



The energy revolution

in air-conditioning and
refrigeration compressors



The Turbocor
family of
compressors

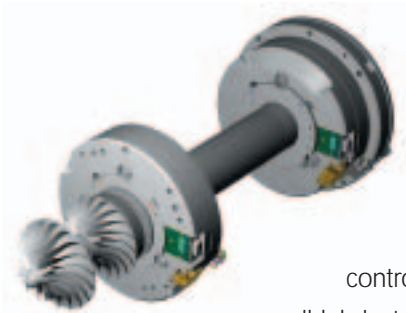
Danfoss
 **TURBOCOR**

This award-winning technology is the proud recipient of the ASHRAE/AHR Expo Energy Innovation Award and represents the future of

21st-century compressor technology.



The TurboCocor compressor is the world's first totally Oil-Free compressor specifically designed for the Heating, Ventilation, Air Conditioning and Refrigeration (HVACR) industry. The convergence of aerospace and industrially proven magnetic bearings, variable-speed centrifugal compression and digital electronic technologies enables the TurboCocor family of compressors (nominal 60-150 ton capacity range) to achieve the highest compressor efficiencies, cost effectively, for middle-market, water-cooled, evaporative-cooled and air-cooled HVACR applications.



Totally oil-free operation

High friction losses and the maintenance-intensive oil management hardware and controls associated with conventional oil-lubricated bearings are now totally eliminated by the utilization of modern magnetic bearing technology, enabling outstanding energy efficiency and reliable, long-life frictionless operation. The TurboCocor compressor's one moving part (rotor shaft and impellers) is levitated during rotation by a digitally controlled magnetic bearing system consisting of two radial and one axial bearing. Position sensors at each magnetic bearing provide real-time repositioning of the motor rotor over six million times a minute insuring precise timing.

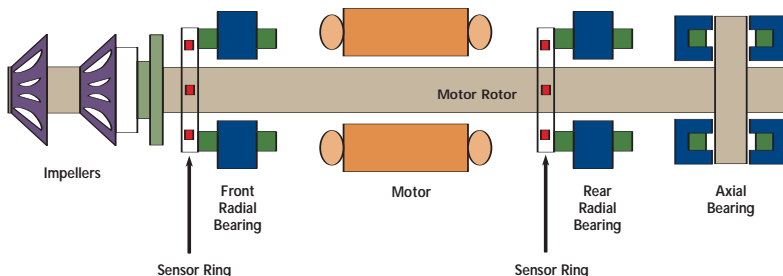
Magnetic bearings levitate the rotor shaft

Variable-speed drive centrifugal compression

The well-proven energy performance advantages of variable-speed centrifugal chiller compressors are now brought to mainstream middle-market applications through the use of high-speed, two-stage centrifugal compression with integral variable-speed drive. Compressor speed is reduced as the condensing temperature and/or heat load reduces, optimizing energy performance through the entire operating range from 100% to 20% or below of rated capacity. Operation to near zero loads are achievable via an optional, digitally controlled, load balancing valve.

Onboard digital electronics

The world's first truly "smart" compressors, Danfoss TurboCocor utilize on-board digital control electronics to proactively manage compressor operation while providing external control and web-enabled monitoring access to a full array of performance and reliability information. It also provides many of the control functions that have been previously performed by the power and control panels of the chiller or rooftop package, saving product costs.



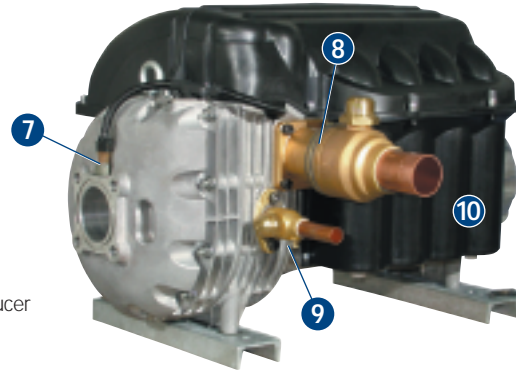
The **Turbocor family** of compressors



- 1 Power electronics enclosure
- 2 Main power wiring enclosure
- 3 Service enclosure (access to replaceable circuit board modules)
- 4 Lifting lugs
- 5 Suction connection

