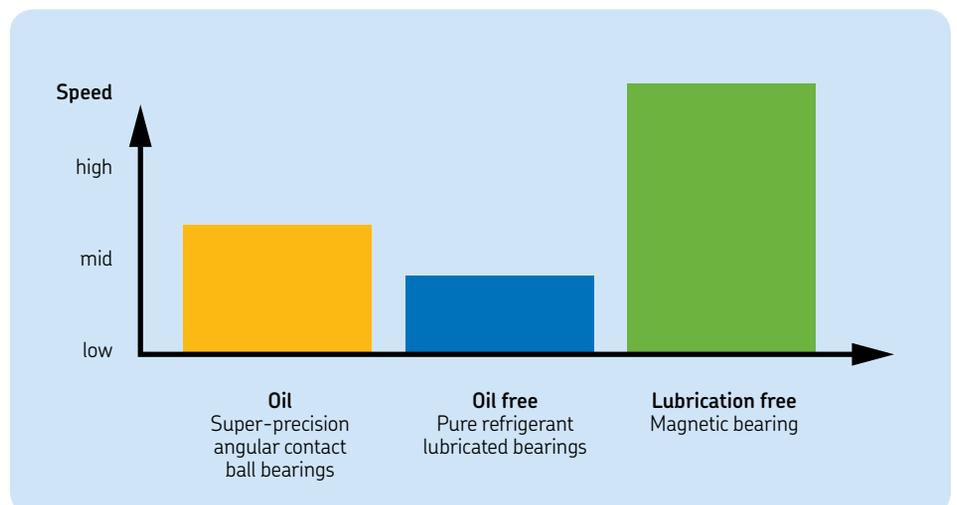
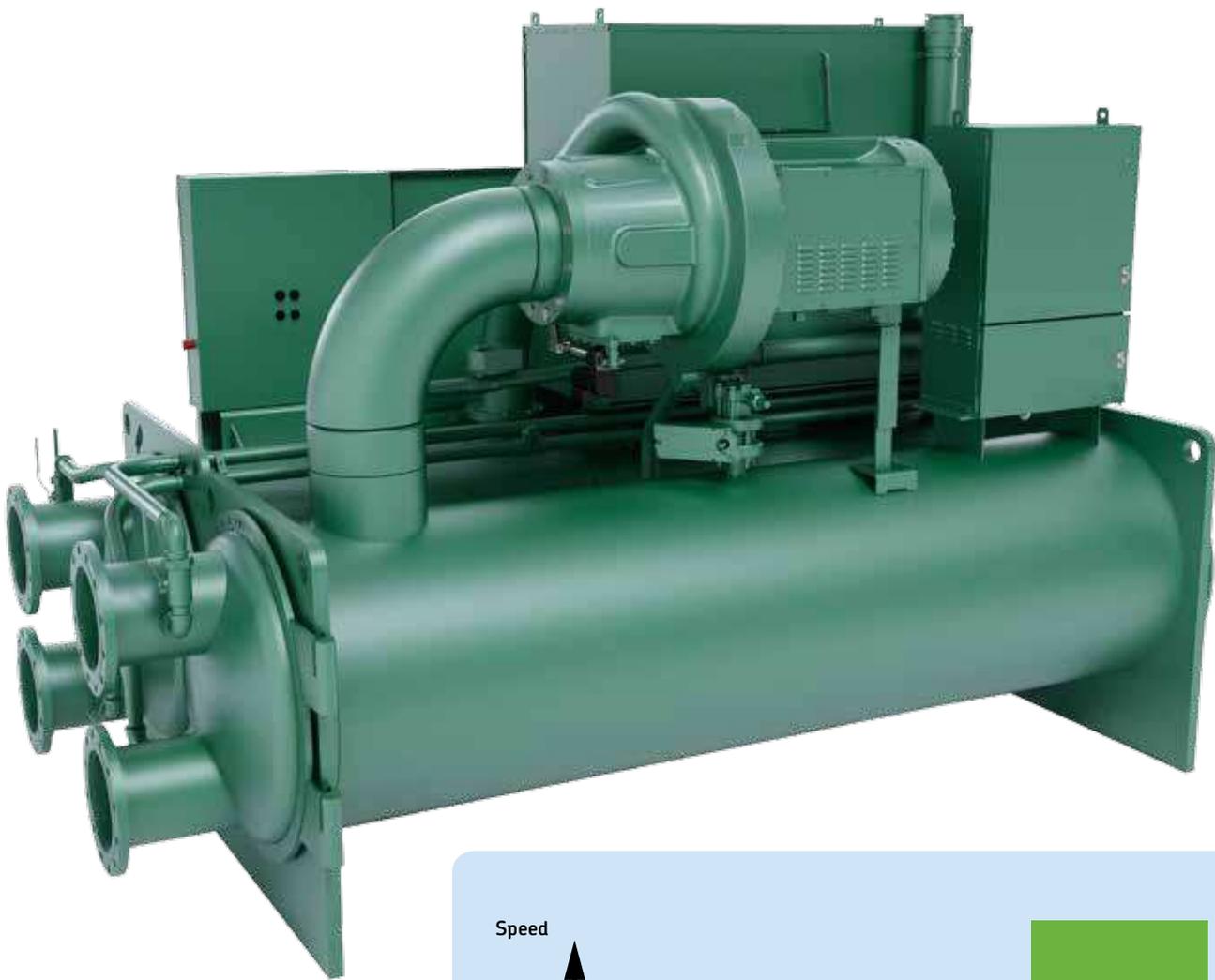


