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Scroll Compressors for AC & R Applications

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Maneurop, France was the first European manufacturer to introduce its scroll compressor range in July 1992. Danfoss, Denmark purchased Maneurop in 1993 and launched the Danfoss Maneurop PerformerR

The concept of a scroll compressor was originally proposed almost a hundred years ago but progress in its further development and commercialization was delayed because of technical problems in machining the scroll with tolerances in the region of 10 microns and below.

Commercial air conditioning equipment manufacturers all over the world who incorporate hermetic compressor technology in their products are faced with new technical challenges as their design must comply with environmental regulations and must achieve ever higher energy efficiency levels. Reduced sound and vibrations are also high on the priority list of end users of these products. The compressor is the key element in supplying a product that meets these requirements and these challenges set the pace for scroll development.

There are a number of scrolls in production worldwide with differing design approaches. Launched in 1997 the Danfoss Maneurop Performer® scroll compressor represents one of the most advanced scroll technologies on the market which has demonstrated its durability and reliability a wide variety of applications from liquid chillers to split air conditioners from rooftop units to close control air conditioners and from heat reclaim to heat pump units.

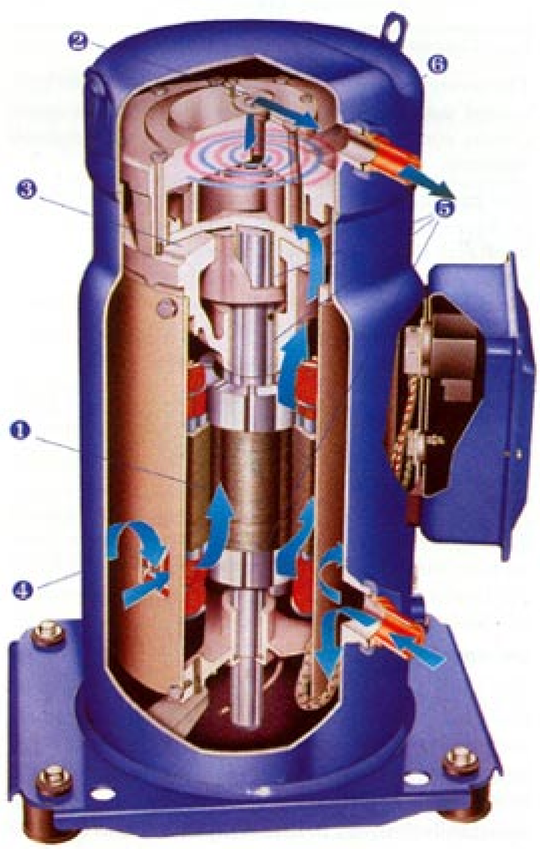


Fig. 1 Inside view of a Maneurop scroll

The principle of scroll compression

In a Maneurop Performer® scroll compressor, the compression is performed by two scroll elements which are located in the upper part of the compressor, above the motor. (See **Figure 1**) Suction gas enters the compressor at the suction connection. The gas flows around the motor and enters its housing at the bottom side through openings. Oil droplets separate from the suction gas and fall in the oil sump. All gas passes through the electrical motor ensuring full motor cooling in all applications.

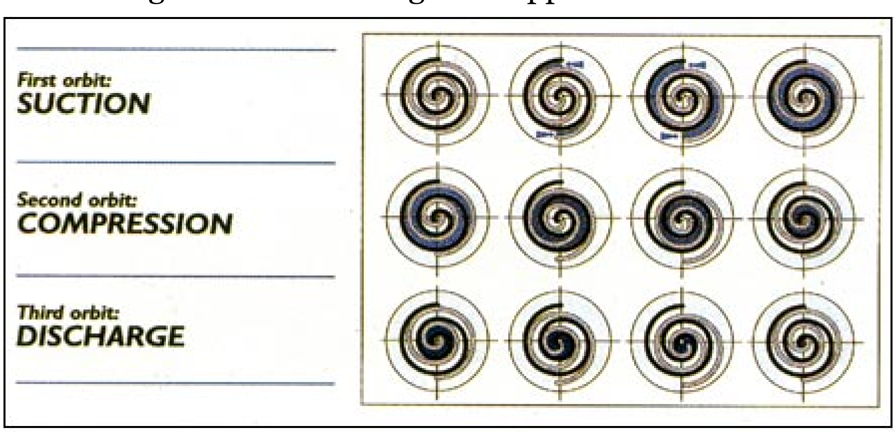


Fig. 2 Compression process of a Maneurop scroll

After leaving the electric motor, the gas enters the scroll elements. There are two scroll elements; an orbiting scroll and a fixed scroll. **Figure 2** shows the compression process. The center of the orbiting scroll describes a circular path around the center of the fixed scroll. This movement creates compression pockets between the two scroll elements.