- 6 Mounting feet
- 7 Pressure/temperature transducer
- 8 Discharge connection
- 9 Economizer connection
- 10 Energy storage capacitors

Manufactured from aircraft grade aluminum castings with high strength thermoplastic electronics enclosures, the Turbocor compressor is a rugged workhorse, designed for long operating life.



Unprecedented energy efficiency for middle-market applications

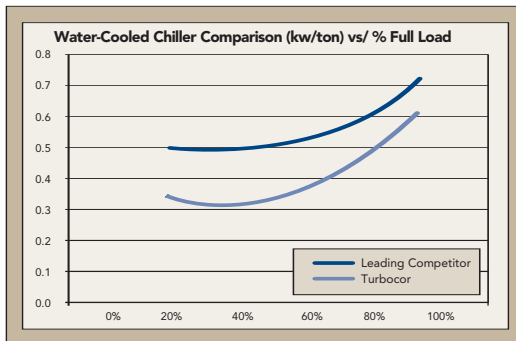


Chart 1

Outstanding energy savings from digitally controlled frictionless two-stage centrifugal compression means significant reductions in operating cost and environmental emissions associated with energy production.

Chart 1 shows the full and part load performance curve of the Turbocor compressor compared with a typical oil-flooded screw compressor on a 75-ton water-cooled chiller. The integrated part load values (IPLV) yields a 30% plus improvement in many applications.

Typical water-cooled chiller operating cost savings calculation

	Turbocor	Screw Compressor	Savings
IPLV kW/TR	0.41	0.63	0.22
Tons capacity	75	75	—
kW	30.75	47.25	16.5
Annual operating days	180	180	—
Operating hours per day	10	10	—
Total annual kWh	55,350	85,050	35,640
Power cost (\$/kWh)	\$0.10	\$0.10	—
Annual operating cost	\$5,535.00	\$8,505.00	\$2,970.00
2-year savings			\$5,940.00
3-year savings			\$8,910.00

Environmental Impact: Extending this example, the 35,640-kWh energy savings through the use of a Turbocor compressor yields an **annual CO₂ emissions reduction of over 53,000 lbs** (U.S. EPA average emissions).

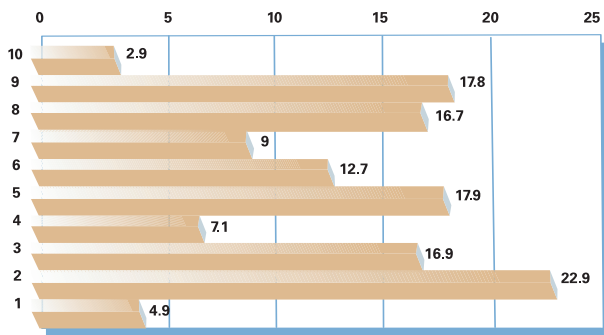
And this is an energy efficiency advantage that will last a lifetime.

Turbocor compressors are not only more efficient, they are also Oil-Free, offering a huge advantage in sustainable performance over the entire lifetime of the application. Why? Oil has some very costly consequences – energy robbing consequences.

Let's consider one example: a flooded evaporator chiller design. In these designs, oil used for lubrication frequently migrates to the evaporator. Once in the evaporator, it can coat the tubes degrading the tubes' ability to transfer heat. While many of today's chillers have designs that minimize this oil loss, or incorporate oil recovery devices, the very best way to assure oil contamination never occurs is to eliminate oil all together.

