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Latent Performance of Unitary Equipment

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Improper humidity control is caused by factors such as the mismatch between the building latent load and equipment latent capacity, inappropriate HVAC equipment operation (i.e., turning the equipment off when the building is vacant), building defects (i.e., improperly installed vapor barriers, etc.), or inappropriate building operation (i.e., incorrect building pressurization).

Increased interest in maintaining proper indoor humidity levels stems from the need to achieve appropriate occupant comfort and acceptable indoor air quality, while minimizing energy use. The proper application, selection, sizing, and operation of the HVAC equipment are the keys to controlling humidity levels. This requires that the HVAC system meet sensible and latent loads, not only at the design conditions (full load), but also over a broad range of off-design conditions (part loads).

When addressing moisture control, it is common to discuss *sensible* loads (i.e., temperature-related), *latent* loads (i.e., moisture-related) and the *sensible heat ratio* (SHR; defined as the ratio of the sensible load to the total load, sensible plus latent). However, there is a difference between equipment SHR (occurs at the evaporator coil) and application SHR (occurs in the conditioned space).

Equipment SHR is largely a function of the coil apparatus dew point — the larger the temperature difference between the coil temperature and the entering air wet-bulb temperature, the greater the ability the coil has to remove excess moisture. How the equipment is designed, maintained, and controlled governs the coil temperature.

Application SHR is largely a function of equipment selection/operation and the latent loads generated within the building, infiltrated through the envelope, or introduced as ventilation requirements. Part-load operation can affect equipment SHR, as well as application SHR.

As an example, many commercial HVAC systems operate with continuous fan while allowing the compressor to cycle on and off based on thermostat setpoints (sensible control). Hence, under part-load conditions, continuous fan operation with an "off" compressor increases the evaporator temperature and could allow moisture on the coil to evaporate and be reintroduced into the building, raising the humidity level in

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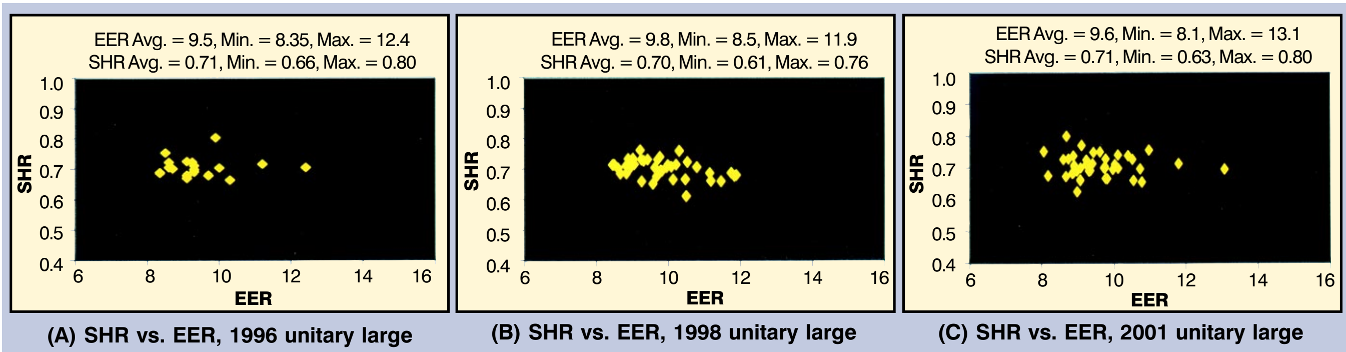


Figure 1: SHR as a function of EER for large unitary products from the 1996, 1998 and 2001 certification test reports.

the conditioned space. (For the balance of this article, discussion on SHR applies only to the equipment.)

A study was performed to assess whether the latent capacity of unitary equipment is a function of efficiency. Another objective was to determine if the latent capacity of unitary products has declined over the years as efficiencies have increased. The sensible heat ratio (SHR) of large unitary equipment (cooling capacity between 65,000 and 240,000 Btu/h [19 to 70 kW]) was analyzed as a function of the energy efficiency ratio (EER). In addition, SHR data from previous studies[1,2] on small unitary equipment (cooling capacity below 65,000 Btu/h [19 kW]) was examined and updated with recent data to analyze trends with respect to EER and seasonal energy efficiency ratios (SEER).

