

# Grounding of HVAC Motor Shafts Protects Bearings, Lowers Repair Costs



## Overview

Maximum energy efficiency is the cornerstone of a long and growing list of building certification initiatives such as LEED, Green Globes, Zero Energy Buildings, Living Building Challenge, and Energy Star for Buildings. And variable frequency drives (or VFDs) are a key tool in achieving this energy efficiency. By allowing motors to run at less than full speed, VFDs let HVAC system designers match capacity to changing heating/cooling loads, dramatically reducing energy costs. But VFDs can also damage the bearings of the motors they control — often in as little as 3 months! To ensure the reliability of VFD-driven HVAC motors and lock in energy savings from VFDs, proven long-term bearing protection is essential.



## Introduction

### VFD-Induced Currents Destroy Bearings, Kill Motors

Challenged to reduce energy consumption, facility managers are installing variable frequency drives (VFDs, also known as inverters) in heating, ventilation, and air conditioning (HVAC) systems. By allowing motors to run at less than full speed, these drives can yield energy savings of 30% or more, but they also induce currents that can damage bearings and shorten motor life. The resulting repair costs can wipe out any savings from VFD use. To make HVAC systems truly reliable as well as energy-efficient, proven long-term bearing protection is needed.

Many HVAC fans and pumps run continuously, but often at reduced loads. Because the energy consumption of such devices correlates to their flow rate cubed, the motors that drive them will use less power if controlled by a VFD. In fact, reducing a fan's speed by half cuts the horsepower needed to run it by a factor of eight. In light of this, throttling mechanisms that restrict the work of a motor seem old-fashioned and wasteful.

Although the energy-saving potential of VFDs was never in dispute, for years the true cause of VFD-induced bearing failure was often misdiagnosed. Eventually, repair shops and testing consultants proved that the high peak voltages, fast voltage rise times, non-sinusoidal shaft currents, and parasitic capacitance associated with typical pulse-width-modulated VFDs lead to the cumulative erosion of bearings. Since many of today's motors have sealed bearings to keep out dirt and other contaminants, electrical damage has become the most common cause of bearing failure in VFD-controlled AC motors.

Without mitigation, voltages repeatedly build up on the motor shaft to a certain threshold, then discharge in short bursts along the path of least resistance, which all too often runs through the motor's bearings. The discharge rate tends to increase with carrier frequency.

Continued discharges result in the pitting [Figure 1] of the balls and race walls through electrical discharge machining (EDM). Concentrated pitting at regular intervals along the race wall can cause washboard-like ridges called fluting [Figure 2], a source of vibration and noise that can reverberate through ductwork. By the time such damage can be heard, bearing failure is often imminent.

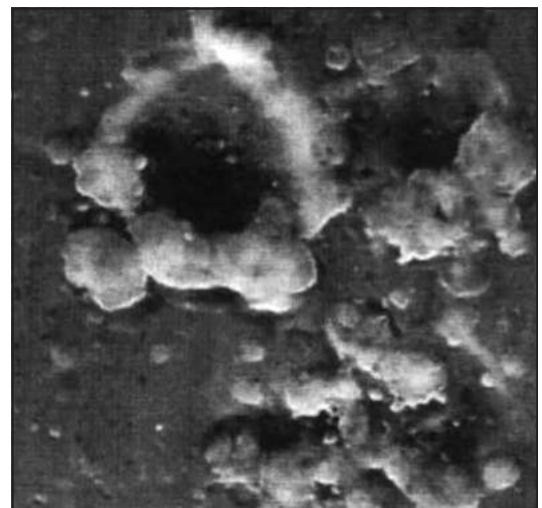


Figure 1

*Pitting of a bearing race wall (magnified) —  
the result of VFD-induced electrical discharges  
from the motor shaft.*

Figure 2

*Taken from a failed motor, the “fluted” bearing race wall (left) resulted from VFD-induced bearing currents. Protected by an AEGIS® Bearing Protection Ring, the bearing race on the right is undamaged.*



### **NEMA Standards Call for Shaft Grounding**

Standards issued by the National Electrical Manufacturers Association (NEMA) highlight the need for extra bearing protection for VFD-driven motors.

NEMA Standard MG1, Section IV, Part 31, Definite-Purpose Inverter-Fed Polyphase Motors, (to be addressed by Construction Specifications Institute specification 23 05 13 for HVAC motors), recommends bearing insulation at one end of the motor if the NEMA motor frame size is 500 or larger and the peak shaft voltage is greater than 300 millivolts. In these larger motors, bearing damage may be due in part to magnetic dissymmetries that result in circulating end-to-end shaft currents.