Low pressures suction gas is trapped in each peripheral pocket as it is formed; continued motion of the orbiting scroll seals the pocket, which decreases in volume as the pocket moves towards the center of the scroll. Maximum compression is achieved when a pocket reaches the center where the discharge port is located.

This happens after three complete orbits.

The compression is a continuous process. When gas is being compressed in the second orbit, another quantity of gas enters the scrolls and a quantity of gas is being discharged at the same time.

A check valve is located directly above the fixed scroll discharge port. This prevents the compressor from running backwards after the power has been switched off. Finally the discharge gas leaves the compressor at the discharge connection.

Design features

The second generation Performer® scroll has several features that help improve performance and reduce energy consumption to a level where the Maneurop scroll consumes 12% less power than and equivalent reciprocating compressor.

Specifically designed to reduce pressure losses 1 and 2

Low pressure

Pressure drops in refrigeration equipment waste energy. The new design limits refrigerant gas pressure drop inside the compressor.

Motor gas path flow dimensions have been increased. Refrigerant passes between he rotor and the stator and into the slots around the stator. This considerably reduces pressure losses.

Additionally, this design permits extremely efficient motor cooling and guarantees excellent service life for this fundamental compressor component.

Suction pressure losses have thus been reduced considerably.

High pressure

During the discharge phase, pressure losses occur when the refrigerant flows through occur when the refrigerant flows through the check valve and the other gas channels. To obtain a more efficient discharge process discharge ports have been enlarged and the gas pocket opening process has been optimized.

To optimize the path section, the check valve is now based on an annular valve design.

Bearings and a thrust bearing which absorb less energy5 and 3

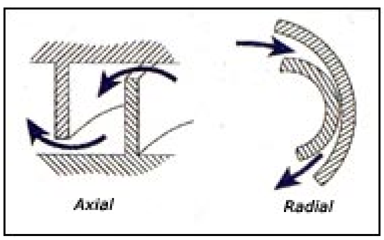
The compressors are now fitted with journal bearings to counteract compression loads. The axial loads on the orbiting scroll caused by the pressure for the gases between the two Scrolls are counteracted by a hydro-dynamic thrust bearing.

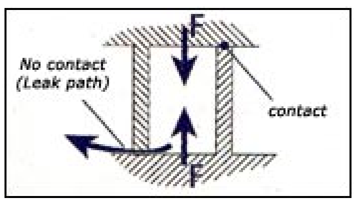
The bearings, thrust bearing designs and lubricant were all selected to optimize compressor efficiency.

Inter-scroll leakages reduced to the strict minimum 6

Compressor performances are directly related to internal leakage and other losses. To ensure hermetic sealing and reduce:

- Axial leakage (between scroll vane tip and opposite scroll baseplate)
- Radial leakage (between scroll vane flanks) the choice of technology is essential.

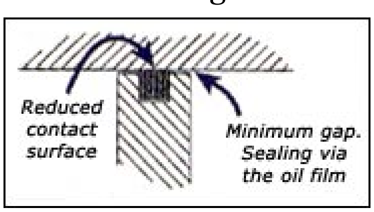




The technologies used by the competition seal the tips of the scrolls by pressing them firmly onto each other. This technology has two serious drawbacks as shown in he diagrams alongside.

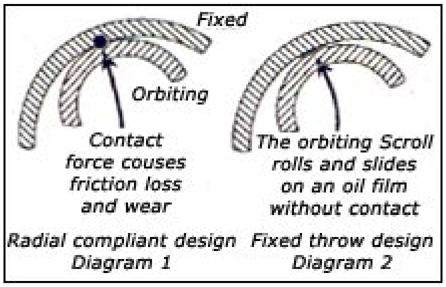
<u>Axial sealing system</u>

Using technology which is totally different from most of its competitors - a unique concept which maintains the two scrolls in dynamic contact via a floating seal to guarantee perfect axial sealing with low contact forces. This reduces energy losses caused by friction.



