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Design and Application of small Screw Compressors - Part 2

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Assessment criteria for the use and economy of screw compressors today still often relate to a historical level of development. With this new compressor generation, completely new factors come into play, leading to a significant increase in applications combined with low investment costs and maximum energy efficiency.

Despite the advanced stage of development of modern screw compressors the lower size limit for economic use in commercial refrigeration plants is with a displacement above approximately 80 m3/h. this means that they only cover the upper capacity range of the reciprocating semi-hermetics that are commonly installed in such systems.

This is the reason why screw compressors are mainly used for applications where high cooling capacity is required.

Parallel systems (**Fig. 10**) of medium and large capacity are a common application, for example in:

- medium and low temperature systems in th food industry
- in supermarkets
- distribution centres
- in processing technology
- and in marine refrigerating and air conditioning plants

R22 and chlorine-free HFCs as well as NH_3 - with open compressors - can be used as refrigerants. Even with high pressure levels single stage operation is possible.

Screw compressors for use with long pipe runs are usually designed with individual oil circulation. This consists of an oil separator, the oil line leading to the compressor with an oil filter, a flow switch, a solenoid valve and - if necessary - an oil cooler. This means that the expense involved is relatively high for systems with single compressors and then only worthwhile where the capacity limitations of semi-hermetic reciprocating compressors would make a complex parallel system or a large open industrial compressor necessary.

The situation is quite different for systems that are to be designed with parallel compounded compressors for reasons of optimal adaptation, of capacity and operating safety. In these cases a decentralized oil circulation system proves to be a significant advantage. It even makes system design much simpler than with reciprocating and scroll compressors - an oil equalizing system, which is another potential fault source, is not necessary.

For factory produced refrigerating units and liquid chillers in A/C and medium temperature cooling, semi-hermetic compact screws can be used to great advantage. In this case the oil separator is directly flanged onto the compressor housing. The piping requirement is thus the same as with reciprocating compressors.

Semi-hermetic screw compressor

Parallel systems with Screw compressors

Parallel systems are the main application of these small screw compressors. After many years of practical experience the concept has now proven to be extremely economical and safe in operation. Some special features of these parallel systems are simple installation, high operating safety, minor vibration levels, low investing and servicing costs and extremely efficient part-load operation.

Unlike the arrangement of parallel systems usual for large industrial screw compressors (with individual oil separators), for this series a much simpler design was developed using only one separator (and a single oil reservoir) for all compressors. In this way various compressor sizes and version can be combined and even suction pressures can differ.

The compressors are supplied with oil directly from the oil separator via a central pipe connection which branches out to the individual units. Oil filters, oil flow switches, oil solenoid valves and sight glasses (to check oil flow visually) are all individually allocated and thus guarantee optimal monitoring and control A discharge gas temperature protection device (PTC) which limits the maximum permitted temperature both of discharge gas and of the oil is standard equipment.

System design and pipe runs are arranged so that oil flooding of the compressor during standstill is effectively prevented. Even in the rare case of the oil solenoid valve developing a leak there is little danger of damage to the compressor. If the compressor is partially flooded, there is an unloading of the hydraulic pressure peaks by means of the capacity control which automatically opens when starting. With full flooding the rotors lock up causing the motor protection device to switch off the compressor.

Extremely low vibration levels and low discharge gas pulsation are two particularly attractive features of screw compressors. These properties contribute significantly to reducing the danger of pipe fractures, which, as is well-known, is a main cause of refrigerant emissions and service costs.

The space requirements of parallel systems with screw compressors tend to be lower than those of reciprocating and scroll compressors. Because of the simple method of capacity control (also possible with low temperature cooling) the number of compressors can be reduced as necessary. In addition, when a frequency inverter is used the whole speed range of up to 4500 rpm can be utilized - cooling capacity then increases by approximately 50% compared with the usual 50 Hz operation.

The relatively small physical size of screw compressors must also be considered; even the open version is very compact due to the directly flanged-on motor. A further factor is the higher specific cooling capacity, caused by a very stable behaviour for volumetric efficiency over pressure ration. In particular with low temperature and operation with sub-cooler circuit (economizer) the displacement of screw compressors can thus be much smaller than with reciprocating compressors (see also **Fig. 13**).

The space requirements of oil separators (including oil control systems with reciprocating and scroll compressors) are similar for all types.