Evolving chiller performance

SKF solutions for centrifugal compressors in chillers



Need to optimize your centrifugal





compressor efficiency?

Boost direct drive and gear drive performance with SKF

Offering both higher efficiency and capacity than other compressor types, centrifugal compressors have long been the preferred choice for large chiller applications. Today's modern centrifugal compressors with direct drive motor systems offer an even more compelling option in terms of energy efficiency, simplicity and reliability.

Mounting the impeller directly on the motor shaft means no more gearbox and lubrication of gears. Eliminating both reduces overall complexity and cost while improving compressor efficiency and reliability.

At SKF, we understand the many challenges involved in developing a robust, cost-effective centrifugal compressor. We've been helping leading chiller OEMs develop solutions for both gear drive and direct drive models for many years. Regardless of your compressor type, our broad range of products, solutions and application expertise makes SKF your partner for success.

Proven centrifugal compressor solutions

As the leading supplier of bearings and engineering solutions to the compressor industry, SKF has been at the forefront of direct drive development since the 1990s. Long-term co-development projects with leading chiller manufacturers have facilitated the development of several SKF advancements. Whether you are looking to upgrade to a lower friction high-speed output shaft on your gear drive machine, or develop a direct drive solution, SKF's proven centrifugal compressor solutions will help you achieve your goals.

The magnetic system from SKF is an oil-free solution that features a permanent magnet motor and active magnetic bearings, a combination that enables energy savings of at least 10% versus conventional centrifugal compressor designs.

Pure refrigerant lubricated bearings from SKF utilize a low-viscosity refrigerant, offering an oil-free solution that also enables energy savings of at least 10% versus conventional centrifugal compressor designs.

Oil-lubricated rolling bearings use an oil-refrigerant mixture for lubrication – one that can help boost energy efficiency by 3-4% versus conventional designs.

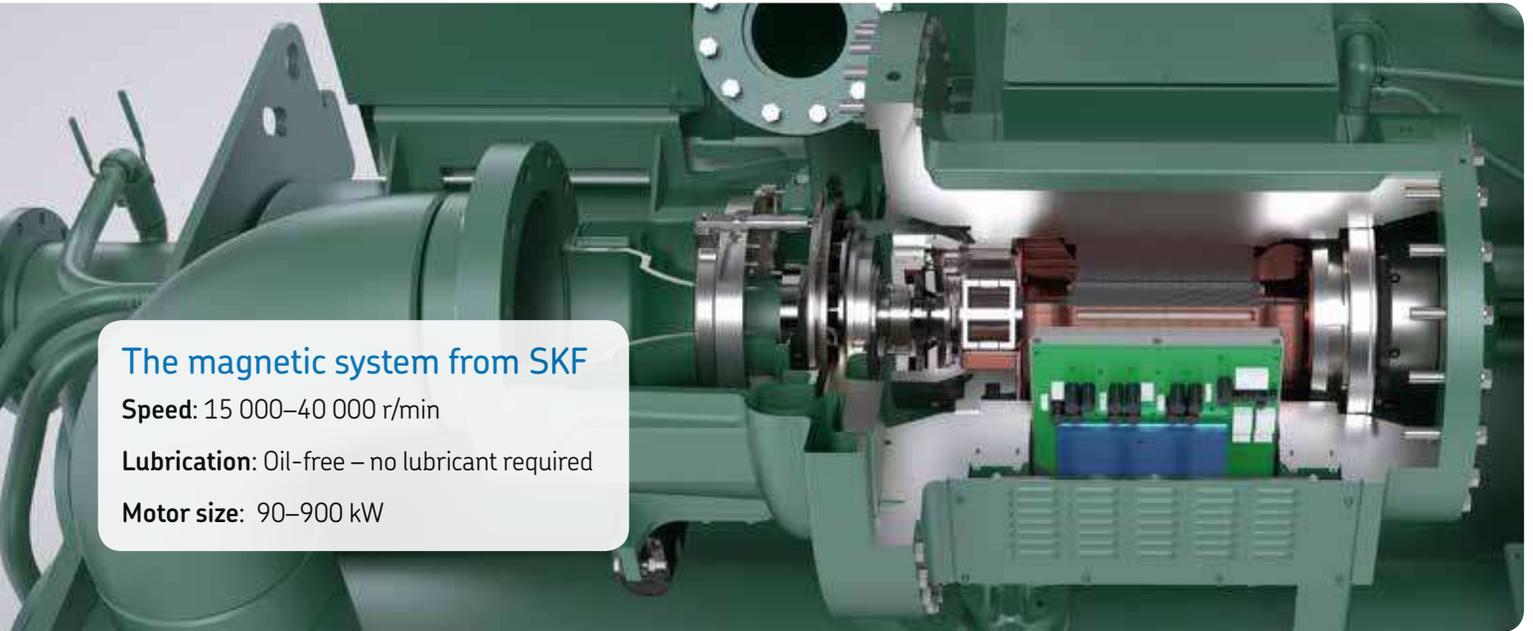
Actuators from SKF can be used to control inlet guide vane and diffuser vanes, replace check valves and optimize compressor control and energy efficiency.

