

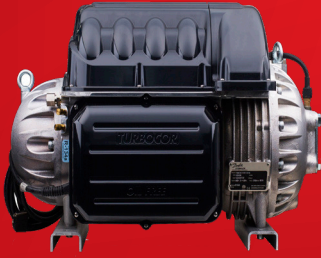
ENGINEERING
TOMORROW

Danfoss

Danfoss Turbocor® compressors

Making a world of difference

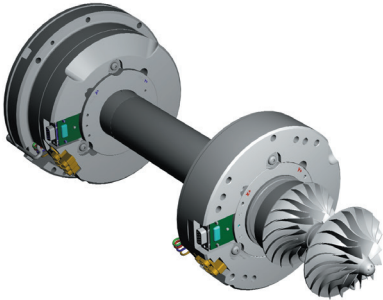
Danfoss Turbocor® oil-free centrifugal compressors for air-conditioning systems



 **TURBOCOR**

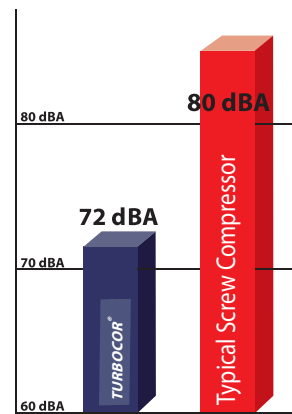
Leading a new era in performance

Today, the world is looking for HVAC technology that makes a difference in efficiency, sustainability and applicability. For mid-range sized commercial and industrial HVAC systems and aftermarket retrofits, Danfoss Turbocor® compressors make that difference with benefits that include:



Magnetic bearings contribute to the most efficient, reliable, quiet and low maintenance centrifugal compressors available.

- Outstanding energy efficiency reduces operating budgets and helps shrink a facility's carbon footprint, thanks to annual energy usage 30% to 50% less than conventional compressors. In the U.S., these high efficiencies may contribute to USGBC LEED® points
- Outstanding sustainability and long service life, because there are no mechanical wear surfaces due to frictionless magnetic bearing technology. No oil, high efficiency and lower weight also contribute to a more sustainable system solution
- Facilitates compliance with national energy codes, such as ASHRAE Standard 90.1 and European Directive 2002/91/EC, and helps satisfy increasingly strict local codes, such as California Title 24 Energy Efficiency Standards for Residential and Nonresidential Buildings
- Reduces CO₂ emissions by cutting kWh with +33% integrated part load value (IPLV) improvement in many applications
- Globally regarded as the environmentally responsible alternative to HCFC's, HFC-134a refrigerant has an Ozone Depletion Potential (ODP) of zero
- Extremely compact size and light weight allows OEMs and contractors to cost effectively install a frictionless, two-stage centrifugal compressor with a much smaller footprint than conventional compressors
- 72 dBA (TT300) sound level eliminates the need for ear protection. These compressors usually cannot be heard above the other sounds in a typical mechanical room and are far more quiet compared to comparably sized screw and reciprocating compressors
- Low maintenance costs are a direct benefit achieved by eliminating the need for servicing refrigerant oil or repairing systems with chronic lubrication problems



Sound level in a typical equipment room.

Energy and CO₂ Emissions Savings Analysis

	Turbocor	Existing Chiller	Savings
Chiller capacity-Tons (kW)	250 (880)	250 (880)	—
IPLV (kW/Ton)	0.34	0.65	—
IPLV (COP)	10.35	5.42	—
Average annual operating hours (h) ¹	5,820	5,820	—
Total annual consumption (kWh) ²	296,820	567,450	270,630
Power cost (USD/kWh)	0.10	0.10	—
Average annual operating cost (USD)	29,682	56,745	27,063 48%
2-year cumulative savings (USD)			54,126
3-year cumulative savings (USD)			81,189
	Turbocor	Existing Chiller	CO ₂ Savings
Average annual CO ₂ emissions (metric Tons) ³	213.1	407.4	194.3 48%

Savings add up economically and environmentally.

Notes:

1. Average annual operating hours includes office buildings, process cooling, data centers, etc.
2. Calculations based on average load of 60%.
3. Calculations based on CO₂ emission factor of 7.18x10⁻⁴ metric Tons [CO₂/kWh] (eGRID2007 v. 1.1, US annual non-based load CO₂ output emission rate, year 2005 data) from U.S. EPA website.

Conversions:

1 [metric Ton] = 2,204.6 [lbs US]

Advancing performance with **advanced technology**

Cut energy consumption up to 50% with variable frequency drive (VFD)

An outstanding Integrated Part Load Value (IPLV) is the result of optimum energy performance through the entire operating range, from 100% to ~20%.

