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Use of Suction-Gas Cooled and Direct Air-Cooled Semi-Hermetic Compressors

By GmbH & Co

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Editor

Traditionally Bock, Germany has been a manufacturer of Open type Compressors for mobile refrigeration and air conditioning applications. Almost a decade ago they recognised the need to include the Semi-Hermetic Compressor range in their series which they have steadily expanded over the years. This article explains the reasons for the development of the Bock Semi-Hermetic design and the radically different Air-cooled version for low temperature applications. - Editor

The semi-hermetic compressors manufactured by Bock in the HA and HG series, which have been produced since 1994, were developed under special conditions. First and foremost was the need to reduce coolant leaks, vital for protecting the ozone layer and reducing the emission of greenhouse gases. This made the hermetic design the most important aspect. Today, along with the reduction of leaks as a focal concern it is equally important to reduce fuel consumption levels. The use of energy optimized compressors has hence become essential in order to satisfy the Kyoto Protocol, in which the endorsing states undertook to reduce the emission of greenhouse gases. Thanks to Bock's development activities, the semi-hermetic Bock compressors HA and HG were already energy optimized. This is one of the main reasons why two series were developed; one for low temperatures (series HA: **Hermetic Air** cooled, **Fig 1**) and one for higher temperatures (series HG: **Hermetic Gas** cooled, **Fig 2**).

Together with these aspects, attention was also paid to optimum quiet running, low compressed gas pulsation and last but not least, price minimization. A good five years after Bock introduced the semi-hermetic compressors, today the program covers all sizes ranging from 13.5 m³/h (series HA3, HG3: 2-cylinder compressors) 122.7 m³/h (series HA6, HG6: 4-cylinder compressors) and 185 m³/h (series HG7: 6 cylinder compressors). The whole range is divided into 19 capacity stages which are ideally graduated to suit all customer requirements. The program covers all normal needs. All in all, today we can look back on a wealth of experience which indicates that the concept of developing two different semi-hermetic compressors was indeed right. The main reason for this is that enables us to offer energy optimised versions for both low and higher temperatures. Energy optimised means on the one hand, minimal losses and, on the other hand, the selection of the right fundamental principle.



Fig. 1 : HA5 Air-Cooled Semi-Hermetic Compressor

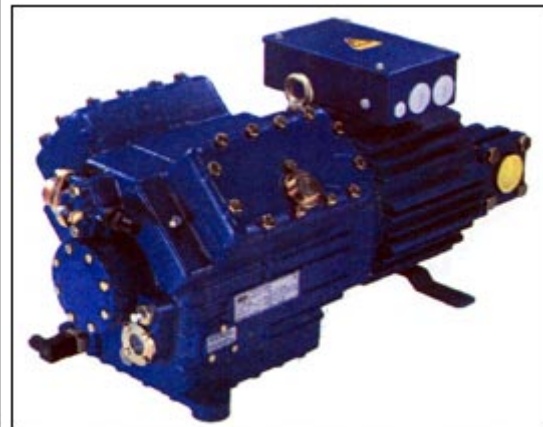


Fig. 2: HG 5 Suction-Gas Cooled Semi-Hermetic Compressor

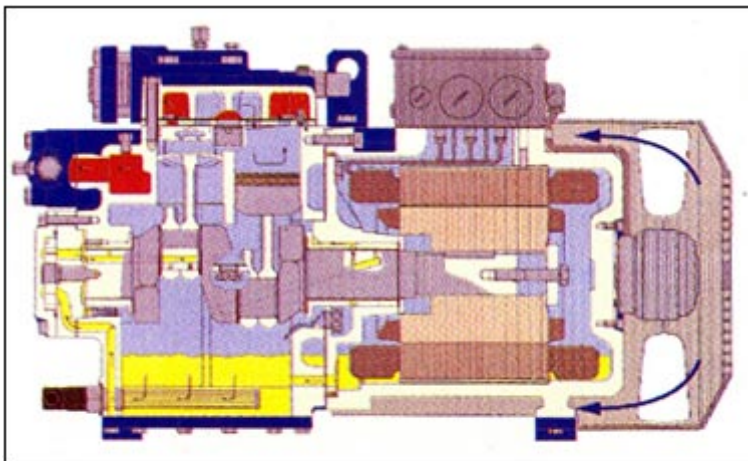


Fig. 3 :Sectional drawing of a HA5 compressor. The suction gas passes through the suction shut-off valve directly into the compressor. The motor is cooled by the fan.

