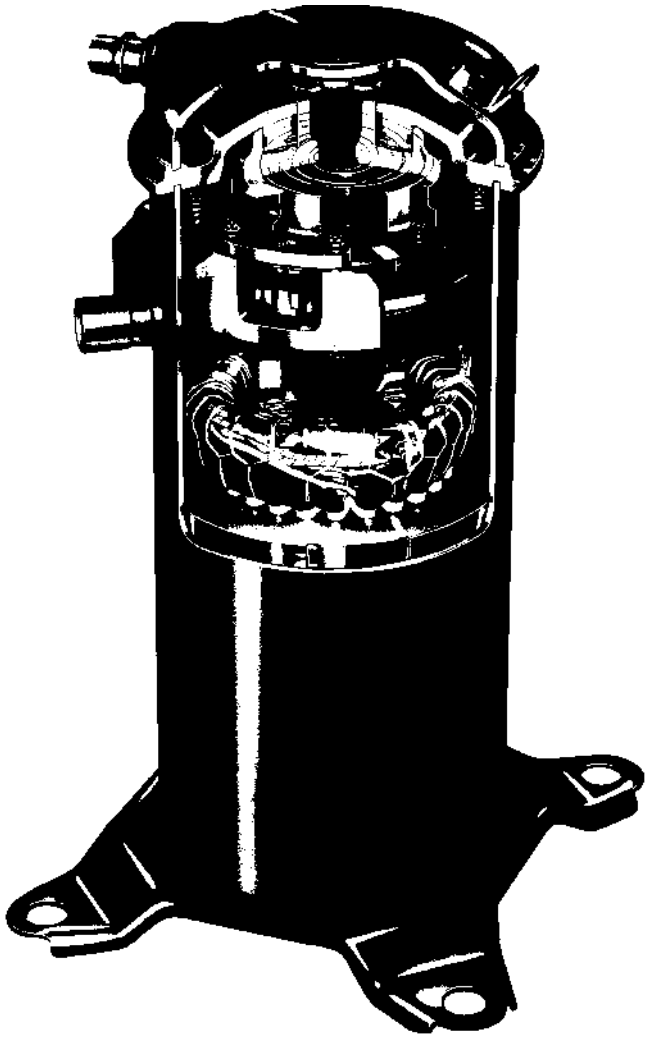
COMPLIANT SCROLL COMPRESSOR TECHNOLOGY



COPELAND COMPLIANT SCROLL COMPRESSOR

LENNOX Industries Inc.

Copeland Compliant Scroll

GENERAL

During the past 30 years, piston compressors have been the workhorse of the residential air conditioner and heat pump market. Piston compressor technology has traditionally offered good efficiency levels and, through proper design and application, have become very reliable for both air conditioner and heat pump applications. In addition, the design and operating parameters of piston compressors are well developed and understood, and the technology presents no particular manufacturing problems.

Industry requirements placed on systems are changing however, with the requirements on compressors changing accordingly. Competition, high energy costs, and pending federal regulations are compelling air conditioner and heat pump manufacturers to develop even more efficient systems for the future. To do this cost effectively (for example, without inordinate heat exchanger size) will require compressor efficiencies higher than piston compressor technology can achieve. At the same time, consumers are beginning to demand improved comfort characteristics from air conditioner and heat pump systems. In addition, system sound level is becoming a greater concern, with an increasing number of local regulations placing restrictions on the sound levels of systems.

In the future, market demands will move the air conditioning industry to expand its product lines into modulated systems (two speed, variable speed, etc.) in order to further improve efficiency and comfort levels. These requirements will pose even greater challenges on compressor technology.

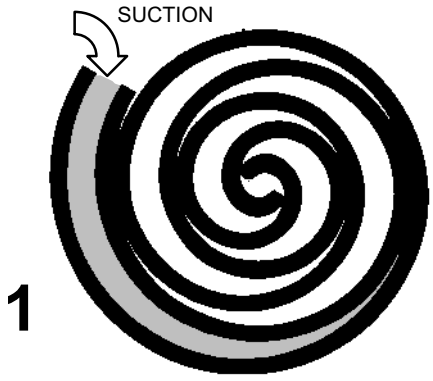
These demands will lead the air conditioning industry away from piston compressor technology to more advanced, and inherently superior, compressor technologies. Scroll compressor technology offers many features required to meet the future needs of air conditioner and heat pump systems.

HOW A SCROLL WORKS

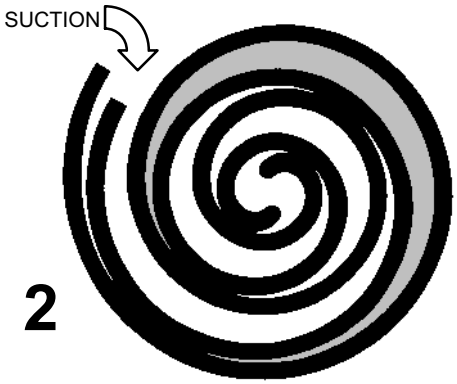
The scroll is a simple compression concept centered around the unique involute spiral shape of the the scroll and its inherent properties.

