COMPRESSOR HANDBOOK

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CHAPTER 12
SCROLL COMPRESSORS

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Initial patents for the scroll concept date back to the early 1900's. Unfortunately the technology to accurately make scrolls did not exist and the concept was forgotten. In 1972, the scroll concept was re-invented.

The potential and advantages of the scroll compressor over reciprocating compressors were immediately recognized by the refrigeration industry. Because of the tremendous pressure for better efficiency of refrigeration compressors in the early '70s, there was a strong incentive to pursue the scroll: the balanced rotary motion reduced noise and vibration; there were no valves to break; and valve noise and valve losses were eliminated; fewer parts were needed; and rubbing velocities, along with associated frictional losses were lower. Not only did the scroll compressor offer improved efficiency, it also had the added benefit of greater reliability, smoother operation and lower noise. Today, scroll compressors are used extensively for residential and automotive air conditioning by many well known companies.

The development of scroll type compressors for air has not been as rapid. Air is much more difficult to compress than refrigerant, especially when oil is not used for sealing and cooling. By the '90s, machine tool technology had progressed to the point where scrolls could be accurately made and the first dry, oilless scroll compressor was introduced in January, 1992. The oilless scroll air compressors had the same inherent features as the scroll refrigeration compressor when compared to reciprocating oilless air compressors, durability, reliability, lower noise and vibration.

Currently scroll refrigerant compressors are well established as the standard of the industry. Scroll air compressors are extending from the initial three and five horsepower models into larger and smaller sizes from one to ten horsepower. Figure 12.1 shows typical scroll air compressors ranging in size from 1/8 to 1.0 hp.

Recently introduced technology is expected to make scroll air compressors practical in the fractional horsepower sizes.

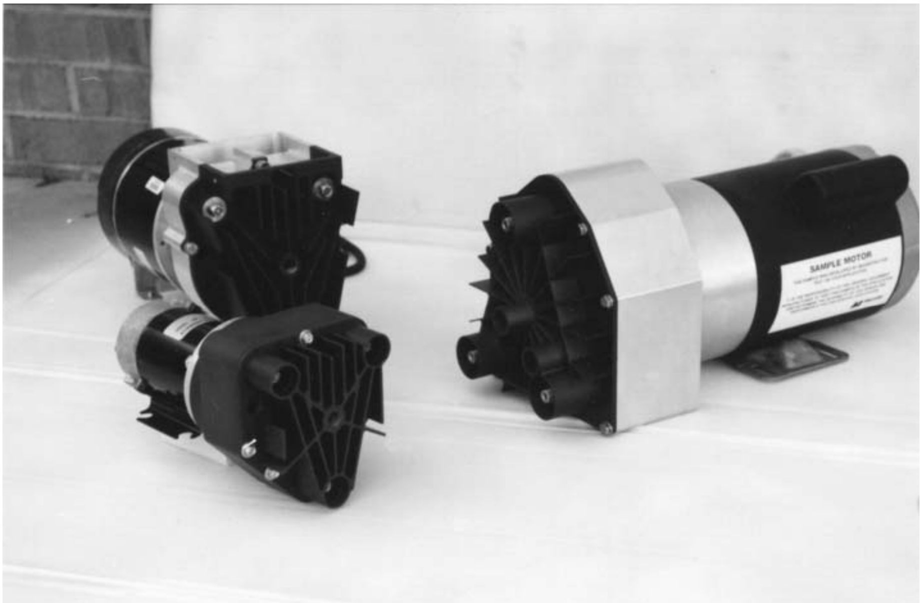

FIGURE 12.1 Scroll air compressors from 1/8 to 1.0 HP.

12.1 PRINCIPAL OF OPERATION

The fundamental shape of a scroll is the involute spiral. The involute is the same profile used in gear teeth. An involute is a curve traced by a point on a thread kept taut as it is unwound from another curve. The curve that the thread is unwound from, that is, used for scrolls, is a circle. The radius of the circle is the generating radius.

A scroll is a free standing involute spiral which is bounded on one side by a solid flat plane, or base.

A scroll set, the fundamental compressing element of a scroll compressor, vacuum pump or air motor, is made up of two identical involutes which form right and left hand components. One scroll component is indexed or phased 180 degrees with respect to the other to allow the scrolls to mesh, as shown in Fig. 12.2. Crescent shaped gas pockets are formed bounded by the involutes and the base plates of both scrolls. As the moving or orbiting scroll is orbited about the fixed scroll, the pockets formed by the meshed scrolls follow the involute spiral toward the center and diminish in size (the motion is reversed for an expander or air motor). The orbiting scroll is prevented from rotating during this process to maintain the 180 degree phase relationship of the scrolls.