Minimal Losses

In order to minimize losses, Bock's development work has taken account the following points:

- Reducing friction minimized friction thanks to the omission of the shaft seal, and the shaft seal, and the use of improved sleeve bearings. Tests with various sleeve bearings indicated that there are scarcely any effects on the drive output and refrigerating capacity. Endurance tests have succeeded in improving operating safety and extending the service life.
- Improving volumetric efficiency: A reduction of the dead space would result in a greater mass flow and thus greater refrigerating capacity and drive output. Altogether this would result a slight improvement in the refrigerating capacity coefficient. The disadvantage is the reduced operating safety. In the case of liquid shocks for example, the risk of valve lamellae breaking is greater when the dead space is smaller. Experiments have been carried out to fulfill both requirements for operating safety and maximum output.
- Reducing pressure losses: The valve system, the suction and discharge control and the cross section surfaces at inlet and outlet were selected in such a way as to keep the pressure losses low.
- Oil pump: The oil pump may only consume as much energy as necessary to guarantee adequate lubrication of the bearings. Here a safety factor has been taken into account because of the need for extreme operating safety, so that the oil pump is basically oversized.
- Integrated fan for the HA compressor: the fan output is as low as possible, just enough to cool the motor. The required fan output depends on the operating point, and that has an effect on the operating range. Although the choice of the lowest possible fan output has restricted the operating range for high temperatures, these are decisive advantages in energy consumption at low temperatures. Here the fan output accounts for only 4% of total power consumption.

During the development phase, experiments and theoretical studies were carried out for all the above points. Together with the company's many years of experience in making compressors, we have made no compromises when it comes to performance and operating safety.

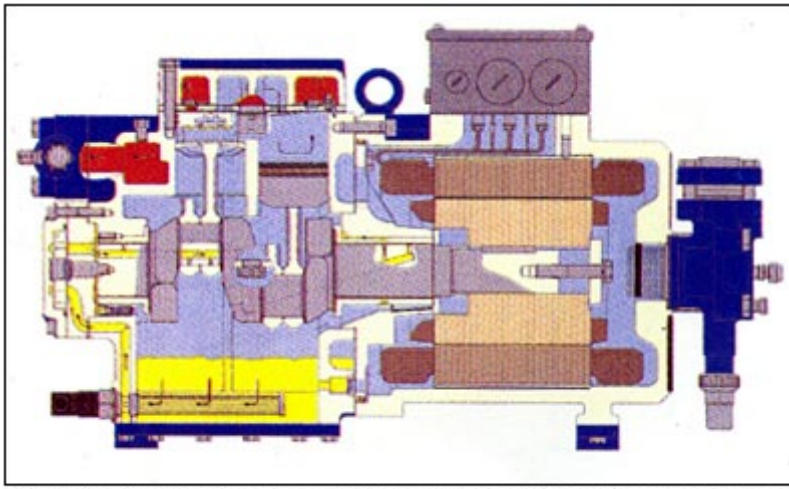


Fig. 4 : Sectional drawing of a HG5 compressor. The suction gas is guided across the motor housing.

Selection of the Right Fundamental Principle

As far as choosing the right fundamental principle is concerned, it must be borne in mind that the refrigerating capacity decreases with increasing suction gas temperature. Hence Bock offers a choice between direct suction compressors (HA), see **Fig 3**, with practically no heating up of the suction gas (for use at low temperatures), and the classical suction gas cooled compressors (HG), see **Fig 4**, in which the suction gas is used to cool the motor (for use at higher temperatures). The restrictions on both version are, on the one hand, the need to produce the required refrigerating capacity and, on the other hand, the need to minimize the extent to which the suction gas is heated up.

