- AC systems can be optimized for improved latent removal.
  - Various technologies can be added, such as heat pipes, subcool/reheat, and enthalpy exchange between supply and return air streams to lower SHR.

• One relatively straightforward and important method of optimizing the system for RH control is reduced air flow.
• Lower cfm/ton can be implemented on a one-time basis or adjusted in real time with advanced controls and an integrated humidistat.



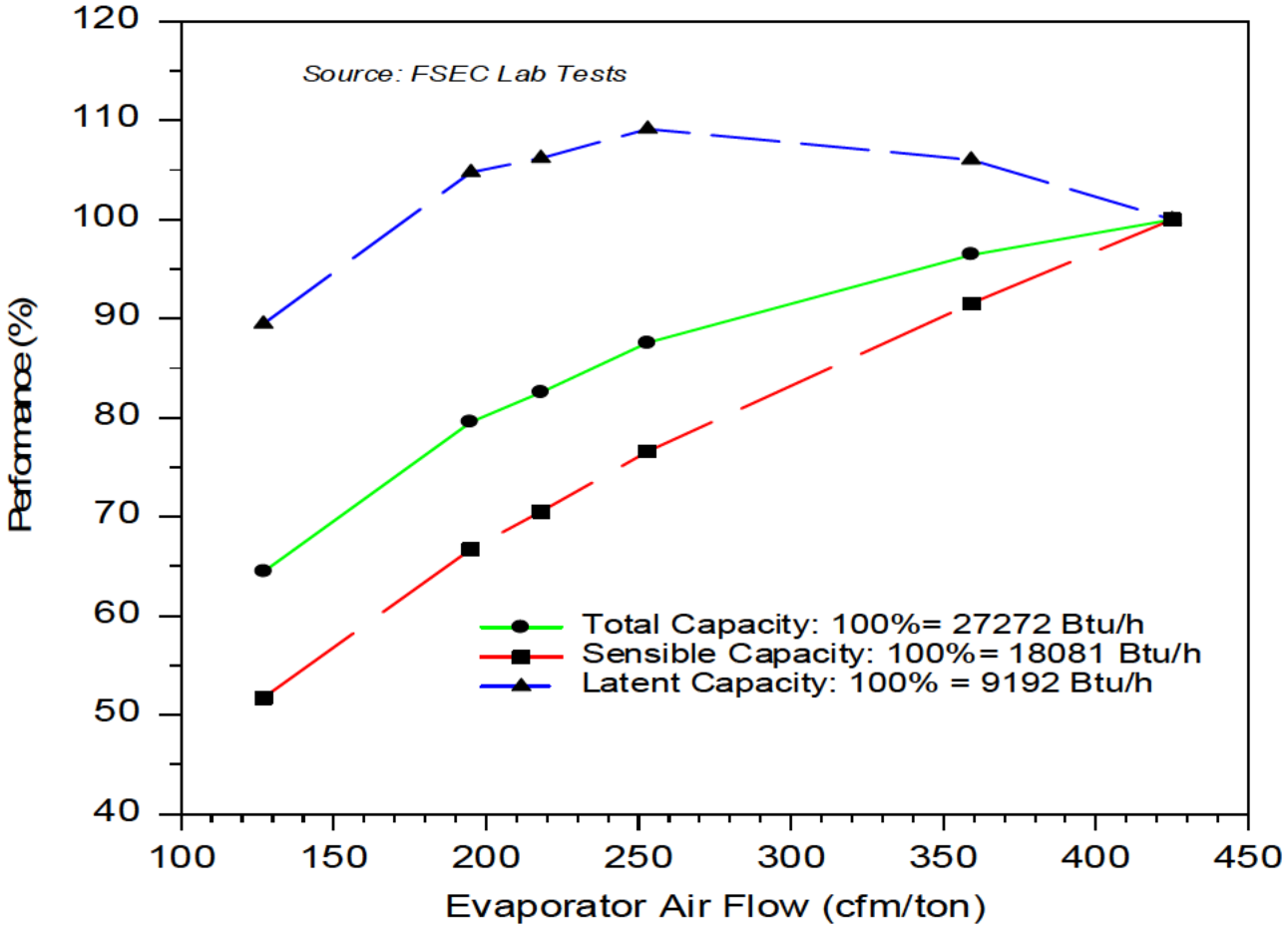
Impact of Reduced Air Flow

Going from 425 to 280 cfm/ton reduces capacity by 10.5% but efficiency by only 5.9%. SHR declines from 66% to 59%. A 20% reduction in sensible cooling capacity yields 25% longer runtime which also helps in RH control.