Tested technology and support

Supported by many years of operation in the field, these proven solutions are allowing the development of the next generation of high-efficiency, low-maintenance chillers. Backed by our industry-leading engineering support and global footprint, high-speed centrifugal compressor solutions from SKF can help your team realize several benefits:

- Reduced energy use
- Eliminated oil lubrication
- Reduced maintenance requirements
- Reduced total cost of ownership
- Streamlined machine development
- Faster, leaner manufacturing

The magnetic system from SKF



The magnetic system from SKF

Speed: 15 000–40 000 r/min

Lubrication: Oil-free – no lubricant required

Motor size: 90–900 kW

No contact, no wear, no worries

The magnetic system from SKF combines a high-speed permanent magnet motor and active magnetic bearings with integrated controls, allowing OEMs to harness the efficiency benefits of variable speed drive technology. SKF motors can be single or double stage without any design change.

Electromagnets levitate the compressor shaft, allowing it to rotate without contact. A control system actively monitors shaft position and continuously adjusts the current in the bearing coils to maintain stable shaft position.

Energy and space-saving design

This solution eliminates the mechanical contact and the losses that occur with bearings that require lubrication, significantly cutting energy consumption and costs. Offering higher power density and a smaller footprint than conventional solutions, the SKF magnetic system frees up new design possibilities for OEMs and simplifies maintenance for end-users.

Oil-free efficiency

By eliminating the need for oil lubrication, the magnetic system from SKF also improves heat transfer efficiency in the evaporator and condenser.

Extremely quiet operation

The system's vibration- and nearly friction-free performance capabilities enable super-quiet operation.

Key system components

Permanent magnet motor

- Low energy use and cooling requirements
- More energy efficient than induction motors at full and partial load
- Higher power factor/lower current draw than induction motors
- High rotor stiffness enables high speed operation
- Uses smaller size VFD than induction motors

Active magnetic bearings

- Accommodate instant and frequent start-ups and transient surge forces
- Active control system enables vibration-free performance
- Capable of speeds in excess of 40 000 r/min
- Magnetic levitation of the rotor means low friction and no need for oil