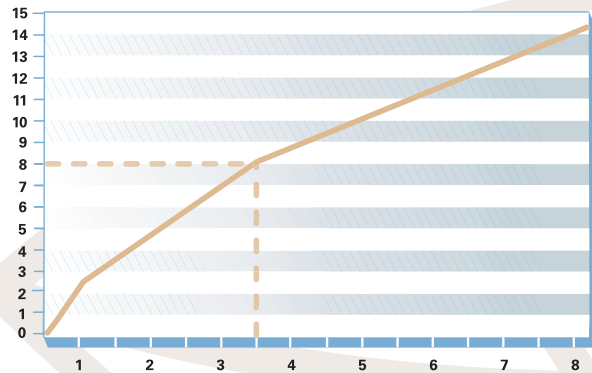
And just how much oil typically was found in evaporators of older CFC flooded evaporator designs and how much did that oil degrade the performance of the chiller? To help answer those questions, an ASHRAE research project, 601, was designed to document the percentage of oil in refrigerant in older CFC chillers. The results of this project are shown in Fig. 1; results that show that in older CFC-11 chillers the average oil content was 13 percent with an impact on efficiency of over 15 to 20 percent!

Figure 1 — Oil content found in samples of older CFC centrifugals



* Data taken from ASHRAE research project 601.

Figure 2 — Percent efficiency loss



Charts reprinted courtesy of Trane

Given this concentration of oil in the refrigerant, what is the impact on the efficiency of the chiller? To answer that question, one company, Trane®, conducted extensive laboratory experiments. Fig. 2 illustrates the results of that testing, showing a full 8% efficiency hit even at only 3½% oil content in the refrigerant.

How much money would this level of oil contamination cost owners? Consider the following 300-ton chiller example:

- A 300-ton chiller
- 2000 equivalent full-load operating hours (ELFH)
- \$0.10/kWh (a combined rate accounting for both kWh and demand)
- 0.596 kW/ton (ASHRAE 90.1 minimum IPLV efficiency – centrifugal chillers, 150-300 tons)

Consumption: 300 tons x 2000 EFLH x 0.596 kWh/ton x \$0.10 = \$35,760/year

An 8 percent efficiency impact would cost an owner nearly \$3,000 per year and, over the 25-year lifetime, over \$70,000 – more than the initial cost of the entire chiller.

It's easy to gain the **energy advantage** in HVACR applications

Easy to work with

Designed for HVACR applications by HVACR engineers, the Turbocor compressor is virtually a “plug-and-play” solution. It features the same standard suction, discharge and economizer ports as conventional compressors. It mounts in the standard way. It can use the same power wiring with a single control and monitoring connection.

Easy on product cost — this frictionless magnetic bearing design needs no oil management system. And because there's no oil to coat the heat transfer surfaces, the unit's high efficiency can be maintained over the lifetime of the product. The outstanding efficiency of the Turbocor compressor gives equipment manufacturers the option to offer the highest efficiency/lowest emissions, cost effective performance in its tonnage range.

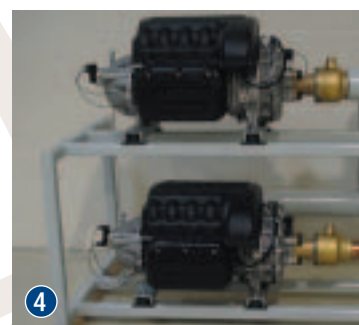
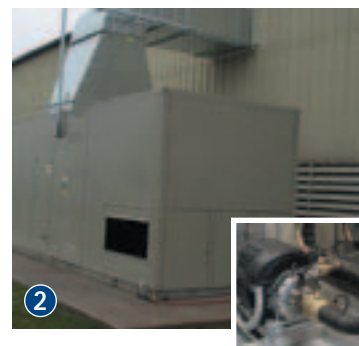
Easy on the ears — a sound level less than 70 dBA, with virtually no structure-borne vibration, eliminates the need for expensive attenuation accessories.

Easy to handle — 265 pounds (120 kg) is less than 20% of the weight of competitive compressors with an approximate 50% smaller footprint.

Easy refrigerant choice — since the Turbocor compressors are optimized for HFC -134a, a well known, environmentally responsible, refrigerant.

