Exploring the Best Compressor SOLUTION for 13 SEER

An engineering analysis indicates that both scroll and reciprocating technologies have their place for 13 SEER equipment

BY SCOTT HIX

A ruling by the 2nd Circuit Court of Appeals in New York early in 2004 overruled a Bush Administration decision to make the minimum seasonal energy efficiency rating (SEER) 12 rather than 13 come Jan. 23, 2006 for residential air-conditioning and heat pump equipment.

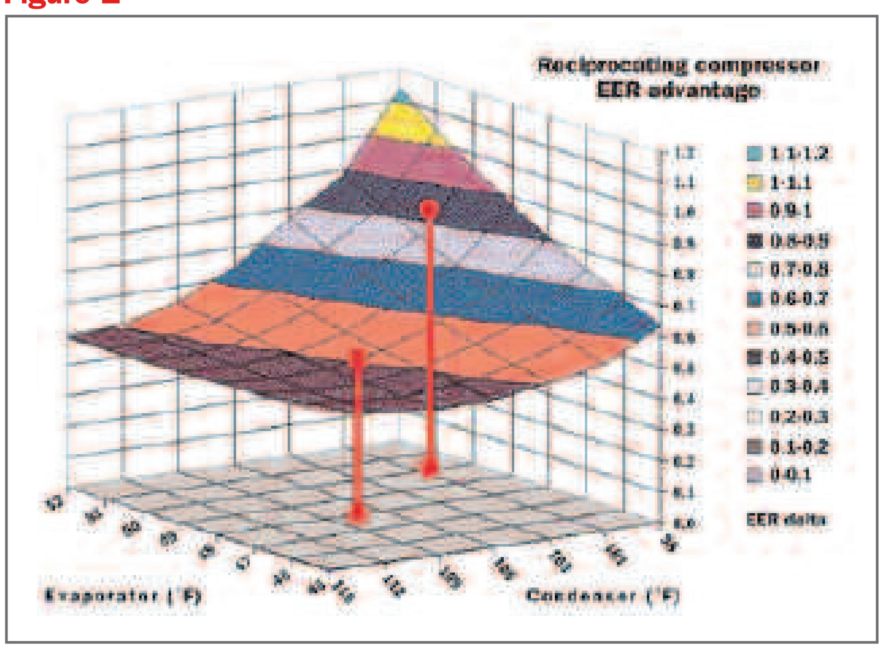
As original equipment manufacturers had been planning their product lines around a 12 SEER minimum, this ruling has caused most of the major oems to suddenly rethink their strategy as they prepare their product lines to comply with the new 13 SEER requirement.

One of the major questions oems face in the design of new 13 SEER equipment is: What compression solution best meets the design requirements in regard to efficiency, sound, reliability and applied cost? It has been proposed by some that reciprocating technology is outdated with the 13 SEER minimum and the industry will turn exclusively to scroll technology. However, the field and laboratory research data does not back up this claim.

So what is the best compression solution for 13 SEER applications? The answer is that there is no simple, single answer. Neither scroll nor recipricating is the single best compression solution for all applications. Nonetheless, a thorough engineering analysis will show that both technologies have their place. Exploring the difference in these two technologies will explain the suitability of reciprocating technology in 13 SEER applications and demonstrate when scroll is in fact the superior solution.

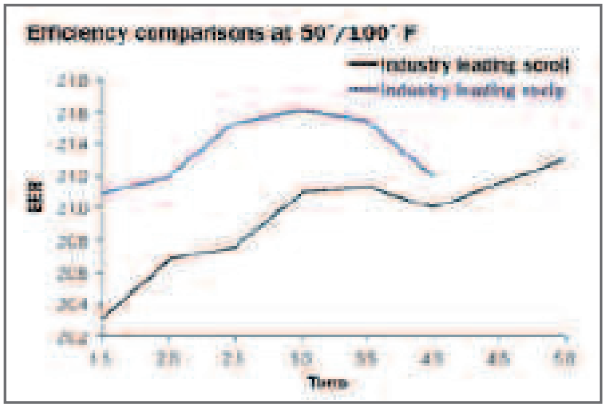
When choosing between reciprocating and scroll in a 13 SEER application, contractors and manufacturers