Magnetic bearing controller

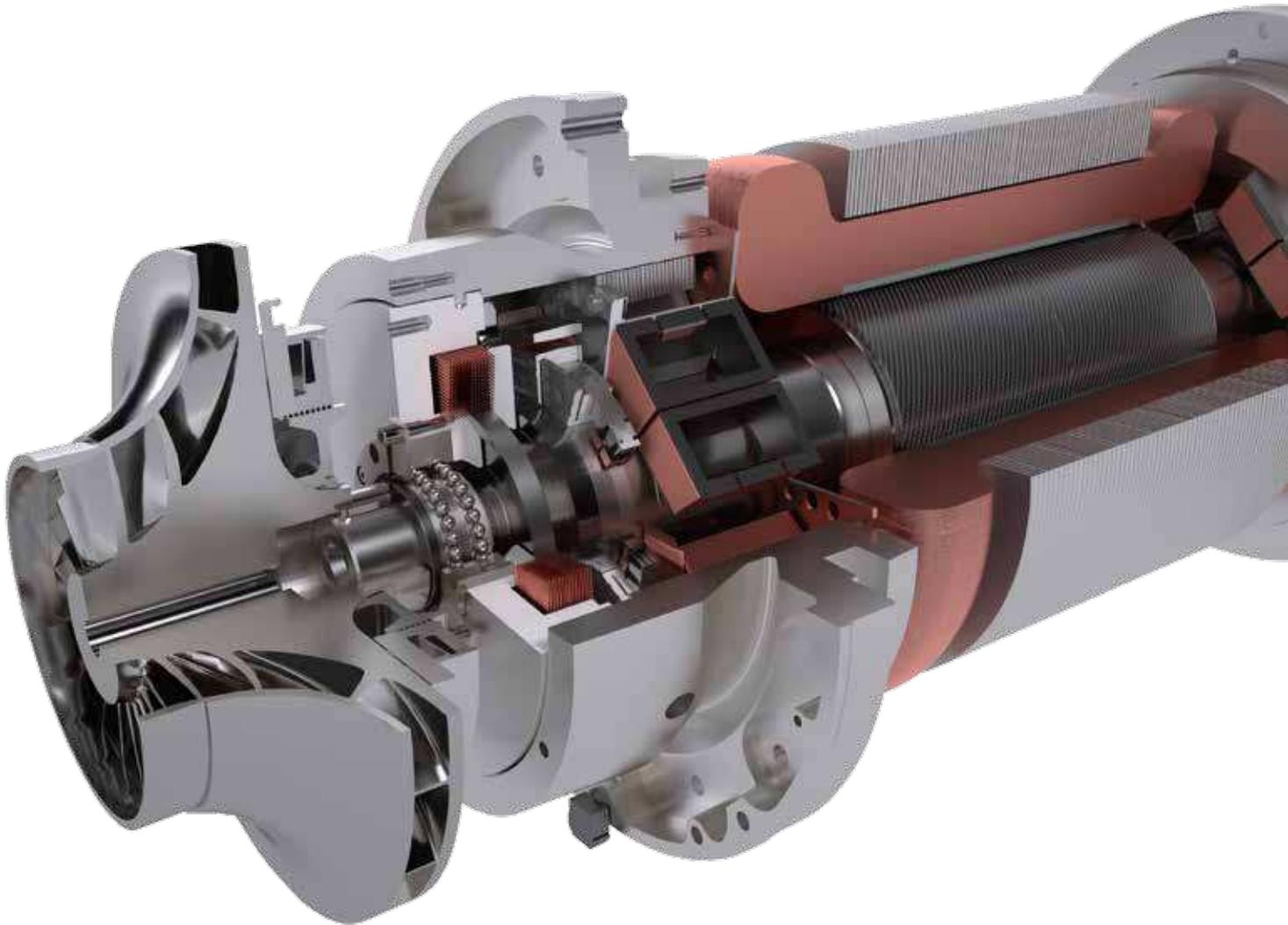
- Tracks and registers rotor position up to 15 000 times per second
- Controls rotor position to within a micron-sized orbit
- Continuously corrects rotor position by adjusting the power supplied to each electromagnet
- Instrumentation for integration into the compressor control system
- Actively monitors compressor performance

Why SKF for magnetic solutions?

SKF is a leading producer of magnetic bearings and high-speed permanent magnet motors, thanks to our acquisition of S2M, a pioneering technology company that has been refining contact-free, levitating bearing technology for more than 30 years. When you work with SKF, our engineers will help you find the optimum magnetic system solution for your application, then recommend a suitable VSD from various manufacturers.



The magnetic system from SKF is part of the SKF Beyond Zero portfolio, a range of products and solutions with quantified environmental benefits.



Pure refrigerant lubricated bearings from SKF

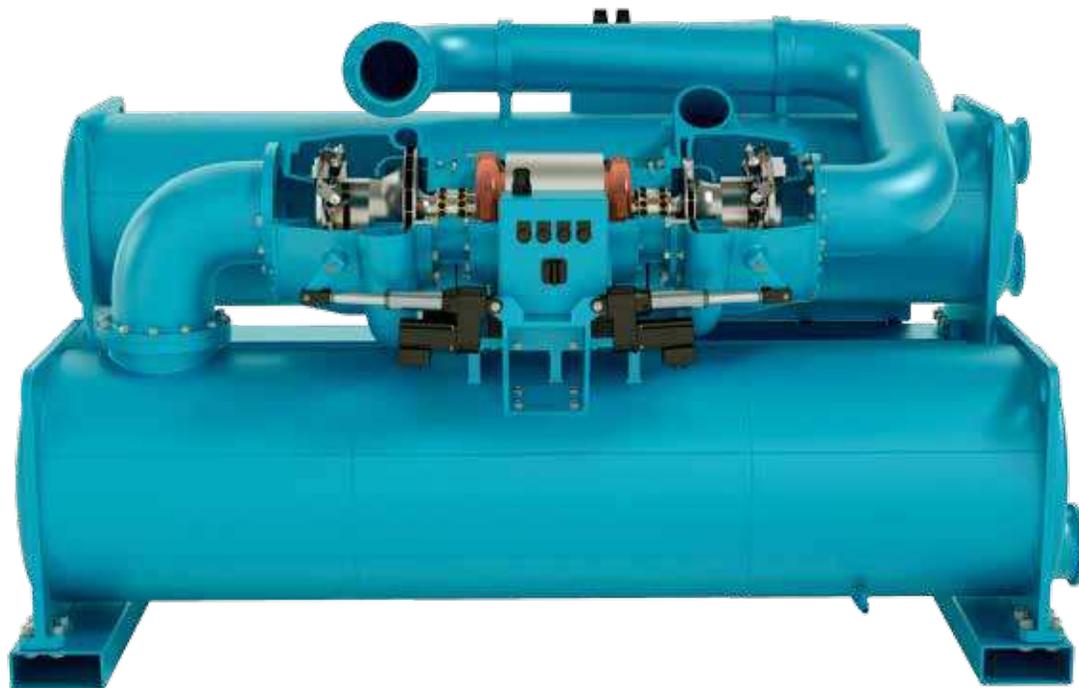
Pure refrigerant lubricated bearings from SKF