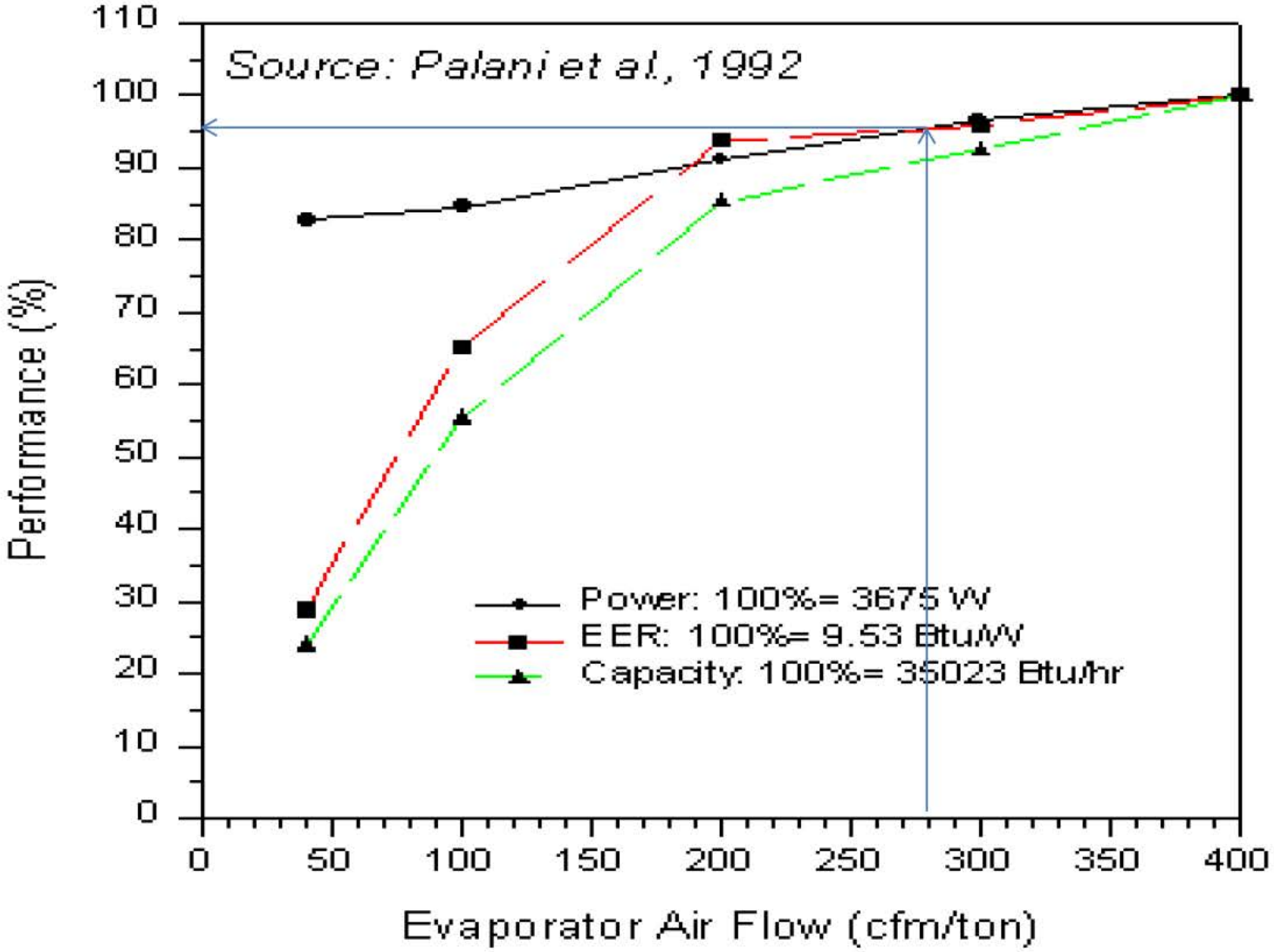


Source: Parker et.al., 1997.