Figure 1



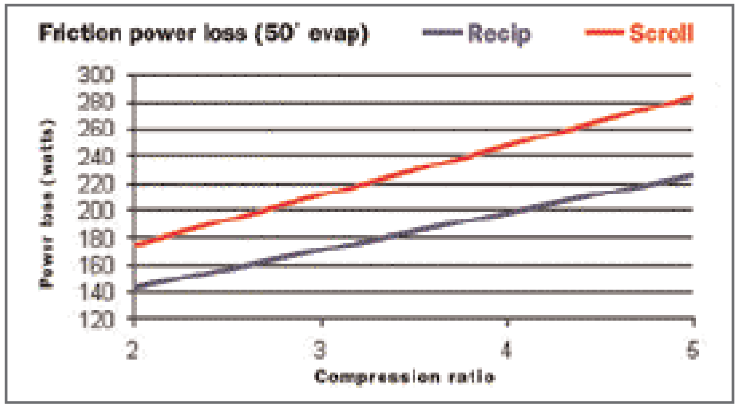
The efficiency of the reciprocating compressor gets better as condensing temperatures decrease and evaporating temperatures increase when moving to 13 SEER.

Figure 2



For systems greater than 3.5 tons, the efficiency of the reciprocating compressor begins to drop in comparison to the scroll, while the scroll efficiency improves.

Figure 3



A comparison of power loss due to the friction of the scroll versus the reciprocating machine at various compression ratios.

must learn to differentiate between reciprocating and scroll on a number of factors, including:

- What is the system size (tons)?
- Is this a low-cost, entry-level brand or a high-tier brand?
- Is applied cost a driving factor?
- How important are sound and vibration levels?
- What compression ratios are expected in normal operation?

There are many other factors to be considered, but the point is that the decision cannot be based on any one of these factors alone. Only by considering all of them will the system designer — or re-designer in the case of replacement compressors — come to a conclusion as to which technology best fits the application.

Efficiency

While some have postulated that the move to 13 SEER would force the industry to scroll technology, this is simply not the case. At the lower condensing temperatures and higher evaporating temperatures in the new 13 SEER systems, a reciprocating compressor is even more efficient than a scroll for applications around 3.5 tons and below. Figure 1 shows the difference between the leading scroll and reciprocating compressors and illustrates what happens with the move to 13 SEER.

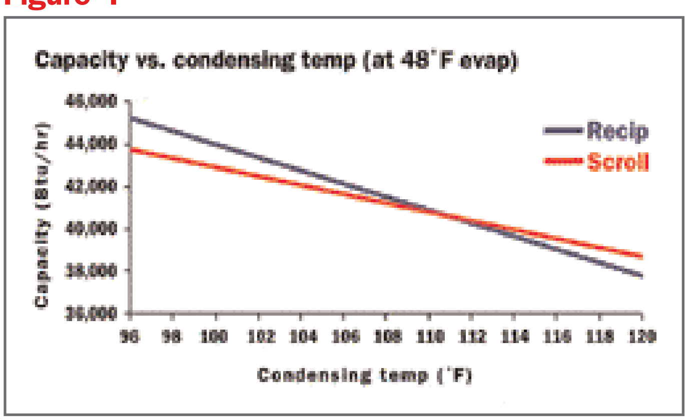
As seen in Figure 1, the efficiency of the reciprocating compressor gets better as compared to the scroll as condensing temperatures decrease and evaporating temperatures increase. At a typical operating condition of 50º F evaporator and 100º F condenser, the efficiency of the reciprocating compressor exceeds that of the scroll compressor up through 3.5 tons.

However, the chart in Figure 2 illustrates the reason, in regard to efficiency, a single compression solution is not optimum for all applications. For systems greater than 3.5 tons, the efficiency of the reciprocating compressor begins to drop in comparison to the scroll, while the scroll efficiency gets even better at higher displacements.

Some manufacturers push scroll technology for all applications regardless of numerous factors important to the design. Often scroll engineers speak in terms of volumetric efficiency because it is a fact that scroll compressors have higher volumetric efficiency than the reciprocating compressors.

