

Magnetic Levitation Chiller Technology

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Introduction

Magnetic bearing technology has successfully been in use for over 70 years. The first magnetic bearing technology patents were issued in the 1940s to a University of Virginia professor who was developing the technology for use in ultracentrifuges. Since then, magnetic bearing technology has been implemented in many products such as industrial machinery, maglev trains, and even artificial hearts. The magnetic bearing system levitates the compressor shaft, and the shaft practically rotates in air. Having no surface contact, no friction in magnetic bearing systems, leads to infinite life of the bearing with no wear and tear.

About the Author

Shailesh Nigam is a mechanical engineer with additional qualification in marketing management, having more than 24 years of HVAC industry experience. After a brief stint in Fedders Lloyd in 1992, he moved to Blue Star in project sales and worked there till 2000. This was followed by a spell at McQuay in Kuwait, and one at Trane, before he returned to join Daikin Air-conditioning India in 2010. He is currently DGM – Applied Business, a corporate role, heading marketing and product management.

Types of Water Chillers

Water chillers are used in a variety of air conditioning and process cooling applications. They are used to produce chilled water that can be transported throughout a facility using pumps and pipes. This chilled water can be passed through the tubes of coils to cool the air in an air conditioning application, or it can provide cooling for a manufacturing or industrial process. Systems that employ water chillers are commonly called chilled water systems.



Figure 1: A Maglev chiller

There are several types of water chillers. They differ from each other based on the refrigeration cycle or the type of compressor they use.

Water chillers using the vapor-compression refrigeration cycle vary by the type of compressor used. Reciprocating and scroll compressors are typically used in small chillers. Helical-rotary (or screw) compressors are typically used in medium-sized chillers. Centrifugal compressors are typically used in large chillers.

The centrifugal compressor uses the principle of *dynamic compression*, which involves converting energy from one form to another, to increase the pressure and temperature of the refrigerant. It converts kinetic energy to static energy.

The core component of a centrifugal compressor is the rotating impeller. The center, or eye, of the *impeller* is fitted with blades (inlet guide vanes) that draw refrigerant vapor into radial passages that are internal to the impeller body.

The rotation of the impeller causes the refrigerant vapor to accelerate within the *impeller passages*, increasing its velocity and kinetic energy. The accelerated refrigerant vapor leaves the impeller and enters the *diffuser passages*. These passages start out small and become larger as the refrigerant travels through them. As the size of the diffuser passages increases, the velocity, and therefore the kinetic energy, of the refrigerant decreases.

The first law of thermodynamics states that energy is not destroyed – only converted from one form to another. Thus, the refrigerant's kinetic energy is converted to static energy or static pressure. Refrigerant, now at a higher pressure, collects in a larger space around the perimeter of the compressor called the volute. The volute also becomes larger as the refrigerant travels through it. Again, as the size of the volute increases, the kinetic energy is converted to static pressure.

Due to its pressure and temperature, the refrigerant leaving the compressor is in a condition that allows its heat to be rejected in the condenser.

Magnetic levitation chillers, also known as Maglev chillers, are oil free chillers operating on the magnetic bearing technology.

Like other centrifugal compressors, the magnetic levitation technology utilizes centrifugal energy, imparted to the refrigerant gas by a rotating impeller, to increase pressure. However, unlike



Figure 2: Magnetic bearings

a standard centrifugal chiller in which the compressor shaft/impeller assembly rides on conventional bearings, in magnetic levitation technology products a magnetic bearing system levitates the shaft/impeller assembly inside the compressor body. This frictionless system has multiple benefits.

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Unlike a standard centrifugal chiller, which utilizes conventional touch bearings, there are no moving contact surfaces within the magnetic levitation technology compressor. This frictionless compressor design contributes significantly to the efficiency of the chiller. Additionally, because there are no moving contact surfaces, mechanical wear issues are non-existent and oil, and an associated oil management system, are not required nor used. The oil-free design enhances efficiency and promotes sustainable performance.

Magnetic levitation technology chillers essentially have variable frequency drives. The VFD is integral to the compressor body on the smaller size compressor design, whereas it is housed in a separate panel on large compressor chillers. The VFD is a significant contributor to the industry-leading efficiency of Maglev chillers.

Magnetic levitation technology compressors have excellent unloading capabilities and do not require the utilization of inefficient hot gas bypass. Other salient features are:

- Semi-hermetic, direct drive motor,
- Suction gas inlet and inlet guide vanes (IGVs work in conjunction with the VFD to react to load requirements – open with higher load, close with unloading),
- Shaft assembly – two stage compression (two impellers) for smaller size compressors; larger size compressor design has single stage (one impeller) compression.

What happens to this high-speed machine when there is sudden power failure? On the smaller size compressor, there is bay of capacitors across the back of the compressor. And larger compressor utilizes similar regenerative power for controlled coast-down.

Capacitors are charged at start-up. In the event of a power outage and unit shutdown, the energy stored in the capacitors will be fed back into the system to allow the shaft to spin down gently while still remaining levitated. Finally, when the capacitors are discharged and there is not enough power to keep the shaft levitated, it will gently sit down onto the touchdown bearing system. Coast-down from 100% load takes approximately 30 seconds.