Impact of Air Flow



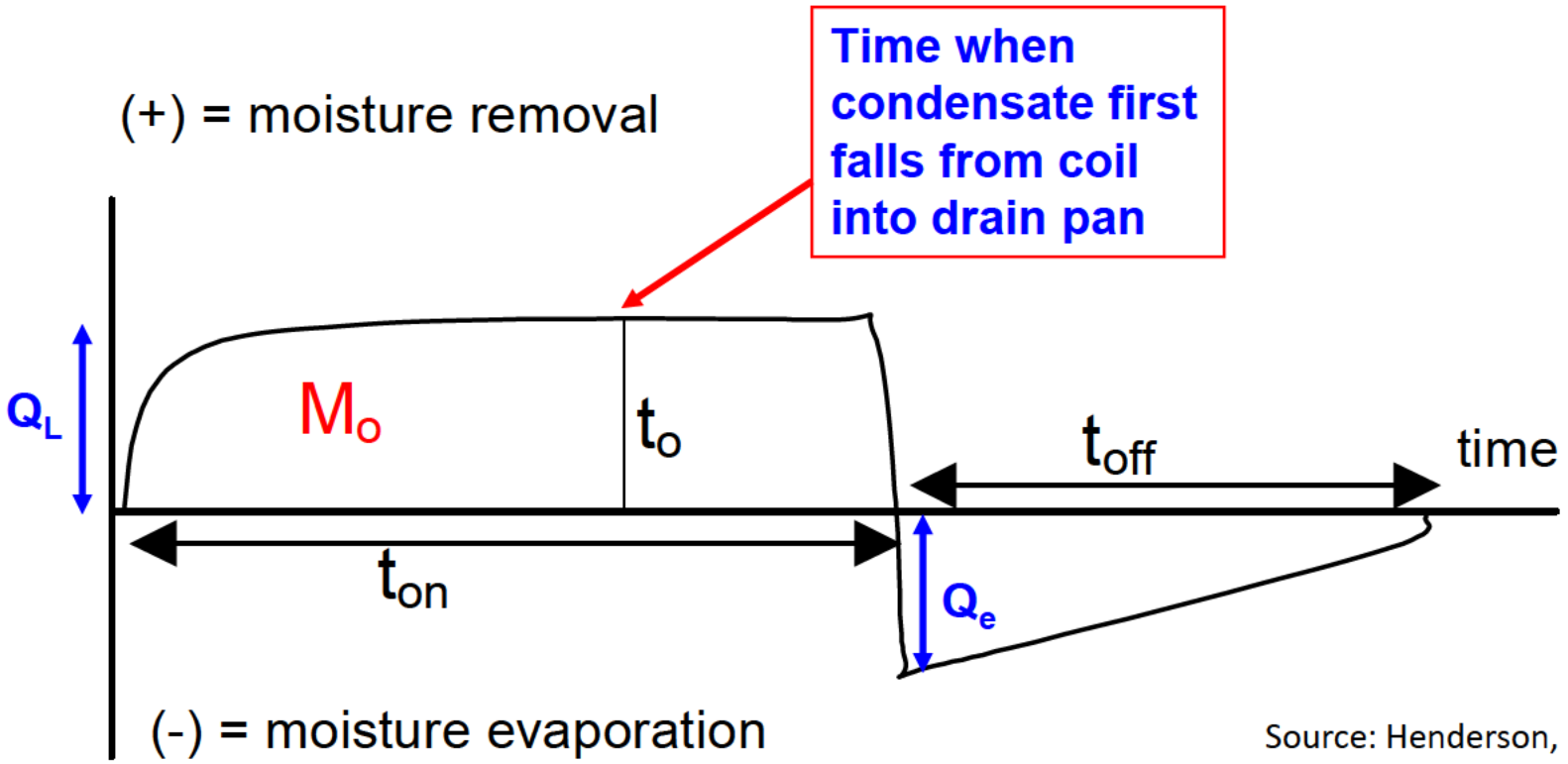
Air Flow vs. AC Performance



Technical Approach

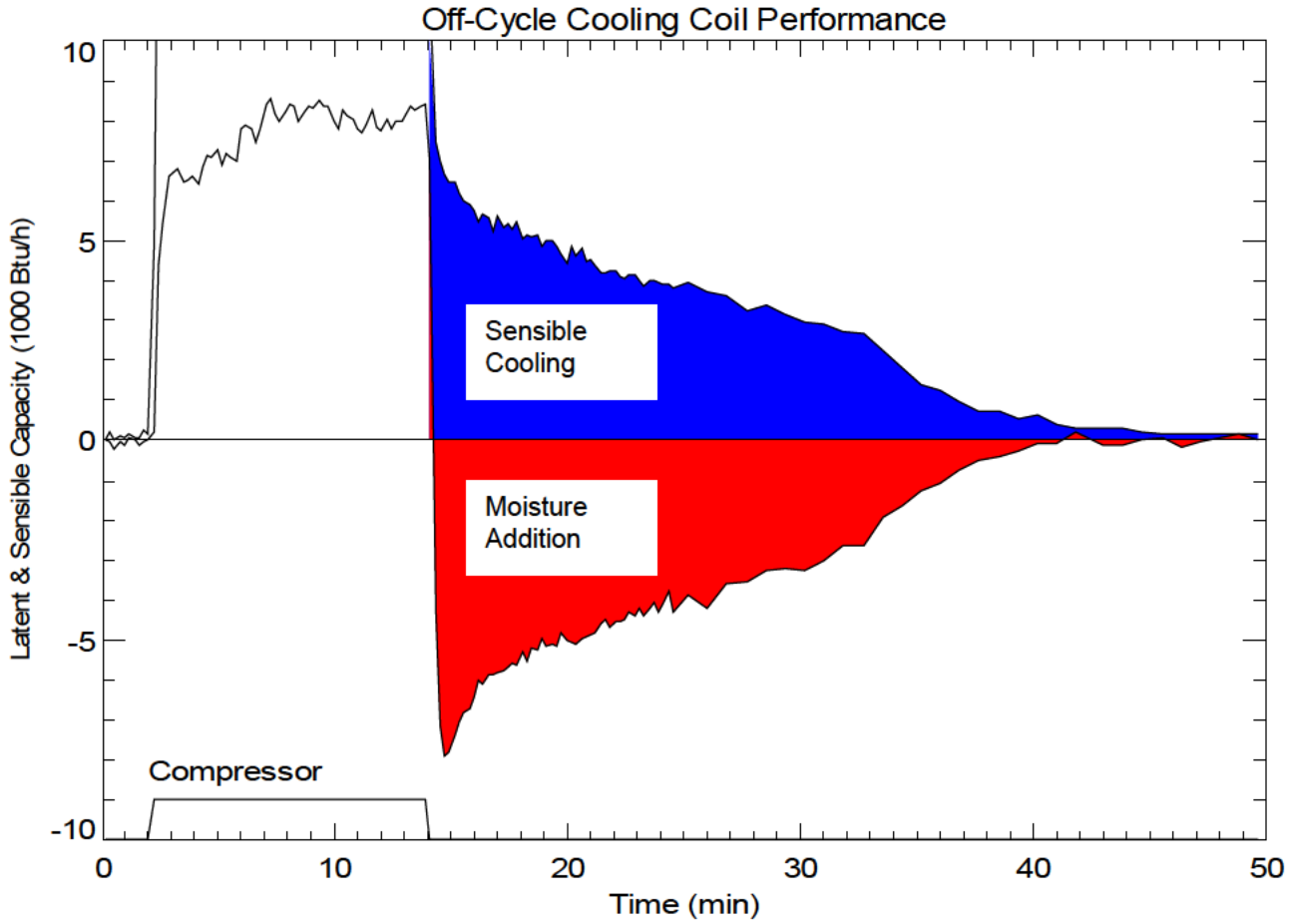
- Low sensible cooling load environments exist in some high efficiency single-family homes and many multi-family residences.
- Traditionally, AC systems are sized to meet peak cooling events plus a safety margin.
  - Therefore, AC systems are substantially oversized for most hours of the year.
  - This can lead to short-cycling which can diminish overall cooling efficiency and latent performance.

Latent Cooling Performance with Continuous Fan Operation



Source: Henderson, 1998.

Continuous Fan: Moisture Re-evaporation



Henderson, Hugh. *The Impact of Part Load Air Conditioner Operation on Dehumidification Performance: Validating a Latent Capacity Degradation Model*. IAQ 98, Paper #98-32, February, 1998.