Speed: 3 000–18 000 r/min

Lubrication:

Oil-free – refrigerant-lubricated

Motor size: 100–750 kW



Refrigerant as lubricant

Centrifugal compressors using low-viscosity refrigerants have traditionally been gear-driven designs that use hydrodynamic bearings lubricated with an oil-refrigerant mixture. This design requires both a lubrication system and an oil separator to provide an oil-rich mixture to the gears and bearings and a refrigerant-rich mixture to the evaporator and condenser.

Pure refrigerant lubricated bearings from SKF offer a much simpler solution – they use the refrigerant as pure lubricant, a breakthrough that reduces chiller energy consumption while simplifying system design and maintenance requirements. These hybrid bearings are not used in gear-driven compressors, as oil is needed for lubrication of the gears and thus also available to lubricate bearings.

A proven hybrid bearing solution

Pure refrigerant lubricated bearings from SKF feature ceramic rolling elements and rings made of high nitrogen stainless steel that is heat-treated in a process developed by SKF. The result is a steel with a much finer microstructure than conventional bearing steel, significantly enhancing fatigue resistance and corrosion protection.

Now operating trouble-free in the field for more than a decade, pure refrigerant lubricated bearings from SKF offer several benefits:

- Increased chiller efficiency
- Extended bearing service life
- Oil-free operation
- Increased bearing service life
- Simplified maintenance
- Lower lifecycle costs