Easy to control — onboard digital electronics make the Turbocor compressor “the compressor” with a brain. Inside, the compressor is totally self-correcting and incorporates a system of sophisticated self-diagnostics, monitoring and control. Outside, you can tap into this intelligence by using control outputs in various forms— including web-enabled monitoring and control.

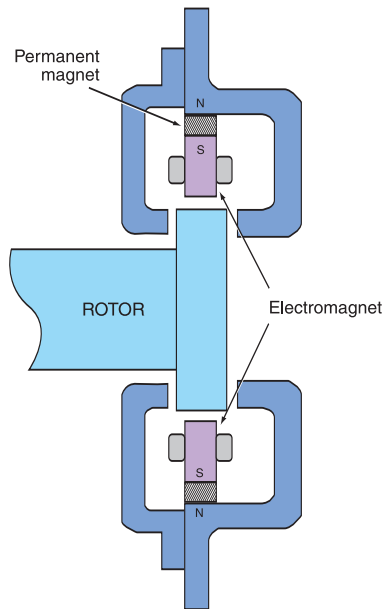
Easy on energy — the Turbocor compressor enables chiller and rooftop manufacturers to achieve the necessary product efficiency levels to meet and exceed ASHRAE 90.1 and the California Title 24 requirements for energy efficiency.



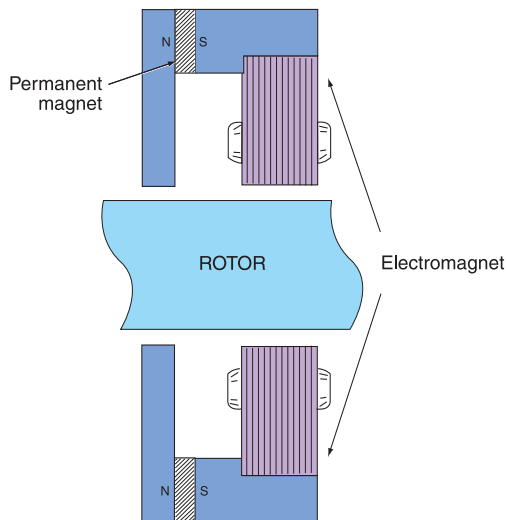
- 1 Water-cooled chiller applications
- 2 Rooftop and packaged system applications
- 3 Air-cooled chiller applications
- 4 Multiple compressor applications

Aerospace and industrially proven technologies

Mechanical components



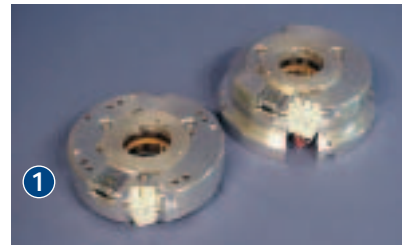
Cross-section of axial bearing



Cross-section of radial bearing

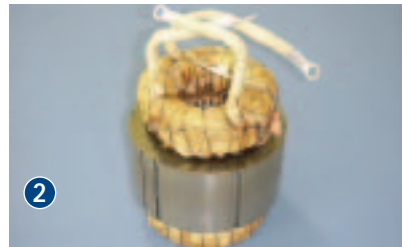
1 Magnetic bearings and bearing sensors

- Composed of both permanent and electromagnets
- 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 bearing control