Two identical scrolls are mated together forming concentric spiral shapes. Refer to Figure 1.

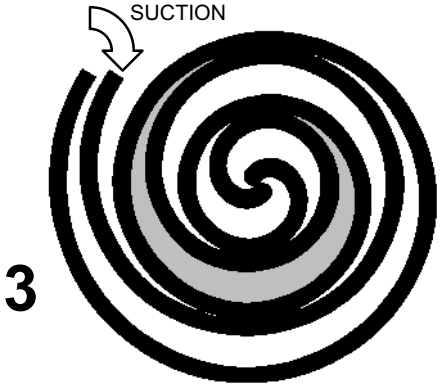
SCROLL GAS FLOW



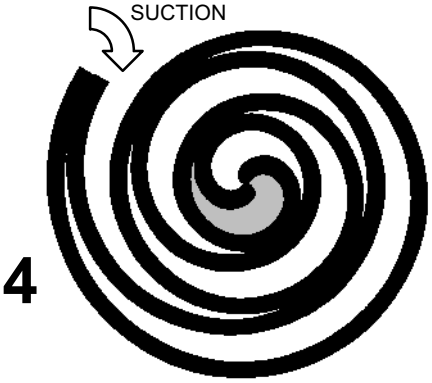
Compression in the scroll is created by the interaction of an orbiting scroll and a stationary scroll. Gas enters an outer opening as one of the scrolls orbits.



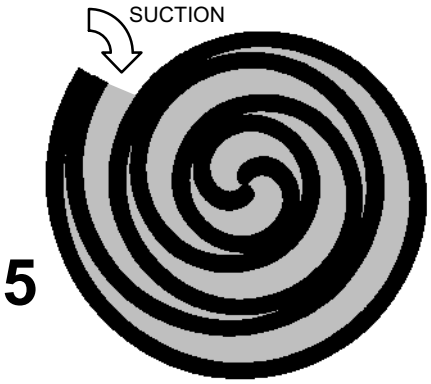
The open passage is sealed off as gas is drawn into the scroll.



As the scroll continues to orbit, the gas is compressed into an increasingly smaller pocket.



By the time the gas arrives at the center port, discharge pressure has been reached.



Actually, during operation, all six gas passages are in various stages of compression at all times, resulting in nearly continuous suction and discharge.

FIGURE 1

During compression, one scroll form (fixed scroll) remains stationary while the other scroll form (orbiting scroll) is allowed to orbit around it. Note that the orbiting scroll does not rotate or turn but merely "*orbits*" the stationary scroll.

The orbiting scroll draws gas into the outer crescent-shaped gas pocket created by the two scrolls. The centrifugal action of the orbiting scroll seals off the flanks of the scrolls.

As the orbiting motion continues, the gas is forced toward the center of the scroll and the gas pockets become compressed. When the compressed gas reaches the center, it is discharged vertically into a chamber and discharge port in the top of the compressor. The discharge pressure, forcing down on the top scroll, helps seal off the upper and lower edge tips of the scrolls.

During a single orbit, several pockets of gas are compressed simultaneously, providing smooth, continuous compression. Both the suction process (outer portion of the scroll members) and the discharge process (inner portion) are continuous.

ADVANTAGES OF THE SCROLL DESIGN

When compared to piston compressor technology, the scroll compressor offers several significant advantages:

Scroll is Simple

Only two components, a fixed scroll and orbiting scroll, are required to compress gas. These two components replace the approximately fifteen components in a piston compressor which are required to do the same work (refer to Figure 2).

Scroll is Efficient

The Scroll compressor offers three efficiency advantages over a piston compressor:

1. The suction and discharge processes of a scroll compressor are physically separated, reducing heat transfer between suction and discharge gas (refer to Figure 3). In a piston compressor, the cylinder is exposed to both suction and discharge gas, resulting in high heat transfer. This reduces the efficiency of the compressor.