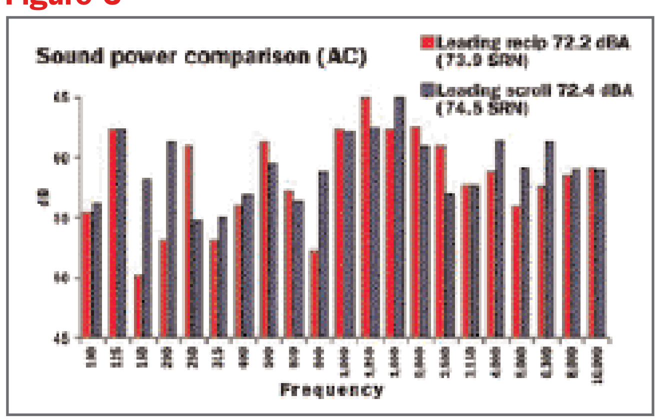
However, scroll compressors also lose much more power in friction than the reciprocating machine. In fact, the scroll power loss to friction is nearly 30 percent more than a reciprocating machine and, therefore, the mechanical efficiency is much lower. What a scroll gains in volumetric efficiency, it gives up in mechanical efficiency. The chart

Figure 4



The match point in a typical 13 SEER system is somewhere around 48˚ F evaporator and 112˚ F condensing temperatures.

Figure 5



The sound lab data for the compressor.

in Figure 3 shows a comparison of power loss due to friction of the scroll versus the reciprocating machine at various compression ratios.

However, volumetric efficiency is important because at lower condensing temperatures the mass flow from a reciprocating machine will be higher than that of a scroll for equal system rated capacity. This results in a reduced system efficiency that must be made up in higher compressor efficiency.

Another important result of this is that a smaller reciprocating machine, as rated at the ARI condition (45º/130º F), can be used in comparison to the scroll. This translates into lower applied costs.

For example, to match the rated capacity of a typical 3-ton scroll (34,000 Btu at the 45º/130º F point) in a 13 SEER system, a system designer would not use a 34,000 Btu reciprocating compressor. Instead, the designer would choose a 32,000 Btu compressor as rated at the 45º/130º F condition.

The match point in a typical 13 SEER system is somewhere around 48º F evaporator and 112º F condensing temperatures. As seen in Figure 4, the capacity at the system rating condition will be equal using a reciprocating compressor with a smaller displacement, and the excess capacity at the lower condensing temperature is minimized. With the smaller displacement, a smaller, lower torque motor is required and cost is improved in comparison to the scroll.

Sound levels

Another important consideration in the choice of compression technology is sound level, in both the compressor and the system. While high-efficiency reciprocating compressors suitable for high SEER levels have been available in the market for many years, they have traditionally been louder than comparable scroll compressors.

With the increased use of scroll compressors in the market over the past several years, customers have come to expect quieter systems. Compressor engineers have addressed this problem, and the new generation of reciprocating compressor is not only very efficient, it is also very quiet.

New reciprocating compressor shell designs, along with innovative gas management, resulted in compressor sound levels on a dBA rating equal to the comparable leading scroll compressors. When pure tone adjustments are made to compensate for the sensitivity of the human ear, the reciprocating technology can be even quieter than the leading scroll compressor.

The chart in Figure 5 shows sound lab data for the compressor alone. While the dBA levels are equal, the sound quality as measured by the pure tone adjusted sound rating number (SRN) shows the leading reciprocating compressor to be quieter than the leading scroll by about 0.6 dB.

But this is not the whole story because the sound level of the compressor alone in the lab does not totally predict the result in the system. In addition to system design fundamentals like the chosen fan system and sheet metal and coil structure, system sound is driven by compressor airborne sound levels (such as depicted in Figure 5), pulsations in the gas stream and vibrations.

The scroll compressor puts significantly more vibration energy into the condensing unit base pan and tubing connections than the reciprocating compressor because the scroll mechanical unit is hard mounted in the compressor shell. Therefore, all of the mechanical imbalance and startup torque must be absorbed by the condensing unit and tubing.

In the reciprocating machine, the mechanical unit is mounted on springs within the compressor shell, thereby passing less energy into the system. Suction gas pulsations are even lower in the new reciprocating compressors than the already-low levels of traditional reciprocating machines due to the innovative suction gas management employed to reduce compressor sound levels.

All of this adds up to lower system sound levels. In an independent lab, it has been shown in back-to-back testing in a 3-ton, 14 SEER system that the new reciprocating technology can be even quieter than the scroll compressor. In this testing, the production system using a leading scroll compressor tested at 77.8 dBA. The leading reciprocating compressor was then installed into the same system, which then tested at 76.2 dBA (1.6 dBA quieter).