For better understanding, **Fig.5** illustrates the losses of a drive motor for semi-hermetic compressors as a function of the evaporation temperature. The drawing is based on a Bock HA compressor with R404A, the parameter is the condensation temperature.

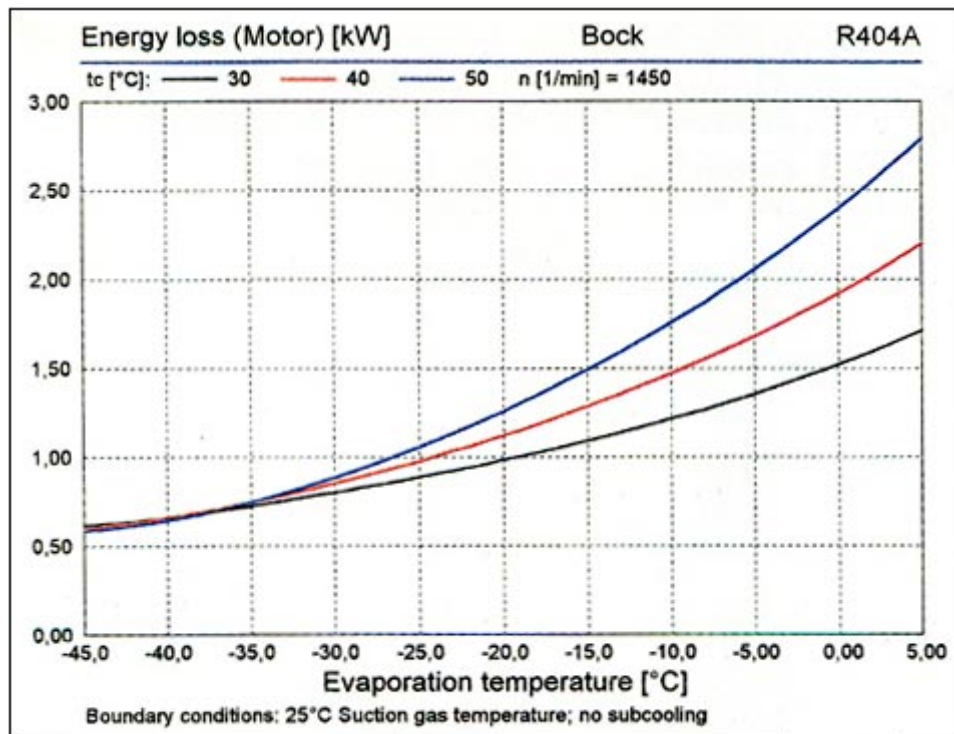


Fig. 5 : Losses of a drive motor for semi-hermetic compressors as a function of the evaporation and condensation temperatures.

For low evaporation temperatures, all lines come close to an end value which represents the idling performance. This is around 600 W for this motor. The motor output increases considerable with increasing evaporation temperature. In the case of the air-cooled HA compressor, about 1.3 kW losses can be conveyed to the environment via the housing surface. This means that the operating range is restricted at high evaporation temperatures. This results in a maximum permissible evaporation temperature of (-)15°C at $t_c = 40^\circ\text{C}$. At low evaporation temperatures, it is obvious that the cooling capacity of 1.3 kW provided by the fan is far higher than required to cool the motor. The positive result is that the refrigerating capacity can be effectively used to cool the cylinder heads. This means a low discharge end temperature event very high pressures. Experiments here indicated, for example, that when using R22, the discharge end temperature also decreases with decreasing proves the effectiveness of the cooling. The maximum discharge end temperature, measured at the discharge outlet, is 130°C for R22 at 40°C condensation. The maximum occurs at hour (-) 30°C evaporation, i.e. the discharge end temperature reduces at both rising and falling evaporation temperature.