The compressor or vacuum pump's inlet is at the periphery of the scrolls. Air is drawn into the compressor as the inlet is formed as shown in Fig. 12.2. *b, c,* and *d.* The entering gas is trapped in two diametrically opposed gas pockets, Fig.

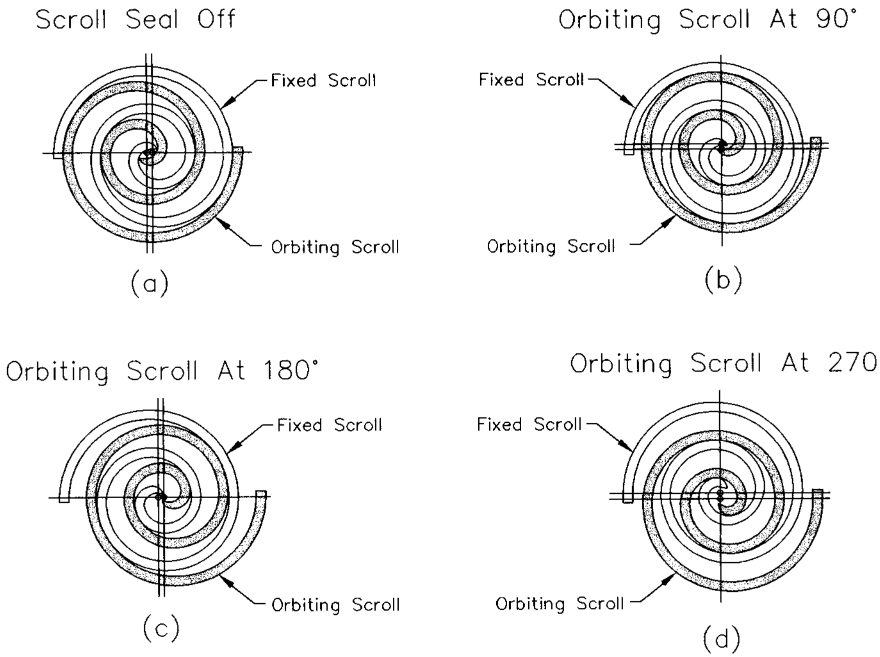

FIGURE 12.2 Scroll compressor operation.

12.2 *a*, and compressed as the pockets move toward the center. The compressed gas is exhausted through the discharge port at the center of the fixed scroll. No valves are needed since the discharge is not in communication with the inlet. Figure 12.2 shows the scroll positions as the line connecting the centers of the two scrolls is rotated clockwise, illustrating how gas pockets diminish in size as the orbiting scroll is orbited.

12.2 ADVANTAGES

Scroll refrigerant compressors, air compressors and vacuum pumps have the following advantages:

- Scroll compressors can achieve high pressure. The pressure ratio is increased by adding spiral wraps to the scroll. Pressures as high as 100 to 150 psig can be achieved in a single-stage air compressor.
- Scroll compressors are true rotary motion and can be dynamically balanced for smooth, vibration-free, quiet operation.
- There are no inlet or discharge valves to break or make noise and no associated valve losses.
- Scroll compressors can be oil flooded, oil lubricated, or oil free.

- Due to the unique orbital motion, the rubbing velocities of the sliding seals are significantly less than piston rings or vanes for comparable speeds. Rubbing velocities are typically 30 to 50% less, resulting in greater durability.
- Air is delivered continuously, therefore there is very little inlet or discharge pulsation and associated noise.
- The scroll compressor has no clearance volume that gets re-expanded with associated losses. The compression is continuous.
- Noise levels 3 to 15 dBA lower than other compressor technology are typical.

Table 12.1 gives some typical performance for scroll compressors operating on air.

12.3 LIMITATIONS

Although scroll compressors continue to expand into larger and smaller sizes, there are limitations. Since the scroll has a leakage path at the apex of the crescent shaped pockets, there are limits to how small a scroll compressor can be as a function of discharge pressure. Large displacement scroll compressors become large in diameter and the moving or orbiting scroll becomes massive. The maximum centrifugal force generated by the orbiting scroll gives a practical maximum size in a single-stage scroll.

12.4 CONSTRUCTION

Minimizing leakage of compressed gases within the scrolls is the key to performance in a scroll compressor.

There are two primary leakage paths in a scroll compressor. There is a leakage path at the apex of the crescent shaped air pockets where the scroll involves are

TABLE 12.1 Typical Performance Data of Scroll Air Compressors

Nom. power (HP)	Speed (RPM)	Disch. press. (PSIG)	Air flow (ACFM)	Sound power (dBA@ 1 m)
5.0	3050	120	15.0	59
3.0	2630	120	9.0	59
1.0	3450	100	4.0	NA
0.3	1750	30	3.0	49
0.02	3000	10	0.3	39

in closest proximity. This leakage is minimized by running the scrolls with a very small gap at these points. The size of the gap at the apex of the air pockets is a function of scroll geometry, and the scroll geometry is a function of the scroll manufacturing process.