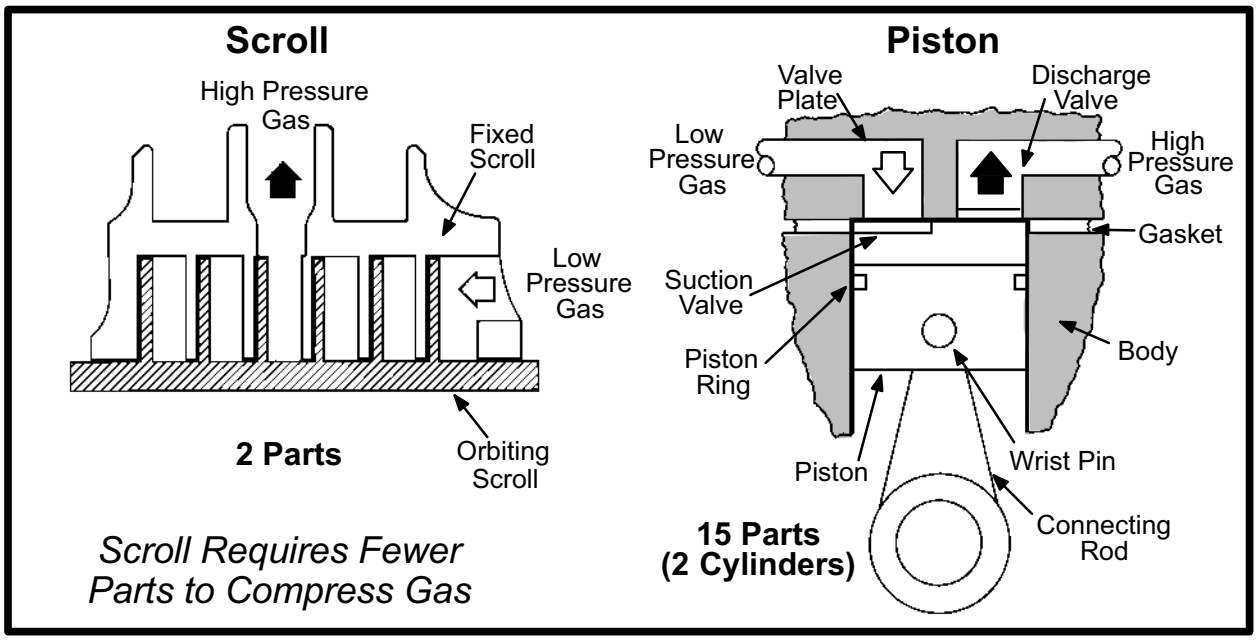


FIGURE 2

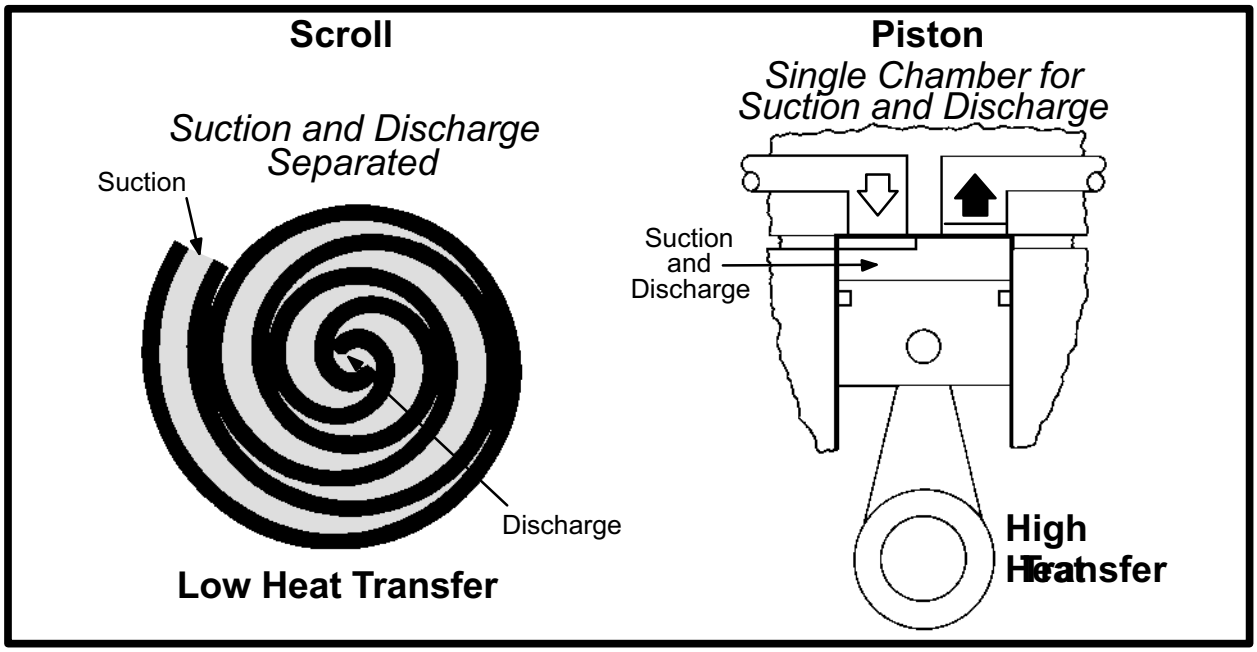


FIGURE 3

2. The scroll compression and discharge process is very smooth. A scroll compresses gas in approximately 1-1/2 revolutions as compared to less than half of a revolution for a piston compressor. The discharge process occurs for a full 360 degrees of rotation versus 30-60 degrees of rotation for a piston compressor (refer to Figure 4).