The Danfoss Turbocor® compressor uses an integrated variable frequency drive to reduce compressor speed and maximize energy cost savings as the condensing temperature and/or heat load decreases.

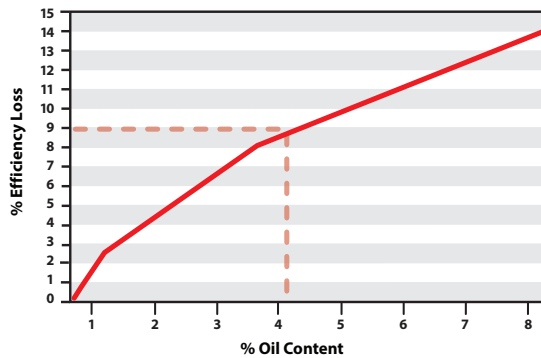


Figure 1: Percent efficiency loss.

Run 100% oil-free with magnetic bearings

Conventional compressors and chillers consume more energy due to the presence of lubricating oil that hinders heat transfer. Even a chiller with an oil content of 4% may lose 9% efficiency. (Figure 1)

Many chillers are overcharged with oil (Figure 2) resulting in actual energy efficiency much lower than the equipment's rating.

Friction-free magnetic bearings eliminate the cost of those inefficiencies as well as the maintenance costs associated with oil service.

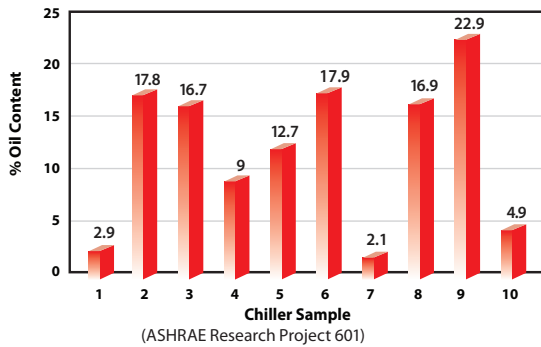


Figure 2: Oil content found in samples of older technology centrifugal chillers.

One moving part (motor rotor shaft and impeller assembly) is levitated during rotation by a digitally controlled magnetic bearing system consisting of one axial and two radial bearings, which completely eliminates any metal-to-metal contact and wear surfaces.

Sensors at each magnetic bearing monitor the shaft location 100,000 times per second ensuring precise positioning.

Get smart with 100% digital control

Control strategies translate into energy savings. As the first truly "smart" compressor design, Danfoss Turbocor® compressors use on-board digital control electronics to manage compressor operation proactively to optimize performance, while providing external control and web-enabled monitoring with a BAS or EMS to deliver the best energy savings.

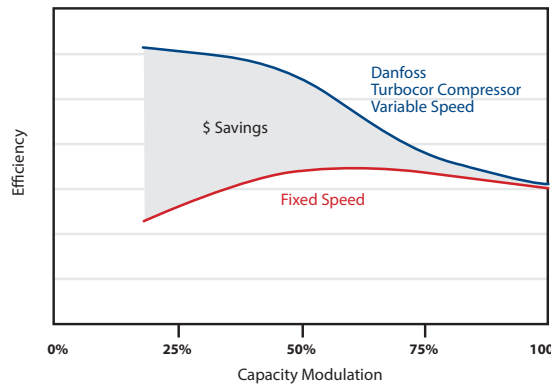
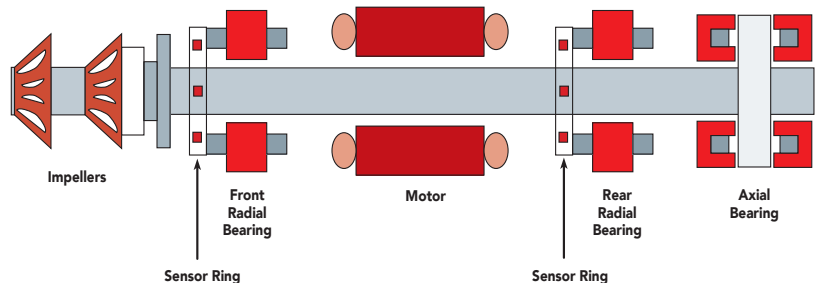


