



Efficient, quiet and oil-free

Frictionless chiller technology sets new standard for efficiency and quiet operation

Energy efficiency is a key driver in HVAC technology development. Refrigerant compressors can require very large prime movers, so improvements to both compressor technology and prime mover technology are major goals for

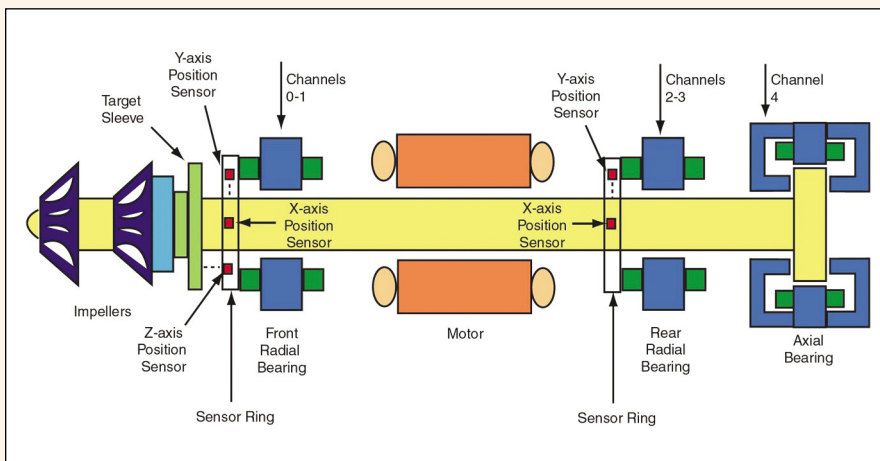
HVAC research and development. Frictionless chillers, the newest generation of chiller technology, achieve both goals. Designed with oil-free magnetic bearing technology and high-speed impellers, McQuay® frictionless chillers can operate as low as 0.375 kW/ton IPLV, the most efficient performance in its tonnage range in the industry. Full load performance as low as 0.62 kW/ton IPLV is about 32 percent more efficient than screw compressor chillers. These IPLV, when applied in a

high efficiency HVAC system, can help save significant operating costs and earn points for Leadership in Energy and Environmental Design (LEED) Energy and Atmosphere, Credit 1.

Magnetic bearings eliminate noise and oil

The Danfoss Turbocor compressor behind frictionless chiller technology uses magnetic bearings—a technology already employed in advanced engineering applications such as the aerospace industry. At about one-fifth the weight of a conventional compressor, and with impeller speeds of 30,000 rpm on a three or four inch diameter impeller (compared to 3,600 rpm on a 40-inch diameter impeller), the magnetic bearing technology can significantly reduce HVAC operating costs.

Traditional centrifugal compressors use roller bearings and hydrodynamic bearings; both types of bearings consume power, and both require oil and a lubrication system. Recently, ceramic roller bearings have been introduced to



The frictionless compressor shaft, the compressor's only moving component, rotates on a levitated magnetic cushion. One axial and two radial magnetic bearings hold the shaft in position.

the HVAC industry, which avoid the oil issues and reduce some of the power consumption.

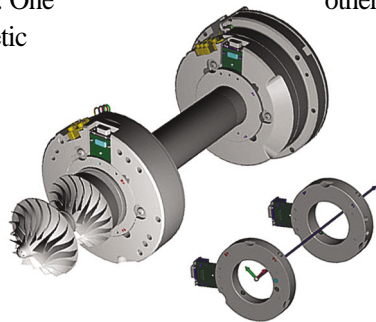
However, magnetic bearing technology is significantly different from other bearing technologies. A digitally-controlled magnetic bearing system, including both permanent magnets and electromagnets, replaces conventional lubricated bearings. The frictionless compressor shaft is the compressor's only moving component, and it rotates on a levitated magnetic cushion. One axial and two radial magnetic bearings hold the shaft in position.

When the magnetic bearings are energized, the motor and impellers become levitated in mid-air. Permanent magnetic bearings do the primary work, while five digitally controlled electromagnets provide the fine positioning. Four separate positioning signals hold the levitated assembly to a tolerance of 0.00005 inches. As the levitated assembly moves from the center point, the electromagnets' intensity is adjusted to correct the position. These adjustments occur six millions times a minute. The software has been designed to auto-compensate for any out-of-balance in the levitated assembly.

Because the compressor rotor and impeller shaft float on a layer of air, there is no metal-to-metal contact noise or vibration common with conventional bearings. Measured according to ARI Standard 575, sound pressure ratings at one meter are as low as 77 dB(A) for

the McQuay frictionless chiller.