<u>Radial sealing system</u>

Leading edge machining technologies ensures exceptionally high geometrical land dimensional accuracy. Radial compliant design (i.e. the contact between the flanks of the scrolls) is no longer necessary (**diagram 1**). Sealing is via an oil seal with no mechanical contact between the scrolls (**diagram 2**)



Less vibration and fewer decibels

The compactness of the new design, the reduction in the number of moving parts and extremely accurate machining are all new developments which make scroll compressors better balanced and significantly reduce vibration and noise levels.

Leading-edge production technology 6

Due to major investments in innovative, leading-edge machining technologies tolerances are measured in microns.

This extraordinary accuracy, combined with "high scroll involutes" reduces inertia forces, vibrations and noise generated by the compressor and considerably reduces noise levels during compression.

A "quieter" design 4

The design of the base, an integral part of the lower compressor shell and new rubber grommets reduce the load transmitted to the structure by a factor of 4 and also contributes to a reduction in the levels of noise radiated by the system and in vibrations transmitted to the unit in which the compressor is installed.

The journal bearings used in these new generation compressors also contribute to their exceptional acoustic and vibration properties.

The new silent discharge check valve, efficient on the whole compressor application ranges, prevents reverse rotation at shut-down (i.e. no rattling and no shut-down noise.).

Even greater reliability

The simplified design, the reduction of the number of moving parts and enhanced stability achieved by high precision machining technologies reduce stresses and strains inside the compressor.

All Maneurop scroll compressors are designed and tested to guarantee they meet customer expectations. And the results give exceptionally long service life and enhanced reliability.

The quality quest of every compressor means that eventually end users can forget they exist. Compressors must be trouble-free components for manufacturers, installers and maintenance personnel alike.

Why scroll compressors are superior to recips

Having read this article thus far it will be obvious to the average reader that the technology of the scroll compressor is far superior to reciprocating technology and there are several reasons for this:

• Reliability

On an average, the scroll has 64% fewer moving parts. There are no pistons, connecting rods, suction and discharge valves, springs and the heavy crankshaft. Due to its rotary action there is much less torque in scroll compressors compared to the high torque generated by the pumping action of a reciprocating compressor. This combined with fewer moving parts reduces the stress on scroll compressors thus increasing their life and reliability.

• Greater tolerance to liquid slugging

Due to its compliant rotary design the scroll compressor can handle some amount of liquid slugging without damage unlike the reciprocating which cannot tolerate liquid slugging and is the major cause of failure of the reciprocating. This feature further enhances the reliability of the scroll.

• Lowers noise and vibration

Scrolls, due to their inherent design and rotary action have low vibration and sound levels compared to recips. Scrolls are not spring isolated inside the welded well land isolation is external only. A silent discharge check valve prevents reverse rotation shut down without any rattling and shut down noise.

• Energy efficient

Because of its higher volumetric efficiency, fewer moving parts, lower internal pressure drop and better machining tolerances the scroll compressor consumes 10 to 12% lower power than the recips.

Capacity limitations

Performer® compressors are available in sizes from 20kW (7 tons) to 50 kW (15 tons). This range will be extended upwards by the addition of new 60 and 75 kW (20 and 25 ton) models.

The need for larger capacity hermetic systems has led to the development of multi-compressor units using new scroll technology.

Why hermetics are mainifolded

Although there are many reasons for manifolding - installing compressors in parallel - two of the most important factors are part load efficiency and standardization of compressors.

Part load efficiency is greatly improved by using manifolding and cycling off the individual compressors in a set rather than unloading a large compressor. In a parallel system each compressor always operates at 100% load, therefore the part load efficiency is very near the cull load efficiency.

Conventional compressor unloading methods impose a serious penalty for part load operation efficiency.

The second of the reasons mentioned above, standardization of compressors, can be easily illustrated by a review of the present tandem range of units from Maneurop.