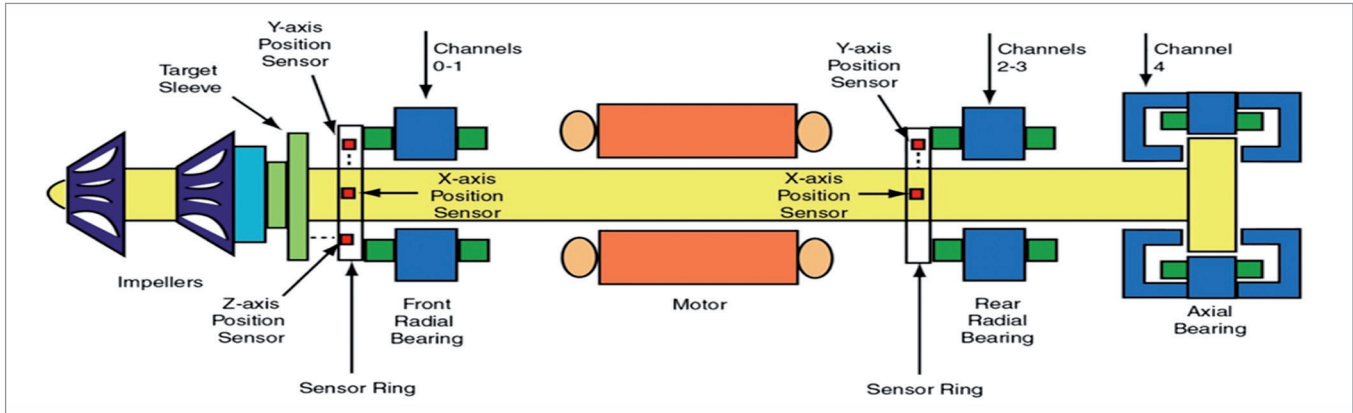


Figure 3: Schematic of a magnetic levitation centrifugal compressor

Working of a Maglev Compressor

Let us take a look at the general theory behind magnetic bearing compressor design. The schematic in Figure 3 displays the general arrangement of the shaft/impeller assembly, motor and magnetic assemblies inside a dual impeller compressor.

The position of the shaft is constantly monitored by 5 axis proximity sensors; these signals are sent to the digital controller, which then sends a command to the 5 separate pulse width modulators (PWM), repositioning the shaft on a continual basis.

Movements of less than 0.00002" are sensed and adjustments are made accordingly. This process occurs 100,000 times per second.

There are front and rear electromagnetic radial bearings and axial (thrust) permanent magnet bearings. When the compressor is powered, bearings are magnetized to levitate the shaft/impeller assembly. Sensors communicate thousands of signals per second back to the compressor control module to keep the shaft perfectly aligned while spinning.

Capacitors are charged at start-up. In the event of a power outage (approximately 1 second of power interruption or voltage dip/spike in excess of 10%) and consequent unit shutdown, the energy stored in the capacitors will be fed back into the VFD and magnetic bearing system to allow for the shaft to spin down gently while still remaining levitated.

Finally, when the capacitors are discharged and there is not enough power to keep the shaft levitated, it will gently sit down into the touchdown bearing system. Coast-down from 100% load to zero rotation takes approximately 30 seconds. The touchdown bearings, dependent upon compressor size, are made of either a carbon material or roller-type bearings.

An important feature of the magnetic bearing chiller is that it is designed to be oil-free. As there is no physical contact of the shaft/impeller assembly with any other components while the system is in motion, oil – and consequently an oil maintenance system – is not used.

Most technicians with centrifugal chiller experience will vouch that their most troublesome chiller maintenance issue pertains to the oil system. Even if the oil system is working correctly, a strict

maintenance regimen is required to ensure that it keeps working correctly. This burden is avoided with the magnetic levitation technology.

Oil is a 'necessary evil' in any conventional system, which is completely absent in Maglev systems. Oil in a conventional system gets carried to the evaporator and condenser and does not return completely to compressor. This oil makes a very thin covering on the tube surface, which hinders heat transfer resulting in performance loss of the chiller. Oil free magnetic bearing design ensures sustainable performance of the chiller. Absence of oil managements system results in lower maintenance cost and substantial saving.

Conclusion

Recent studies have shown that oil can have a drastic effect on more than just maintenance obligations and costs. Articles published in the *RSES Journal* and the *Air-Conditioning, Heating, Refrigeration NEWS* have highlighted the effects of oil buildup in the chiller on capacity and performance. A table published in the *NEWS* (Figure 4) shows that oil accumulation in the evaporator can have devastating effects on chiller performance. Maglev compressors offer sustainable performance – the capacity and efficiency you achieve on the last day you run the chiller should be the same as the day you started it up.

OIL CONTAMINATION	
Oil in Evaporator	Performance Loss
1-2%	2-4%
3-4%	5-8%
5-6%	9-11%
7-8%	13-15%

Figure 4: Performance loss of chiller due to oil contamination in evaporator

Due to no metal-to-metal contact, sound level is in the range of 76 dBA, which is extremely low.

Magnetic bearing compressor is a futuristic technology with more and more manufacturers adopting it to attain sustainable performance and greener environment.