2 Permanent-magnet synchronous motor

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



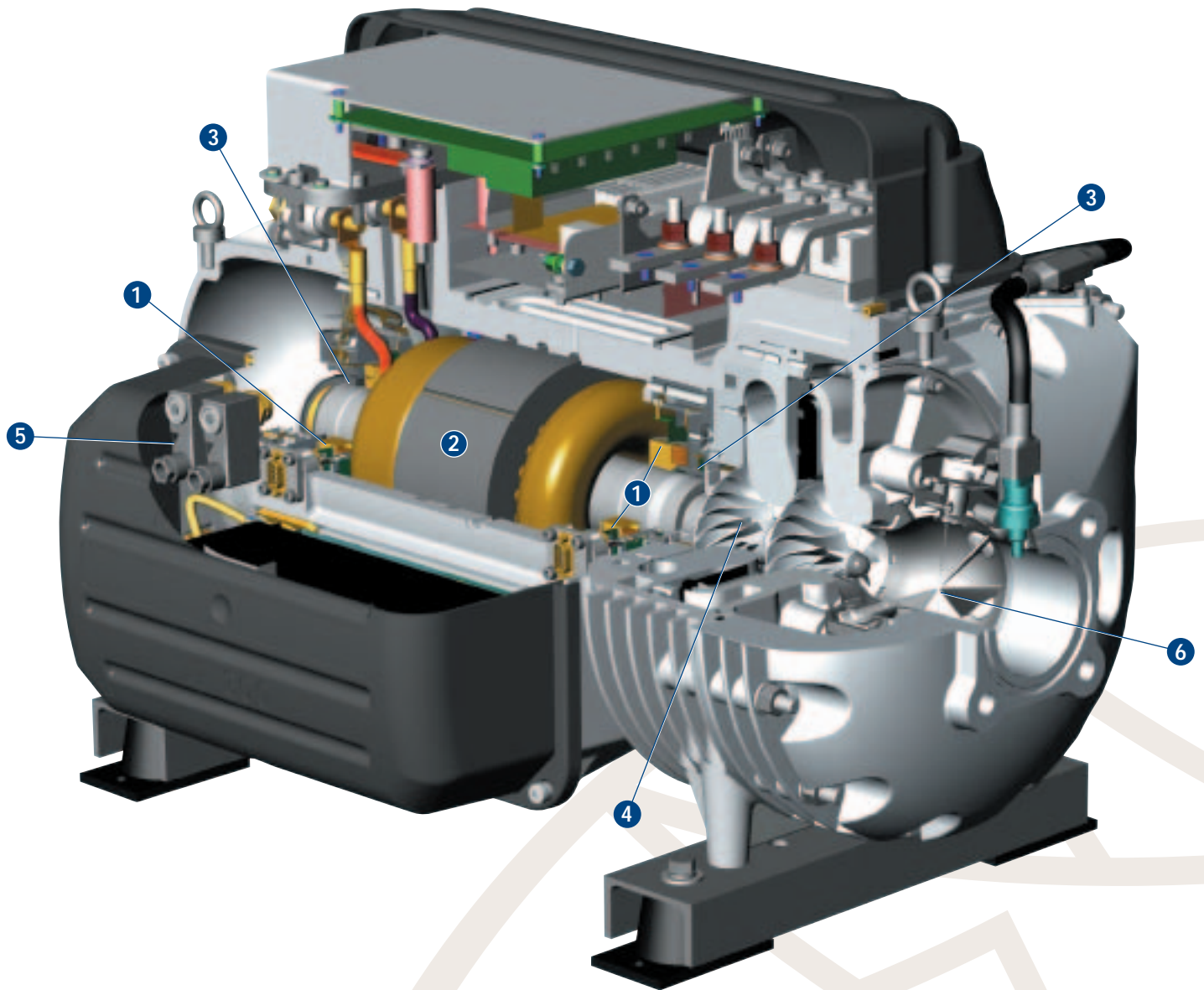
3 Touchdown bearings

- Carbon-lined radially and axially located bearings support the rotor when the compressor is not energized
- Prevents contact between the rotor and other metallic surfaces