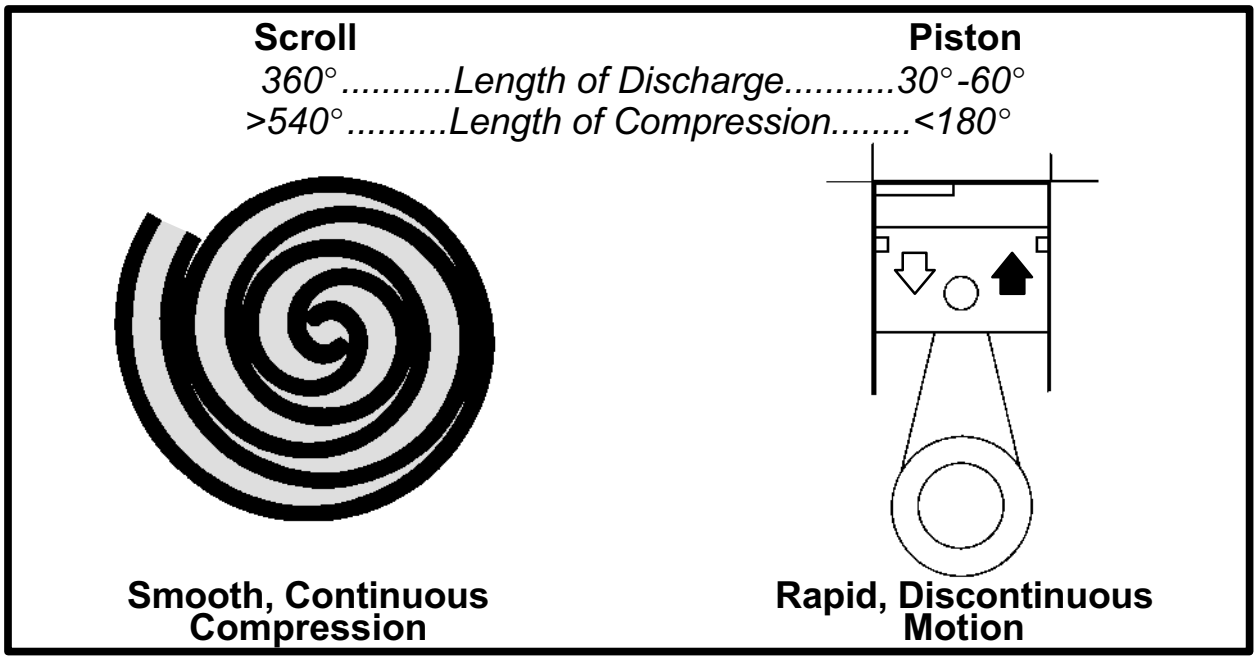


FIGURE 4

3. The scroll compressor has no valves. While a piston compressor requires both suction and discharge valves, the scroll design does *not* require a dynamic valve (refer to Figure 5). This eliminates all valve losses.