Previously 10, 15, 20, 25 and 30 HP compressor requirements were covered with 5 separate compressors. With manifolding, these needs are now covered by 2 basic compressors and tandem combinations, reducing the number of single compressors to be used from 5 to 2.

Design challenges

Developing such systems required evaluation and testing of the following:

Gas flow via oil sump.

Contrary to semi-hermetics, suctions gas flows via the sump in an hermetic designed compressor - it is therefore difficult to maintain equal pressure in the sumps of compressors mounted in parallel.

This can be achieved using a large pressure equalizer line, but in this configuration and under part load the inactive compressor is constantly vented by cool suction gas bypassing the normal suction gas route and reaching the active compressor via the equalizer line.

The end result of such a configuration is refrigerant migration into the oil and potential condensation of liquid refrigerant in the motor compressor assembly.

This led to the development of as small diameter of equalization line to prevent gas bypass.

Oil equalization

It ensures the basic function of transferring - balancing - oil between compressors. The design and location of the oil equalization line is critical as it may lead to compressor oil starving, overfilling or contribute to refrigerant migration as explained above.

Compressor sequence versatility

The sequence of operation shall be flexible enough to help equalize the running time of the compressors (this function is not fulfilled in a large compressor with an unloader).

It will be explained later in this article how it works with two compressor systems and why a fixed sequence of loading and unloading is required in three and four compressor configurations.

Interconnecting piping design

This is an area where the manufacturer can use its research and testing capabilities to the user's benefit.

Using factory designed and tested parallels systems guarantees smooth start-up and predictable reliability with a well designed piping configuration avoiding problem such as pipe vibrations, noise or ultimately pipe ruptures.

Compressor cycling influence

This is also a part of the manufacturers development program to make sure that whatever be the compressor cycling frequency, the oil management and the piping resistance are checked and comply with the engineering specifications.

Important note: in no case should the specified compressor cycling limit be exceeded i.e. Performer® compressors, 12 starts per hour.

Compactness serviceability

This has a lot to do with the way the compressor are designed, the way they are piped in parallel to insure a compact, easy to maintain, and easy to service design.

Application envelope

The domain of application and refrigerant types are evaluated to meet the requirements of the intended applications.

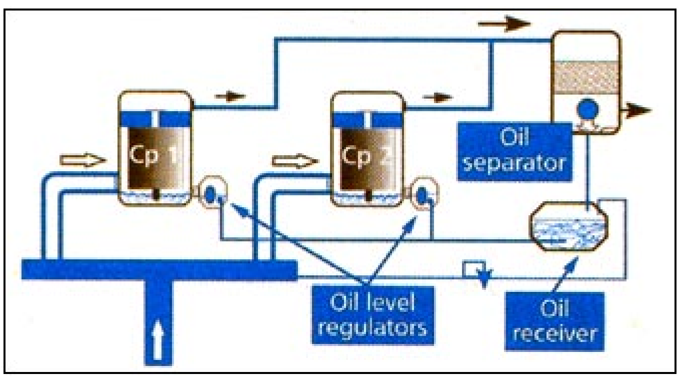
There is one last challenge which remains the responsibility of the air conditioning system designer and which conditions the success of the equipment: oil return from the circuit.

Oil management concepts

As explained, one of the challenges of manifolding is oil management. To ensure suitable distribution, several systems can be used.

Mechanical systems:

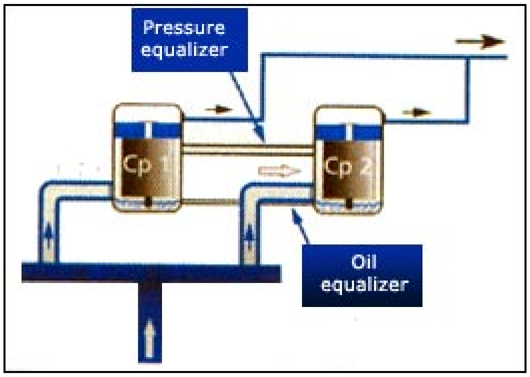
An oil separator feeds, via and oil reservoir, oil level regulators fitted on each compressor. Such a system allows good, predictable oil management and is acceptable in systems with a larger number of compressors, and multiple evaporators. However, this system requires a larger number of active components, each one having a risk of failure, and a significant cost. Besides, an additional amount of oil is required, which further increases the price of the whole system. Such oil management systems are widely used, particularly in large capacity refrigeration systems.