Eliminating conventional lubricated bearings eliminates the need for oil, whose main function is to lubricate the compressor bearings. Gone, too, is the maintenance-intensive oil management hardware and the controls associated with them: oil pumps, coolers, heaters and filters; temperature control valves; temperature and pressure sensors; and interconnecting piping. Only a very small amount of oil is required to lubricate the other system components, such as seals and valves, and often even this small amount of oil is not needed.



Rotor shaft and electromagnetic cushions.

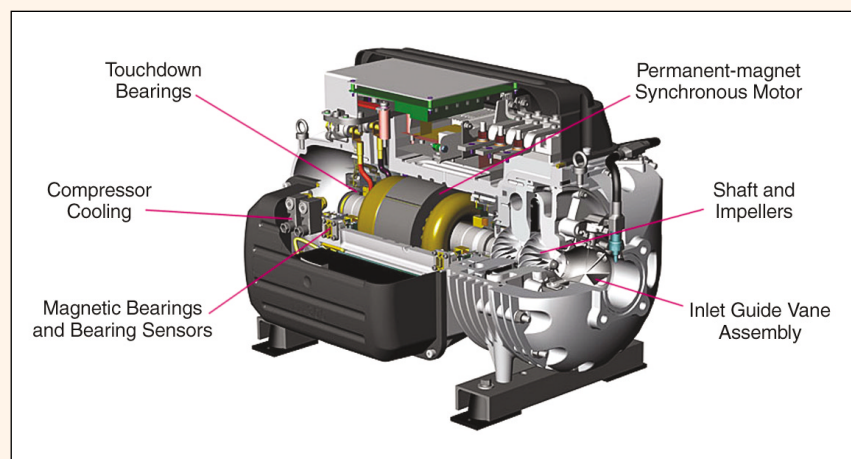
Avoiding oil management systems means avoiding the capital and operating costs of oil pumps, sumps, heaters, coolers and oil separators.

Permanent-magnet motor reduces startup in-rush current to five amps

Most hermetic compressors use induction motors that are cooled by refrigerant. Induction motors have copper windings which, when alternating current is run through them, create the magnetic fields that cause the motor to turn. These copper windings are bulky, adding size and weight to the compressor.

Frictionless chillers employ a permanent magnet motor with a completely integrated variable frequency drive. Permanent magnet motors do not require motor windings, so they are much smaller and lighter than induction

Mechanical components of the Danfoss Turbocor compressor are controlled by onboard digital control electronics to manage compressor operation while providing external control and web-enabled monitoring access to a full array of performance information.



motors—about one-fifth the weight of a conventional compressor.

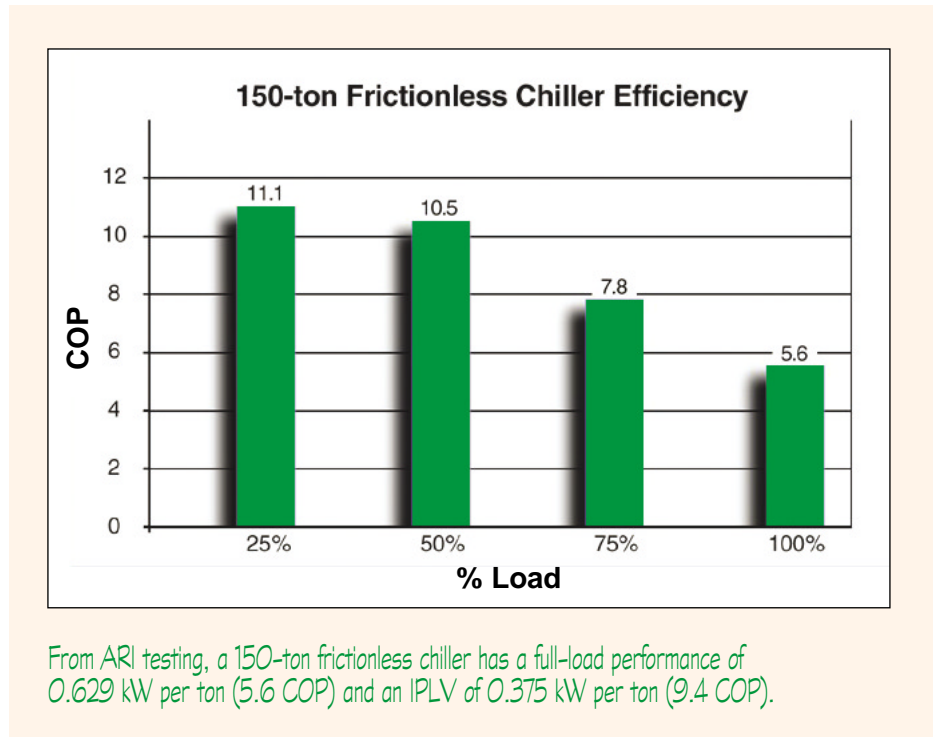
Unlike typical induction motors, no current is required to magnetize the motor's rotor. As a result, the compressor has an extremely low startup in-rush current: less than five amps, compared to 500 to 600 amps for a traditional screw compressor with a cross-the-line starter.