The ideal system

- The ideal AC system would then be able to modulate its total capacity to meet variable loads and to adjust SHR to meet a variable latent load ratio.
- A 2-ton Nordyne AC, for example, can operate at 0.8-ton capacity at low speed. Therefore, the unit will operate continuously for extended periods.
- The coil remains cold for extended periods providing enhanced latent cooling and avoiding evaporation from the coil that occurs between cycles.
- Furthermore, this AC unit can also modulate air flow in response to an RH set-point, reducing air flow to as low as 180 cfm/ton and achieving low SHR values.

Technical Approach

- Optimization of the AC system may allow low-load homes to achieve good RH control most of the time.
  - During some hours of the year, dehumidifiers (or similar) may be required to meet latent loads.
- It should be recognized that efforts to reduce envelope-related sensible loads to very low levels may not be cost-effective or may not even save energy if they result in the use of dehumidifiers on a consistent basis.
  - Keep in mind that dehumidifiers are fairly efficient space heating appliances (i.e., heating COP ~2 to 2.9) that also remove moisture from the room air.

Energy Star Dehumidifiers

Top energy performers

Manufacturer	Liters/day	Liters/kWh
Therma-Stor	47.9	2.75
Whirlpool	30.8	1.85
Midea Refrig.	24.0	1.75
L.G. Electronics	30.8	1.73
Friedrich	23.7	1.70
GE Appliances	23.7	1.70
De'Longhi Amer.	22.6	1.40

http://208.254.22.7/index.cfm?c=dehumid.pr_dehumidifiers

Recommended Guidance

- Variable capacity AC systems are available which can meet variable sensible and latent control targets.
- Nordyne and Carrier offer AC systems which vary cooling capacity from approximately 40% to 100% of nominal capacity.
  - By modulating cooling capacity, frequent on/off cycling is avoided, which in turn improves efficiency and latent cooling performance.
  - By modulating cfm/ton, SHR is reduced and RH control is enhanced.

Recommended Guidance (cont'd)