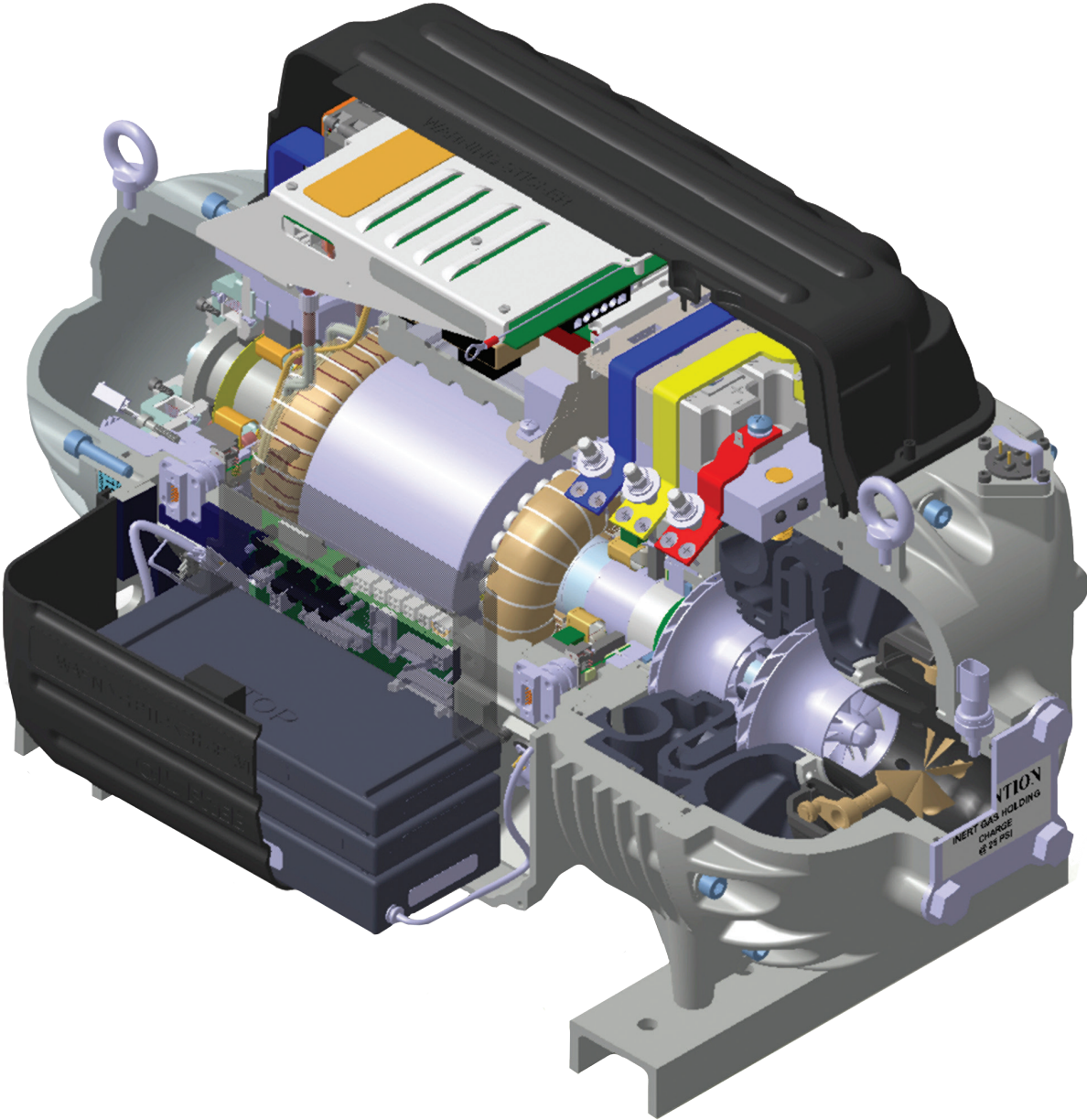
Figure 3: Frictionless design is more efficient over entire range.

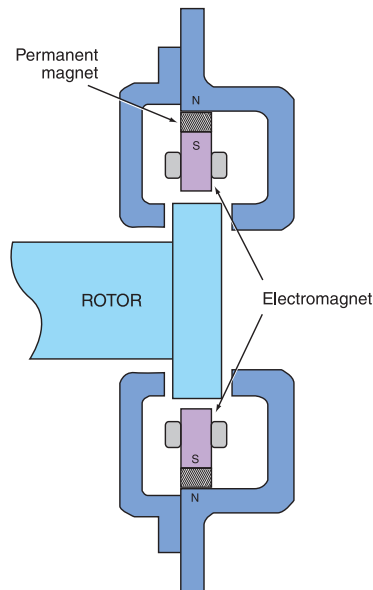
(Comparison with fixed speed conventional compressors)