When the compressor is not running, the shaft assembly rests on graphite-lined, radially located touchdown bearings. The magnetic bearings normally prevent contact between the rotor and other metallic surfaces. If the magnetic bearings fail, the back-up bearings prevent a compressor failure.

The compressor uses capacitors to smooth out ripples in the DC link in the motor drive. Within a millisecond of a power failure, the motor becomes a generator, keeping the capacitors charged during the brief coast-down period. The capacitors, in turn, provide enough power to maintain levitation during coast-down, allowing the motor rotor to come to a complete stop and de-levitate as normal. This feature allows the compressor to see a power outage as simply a normal shutdown.

Increased energy efficiency at part load

Using high-speed centrifugal impellers with integral variable speed drive reduces the compressor speed as the condensing temperature and/or cooling load decreases. This optimizes energy performance across the entire operating range, especially at part-load conditions. In the 75-ton range, high speed centrifugal impellers are only about three



to four inches in diameter, rotating at 30,000 rpm. In comparison, low-speed machines with impeller diameters of two to three feet rotate at 3,600 rpm.

Integrated part load values (IPLV) are rated 0.385 for a 150-ton (nominal) machine, compared to more typical IPLVs of 0.5 to 0.6 for many screw and centrifugal chillers. Test results show the frictionless chiller operates most effectively at 25 to 60 percent of its load, which is where chillers typically experience the majority of their run time.

Using high speeds and small diameter impellers in compressor design allows a large volume of refrigerant to be moved in the system with a small compressor. Small compressors will reduce the size of the chiller package, minimizing the cost of the chiller as well as the size of the equipment room. The McQuay frictionless chiller fits through a standard

three-foot wide door, reducing installation time and costs.

While higher rpm may appear to mean higher stresses, this is not the case. Dynamic stress on the impeller is proportional to tip speed (the airflow movement, measured in feet per second, as it leaves the tip of the impeller), not rpm, so a larger impeller spinning slowly, or a small impeller spinning quickly both see similar stresses.

High-speed technology is actually commonplace. The turbocharger in a car or diesel engine spins over 100,000 rpm, and gas turbines in aircraft spin at over 50,000 rpm. These high-speed machines operate at four to five times critical speed, while positive pressure compressors operate below the first critical speed.

Controls

The digitally controlled magnetic bearing compressor provides diagnostic and performance information through Modbus® communication to the refrigeration system, which then communicates chiller status and control data to the building automation system using a Modbus, LONMARK® or BACnet® network.

McQuay frictionless chiller shows significant energy savings

The McQuay frictionless centrifugal chiller is the first in the industry to utilize magnetic bearing technology. Currently being specified for applications in the 110 to 175-ton range, the McQuay frictionless chiller is designed for HFC-134a refrigerant. Using the McQuay Energy Analyzer™ program,

virtual test sites in four locations provide estimated operating costs and payback times for a 150-ton frictionless chiller (see table below).

150-ton frictionless chiller annual energy savings and payback comparison.

Location	Phoenix	Chicago	Tampa	New York City
Chiller type	Reciprocating vs frictionless	Reciprocating vs frictionless	Reciprocating vs frictionless	Centrifugal vs frictionless
Building type	3-story office	3-story office	3-story office	3-story office
Square footage	58,200	69,000	67,800	69,600
Design cooling load (tons)	150	149	150	150
Annual cooling ton-hours	241,121	116,256	312,305	119,521
On-peak charge	6¢ per kwh	5¢ per kwh	6.4¢ per kwh	10.9¢ per kwh
Off-peak charge	6¢ per kwh	2.1¢ per kwh	4.4¢ per kwh	10.9¢ per kwh
Summer demand	\$1.75 per kw	\$16.41 per kw	\$8.12 per kw	\$20 per kw
Winter demand	\$1.75 per kw	\$12.85 per kw	\$8.12 per kw	\$20 per kw
Capital-cost difference	\$18,000	\$18,000	\$18,000	\$12,000
Interest rate	6%	6%	6%	6%
Energy savings	\$5,197	\$5,035	\$9,919	\$4,587
Simple payback (years)	3.46	3.57	1.81	2.62
Net present value	\$96,278	\$92,872	\$195,914	\$87,880
Internal rate of return	36.72%	35.8%	63.3%	46.27%