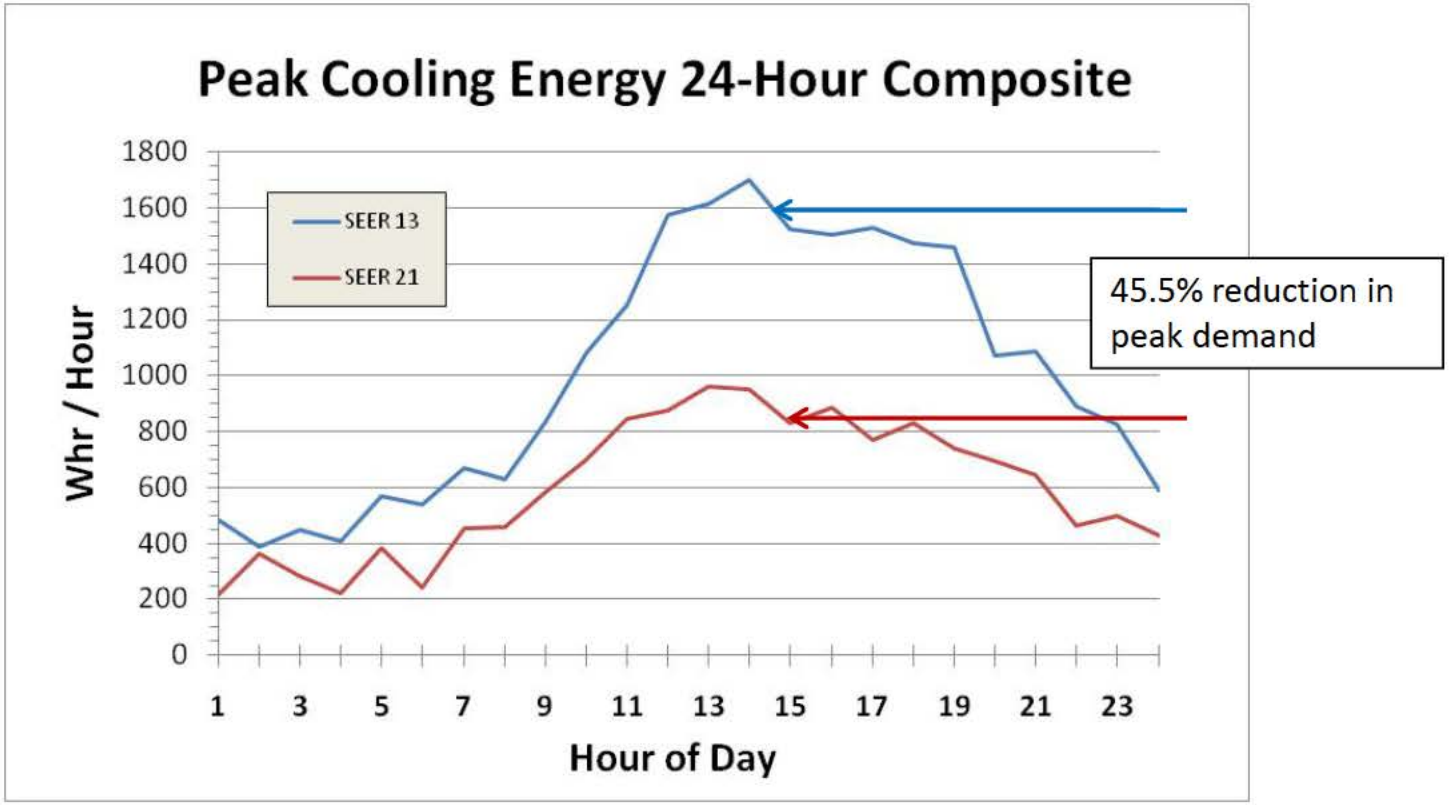
- Indoor ductwork is an ideal compliment to these variable capacity systems because the hours of operation are typically twice that of fixed capacity systems.
- As sensible loads decline, the number of hours per year when heat producing conditioning appliances (e.g., dehumidifiers) are needed will potentially increase.
  - On the other hand, optimized AC systems may meet the latent load requirement in moderately low-load homes.
    - In extremely low-load homes, some operation of dehumidifiers may be necessary.
  - It should be a Building America research objective to investigate ways to limit the hours per year that dehumidifiers are used, because they are very inefficient space cooling devices.