Analysis

The study focused on large unitary equipment with cooling capacities between 65,000 and 240,000 Btu/h (19 to 70 kW). Detailed data on SHR and EER from reports of the 1996, 1998 and 2001 ARI certification test program was examined. In total, 104 test reports were examined (20 for 1996, 42 for 1998, and 42 for 2001). These reports represent more than 50% of all certification test reports generated during these years, from 12 different manufacturers. Although the certification program from which the data was gathered is managed by ARI, the tests were all conducted by an independent testing laboratory that has been conducting tests on unitary large products for over a decade and on small unitary products for more than 40 years.

For unitary small products (cooling capacity below 65,000 Btu/h [19 kW]), data on SHR, EER (A and B tests) and SEER were selected from the 2001 certification program. In total, 207 test reports were examined. This represents approximately 40% of all certification test reports generated that year, from more than 25 manufacturers.

The SHR and EER for large unitary products were obtained at the standard ARI rating conditions of 80°F (26.7°C) dry-bulb and 67°F (19.4°C) wet-bulb coil entering air temperatures and outdoor conditions of 95°F (35°C) dry-bulb.[3] For small unitary products, the SHR and SEER were examined at two different ARI rating conditions — the "A" and "B" tests, while the SEER was calculated using the parameters and procedures listed in ARI standard 210/240.[4] The "A" test is run at 80°F (26.7°C) dry-bulb and 67°F (19.4°C) wet-bulb coil entering air temperatures, and 95°F (35°C) dry-bulb outdoor air temperature. The "B" test is run at the same entering air conditions but at an outdoor dry-bulb air temperature of 82°F (27.8°C).

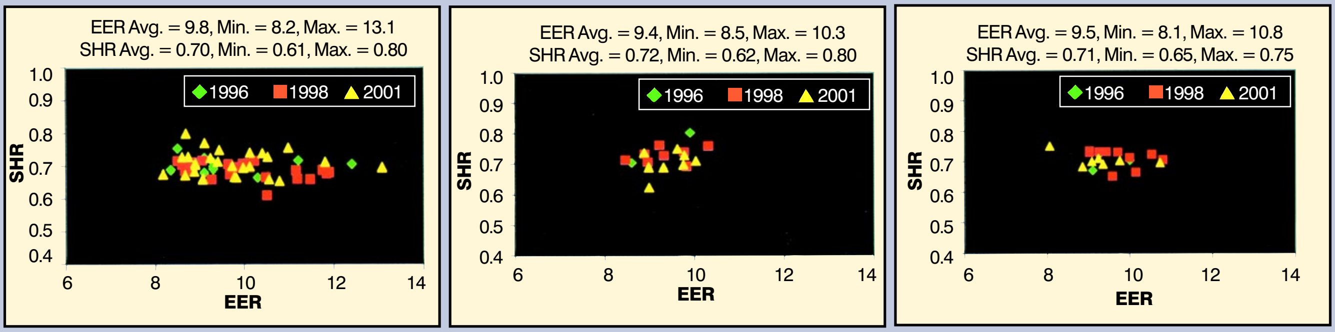
EER, SEER, and SHR were measured under steady-state operation. Also, the data upon which this analysis is based was taken from tests conducted on several types of unitary air conditioners and heat pumps, including single packaged units, split systems, and condensing units (see *Nomenclature* sidebar). Finally, the data collected and reported in this study are actual data from an independent testing laboratory and are not manufacturers' claims or ratings.

Results and Discussion

Figures 1a through *1c* show the SHR as a function of EER for large unitary products from the 1996, 1998 and 2001 certification test reports. EER values vary from as low as 8.1 to as high as 13.1, while the SHR ranges from 0.66 to a maximum value of 0.8. As can be seen, there is no particular trend in the SHR as a function of EER. SHR values seem to be independent of efficiency, as units with low EERs have SHR values in the same range as units with high EERs. On average the SHR was found to be around 0.70 (with a standard deviation on the order of 3%); about the same for 1996, 1998 and 2001 test results. A linear regression analysis also was performed on the data and the R^2 values were found to vary from a maximum of 0.1 to as low as 0.0001, clearly indicating that no correlation exists between the sensible heat ratio and the efficiency.*

The SHR data was also plotted with respect to EER by equipment type and for all years combined as seen in *Figures 2a*

*The relationship between two independent variables is measured in the case of a regression analysis by the determination coefficient R^2. The larger that R^2 becomes, the stronger the relationship between the variables is, with a value of 1 indicating a perfect linear fit.



