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Limitations of SEER for Measuring Efficiency

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Conventional wisdom assumes that a 30% increase in the seasonal energy efficiency ratio (SEER) of a unitary air conditioner or heat pump will result in a 30% decrease in energy consumption. More exactly, a 30% increase in SEER will result in a 30% increase in efficiency when the outdoor temperature is 82°F (27.8°C) and the indoor temperature is 80°F (26.7°C) — the specified rating conditions. Prediction of the actual energy or demand savings of modern cooling and heating equipment with a single indicator can be "seriously inaccurate."[1] As an example, the performance data of an 18-SEER product line is compared to a 10-SEER product line from the same manufacturer.

- Advertised SEER improved 80%, while actual SEER improved 45% to 76%,
- EER at 95°F (35°C) improved only 6%, but dehumidification capacity declined 22%,
- Dehumidification capacity declined during low-speed, high efficiency operation, and
- Heating seasonal performance factor (HSPF) declined 2%.

The value of SEER is subject to misinterpretation, raises false hopes that the efficiency levels of air-source heat pumps and air-conditioning units can be dramatically increased, and confuses comparisons with competing technologies that do not have equivalent indicators. A simple multi-point rating system can be used to replace the more complex SEER calculation and will give a more realistic indication of performance and energy use at a broader set of conditions.

This article discusses the conditions under which equipment is rated. Also, it can be demonstrated that this procedure will result in high SEER values for modern equipment that have modest or nonexisting improvements in efficiency at typical operating conditions.

ARI 210/240 Conditions

SEER is the net total cooling capacity in Btu/h divided by the total power input in Watts with indoor temperatures of 80°F dry bulb and 67°F wet bulb (26.7°C/19.4°C) and an outdoor air temperature of 82°F (27.8°C) with a penalty for cycling degradation.[2] Tests for determining cycling degradation also are conducted with an outdoor temperature of 82°F (27.8°C). For equipment that uses a condenser coil condensate evaporation technique, the outdoor wet bulb is specified to be 65°F (18.3°C). At this condition the outdoor enthalpy (30 Btu/lb [67 kW/kg]) is lower than the indoor value (31.5 Btu/lb [73 kJ/kg]). For two-speed or two-compressor equipment, a bin method calculation is used in which 66% of the outdoor bin temperatures are actually less than the indoor temperature as shown in *Table 1*.

Another factor that tends to inflate SEER is the low required indoor fan external static pressures compared to values typically required in actual installations. Values are shown in *Table 2*. The test method states that a filter should be in place but gives no specifications. It is possible to perform tests with clean, low-efficiency filters. These lower fan pressures can lead to significant improvements in efficiency that would not be completely realized when typical ductwork resistances and filters with higher efficiencies and average loads are considered. Proctor and Parker[3] indicate field-measured data is typically 0.4 in. w.c. (100 Pa) higher than the values in *Table 2*.

Furthermore, dehumidification capacity is not an important consideration. It is possible to obtain ratings with an indoor coil that has significantly higher nominal capacity than the compressor. This is likely to result in a relatively warm cooling coil with a lower dehumidification capacity[4] and much higher unit efficiency since compressor capacity is a strong function of evaporator temperature. For example, scroll compressors will have

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approximately 21% higher capacity with 55°F (13°C) evaporating temperature compared to 45°F (7°C).[5] This practice also can be used to raise part-load efficiency in dual capacity or variable capacity equipment by operating compressors at low capacity while operating fans at high speed. Unfortunately, this results in lower latent capacity at a time when dehumidification requirements are a high fraction of total load.[4] Operating in this mode in climates with moderate and high humidity loads is likely to result in room conditions outside the recommendations of ANSI/ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy.*

A final enhancement to rated SEER is related to the use of 80°F dry bulb and 67°F wet bulb (26.7°C/19.4°C) for the inlet air conditions rather than more typical room air temperatures. These values are consistent with those for other ARI-rated products that are used in applications where the ventilation air is mixed with return air.

As shown in *Figure 1,* mixing room air with outdoor air typically results in air entering the equipment near these standard conditions.[4] Many applications for unitary products mix outdoor air in the zone so that air entering the unit will be near room temperature. Unfortunately, the 80°F/67°F (26.7°C/19.4°C) conditions result in an indoor-to-outdoor temperature difference of only 2°F (1.1°C) at the SEER rating point. The value of air entering the equipment should be near the center of the summer comfort zone.[7] A compromise for dry bulb with metric equivalents would be 77°F (25°C) with 64.4°F (18°C) wet bulb.