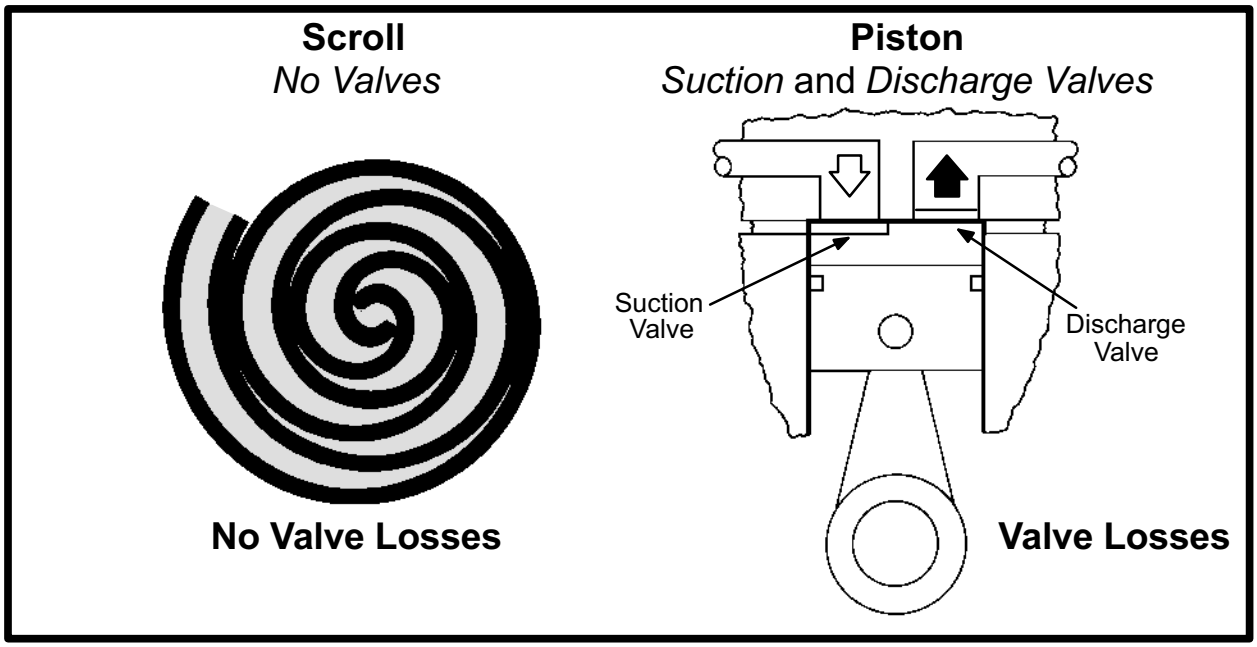


FIGURE 5

The result, as shown in Figure 6, is that the scroll compressor is inherently 10-15 percent more efficient than a piston compressor.

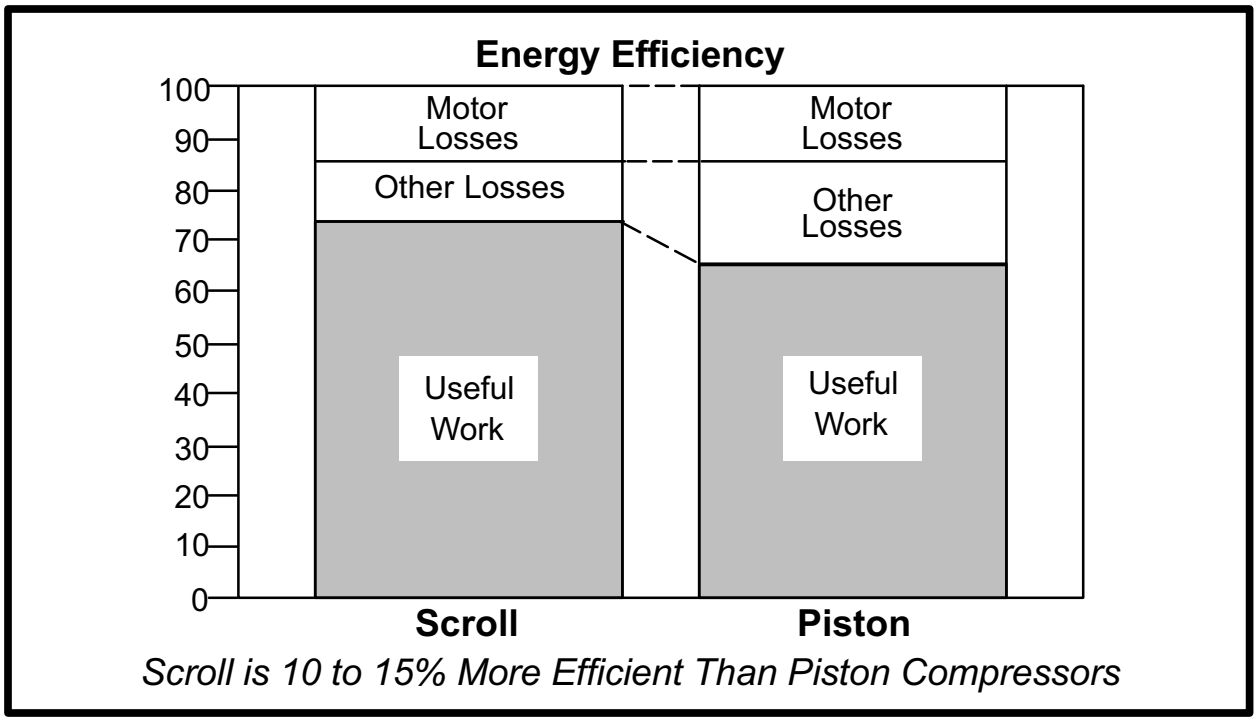


FIGURE 6

Scroll has High Heat Pump Capacity

In heat pump applications, a piston compressor generally lacks adequate capacity to heat a home at low outdoor temperatures. This problem is partially due to the decrease in volumetric efficiency of a piston compressor in low temperature heat pump operation. The loss of volumetric efficiency is due to re-expansion volume within the piston cylinder. Re-expansion gas is that which is compressed but not fully discharged during the discharge process. It subsequently re-expands during the suction process, consuming part of the volume of the cylinder. This volume effectively reduces the displacement of the compressor and reduces the capacity accordingly.