For smaller motors, the same standard recommends insulating both bearings with high-impedance insulation or installing shaft grounding brushes to divert damaging currents around the bearings. For these motors, a VFD can generate high-frequency common mode voltage, which shifts the three-phase winding neutral potentials significantly from ground. Because the damaging voltage oscillates at high frequency and is capacitively coupled to the rotor, the current path to ground can run through either one bearing or both.

The NEMA standard points out, however, that bearing insulation will not prevent damage to other connected equipment. When the path to the bearings is blocked, the damaging current seeks another path to ground. That other path is often through a fan, pump, compressor, air handler, gearbox, encoder, break motor, or other piece of connected equipment, which can consequently wind up with bearing damage of its own.

### **AEGIS® Ring Protects Motor Bearings From Damaging Currents**

Ironically, some products designed to protect bearings from electrical damage, such as conventional spring-loaded grounding brushes, require extensive maintenance themselves. Others, such as ceramic bearings, can shift damage to connected equipment. Many so-called “inverter-duty” motors offer beefed-up winding insulation, but this insulation does nothing to guard against bearing damage. If they are to be truly ready for use with VFDs, these motors also need bearing protection.

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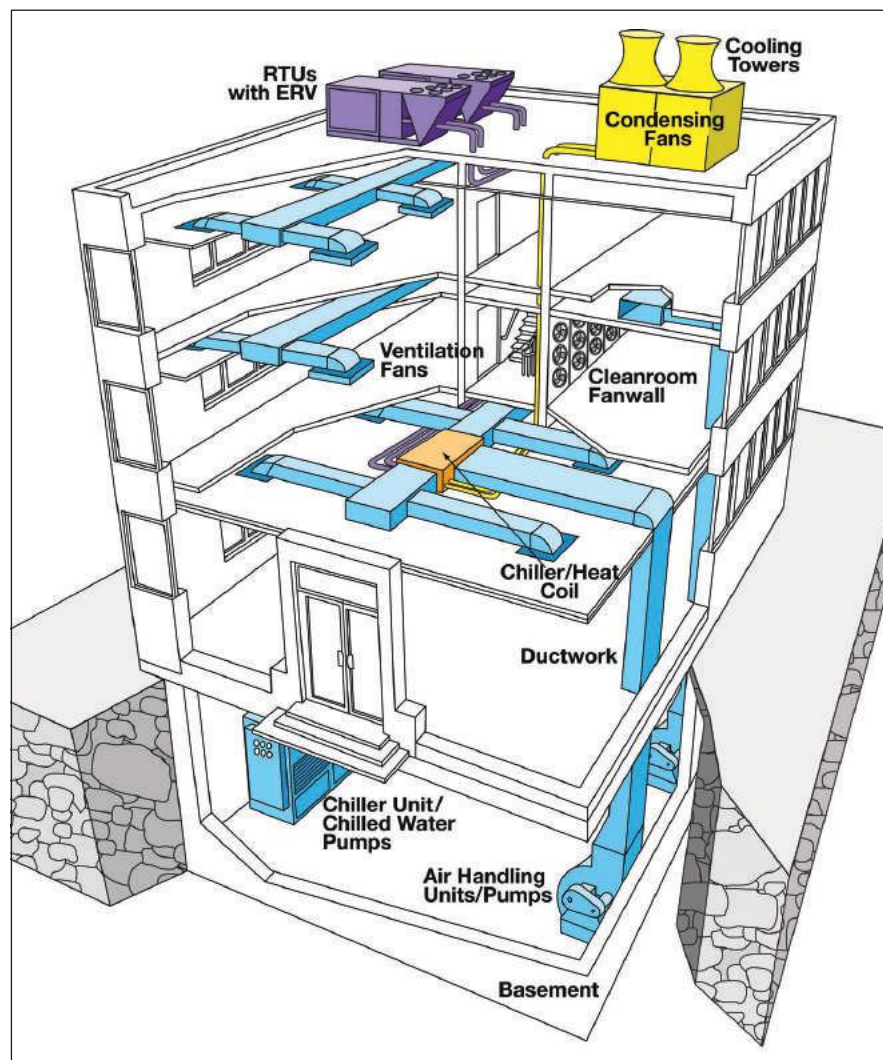
#### Circumferential Conductive Micro Fiber Shaft Grounding Rings

One of the most promising protective devices uses the principles of electron tunneling, field emission of electrons, and ionization to safely and efficiently bleed off damaging currents. Installed around a motor shaft, maintenance-free AEGIS® Bearing Protection Rings provide a very-low-impedance path from shaft to ground, bypassing motor bearings.