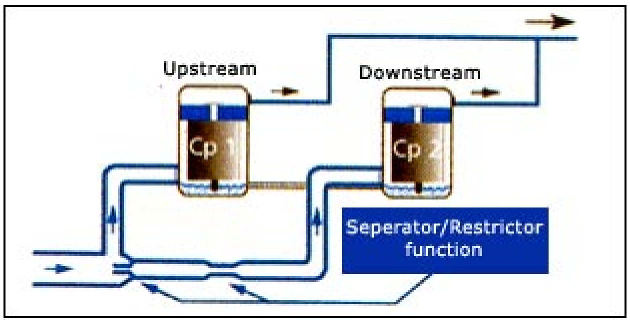
Static systems:

This is one of the most simple and cheapest ways of manifolding compressors: compressor sumps and low pressure shells are interconnected. A large interconnecting pipe, in the top part of the compressor shells, fulfils the compressor shell pressure balancing function. A smaller interconnecting pipe, in the lower part of the compressor (below the oil levels), ensures oil balancing. In addition, the design of the suction header is critical, as it ensures equal distribution or oil returning from the system when all compressors are running.

The success of such a system relies very much on the sizing of the pipe work and small difference in sump pressures can result in significant oil level variations. Furthermore, when one compressor is stopped, condensation of refrigerant in its sump is very likely to occur (cool suction gas bypassing via the large diameter pressure equalizing pipe).



Dynamic systems:

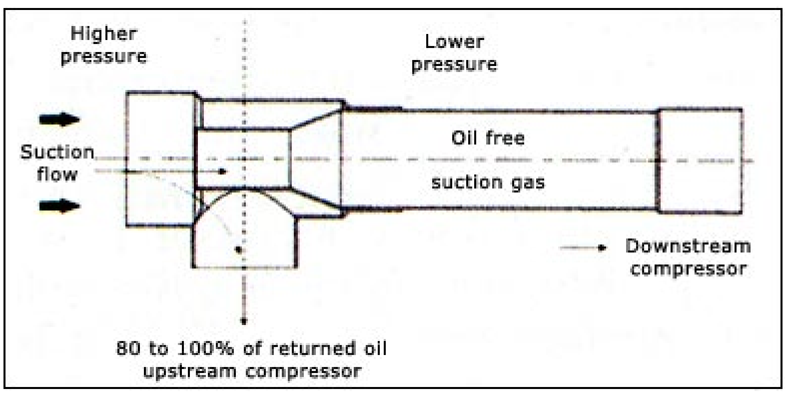


The dynamic system, shown above, provides a truly positive oil management, uniting the advantages of both mechanical and static systems, i.e. flexible oil management allowing a large number of compressors, simplicity and cost effectiveness. Maneurop is using such a system the performer® tandem, trio, trio and quadro units. To explain this system, the compressor which appears first on the suction line shall be called the 'upstream compressor', and the one which is second, will be referred to as to the 'downstream compressor'. In the 'dynamic system', the oil which clings back along the main suction line is separated and returned to the upstream compressor. A slight pressure drop is created in the suction line of the 'downstream compressor', which therefore has a slightly lower sump pressure. Driven by the sump pressure differential, the excess oil from the upstream compressor runs into the downstream compressor pump. To avoid the migration of the normal oil charge from one compressor to the other, the oil equalization line protrudes into each compressor shell, thereby ensuring a real overflow function.