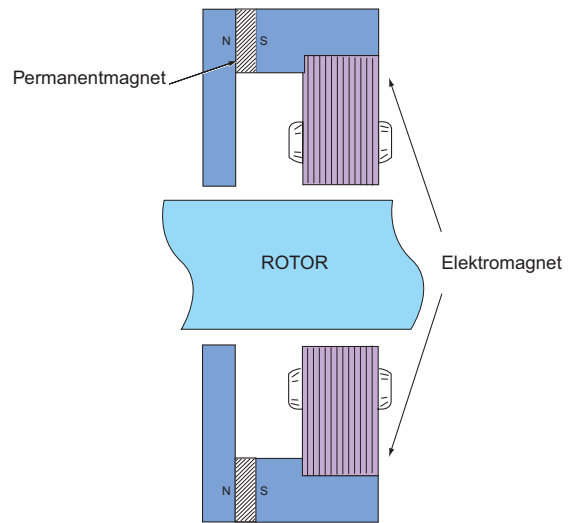
Rotor shaft is levitated using patented magnetic bearing technology.

Delivering
proven technologies





Cross-section of axial bearing



Cross-section of radial bearing

Magnetic bearings and bearing sensors

- Composed of both permanent and electromagnets with a unique, patented design for compact size and reliable high performance
- Enables precisely controlled frictionless compressor shaft rotation on a levitated magnetic cushion
- Bearing sensors, located at each magnetic bearing, feed back rotor orbit and thrust/axial information in real time to the bearing controller

Permanent-magnet synchronous motor

- Powered by PWM (pulse width modulated) voltage supply
- High-speed variable frequency operation affords high efficiency, compactness and soft start benefits

Touchdown bearings

- Radially and axially located bearings support the rotor when the compressor is not energized
- Provides backup, preventing contact between rotor/impeller assembly and other metal surfaces

Shaft and impellers

- Only one major moving compressor component
- Acts as rotor for permanent-magnet synchronous motor
- Impellers are keyed directly to the shaft

Variable frequency drive

- IGBT (Insulated Gate Bipolar Transistor) is an inverter that converts a DC voltage into an adjustable three-phase AC voltage
- Signals from the motor/bearing controller determine the inverter output frequency, voltage and phase, thereby regulating the motor speed
- Converts mechanical energy back into electrical energy. In case of power failure, this patented control scheme allows for a normal de-levitation and shutdown

Soft start module

- Significantly reduces high in-rush current at startup, providing advantages to line power systems and reducing thermal stress on the stator
- The startup in-rush current is only 2 amps vs. typically up to 250-350 amps experienced by conventional compressors in this tonnage range — truly redefining soft starts

Electronic package

- Single point connection to primary power supply
- Rectifier converts AC line power into a high-voltage DC power source
- Capacitors for smooth DC voltage supply
- DC-DC converters for supply and isolation of high and low DC voltages
- Network connection for external control and monitoring
- PWM amplifier for power to electromagnetic bearings
- Compressor bearing and motor controller microprocessor

Designed for **easy** application and **reliable** operation.

Easy and best solution for mid-sized chillers or DX systems

Designed for HVAC applications by HVAC engineers. Provides refrigeration for air conditioning applications with minimum evaporator temperatures down to 15 to 20°F/-9 to -6.6°C (dependent on system pressure ratio). Ideal for chillers or direct expansion air systems in comfort or process cooling applications.

Easy universal fit

All Danfoss Turbocor® models have the same physical size and same connection locations, and utilize the same controls and monitoring interface module - and mounts in the same standard way.

Easy on product and operating costs

Frictionless magnetic bearing design needs no oil management system.

Oil can't coat heat transfer surfaces, so unit efficiency remains high for life, offering customers the highest efficiency/lowest emissions, and the most cost-effective performance in its tonnage range.

Easy to control

Onboard digital electronics are "the brain inside" which makes the Turbocor® compressor totally self-contained while enabling sophisticated self-diagnostics, monitoring and control.

This intelligence is easy to tap with various control outputs - including ModBus and web-enabled monitoring and control.