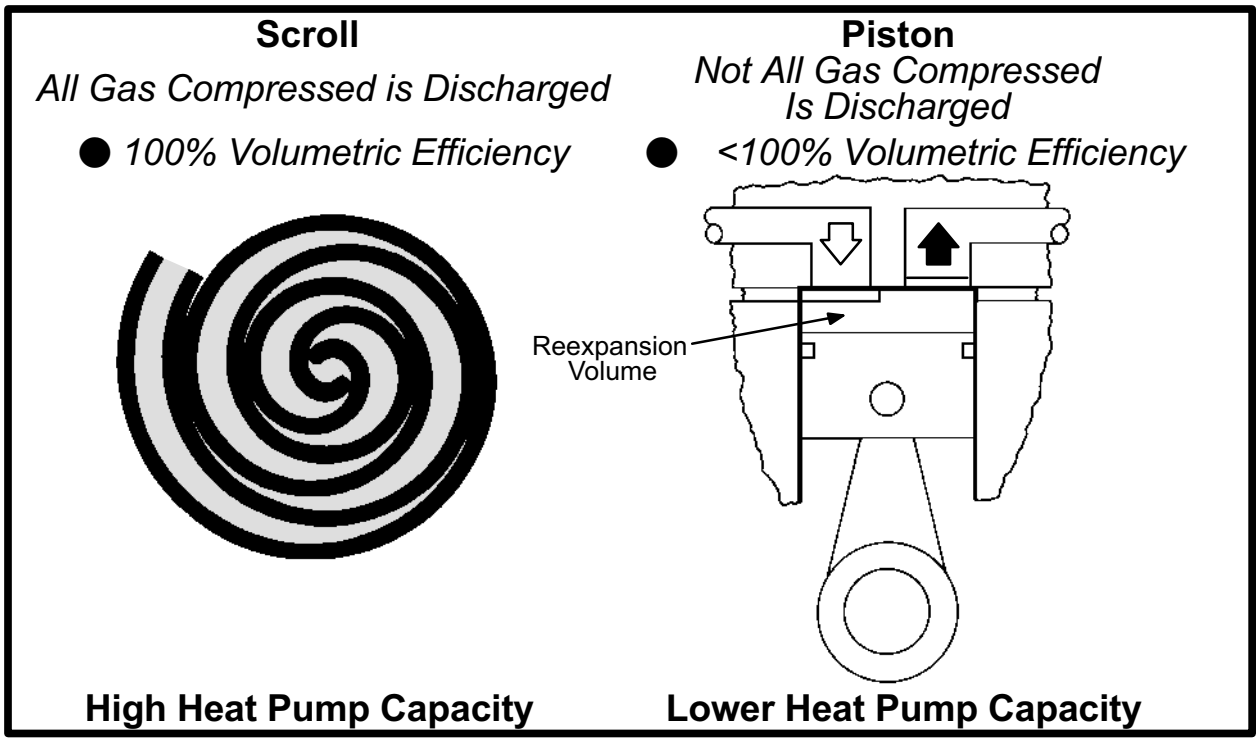


FIGURE 7

A scroll compressor has *no* re-expansion volume (refer to Figure 7). All gas that is trapped in the compression process in the outer pocket of the scroll members is released through the discharge port. This means that the scroll compressor inherently has a higher heat pump capacity than a piston compressor at a given outdoor temperature.

Scroll is Quiet

A scroll compressor has extremely limited motion which, unlike a piston compressor, can be perfectly balanced. Because suction and discharge flow is continuous, a scroll compressor has very low gas pulses. No dynamic valves are required in a scroll compressor, so valve noise, a common problem in a piston compressor, is not a factor.

Scroll is Durable

While a piston compressor has been designed to be durable in residential air conditioner and heat pump systems, significant design effort and system cost is required to protect the compressor from liquid slugging and debris in the system. A scroll compressor can be designed to be compliant to both liquid and debris. This can be done by allowing the scroll forms to separate from each

other in the presence of contaminants or liquid. This feature allows a compliant scroll compressor to have superior tolerance to liquid and debris. Compliance has the added benefit of allowing the scrolls to "*Wear-In"* over time; that is, to increase compressor and system efficiency with running time.

Compliance refers to the method in which the two scroll members interact to achieve high efficiency and durability simultaneously. The unique and patented Copeland Compliant Scroll Compressor, with both radial and axial compliance, has several advantages:

1. Continuous flank contact, maintained by centrifugal force, minimizes gas leakage and maximizes efficiency.
2. Radial compliance allows the scroll members to separate in the presence of liquid refrigerant or debris, eliminating high stress in the members and substantially improving the durability of the compressor.
3. Axial compliance allows the scroll tips to remain in continuous contact in all normal operating conditions, ensuring minimal leakage ... without the use of tip seals. This means the scroll performance will *not* degrade over time because there are no seals to wear and cause gas leakage.

Because of the radial and axial compliance feature, the Copeland Compliant Scroll Compressor has unprecedented liquid handling capability. No suction line accumulator or compressor crankcase heater is required. In addition, it is designed to start under any system load. This feature eliminates the need for a compressor start relay or start capacitor. Combined, these characteristics simplify the system design, reduce the system operating costs, and increase the durability of the system.