(A) SHR vs. EER, unitary large
System type: SP-A, SPY-A, SP-W
1996, 1998, 2001

(B) SHR vs. EER, unitary large
System type: RCU-A-CB, RCU-A-C, RC-A
1996, 1998, 2001

(C) SHR vs. EER, unitary large
System type: HSP-A, HRCU-A-CB
1996, 1998, 2001

Figure 2: SHR data plotted with respect to EER by equipment type and for all years combined.

through *2c*. The graphs indicate that SHR is independent of equipment type and has not changed over time. On average, SHR was found to vary between 0.7 and 0.72 for a wide range of EER values. Again, no particular correlation between SHR and EER could be detected as the R^2 values from the linear regression analysis were found to vary from a minimum of 0.04 to a maximum of 0.17.

The latent capacity of small unitary equipment was last analyzed in 1998.[1] The analysis looked at 1994 ARI certification test data on SHR, EER and SEER, and compared it to an earlier study done by ARI in 1986. The major finding of this investigation was that the SHR of small unitary equipment was not a function of efficiency. To determine if the relationship between SHR and efficiency had changed since then, the 2001 SHR data under the "A" and "B" tests were plotted against EER and SEER as shown in *Figures 3a* through *3e*. The graphs indicate no particular relationship between the SHR and efficiency. Under "A" test conditions, SHR varied from 0.59 to 0.79 (with an average value of 0.7), for a broad range of EER and SEER values. The R^2 values from the regression analysis were 0.01 and 0.03 for the EER and SEER respectively, showing again that no correlation exists between SHR and efficiency. Similar conclusions are drawn under "B" test conditions.

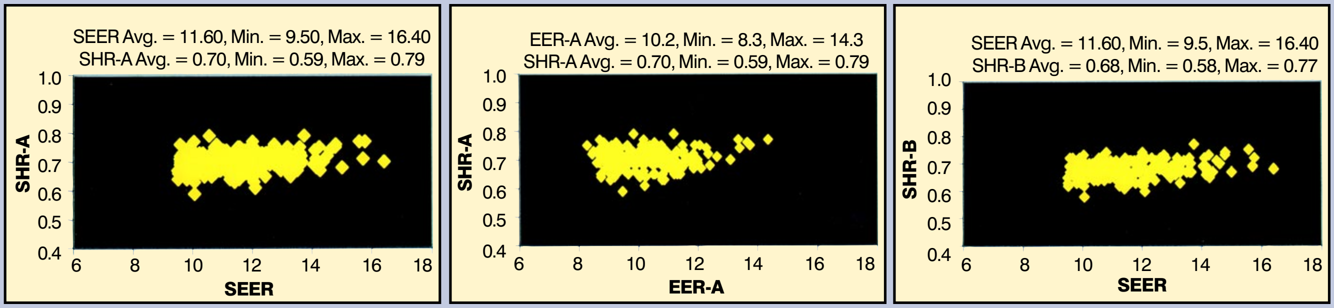
To assess if the SHR of small unitary equipment had changed over the past 30 years, the 2001 data was compared to the data from 1994, 1986, 1976 and 1971 reported in the 1998 analysis.[1] The findings are summarized in *Table 1* and indicate that at "A" test conditions, there has been essentially no change in the SHR over the past 30 years. On the other hand, during the same period of time, the average EER of tested units increased by 60% from 6.4 in 1971 to 10.2 in 2001. Similarly, the SHR at "B" test conditions has been relatively constant (at 0.69) while the average SEER increased by more than 20% since 1986. In summary, the data confirms that the SHR is independent of efficiency and has remained relatively constant over the years.

Conclusions

The analysis of hundreds of independent test reports has revealed that the latent capacity of small and large unitary equipment (under steady-state operating conditions) is independent