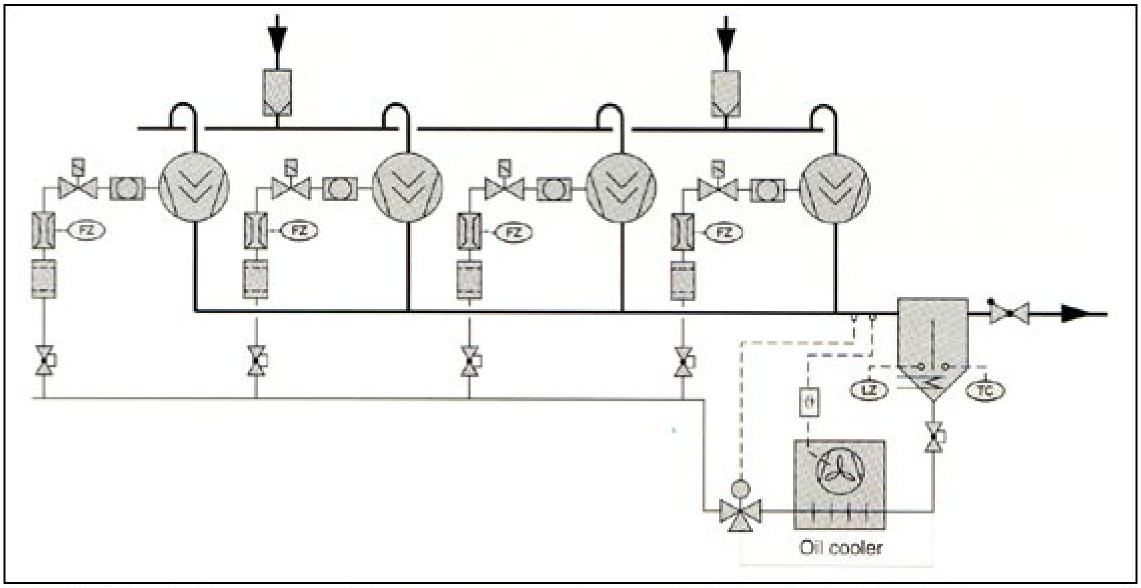

Fig. 10 Parallel system with screw compressors and air-cooled oil cooler

Investment Costs

Generalised statements are often made on the allegedly higher investment costs involved with the use of screw compressors compared with reciprocating compressors. Since such comparisons usually only consider the components, an exact assessment of total costs is not made.

Especially with larger units the lower number of compressors must be considered when screw compressors are used, which reduces the cost of pipe runs and electrical equipment.

Moreover, when a typical single-stage refrigeration cycle is compared with an economizer system (usual with screw compressors), it can be seen that the additional expense of the sub-cooling equipment is more than compensated for by substantial savings with components, pipe runs and the work involved with them. Due to the much lower mass and volume flow in the liquid lines and on the suction side, reductions of up to 40% can be made in compressor displacement, pipe cross-section and the size of expansion and solenoid valves, depending on applications and refrigerants (**Fig 11**).

The potential for savings is lower in connection with liquid lines because of the necessity to insulate them, but with compressors, control components as well as suction lines and their insulation a significant reduction in costs is possible.

Service

The maintenance expenses for screw compressors are extremely low. Due to the dynamic sealing of the working chambers and the low thermal stresses on the oil, the rate of wear or of chemical breakdown is also low. An oil change is therefore only necessary in exceptional cases. As it is usual to have cleaning filters on the suction side in large parallel systems, it is often not even necessary to change the oil filter.

Experience also shows, in particular with parallel systems, that the failure rate with screw compressors is somewhat lower than with reciprocating compressors. This is mainly because of their lower sensitivity to slugging and the optimal monitoring of the oil circuit.

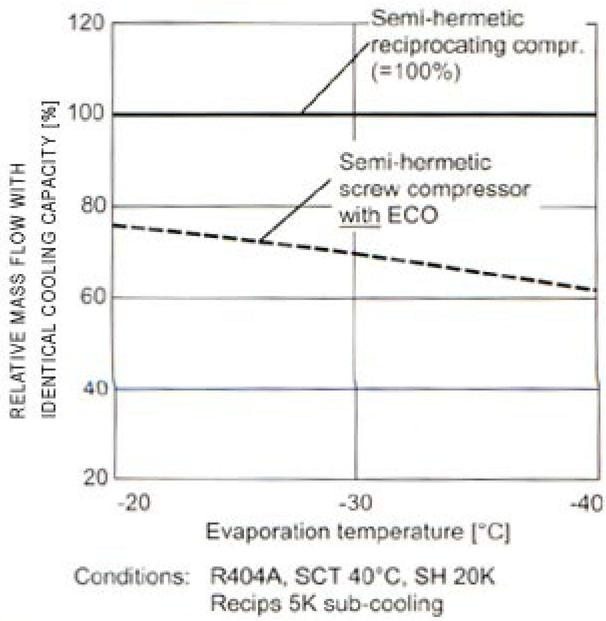

Fig. 11 Comparison of refrigerant mass flow with identical refrigerating capacity

If the compressors do need to be overhauled this is limited to the few moving parts and is therefore relatively inexpensive.