CONSUMER BENEFITS OF SCROLL COMPRESSORS

Figure 8 shows a demand curve for a typical single-family residence. The curve plots the heating and cooling requirements in 1,000 BTUH versus outdoor ambient temperature. This curve is for a residence which requires approximately 36,000 BTUH of cooling (3 tons) at 95°F ambient. Figure 9 shows heating and cooling capacities for a typical piston compressor heat pump system versus outdoor ambient temperature. Comparing system capacity versus residence demand illustrates several items (refer to Figure 8):

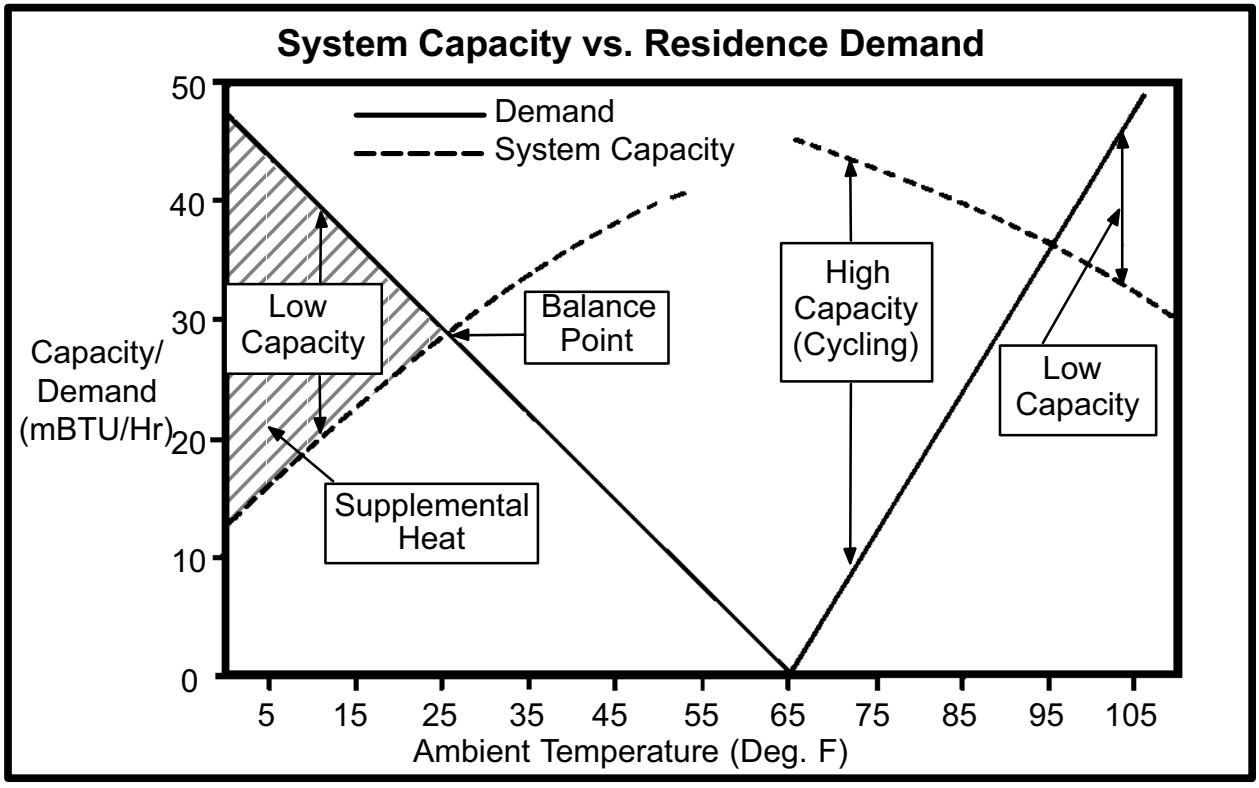


FIGURE 8

1. Above the air conditioning balance point (95°F), both systems have inadequate capacity to maintain comfort in the home.

2. Below the air conditioning balance point, both systems have excess capacity. This presents two problems:

   a. Excess system capacity loads the system coils more heavily than necessary, resulting in less than optimal system efficiency.

b. The system must cycle on and off more often to match the demand of the home, resulting in additional efficiency losses and reducing the comfort in the home due to less latent load removal.

3. In heat pump operation, the heat pump is only able to satisfy the demand of the home down to a certain outdoor temperature (typically around 25°F). Below that temperature, supplemental heat is required, which is expensive to the homeowner.