Reliability and applied costs

Efficiency and sound levels are significant factors when deciding which compression technology is best for a particular application. However, in the final analysis, these two factors are inconclusive in themselves because there is not a very significant difference between the two technologies.

But when we turn our attention to applied cost and reliability, we begin to see the reason one technology is not adequate to span the entire range of residential and light-commercial applications. In other words, there is no one correct solution.

Real-world conditions can sometimes drive compression ratios to levels outside the compressor-operating envelope. Reciprocating machines are routinely qualified at compression ratios as high as 14:1 and are expected to operate at this condition indefinitely without damage.

Scroll compressors cannot operate at a level higher than about 7:1, which is just at the edge of the typical published operating envelope. Therefore, to protect the scroll compressor against this potential failure mode, external pressure switches, discharge line thermostats or other controls are often needed. This drives up applied cost.

In loss-of-charge conditions, the scroll is more susceptible to damage because the scroll set is lubricated by oil entrained in the gas flow. A reciprocating compressor can operate indefinitely with loss of charge without incurring mechanical damage because the lube system continues to operate independently of mass flow. Also, the reciprocating compressor uses return gas flow directly across the internal line-break protector so it is much more sensitive to loss-of-charge and other out-of-control conditions than the scroll.

While a loss-of-charge or some other condition that results in excessive compression ratio would eventually be noticed by the homeowner due to lack of cooling (or in a heat pump maybe not until the utility bill is abnormally high due to auxiliary heat making up the difference), the damage to the compressor may already be done. The reciprocating machine is better able to handle these conditions without expensive external controls.

A scroll compressor has about three times the machined surface area of a reciprocating machine. A scroll set has nearly the same amount of high-precision machining on the small displacements as on the large ones.

A comparison of this high-precision milling in a scroll to the relatively simple turning and boring operations in a reciprocating machine indicates that scroll compressors have more potential for variation in performance and sound levels due to normal process variation. Also, the machining time and associated cost is a much larger fraction of the compressor cost, and it is proportionately larger in the small scroll machines.

Scroll compressors are designed for a particular optimized compression ratio, and they are much more sensitive to changes in compression ratio and potential scroll instability at conditions away from this optimized point. Reciprocating machines have valves that operate effectively over a wide range of compression ratios, as seen in real-world applications, with no concern of the effect of over- or under-compression.

A rapid change in compression ratio is seen routinely in a defrost mode in heat pumps. Since scroll compressors rely on speed and compression ratio to control the scroll stability, this rapid shift causes scroll instability and annoying sound levels during the initiation of the defrost cycle with resulting stress on the mechanical components.

On the other hand, some of scroll's weaknesses at smaller capacity levels become strengths at high-capacity levels in comparison to the reciprocating machine.

As the system capacity is increased and the compressor displacement becomes larger, the machining cost of the scroll becomes proportionately smaller, and the scroll becomes more cost-effective. Also, the larger mass flows in systems greater than 3.5 tons and the resulting stress on valve systems make the reciprocating compressor less reliable in comparison to scrolls on these larger systems.

In addition, the reciprocating machine has to get much larger to allow it to handle the higher mass flow efficiently through valve ports, etc. This causes the cost to go up rapidly, once again making scrolls more cost-effective in larger sizes.

The same cost problem due to machining that works against scroll compressors in the smaller sizes works to the scroll's advantage in the larger sizes. Because the length of the tip seals in the scroll machine is not significantly longer on large-displacement machines than on small ones, the leakage past the tips and the frictional power loss in the scroll set are smaller as a percentage of capacity. Therefore, scroll machines get even better efficiency as the displacement increases.

The best solution

Efficiency, sound, reliability and applied cost must be considered when choosing the correct compression technology. As the industry moves to 13 SEER, oems are considering the initial question, "What is the best compression solution for 13 SEER?" As shown by overwhelming research, there is no single answer that fits all applications.

The correct compression solution is not solely reciprocating or scroll technology. It is both, because each technology is best suited for a particular range of applications. Typically, it will be found that the reciprocating machine offers the best performance for the lowest applied cost in systems with a capacity of 3.5 tons and below, while scroll technology offers the best solution at greater than 3.5 tons.◆

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