As preventive maintenance for motors already in service, these rings can be quickly and easily retrofitted onto any NEMA or IEC motor regardless of shaft size, horsepower, or end-bell protrusion using conductive epoxy and/or the Universal Mounting Kit. The conductive microfibers that line the entire inner circumference in two rows, completely surrounding the motor shaft, boost the ring's electron transfer rate. The rings require no maintenance and last for the life of the motor, regardless of rpm. When installed on VFD-controlled motors, they qualify as sustainable technology under the Federal Energy Management Program.

Figure 3

*To save energy and help make buildings "green," the AC motors in many types of HVAC equipment today are controlled by variable frequency drives and thus are vulnerable to bearing damage. This diagram shows some of these applications where shaft grounding makes motors and systems sustainable as well as energy-efficient.*





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#### Shaft Grounding Proven Effective on Rooftop Unit

Figure 4

*Rooftop HVAC unit in Michigan where a newly installed AEGIS® Bearing Protection Ring reduced shaft currents by 92% to levels well below those that damage bearings.*



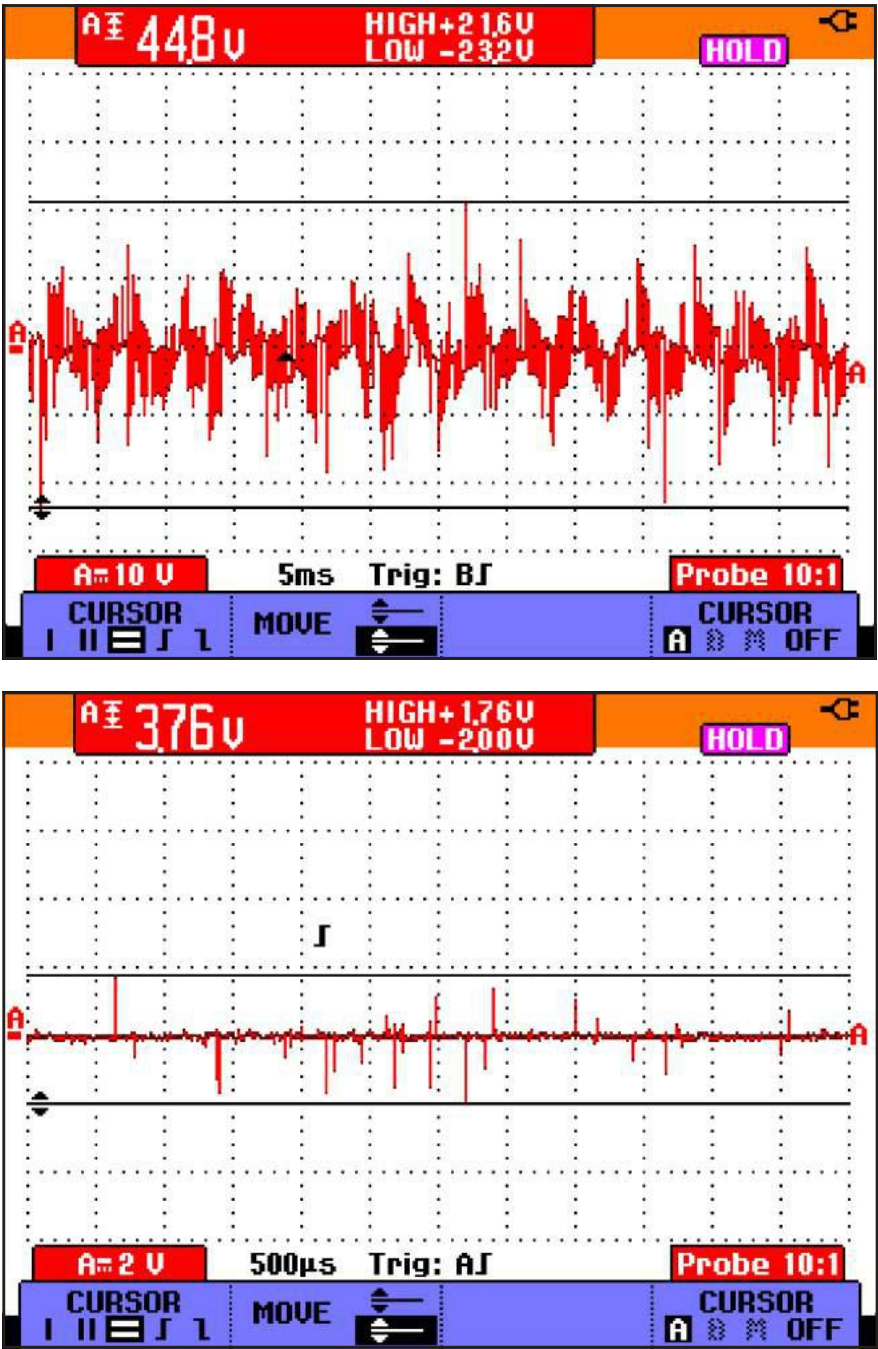
In a continuous 60- $\mu$ sec trace (oscilloscope settings: 10v/div, 5msec/div) with the motor running at 3,600 rpm (80Hz output), discharges from the shaft were 44.8 volts peak-to-peak, high enough to cause pitting of the motor's bearings. After the AEGIS® Shaft Grounding Ring was installed, a follow-up test at 3,600 rpm (oscilloscope settings: 2v/div, 500 $\mu$ sec/div) showed that discharges had dropped to only 3.76 volts peak-to-peak [Figure 5], well below levels that damage bearings.