4 Shaft and impellers

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





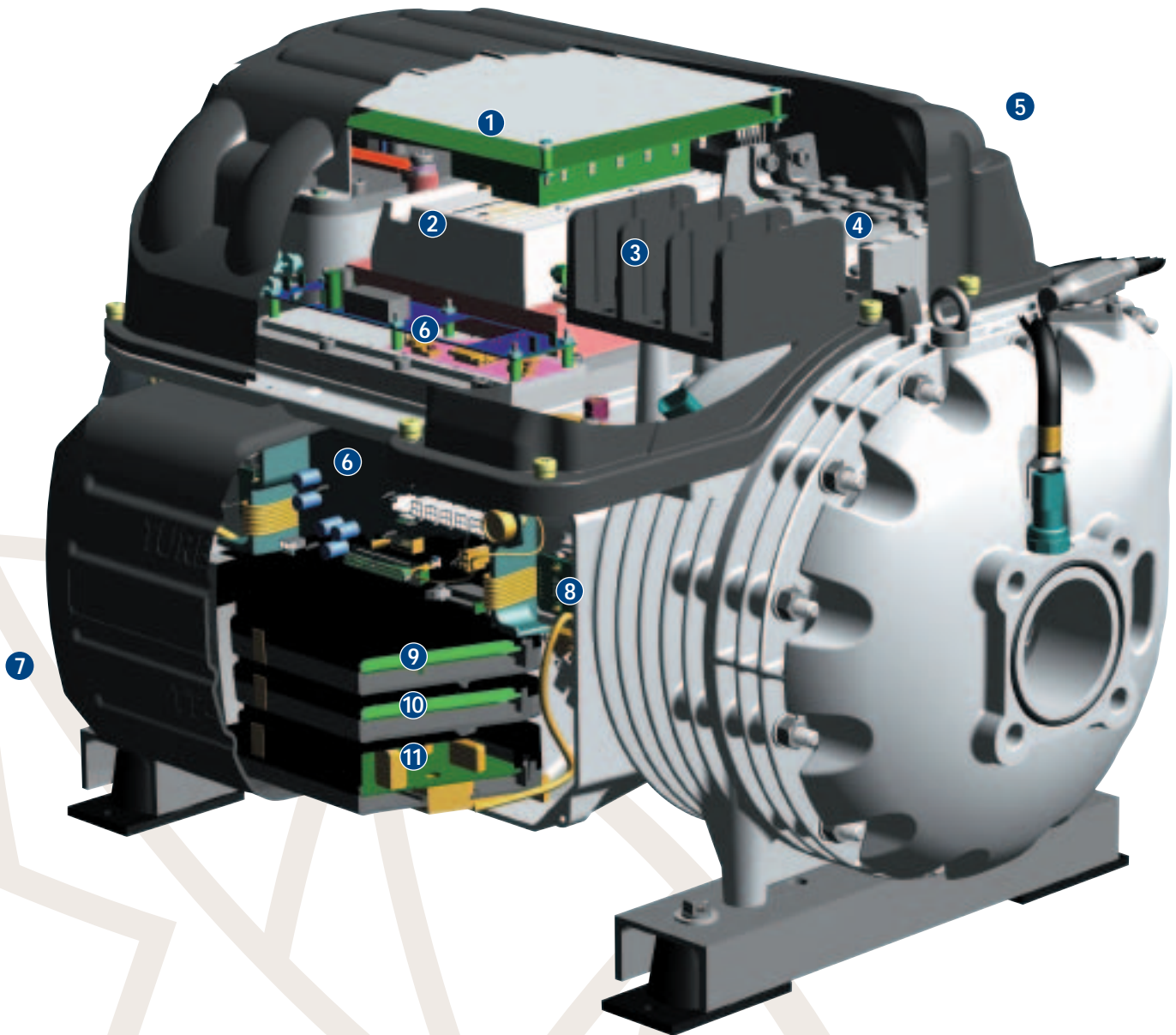
5 Compressor cooling

- Liquid refrigerant flow is controlled electronically, cooling electronic, mechanical and electromechanical compressor components to assure maximum efficiency and safe operation

6 Inlet guide vane assembly

- Trims compressor capacity and is digitally integrated with the variable-speed control, to optimize energy efficiency and compressor performance





Electrical components

- 1 Soft start module**
 - Significantly reduces high in-rush current at startup
 - The startup inrush current is only 2 amps vs typically up to 500-600 amps experienced by traditional screw compressors in this tonnage range – truly redefining soft starts
- 2 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,