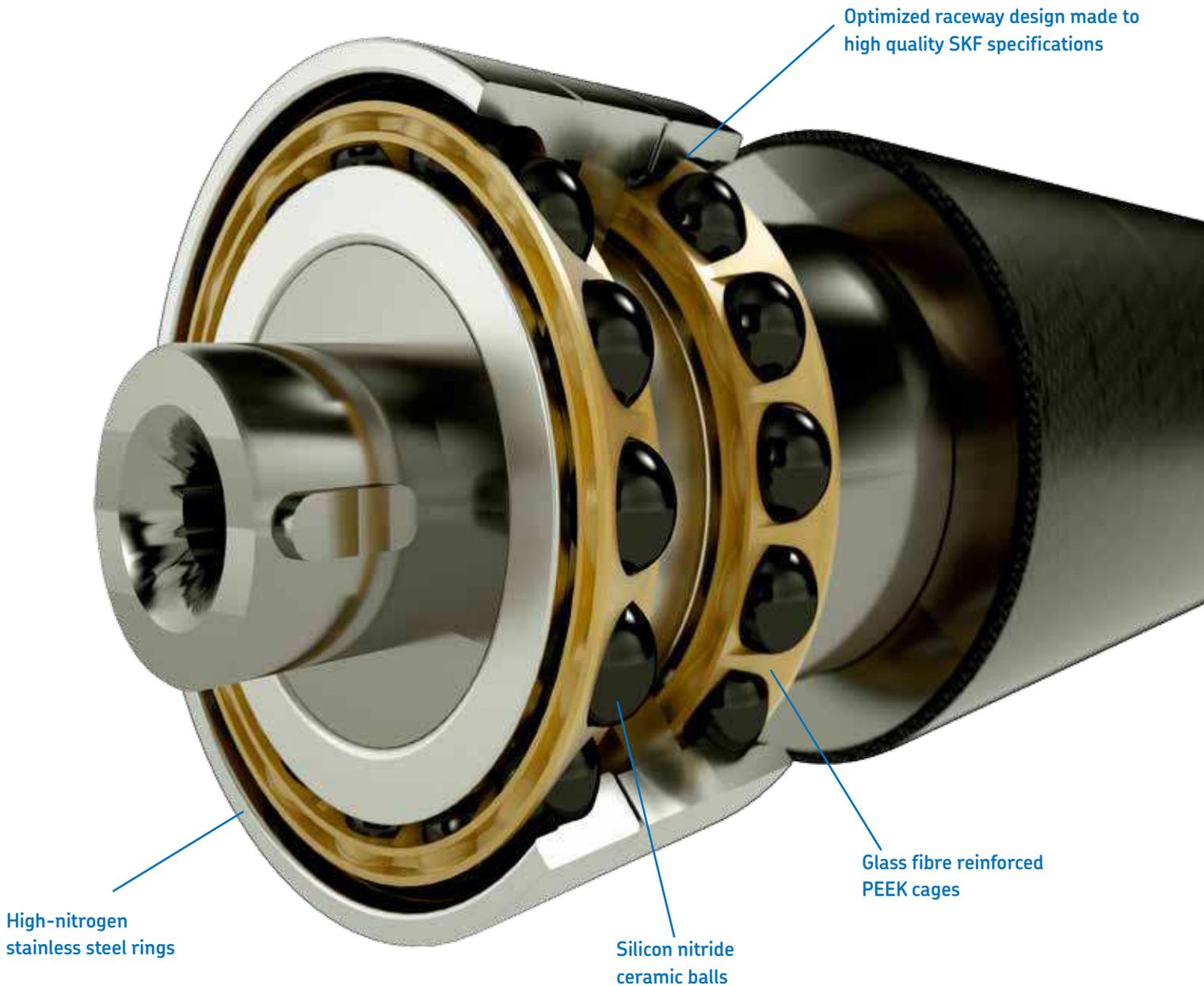
Reliability by design

Silicon nitride rolling elements have a mass just 40% that of steel elements, a reduction that allows higher speeds, lower inertia, more rapid starts and stops, and much more uptime. They also provide electrical insulation that protects the bearings from stray currents.

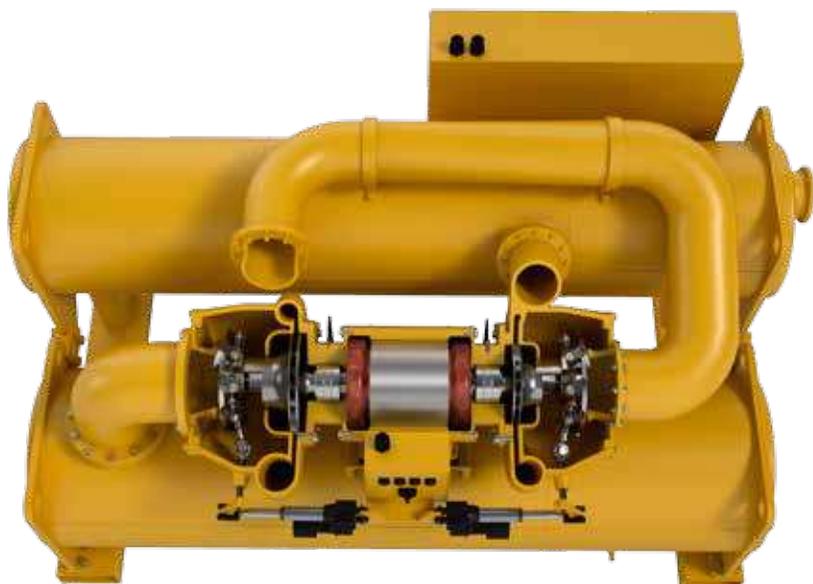
The combination of high quality ceramic balls, rings made of high-nitrogen steel with special heat treatment, glass fibre reinforced PEEK cages, and demanding SKF quality manufacturing standards results in a bearing that can operate reliably with pure refrigerants as lubricant. This simple, oil-free operating solution has been field-tested for more than a decade.



Pure refrigerant lubricated bearings are part of the SKF Beyond Zero portfolio, a range of products and solutions with quantified environmental benefits.



Oil-lubricated rolling bearings



Oil-lubricated rolling bearings

Motor shaft speed: 1 500–3 600 r/min

Impeller shaft speed: 6 000–25 000 r/min

Lubrication: Oil-refrigerant lubricated

Motor size: 100–3 000 kW

Design and performance flexibility

Oil-lubricated rolling bearings from SKF can help boost performance for both gear drive and direct drive compressor designs. For systems under development that will use an oil-refrigerant mixture as lubricant, oil-lubricated rolling bearings from SKF will enable many of the same high-speed, high-efficiency benefits of a permanent magnet motor and variable speed drive. For existing gear-driven compressors, the bearings can be integrated in the high-speed output shaft.