Performance and Operating Costs

As is well-known, when analyzing performance and operating costs, it is very difficult to compare compressors with differing performance characteristics, especially as the dynamic behaviour of the system depends essentially on this factor. This section will therefore examine a more extended range of criteria. Furthermore, the comparative data relates to suction gas superheat (as far as the compressor) of 20K - typical for large commercial systems. Other values considered are 5 K for liquid sub-cooling and, for screw compressors, economizer operation as an alternative.

As the control of the working valves is pressure dependent, during the working process reciprocating compressors adapt to the pressure ratio of the system optimally and thus achieve good coefficients of performance over a wide application range. Because of the direct dependence of volumetric efficiency on pressure ration (re-expansion) the cylinder charge decreases significantly at high condensing pressures and leads to quite a rapid falling off in performance characteristics. This results, on the other hand, in enormous over-capacity at low condensing temperatures (**Fig 12**) and thus in a higher temperature difference at the heat exchangers and in an increasing compressor cycling frequency.

With screw compressors there is a somewhat higher dependence on the pressure difference regarding efficiency, due to the dynamic sealing of the working chambers. This means that with low condensing pressures, even with high pressure ratios, very good isentropic efficiency is achieved. Volumetric efficiency and thus also refrigerating capacity remain stable even at high pressure levels and are significantly higher than for reciprocating compressors.

This is especially true with economizer operation, which is mainly an advantage for low temperature cooling (**Fig 13**).

As there are on average only about 1700 hours with outdoor temperatures of over 15°C in Central Europe, condensing temperatures for refrigerating plants can mainly be held around or below 30°C. However, compressor design necessary for high summer temperatures leads to extremely oversized units for the rest of the year.

This is much less the case with screw compressors, because of their flat performance curves, than with reciprocating compressors (**Fig 12**).

In a parallel system, even with a low number of compressors, it is therefore possible to adapt performance to requirements quite well, as with screw compressors its is possible to control capacity individually in all applications. At the same time cycling frequency is reduced - another advantage contributing to more favourable dynamic properties of the system and thus also to reducing energy requirements and increasing compressor lifespan.