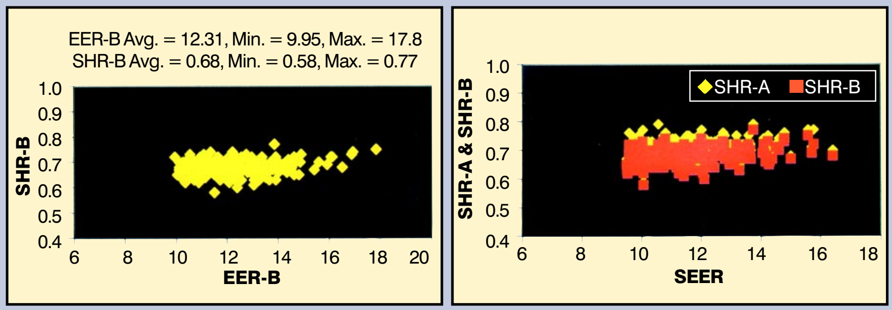
Nomenclature

EER: Energy Efficiency Ratio, defined as the ratio of the cooling capacity in Btu/h to the total power input in watts.
EER-A: Energy Efficiency Ratio at the "A" test conditions.
EER-B: Energy Efficiency Ratio at the "B" test conditions.
SEER: Seasonal Energy Efficiency Ratio, defined as the ratio of the total cooling of the equipment during its normal usage period for cooling (in Btu/h), to the total electrical energy input (in Watts) during the same period.
SHR: Sensible Heat Ratio, defined as the sensible cooling load divided by the total cooling load (sensible plus latent).
SHR-A: Sensible Heat Ratio at the "A" test conditions.
SHR-B: Sensible Heat Ratio at the "B" test conditions.
HRCU-A-CB: Air-cooled split system heat pump (heating and cooling) with indoor fan.
HSP-A: Air-cooled single-package heat pump (cooling and heating).
RC-A: Air-cooled air conditioner with remote condenser.
RCU-A-C: Air-cooled condensing unit, coil alone, without blower.
RCU-A-CB: Air-cooled condensing unit, coil with blower.
SP-A: Air-cooler, single package air conditioner.
SPY-A: Air-cooler, year-round single package air conditioner.
SP-W: Water-cooled, single package air conditioner.



(A) SHR-A vs. SEER, 2001 unitary small (B) SHR-A vs. EER-A, 2001 unitary small (C) SHR-B vs. SEER, 2001 unitary small

These graphs indicate no particular relationship between the SHR and efficiency. Under "A" test conditions, SHR varied from 0.59 to 0.79 (with an average value of 0.7), for a broad range of EER and SEER values. The R^2 values from the regression analysis were 0.01 and 0.03 for the EER and SEER respectively, showing again that no correlation exists between SHR and efficiency. Similar conclusions are drawn under "B" test conditions.



(D) SHR-B vs. EER-B, 2001 unitary small (E) SHR-A &SHR-B vs. SEER, 2001 unitary small

Figure 3: 2001 SHR data under the "A" and "B" tests plotted against EER and SEER.

of efficiency and equipment types. The data indicates that on average, the sensible heat ratio (SHR) is on the order of 0.7 (70%) at entering coil air temperature conditions of 80°F (26.7°C) dry-bulb and 67°F (19.4°C) wet-bulb. In addition, a look at equipment SHR data over many years indicates that the latent capacity of unitary products has remained relatively constant. For small unitary products, SHR has remained at a constant level over the past 30 years while efficiencies have increased by 60%. These improvements in efficiencies are mostly due to better compressors, motors, and heat exchanger surface areas.

Proper selection and sizing of HVAC equipment is essential to control humidity levels in buildings. This entails conducting appropriate design analyses to ensure that the HVAC system meets both sensible and latent loads at full and part-load conditions. Proper sizing and selection is particularly important when outdoor air ventilation is required and/or if the HVAC system operates with continuous fan while the compressor cycles. Additionally, improper space pressurization can increase the infiltration of moist outdoor air to the building, thereby overcoming the capability of mechanical equipment to control excess moisture.

Other factors also exist that could contribute to excessive humidity levels. These factors include high thermostat set points during unoccupied periods, improper system operation, occupancy and ventilation requirements. These factors need to be considered and addressed appropriately to better control humidity concerns within buildings.

	1971	1976	1986	1994	2001
EER-A					
Range	5.0 – 8.5	6.0 –9.8	–	8.0 – 12.1	8.3 – 14.3
Average	6.4	7.3	–	9.9	10.2
SEER					
Range	–	–	7.8 – 12.1	9.2 – 14.7	9.5 – 16.4
Average	–	–	9.6	11.0	11.6
SHR-A					
Average	0.72	0.73	0.72	0.72	0.70
SHR-B					
Average	–	–	0.69	0.69	0.68

Table 1: Comparison to previous ARI studies.

References

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