Gear drive solutions

The traditional driveline used in centrifugal compressors consists of a motor and motor shaft, a gearbox and an impeller shaft. The gearbox is used to increase the speed from motor to impeller. The motor is typically a two or four-pole induction motor, driven directly from the grid with 50 or 60 Hz frequency current.

The advantages of such a driveline are that no VFD is needed and the impeller speed can be set by selecting different gear sets. For larger-size compressors, this may be the only driveline possible since large-size, medium and high-voltage VFDs are prohibitively expensive.

Traditionally, hydrodynamic bearings have been used in these geared drivelines, but newer designs take advantage of the 2% - 4% efficiency gains that rolling bearings allow. Lower bearing friction and improved impeller running accuracy enable the improvement. The lubrication system is also much more simplified and reduced in size.

Low to high-speed applications

Since oil is needed to lubricate the gears, oil is also available to lubricate the bearings. For low-speed motor shafts, standard industrial rolling bearings are used. For high-speed impeller shafts, super precision bearings are required. Depending on speed and bearing size, bearing rolling elements are made of either steel or ceramics. SKF makes a full line of rolling bearings for both low and high-speed shaft designs.

Rolling bearing advantages

- Reduced bearing friction and power loss
- Smaller bearing clearances, improved shaft positioning
- Reduced refrigerant leakage through impeller gaps
- Smaller, simpler lubrication system

Operating benefits

- Improved energy efficiency
- Improved volumetric efficiency
- Reduced manufacturing costs
- Reduced operating costs



Able to boost performance for low to high-speed geared drivelines, SKF rolling bearings offer a range of steel and ceramic rolling element designs.

Actuator solutions

Control costs and refrigerant flow

By optimizing the positioning control of inlet and diffuser vanes, SKF actuators are increasing chiller performance and operational efficiency for leading centrifugal compressor manufacturers.

Offering robust reliability and design flexibility, these actuators can be used on a compressor's inlet and outlet sides. Mounting them to control the position of an inlet guide vane and/or a variable geometry diffuser allows you to fine tune chiller performance for more precise control over your operating points.

Rapid close protection

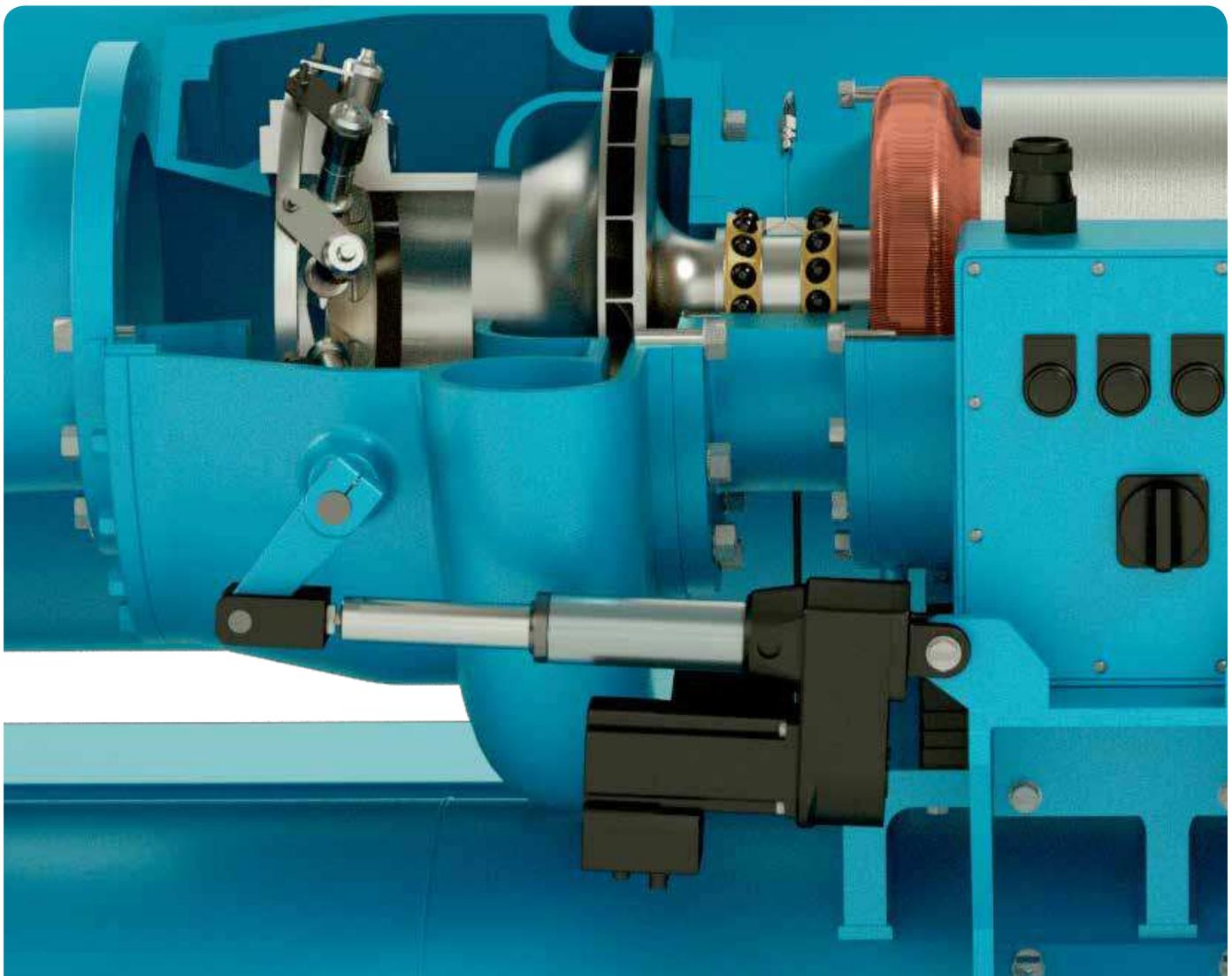
SKF actuators can also help protect the motor by using rapid control of diffuser and inlet guide vanes. This function can replace the use of a check valve which is used to prevent backward flow of refrigerant in case of a power outage. The SKF actuator provides the protection of the check valve without the efficiency loss commonly associated with them, which can be as much as 1%.