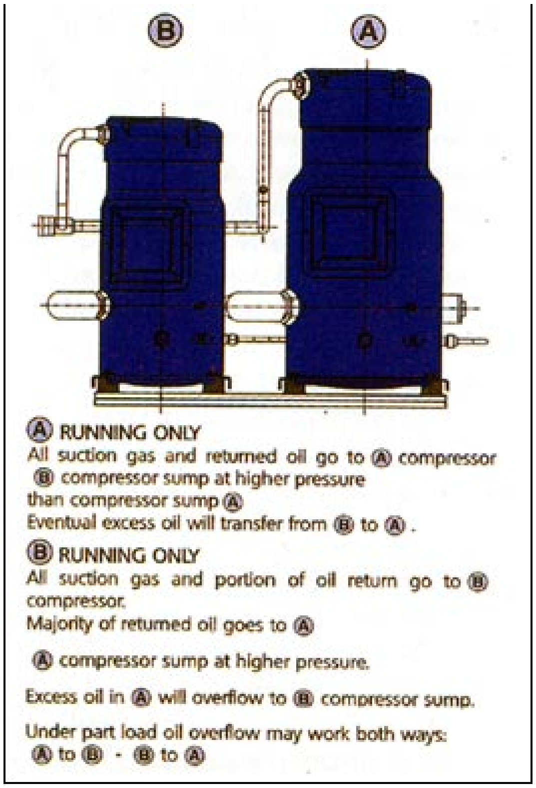
Suitable oil management, with no mechanical component or pressure equalization line is thus created. The active components, are calibrated and qualified by the manufacturer to allow up to four compressors in parallel with a minimum cost.

Suction oil separator / gas restrictor

This drawing shows the technique which provides a preferred oil return,. It insures that the oil returning to the 'compressor set' from the system will always be returned to the upstream compressor. The suction line oil separator/gas restrictor is an integral part of the manifolding suction piping. Since oil being returned via the suction line tends to cling to the walls of the tube, the design of the suction line separator is quite simple. BY placing a small diameter tube from the downstream compressor into the outlet of a tee opposite the suction inlet, the oil among the wall is drawn past this smaller tube and into the upstream compressor. The placement of the small tube inlet as well as its diameter are critical in order to maintain oil separation over the entire range of operating conditions. The second function of the component is to create a small suction line pressure drop in the suction line of the downstream compressor. In this way a lower sump pressure is maintained in the downstream compressor. Any excess oil in the higher pressure sump can be driven to the lower pressure sump. The required pressure drop is obtained by turning the inlet section and length of the restrictor orifice tube.



Part load operation

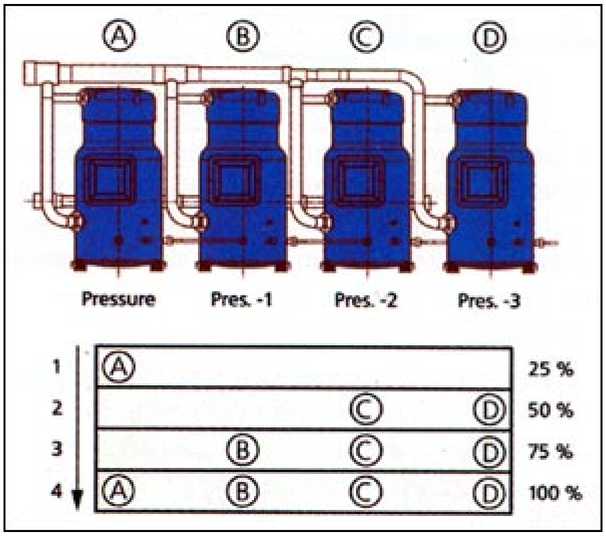


Trio and quadro configuration

Successful results in the implementation of dynamic systems in tandems has allowed further investigation into the use of scroll compressors in large capacity applications, with the manifolding of three and four compressors.

In such assemblies, the same principle of oil management is used, based on preferred oil return to the upstream compressor A. Here again, sumps pressure differential is created, so that when all compressors are running, sump pressure PA>B>C>D. The ½" oil equalization line is fitted between the oil equalization connector of compressor A to the oil equalization connector of compressor B; compressors B, C and D are interconnected between slight glass fitting and oil equalization connectors.

Such an arrangement allows part load operation with 25%, 50%, 75% of cooling capabilities for a quadro. However, unlike the tandem, fixed loading sequences will have to be respected to ensure reliable operation.



Conclusion

The described method of paralleling compressors will help refrigeration system designers are the full advantage of the Performer® scroll technology.

The system relieves the design engineers from the fears, doubts and uncertainties relative to oil equalization and interconnecting piping design and testing.

It provides opportunities for modern large capacity equipment with improved overall performance making the best of both scroll and hermetic technologies.