On board **digital electronics**

this patented control scheme allows for a normal de-levitation and shutdown

3 Three-phase terminal block

- Connection point for primary power supply

4 Rectifier

- Converts AC line power into a high-voltage DC power source for motor, bearings and control operations

5 Capacitors

- Energy storage and filter for smooth DC voltage
- Provide power to the magnetic bearings, along with motor rotation, to ensure rotor shaft levitation through compressor coastdown in the event of an external power loss

6 DC-DC converters

- Supplies and electrically isolates the high and low DC voltages required for the control circuits

7 Controls connection

Network connection for external control and monitoring

8 Bearing sensor feedthroughs

- Hermetically sealed connections enabling the transfer of power to the electromagnetic bearings and shaft position and rotation signals to the control modules

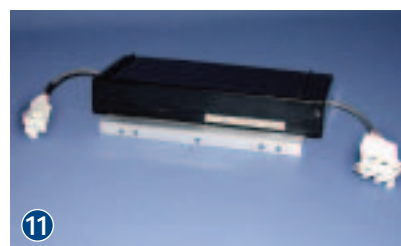
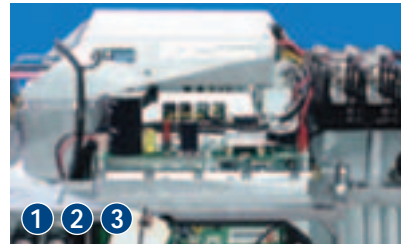
9 Driver Board/EXV Control

10 Compressor and bearing controller

- Central processor of the compressor system
- Continuously updated with critical data from the motor/bearing and external sensors that indicate the compressor and chiller/rooftop package operating status
- Software enabled, it responds to changing conditions and requirements to ensure optimum system performance
- Computes the required shaft position signals that control the magnetic bearings
- Processes motor current information to control motor speed

11 PWM amplifier

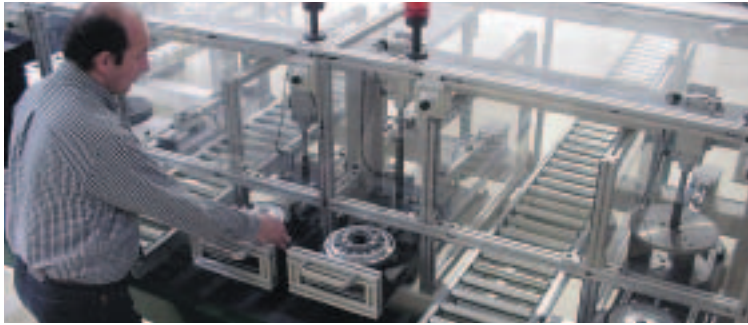
- Supplies power to the electromagnetic bearings



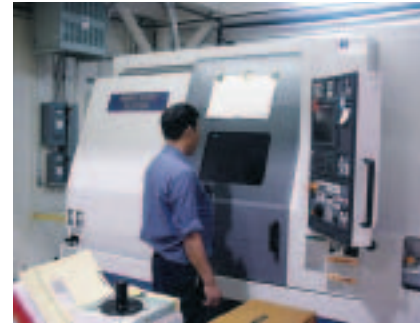
Advanced technology

from design through manufacturing and testing

Manufacturing

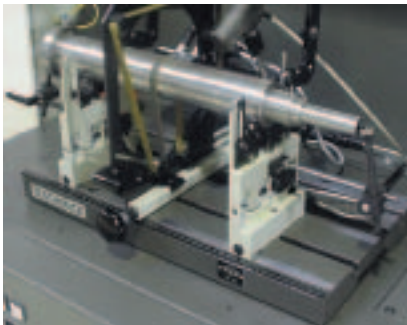


Automated assembly

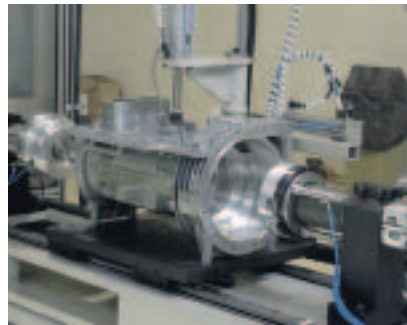


Computer-controlled manufacturing centers

Quality control



Precision balancing



Advanced computer measurement and verification of components



Statistical process control ensures continuous improvement in methods and procedures