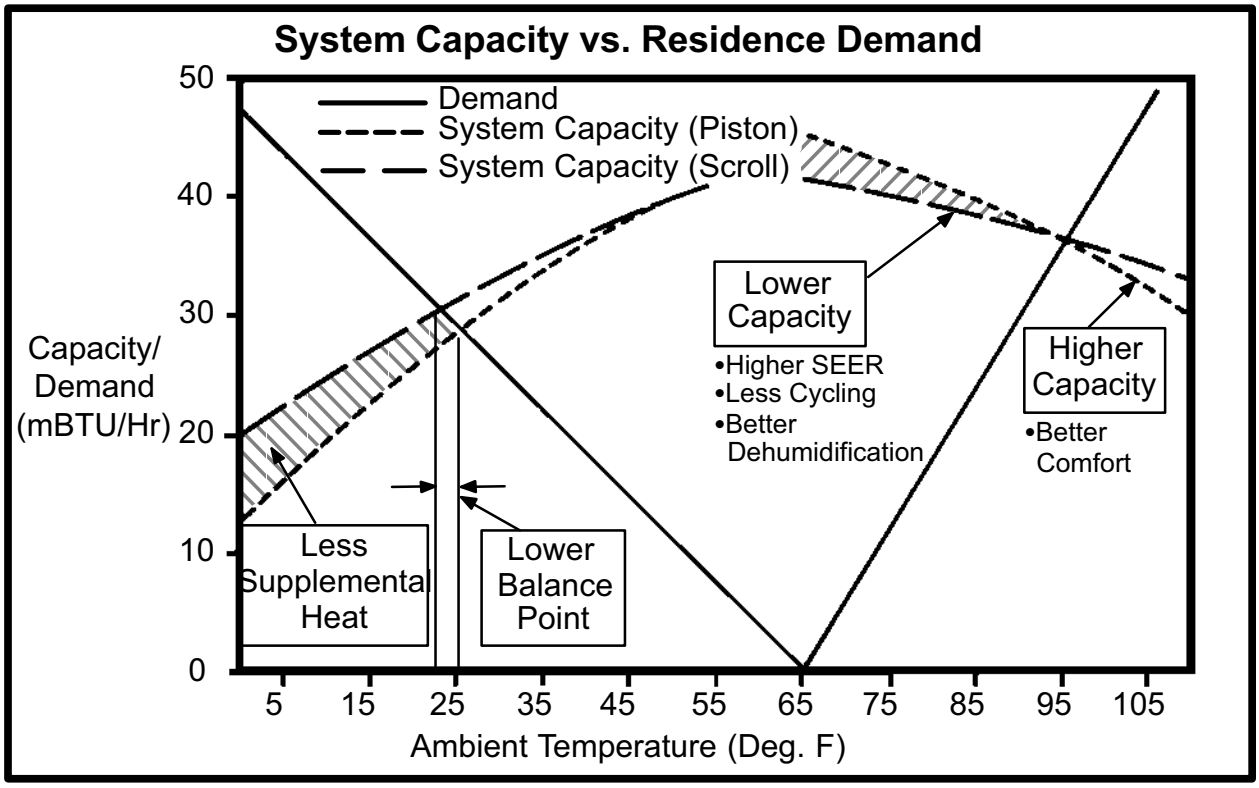


FIGURE 9

A comparison of the capacity curves of the scroll compressor system with the piston compressor reveals the following improvements in system performance which occur as a result of the high volumetric efficiency of the scroll compressor (refer to Figure 9):

1. The scroll compressor system has a higher capacity in high outdoor temperature air conditioning, resulting in increased comfort in the home.

2. The scroll compressor system has less capacity in moderate outdoor temperature air conditioning, resulting in reduced coil loading and improved effi-

ciency, as well as less cycling for improved dehumidification and increased comfort in the home.

3. The heating capacity of the scroll compressor system is higher than the comparable piston compressor system. This results in a lower balance point and less supplemental heat requirements for the scroll compressor system. In addition, the increased heating capacity of the scroll compressor system will result in warmer air temperatures at the registers for increased comfort in the home.

The benefits of the improved capacity characteristics of the scroll compressor system are further augmented by the inherent higher efficiency of the compressor. These combined advantages result in scroll compressor heat pump systems having substantially higher efficiency in both the heating and cooling modes.

SUMMARY

The Copeland Compliant Scroll Compressor's inherent high efficiency and durability make the scroll compressor the ultimate technology for compressor designs of the future.

In addition, future system design will move beyond the realm of conventional single-speed systems to more advanced designs utilizing capacity modulation and variable speed. As these designs develop, the scroll compressor will become an even more important compressor technology to the industry. The smooth, continuous compression characteristics of the scroll compressor and the elimination of valving makes the scroll an ideal compressor for enhanced applications such as two-speed and variable speed.

Lennox Industries, Inc. gratefully acknowledges the assistance of Ed Purvis of Copeland Corporation in the development of this manual. Without his help, the manual would not have been possible.

Lennox Form No. CSC 881-L5

Litho U.S.A.