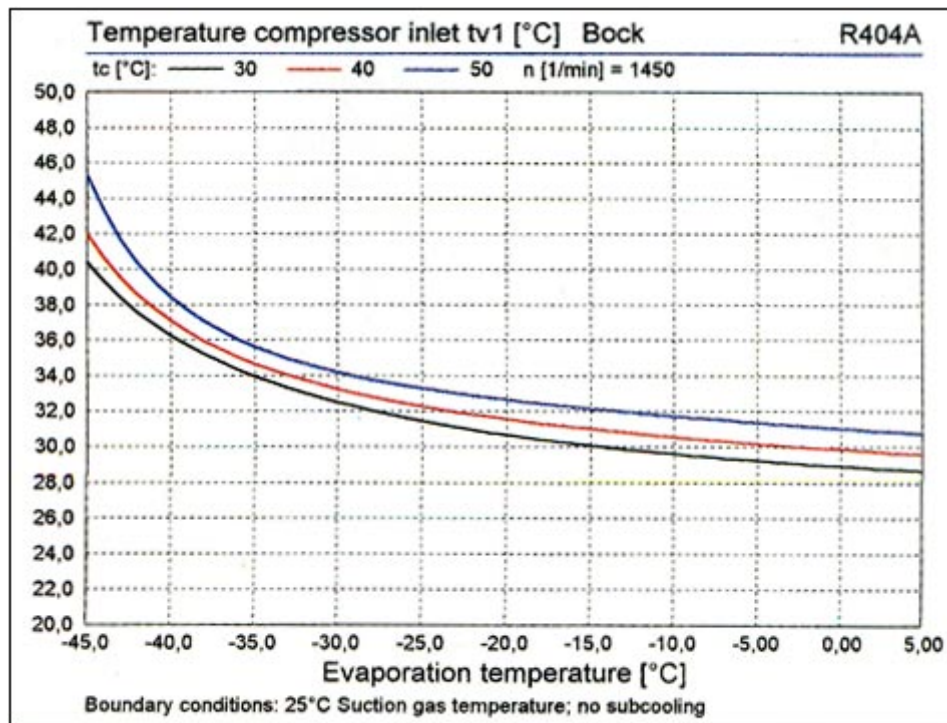


Fig. 6 : Temperature at the inlet into the compressor as a function of the evaporation and condensation temperatures.

In the case of the suction-gas cooled HG compressor, which uses the same drive motor, the losses of the drive motor have to be conveyed via the suction gas. This automatically means that the suction gas heats up. At the same time, the suction gas density is reduced, the mass flow of coolant is reduced and the refrigerating capacity decreases. This illustrates the difference with the direct suction compressor described earlier. The situation for losses is very similar to **Fig. 5** - the losses are negligibly smaller than shown because the drive output is somewhat lower, given the same marginal conditions because of the lower suction gas density. **Fig. 6** shows the actual temperature at the inlet into the compressor as a function of the evaporation temperature.

When the evaporation temperature is high, the suction gas heats up by about 5K depending on the condensation temperature. Although the motor losses decrease with decreasing evaporation temperatures, the suction gas heats up far more because of the coolant mass flow which decreases at the same time. Accordingly, suitable suction gas guidance in the vicinity of the motor must be designed in such a way that the losses can be compensated by the suction gas. This results in the lowest possible heating up of the suction gas and the lowest possible power take-off. In the Bock HG compressor, the suction gas enters the housing on the motor side and flows past the motor into the compressor. The design ensures uniform distribution for the suction gas. In addition, the surface passed by the suction gas is designed for adequate cooling to minimize heating up of the suction gas.

Summary

An essential step towards reducing pollution has been made by converting to coolants with low or no ozone decomposition potential and with the hermetic design of the compressors. The next stages is energy optimization, which has already been implemented in Bock compressors with the improvements described above to minimize losses. This results in considerable advantages in energy consumption levels, as both compressors have been optimised for their corresponding operating ranges. The suction-gas cooled HG compressor is designed with optimum suction gas guidance in the air conditioning range for minimum heating up of the suction gas. The direct suction HA compressor is ideal for low temperature as there is no additional heating up of the suction gas. The integrated air cooling can be effectively used to cool the cylinder heads. This results in greater operating safety with a very large operating range for low temperatures.