Value

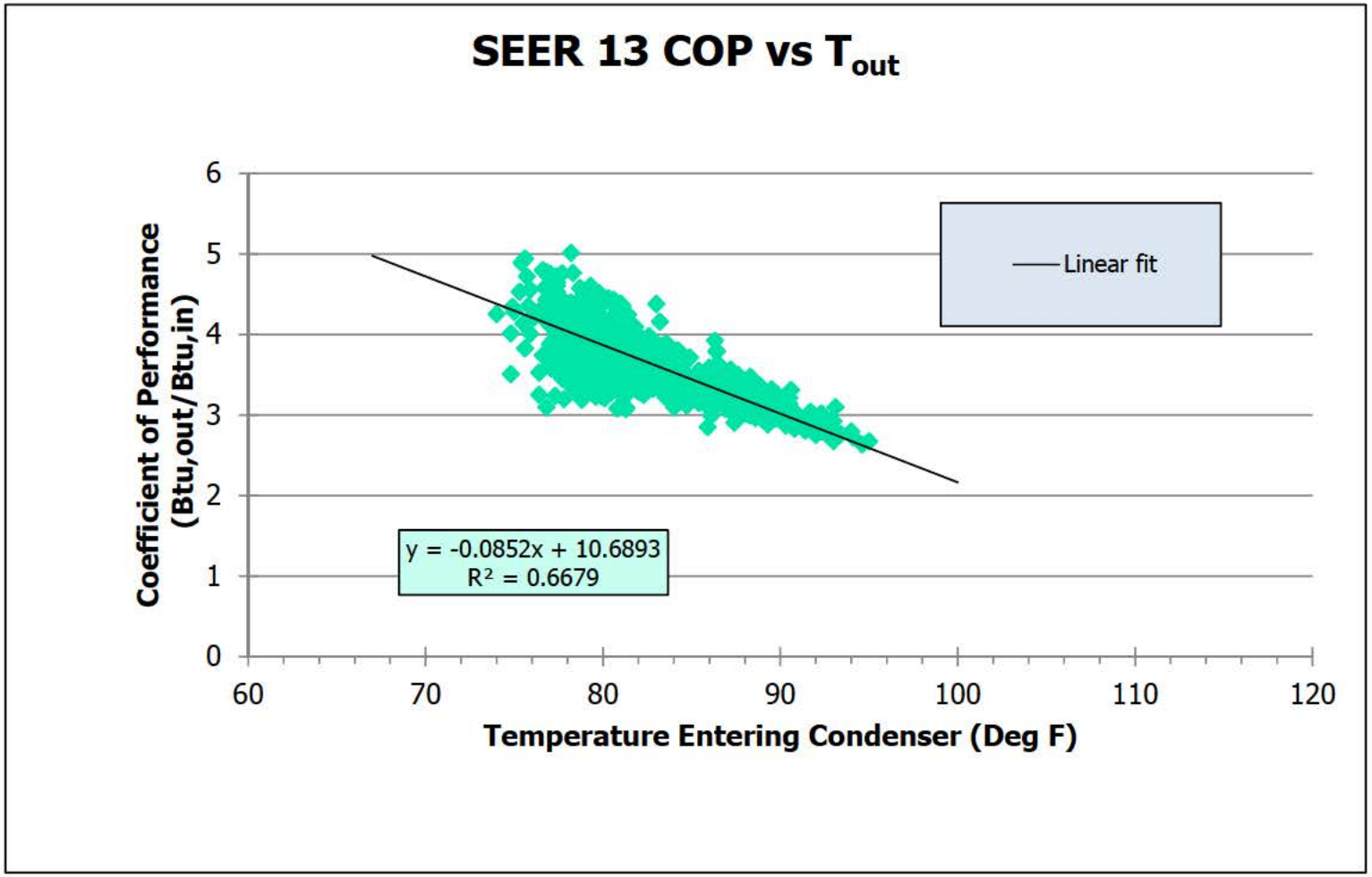
- These variable capacity systems typically cost twice that of a SEER 13 fixed capacity system, but they have higher efficiency.
  - While a 3-ton fixed capacity SEER 13 heat pump might cost $4000, a 3-ton variable capacity SEER 21 might cost $8000.
- Value is provided by these high SEER systems
  - Because they can more readily meet the latent load in low sensible-load residences, thus providing better humidity and comfort control.
  - Because they provide 35 to 40% cooling energy savings.
  - Because they provide large peak demand energy savings, especially when the units are oversized. As such, electric utilities may be motivated to provide incentives.