Easy to maintain

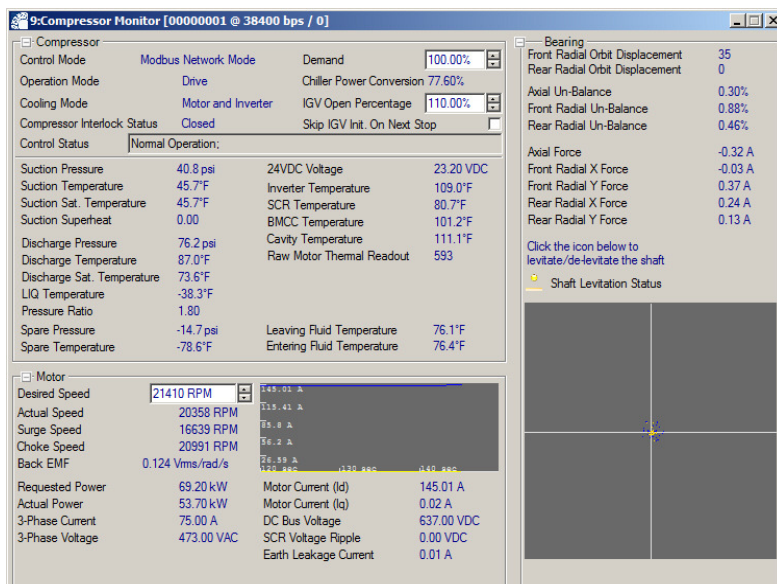
No oil service needs, no wear and tear on mechanical components, only simple preventive maintenance.

Easy refrigerant choice

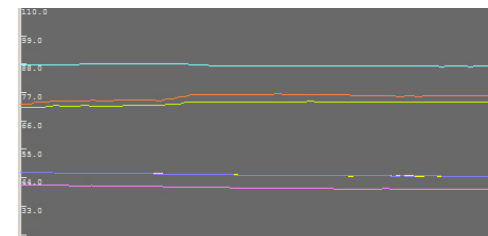
Optimized for HFC-134a, the established refrigerant with zero ozone depletion.

Easy to handle

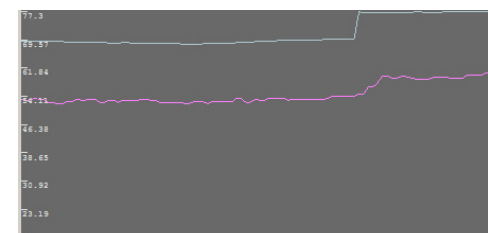
The compressors are under 300 lbs (136 kg), a fraction of the weight of conventional compressors with an approximate 50% smaller footprint.



Pressure and Temperature Trends



Requested/Actual Power Trends





Company Vision - Danfoss will be the world's preferred and primary supplier of Turbocor® compressors centrifugal compressors.

Customer Relationships - Danfoss will enter into partnerships with customers based on mutual respect and adherence to the best practices of business ethics, with recognition that many competitors exist.

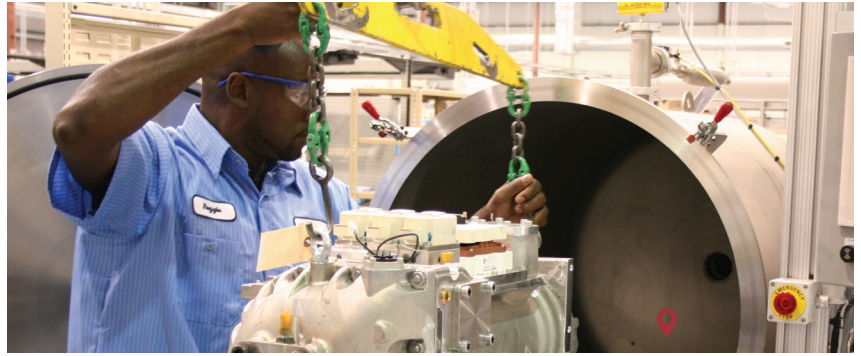


Operational Excellence - Danfoss will competitively deliver a quality product that meets or exceeds that of conventional compressor technology.

Giving you an inside advantage

Advanced design and manufacturing

Since 1993, our international team of designers and engineers has conducted a rigorous development program to produce and improve the Danfoss Turbocor® compressor.



Expert support

Danfoss experts provide comprehensive product and service training programs along with applications support for OEMs and their agents, and end-user customers.

We specialize in ensuring the successful application of HVAC equipment using Turbocor® refrigerant compressors on board.



Global Manufacturing and Support

Danfoss has state of the art manufacturing facilities in Tallahassee, Florida and Shanghai, China. The Tallahassee facility houses a 73,000 square foot manufacturing plant, test facilities, engineering, R&D and administrative offices.

Danfoss experts provide applications support for OEMs, their agents, and end-user customers.

In addition, compressor service centers are located Tallahassee, Frankfurt, Shanghai and Melbourne.



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ISO 14001: 2015 Certified
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