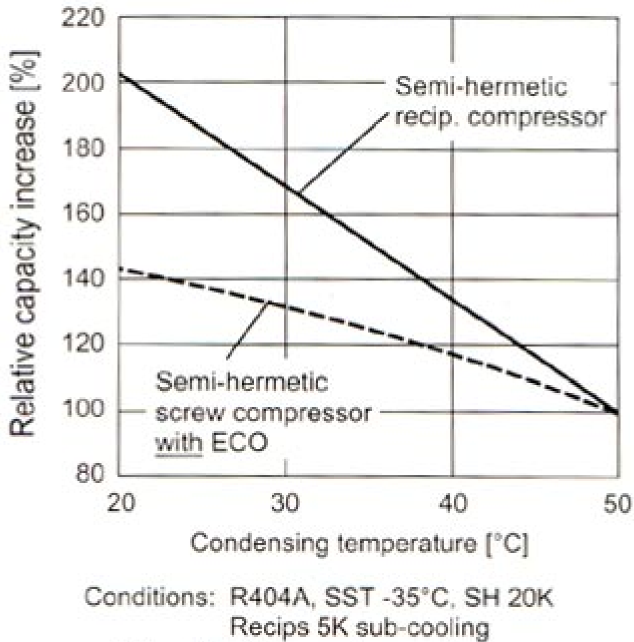

Fig. 12 Comparison of performance characteristic over condensing temperature

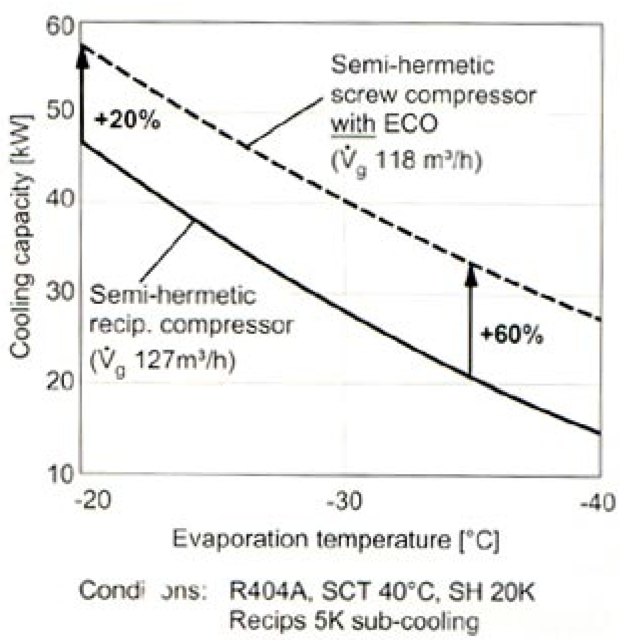

Fig. 13 Comparison of performance characteristic over evaporating temperature

When comparing coefficients of performance and energy costs it is also important to consider the changes in outdoor temperatures (and thus also condensing temperatures) throughout the year. Although **figs. 14 and 15** show slight advantages for reciprocating semi-hermetics at higher condensing temperatures, the situation is just the reverse with lower temperature. Because of the high percentage of running time at reduced condensing temperatures there are only negligible differences in annual energy requirements, a fact that is confirmed by neutral test on real working systems. It is certainly the case that the quality of system design and control has a larger impact and thus offers bigger potential for energy savings.

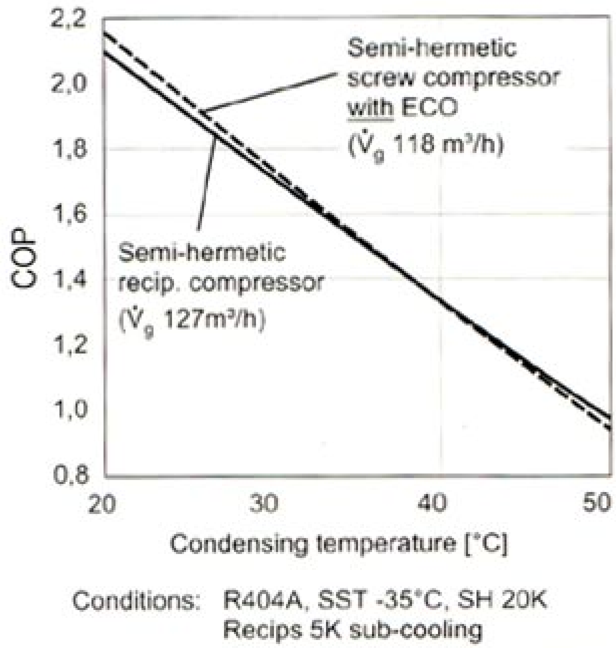

Fig. 14 Comparison of coefficients of performance with low temperature cooling

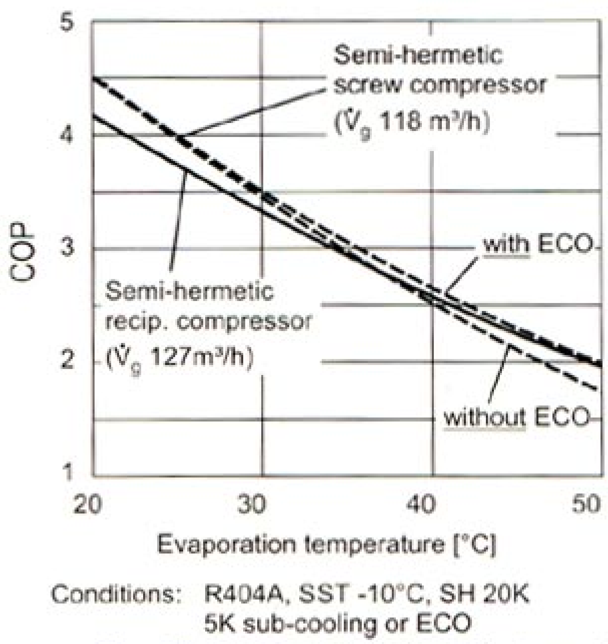

Fig. 15 Comparison of coefficients of performance with medium temperature cooling

Good Prospects

With the introduction of 2-step capacity control for the lower capacity category (displacement of 84 to 118 m^3/h) screw compressors can in future be even better adapted to load requirements. This will mean that even systems with high variations in cooling load can be operated very economically and with a low cycling frequency.

With larger refrigerating systems the trend to liquid chiller units with secondary circuits will open up good prospects for the use of small screw compressors. This will make an extremely space saving and inexpensive design possible. The low levels of suction gas superheat usual with short circuits will also allow operation without additional cooling in many areas or the use of simple, integrated oil cooling systems.

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