Cooling peak demand reduction

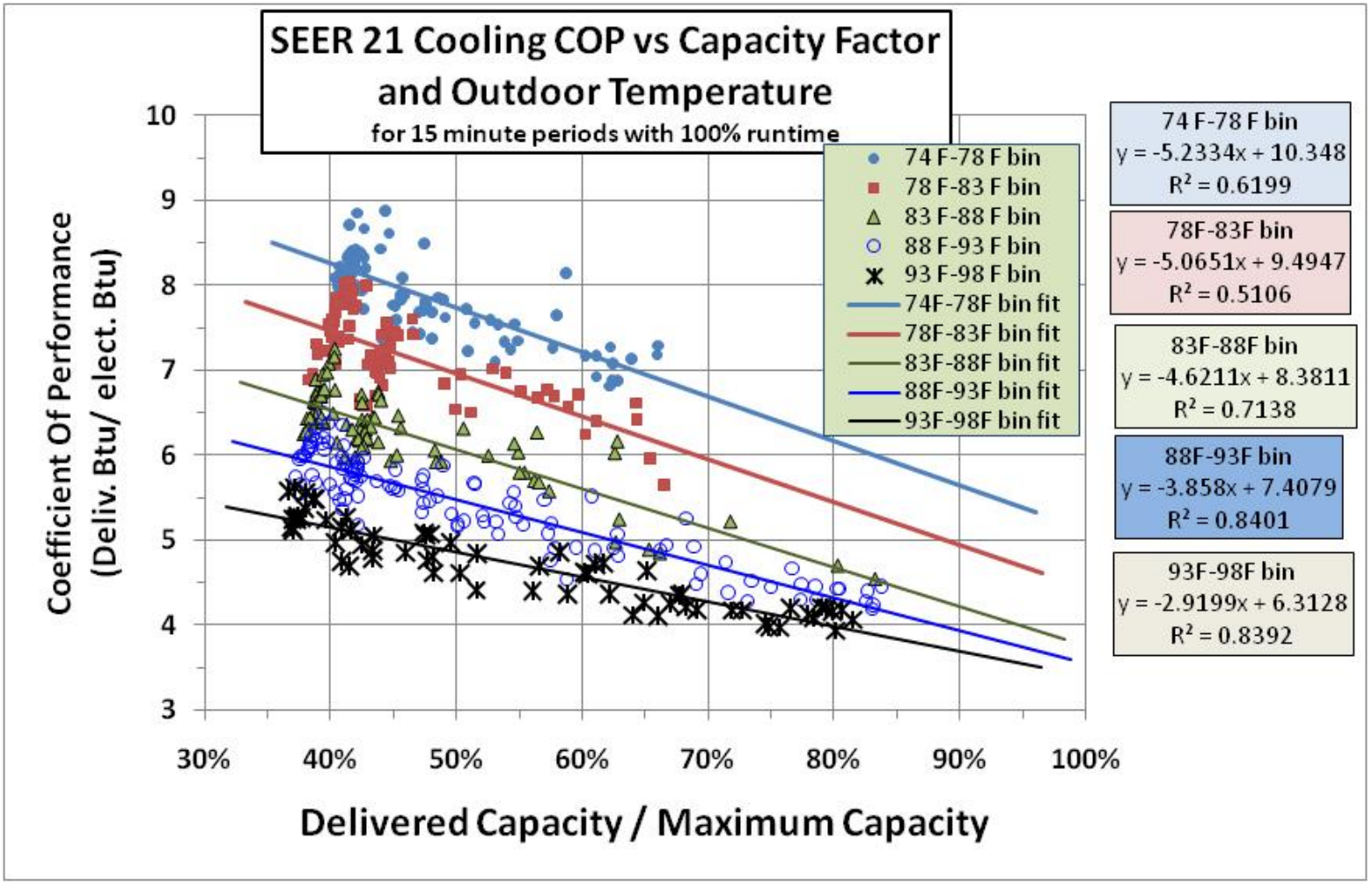
24-hour composite developed from two groups of equally hot summer days for the SEER 13 and SEER 21 systems, when the systems are oversized by about 80%.



SEER 13 cooling efficiency versus outdoor temperature – hourly data



SEER 21 cooling efficiency versus outdoor temperature and capacity factor



Market Readiness

- The Nordyne and Carrier products are currently on the market.
- Cost is a barrier to market penetration.
  - Improved humidity control and comfort can be a selling point.
  - Energy savings can help to pay for some or much of the additional up-front cost.
  - Utility incentives of $1000 to $2000 can be justified based on robust demand savings.
  - Government incentives can be used to account for environmental and other externalities not accounted for in electricity rates (e.g., coal mining mountain top removal, elevated death rates from air and water contamination, national security).
  - Avoiding the first cost, maintenance cost, and energy costs of dehumidifiers can yield more cost-effective and energy-efficient homes.

Pros and Cons

of variable capacity AC systems

- Pros
  - Able to meet a wide variety of sensible and latent loads.
  - Provide improved humidity control without the unwanted energy use of dehumidifiers.
  - Provids very high efficiency operation, for large seasonal and peak demand savings.
  - High initial cost can be offset by seasonal energy savings, government incentives, and utility incentives.
- Cons
  - New technology with limited reliability track record.
  - High initial cost may limit market penetration.

References

- Parker et.al., *Impact of Evaporator Coil Air Flow in Residential Air Conditioning Systems*. Florida Solar Energy Center, 1997. FSEC-PF-321-97. http://www.fsec.ucf.edu/en/publications/html/FSEC-pf-321-97/index.htm
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- Henderson, Hugh. *The Impact of Part Load Air Conditioner Operation on Dehumidification Performance: Validating a Latent Capacity Degradation Model*. IAQ 98, Paper #98-32, February, 1998.
- Carrier Greenspeed heat pumps. http://www.residential.carrier.com/products/acheatpumps/heatpumps/infinitygs.shtml
- Nordyne iQ Drive heat pumps. http://www.heynordyne.com/product-innovation/iq-drive