There is also a leakage path between the tip of the involute and the opposite scroll base. Since the involute is relatively long if stretched out, this path is of primary importance. This leakage path is sealed by either, running the scrolls very close together and using oil to seal the remaining gap or using a floating tip seal as shown in Fig. 12.3. The floating tip seal acts much as a piston ring in a piston type compressor and bridges the running gap between the scrolls. For oil-free compressors, the tip seals are made of self lubricating materials.

Driven by a demand from the refrigeration industry, machine tool builders have improved the speed and accuracy of scroll manufacture. These new machine tools can produce finished scrolls in one to five minutes with involute accuracy of 0.0002 to 0.0005 inch and with good surface finish. Spindle speeds as high as 30,000 RPM are typical machining scrolls made of aluminum or cast iron. Most of the major machine tool manufacturers have standard scroll machining centers.

12.4.1 Lubricated Scroll Compressors

Typically scroll compressors used as refrigerant compressors are oil lubricated. Lubrication greatly simplifies the compressor design. Design features include:

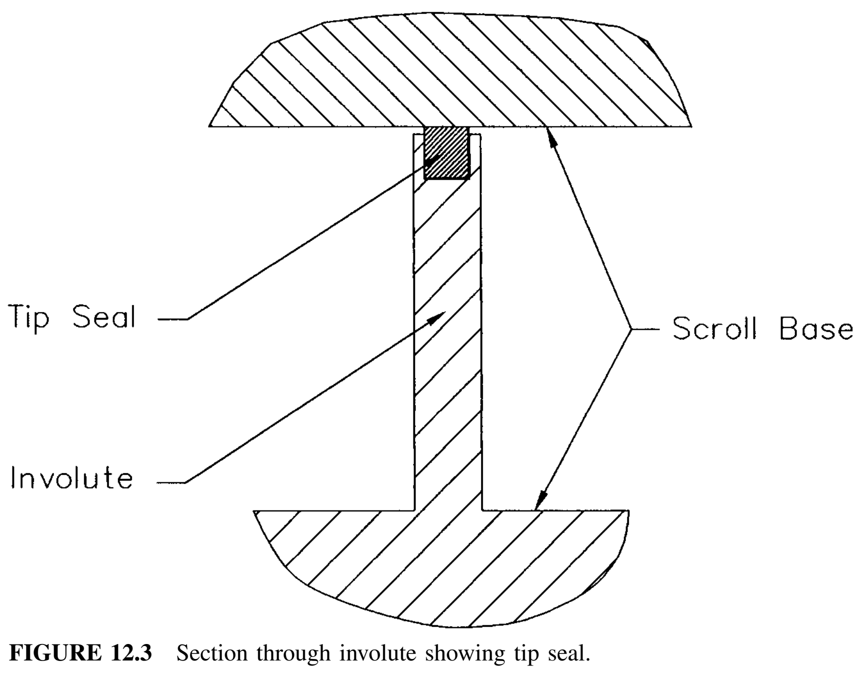

FIGURE 12.3 Section through involute showing tip seal.

FIGURE 12.4 Typical scroll showing idler shafts.

- Cast iron or aluminum scrolls with no special coatings or surface treatment required
- A simple eccentric drive at the center of the orbiting scroll
- A flat plate thrust bearing to support and locate the orbiting scroll axially

Since refrigerant compressor are hermetically closed systems, no special oil clean up is needed at the discharge. The oil can simply circulate through the refrigeration system and return to the compressor to seal and lubricate.

12.4.2 Oilless Scroll Compressors

Oilless or oil-free scroll compressors are typically used for air and other gases where the cost of oil clean up is a factor, or where zero oil can be tolerated in the discharge. Design features include:

- Cast iron or aluminum scrolls coated to improve corrosion and wear resistance
- Tip seals are required for good performance and are made of a self lubricating material.
- Idler shafts supported by sealed rolling element bearings are used to support the axial thrust load, locate the orbiting scroll axially and maintain the 180 degree scroll phase relationship. See Fig. 12.4.

12.5 APPLICATIONS

Scroll compressors can primarily be used in those applications where its advantages are of benefit, specifically low vibration and noise, and durability. Although scroll compressors can be cost competitive, if cost is the most important factor, alternative technology should also be considered.

Some possible applications are given below.

- Residential air conditioning
- Automotive air conditioning
- Process controls
- Pneumatic controls
- Laboratory
- Home health care
- Medical and hospital
- Computer peripherals
- Optical equipment

Scroll compressors can be used where vane or reciprocating compressors are used. They can be dry or oil lubricated.