Temperature Bin °F (°C)	Percent of Hours at Temperature
67 (19.4)	21.4%
72 (22.2)	23.1%
77 (25)	21.6%
82 (27.8)	16.1%
87 (30.6)	10.4%
92 (33.3)	5.2%
97 (36.1)	1.8%
102 (38.9)	0.4%

Table 1: Bin temperature hours used to calculate SEER for dual capacity units.[2]

Equipment Cooling Capacity Rating MBtu/h (kW)	Required External Static Pressure in. w.c. (Pa)
0 – 28 (0 – 8.2)	0.10 (24.9)
29 – 42 (8.5 – 12.4)	0.15 (37.4)
43 – 70 (12.6 – 20.5)	0.20 (49.8)
71 – 105 (20.8 – 30.8)	0.25 (62.3)
106 – 134 (31.1 – 39.3)	0.30 (74.7)

Table 2: Minimum indoor fan external pressures for calculation of SEER.[2]

An Example

A manufacturer recently introduced a product line of two-speed air conditioners and heat pumps with model numbers that imply SEERs of 18.[8] Actual SEERs range from 14.5 to 17.65. The manufacturer also supplies a similar product line that implies a SEER of 10[9] with actual values ranging from 10 to 10.9. Performance data for 5-ton (18 kW) units are given in *Table 3*. These units were chosen to avoid the complications of oversized indoor coils since this is the largest capacity available in these product lines. This manufacturer was chosen because of the clarity of performance data.

The high-speed efficiency of the nominal 18-SEER unit is only 6% higher than the 10-SEER unit when the outdoor temperature is 95°F (35°C) as indicated in the data presented in *Table 3*. Furthermore, this efficiency was achieved at the expense of dehumidification capacity as indicated by the higher sensible heat ratio (SHR = Sensible Capacity ÷ Total Capacity). The increase in SHR from 0.68 to 0.75 represents a 22% reduction in dehumidification capacity.

The EER of the nominal 18-SEER unit at low speed and 85°F (29.4°C) improved to 16.7. However, higher SHRs (0.80 at 80°F/67°F [27°F/19°F] and 0.83 at 75°F/63°F [24°F]) indicate a decline in dehumidification performance during periods when the sensible load will decrease with lower outdoor air temperatures.[4] To prevent unacceptable indoor room humidity level increases, the equipment dehumidification capacity should improve. The fan speed of the nominal 18-SEER unit would likely have to be reduced significantly to lower the coil temperature and provide adequate dehumidification. *Table 3* data indicate the unit in high speed will have an airflow of 430 cfm/ton (710 L/s per kW) with 85°F (29°C) OAT and 75°F/63°F (24°C/17°C) IAT. This results in an SHR of 0.76. The data indicate the SHR will actually rise to 0.83 at low speed where the airflow will be 470 cfm/ton (780 L/s per kW). Designers need data at lower airflows to ensure dehumidification is accomplished. However, this data would typically result in lower capacity and efficiency not reflected in SEER. Thus, simultaneous operation at advertised high efficiency and with high moisture removal capability cannot be expected.

Heating Performance

The two product lines are both available as heat pumps. Published information suggests that the increase in SEER of the two-speed unit does not translate into a similar improvement in HSPF. In fact, the 5-ton (18 kW), 10-SEER heat pump actually has a higher HSPF than the nominal 18-SEER unit. The manufacturer rates 21 outdoor-indoor coil combinations at this capacity and the average HSPF is 8.3 Btu/W-hr for the 10-SEER units. The manufacturer rates 18 coil combinations of the 18-SEER product line and the average HSPF is 8.1 Btu/W-hr.[10] The 18-SEER product line has an average HSPF 2% lower than the 10-SEER heat pump average.

Summary

• SEER ratings are generated based on an outdoor temperature of 82°F (27.8°C) and an indoor temperature of 80°F (26.7°C) for single speed air conditioners and heat pumps.

• SEER ratings for dual capacity units are based on a bin method calculation. The outdoor temperatures used are less than the indoor temperature (80°F [26.7°C]) for 66% of the hours.