#### Another Success With Hospital Air Handling Unit

Another recent test of AEGIS® Rings took place at a community hospital in a suburb of Chicago. A hospital has many reasons to strive for zero motor failures and 100% uptime. Reliable heating and cooling are important for patient comfort, and continuous ventilation is vital for promoting sterility and limiting infections, especially in operating rooms, intensive-care units, quarantine areas, and laboratories.

Figure 5

Motor shaft voltage readings before (top) and after (bottom) installation of the AEGIS® Bearing Protection Ring on a motor in an HVAC unit on the roof of a Michigan department store. The AEGIS® Ring reduced peak-to-peak shaft voltage from 44.8V to a safe level of 3.76V.



This time, the motor was in the building's basement. The TECO 254T 3-phase TEFC motor, controlled by a 480-volt VFD (60Hz output), runs a fan in an air handling unit for several operating rooms [Figure 6]. EST technicians first used a voltage probe and oscilloscope to confirm that VFD-induced voltages were indeed building up on the motor shaft and discharging through the bearings at spikes high enough to cause pitting. The peak-to-peak reading was 11.4 volts (oscilloscope settings: 2 v/div, 200 µsec/div).

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Figure 6

*Installed on a VFD-controlled motor in an air handling unit at a community hospital in suburban Chicago, an AEGIS® Bearing Protection Ring reduced harmful shaft currents by 83% to levels well below those that damage bearings.*



Follow-up readings after the AEGIS® Ring was installed showed that the ring had lowered shaft voltage discharges by 83%.

Because the ring was by now effectively channeling harmful shaft currents away from bearings to ground, the new peak-to-peak reading was negligible (1.92 volts), too low to damage bearings (oscilloscope settings: 2 v/div, 100  $\mu$ sec/div).

EST has recommended that the hospital install AEGIS® Rings on all of its VFD-driven motors to prevent future bearing damage. The ring can be installed on either end of the motor, but the simplest installation is to slide the ring over the drive end of the shaft and fasten it to the end bell. This can be easily accomplished using the new AEGIS® Universal Mounting Kit (uKIT) [Figure 7], which simplifies mounting on virtually any AC motor shaft. The kit includes the proven AEGIS® Shaft Grounding Ring, brackets, and hardware.

Figure 7

*The Universal Mounting Kit includes brackets and hardware that simplify mounting of an AEGIS® Bearing Protection Ring.*



Figure 8

*A large and growing number of motor manufacturers now offer motors with AEGIS® Rings factory installed either outside or inside their motors.*



While retrofits are still the most common way to protect bearings from VFD-induced shaft voltages, a large and growing number of OEMs are now offering motors with AEGIS® Shaft Grounding Rings factory installed [Figure 8].

## Conclusion

For too long, the importance of shaft grounding to protect motor bearings has been ignored or severely underestimated. All VFD-driven motors are vulnerable to electrical bearing damage. A savvy specifier will choose new motors that are truly equipped for use with today's fast-switching VFDs — those with adequate protection against electrical bearing damage as well as winding damage. But for motors already in service, retrofitting with an economical device such as a shaft grounding ring is the best approach.

Operations and maintenance costs can account for 60-80% of a facility's life-cycle costs. When HVAC equipment does not have to be repaired or replaced as often, this percentage drops significantly. VFDs hold the promise of sizable energy savings, but without effective, long-term bearing protection such as AEGIS® Bearing Protection Rings, these savings can be wiped out by high maintenance costs. By diverting bearing currents safely to ground, AEGIS® Rings extend motor life and ensure the reliable, long-term operation of VFD-driven systems, locking in energy savings to make these systems sustainable and truly "green."



31 Winterbrook Road  
Mechanic Falls, ME 04256  
Toll Free US & CA (866) 738-1857  
Tel: (207) 998-5140  
[sales@est-aegis.com](mailto:sales@est-aegis.com)  
[www.est-aegis.com](http://www.est-aegis.com)

The author of this paper  
Adam Willwerth is  
Development Manager for  
Electro Static Technology.