Testing



Test center with web-enabled field compressor monitoring



Life-cycle component and material testing

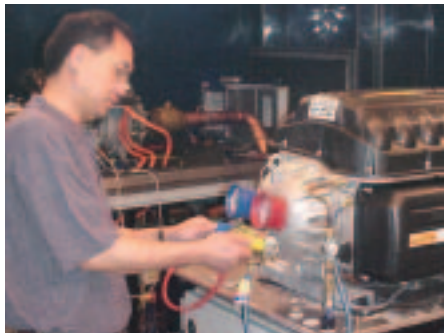


Water- and air-cooled chiller testing facilities

Get expert service and support from a company **on the move**



Danfoss Turbocor headquarters



Factory service and support



Compressors and parts stocking programs

Since 1993, our international team of designers and engineers has conducted a rigorous development program to produce the Turbocor compressor. With that objective now realized, the company has grown to become a commercial enterprise solely dedicated to the design, manufacture, marketing and support of the world's most efficient, cost effective commercial refrigerant compressors.

Located in the heart of Montreal's high technology district and convenient to Montreal/Dorval International Airport, Danfoss Turbocor's headquarters houses a stage-one manufacturing plant, test facilities, engineering, R&D and corporate offices.

The Danfoss Turbocor team of HVACR professionals provides comprehensive product and service training programs along with product applications support to its OEM, ESCO authorized retrofit agents and end-user customers, thus enhancing the successful introduction and field operation of HVACR equipment using Turbocor refrigerant compressors on board.



" Responsible Use "

Danfoss Turbocor is a proud supporter of the U.S. EPA's Responsible Use Vision, a vision that encourages manufacturers, owners, and system designers to invest in those technologies that produce documented sustainability of the highest efficiency/lowest emissions, cost effective products, systems and services.

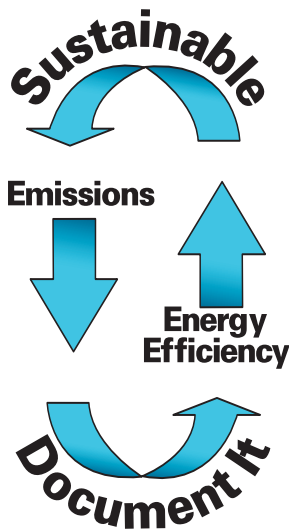
The Responsible Use vision is best described using the following visual. Also at a glance, one can see why, in its tonnage range, the Turbocor family of compressors is uniquely positioned to meet this vision.

The Vision:

Insure the performance is sustained over the entire lifetime of the product, system or service.

Invest in cost effective technologies that produce the highest efficiency/lowest emissions.

And, then, make sure this performance can be documented.



The Turbocor advantage

Oil-Free means no oil to contaminate the refrigerant and degrade performance. Oil-Free also means no parasitic oil losses, no oil pump, oil heater, etc. Oil-Free offers a quantum leap toward true sustainability.

In its tonnage range, the Turbocor compressor family, cost effectively, has the highest efficiency/lowest emissions in the industry.

The Turbocor compressor is a computer that thinks it's a compressor. This inherently provides an ability to document performance at an unprecedented level. Performance that can be viewed and accessed either via dial-up modems or the world wide web.

Bottom line, the message is clear. In its tonnage range, the Turbocor compressor technology provides the very best way to meet the U.S. EPA's Responsible Use Vision – a vision that defines the future for the HVACR industry.



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