Operating benefits

- Increased compressor efficiency
- Greater design flexibility
- Optimized efficiency w/VFD, inlet guide vanes or diffuser
- Reduced warranty claims
- Low acquisition price
- Reduced assembly time

Actuator applications

- Inlet guide vane control
- Variable geometry diffuser vane control
- Hot gas bypass, level control and other valve positions



Proven solutions and support worldwide

A global footprint

Combining capabilities in application engineering, manufacturing and logistics, SKF's global footprint enables expert development and delivery of optimized centrifugal compressor solutions.

Thanks to our efficient logistic services, distributors and dealers network, OEMs enjoy fast, easy access to SKF expertise at key production sites worldwide.

Wherever you need us, dedicated SKF sales, engineering and customer service teams can work with you closely throughout the compressor lifecycle, from design and serial production to operations and maintenance.



■ Vernon, France

SKF Group Brand S2M manufactures the lubricant-free SKF magnetic system, which features a permanent magnet motor and active magnetic bearings.

■ Steyr, Austria

This SKF location produces Pure refrigerant lubricated bearings from SKF that utilize low viscosity refrigerant as lubricant.

■ Villar Perosa, Italy

Combining silicon nitride rolling elements with steel rings, SKF hybrid super precision bearings are manufactured in our Turin-area production facility.

■ Armada, USA

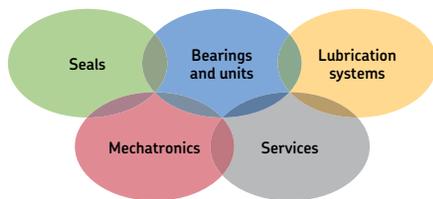
This manufacturing site produces mechatronic actuators that enable several vane actuator applications.

■ Pinghu, China

This SKF location manufactures the lubricant-free SKF magnetic system, as well as mechatronic actuators.

The Power of Knowledge Engineering





The Power of Knowledge Engineering

Combining products, people, and application-specific knowledge, SKF delivers innovative solutions to equipment manufacturers and production facilities in every major industry worldwide. Having expertise in multiple competence areas supports SKF Life Cycle Management, a proven approach to improving equipment reliability, optimizing operational and energy efficiency and reducing total cost of ownership.

These competence areas include bearings and units, seals, lubrication systems, mechatronics, and a wide range of services, from 3-D computer modelling to cloud-based condition monitoring and asset management services.

SKF's global footprint provides SKF customers with uniform quality standards and worldwide product availability. Our local presence provides direct access to the experience, knowledge and ingenuity of SKF people.



SKF BeyondZero is more than our climate strategy for a sustainable environment: it is our mantra; a way of thinking, innovating and acting.

For us, SKF BeyondZero means that we will reduce the negative environmental impact from our own operations and at the same time, increase the positive environmental contribution by offering

our customers the SKF BeyondZero portfolio of products and services with enhanced environmental performance characteristics.

For inclusion in the SKF BeyondZero portfolio, a product, service or solution must deliver significant environmental benefits without serious environmental trade-offs.

The magnetic system from SKF and Pure refrigerant lubricated bearings from SKF provide quantifiable environmental advantages, earning both products a place in the expanding SKF BeyondZero portfolio.