• Data is available to demonstrate that a nominal 18-SEER unit will have only a 6% higher EER at 95°F (35°C) outdoor air temperature than a nominal 10-SEER unit. Thus, the correlation between high SEER and high EER at design tempera-

Operating Temperatures		10 SEER Unit Single Speed at 2,000 cfm (944 L/s)				18 SEER Unit High Speed at 2,000 cfm (944 L/s)				18 SEER Unit Low Speed at 1,000 cfm (472 L/s)			
OAT,°F (°C)	IAT db/wb*	TC MBtu/h*	SHR	Total kW	EER	TC MBtu/h*	SHR	Total kW	EER	TC MBtu/h*	SHR	Total kW	EER
85 (29)	80/67	60.5	0.67	5.90	10.3	60	0.73	5.45	11	27.5	**0.80**	1.65	16.7
	75/63	56.2	0.70	5.73	9.8	55.9	0.76	5.35	10.4	25.5	**0.83**	1.62	15.7
95 (35)	80/67	57.5	**0.68**	6.28	**9.2**	56.8	**0.75**	5.82	**9.8**	26.1	0.82	1.8	14.5
	75/63	53.4	0.71	6.11	8.7	52.9	0.78	5.73	9.2	24.1	0.86	1.78	13.5

***Table 3:** A manufacturer's performance data of standard and high efficiency air conditioners (* [°F – 32] ÷ 1.8 = °C; MBtu/h × 0.2931 = kW)*

tures is inconsistent and can be misleading, especially for variable capacity units.

• The heating seasonal performance factor for a product line of 18-SEER heat pumps is 2% lower than the average HSPF for a series of 10-SEER units. Thus, the correlation between advertised high SEER and high heating efficiency is inconsistent and can be misleading.

• The use of dual (or variable) capacity equipment may result in units that can attain high SEER rating conditions without acceptable dehumidification. However, these units can operated with adequate dehumidification capacity, but system effiiency will decline.

• Since the calculation of SEER does not include a consideration of dehumidification capacity, it is possible to perform the computation with an indoor coil with much greater nominal capacity than the compressor (oversized indoor coil and/or dual capacity unit with compressor in low speed). This will enhance SEER but will more likely lead to indoor humidity levels above the values recommended by ANSI/ASHRAE Standard 55-1992, especially at part-load in humid and moderate climates.

Implications for the Future

Current efforts to reduce energy consumption of unitary equipment are centered upon raising the minimum allowable efficiency using a rating system that has significant limitations. Many consumers and high efficiency advocates may assume that raising SEER by 20%, 30%, or even 80% will result in equivalent energy and demand savings in both cooling and heating modes. Unfortunately, this assumption is likely to be incorrect with high SEER equipment. SEER only applies to air-cooled equipment. Continued reliance on this technology and its associated SEER rating system limits comparison to other, possibly more efficient technologies.

A suggested replacement to the existing SEER rating, that would be no more difficult than the current system for dual capacity equipment, is a multipoint rating system. It is further suggested that the rating have: limits on airflow per unit capacity to ensure efficiency is not attained at the expense dehumidification at all speeds (or capacities); return air temperatures are near the center of the comfort zone; and fan power values are reflective of the requirements of field measured data. Outdoor air temperatures of 68°F (20°C), 86°F (30°C), and 104°F (40°C) are suggested for a three-point standard. However, a compromise would be values of 68°F (20°C), 95°F (35°C) for a two-point standard. Test condition airflow rates should be no more than 400 cfm/ton (660 L/s per kW) at all capacities and 0.4 in. w.c. (100 Pa) should be added to the current ESP values used to rate SEER.

A simplified multi-point rating system will provide several benefits that include:

• Provide verifiable and easily accessible performance data of capacity and demand at extreme conditions for regions with power distribution limitations.

• Enable the development of verifiable, realistic, and easily accessible performance vs. outdoor temperature correlations for bin method energy calculations for specific locations.

• Enable the implementation of airflow or sensible/latent ratio limits that could be climate adjusted for high or low humidity regions.

• More easily comply with ISO rating procedures and international standards development.

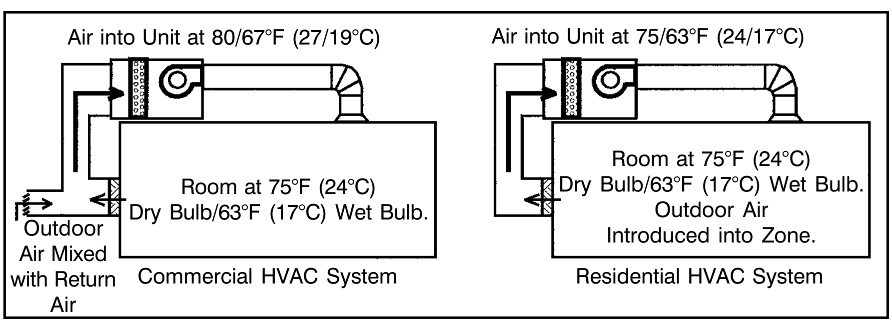

***Figure 1:** Return air temperatures for two cooling systems.*

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