



Protecting VFD Driven Motors from Bearing Currents

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Topics

- Root causes of shaft voltage
- Impact on the bearings
- Possibilities to proof
- Mitigation strategies
- Where to buy

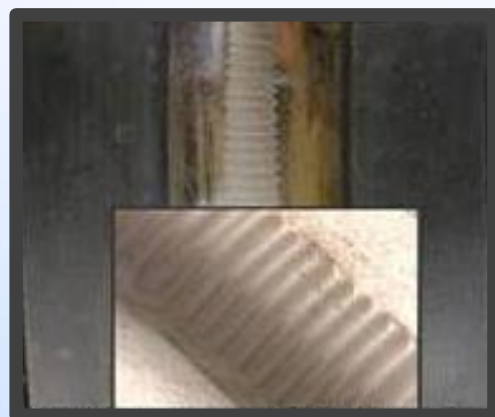
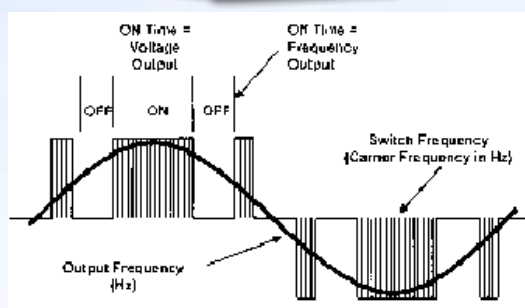


Variable Frequency Drives

Advantages:

- Precise adjustment of torque and speed
- Energy saving potential of 20-50%.
- Optimization of process flows
- Productivity increases and energy savings

PWM Drives can cause



- **Winding failures:**

High frequency transients (dv/dt) can break down the insulation between windings and cause corona discharge arcing which can short out the windings. This problem was resolved with class F or H insulation

- **Bearing failures:**

Because of the inherent voltage imbalance and dv/dt , the voltage pulses are capacitively induced on the motor shaft and can overcome the dielectric of the oil film in the motor bearings. Electrical discharges result in pitting and fluting damage in the bearing, breakdown of lubrication, and fluting failure of the bearing.

Bearing Currents

Capacitive Induced Voltage (want to go to ground)

- **EDM Current**

as a result from capacitively coupled shaft voltage which want to go through the bearings to ground. Its measurable in nearly every VFD-driven motor.

Circulating Currents (circulating between rotor and stator)

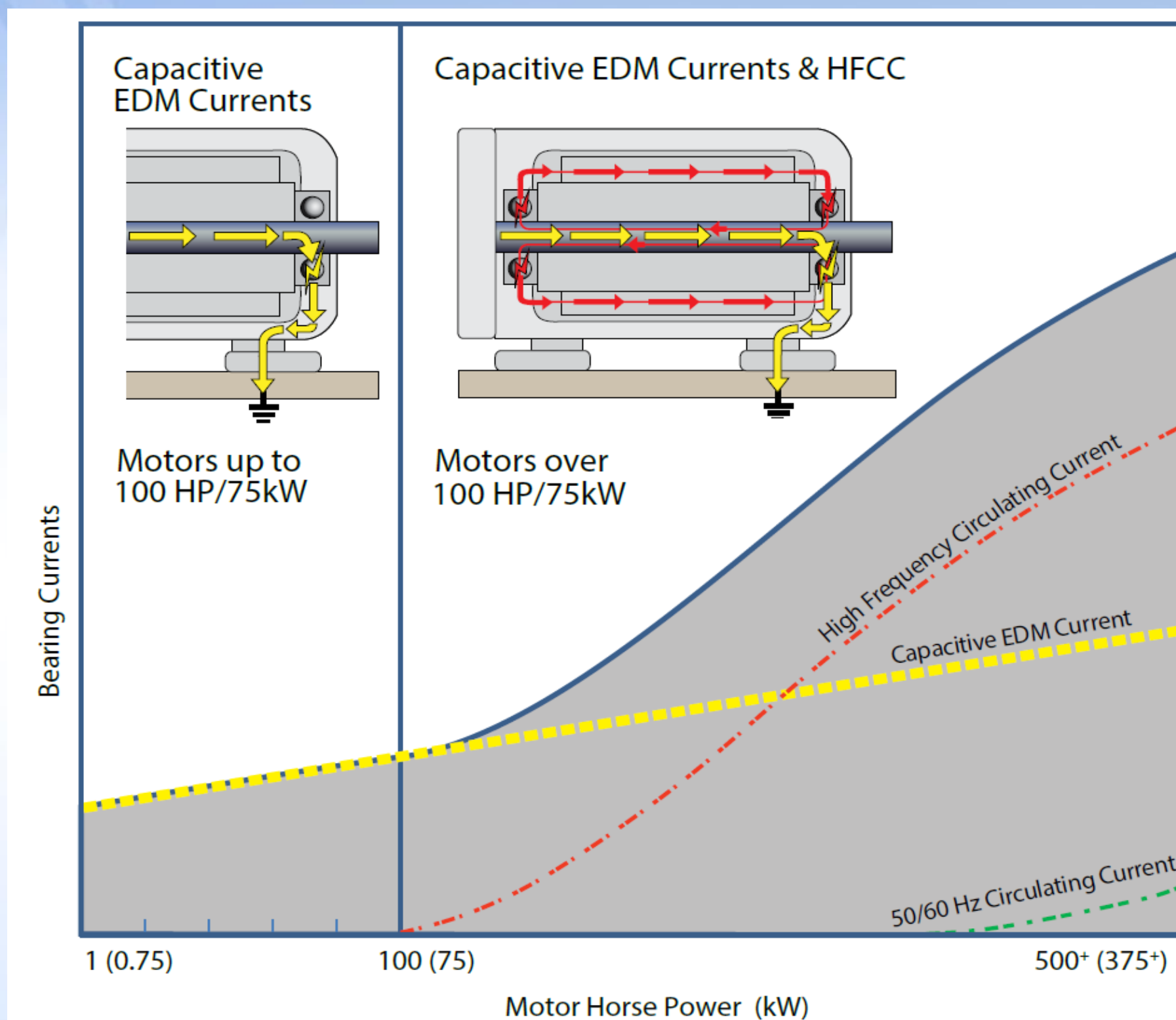
- **High frequency circulating currents**

due to a high-frequency flux produced by common-mode currents. High frequency inductive circulating currents from VFDs are in the KHz or MHz in motors over about 75 KW.

- **50/60 Hz circulating current**

Sine wave voltage sources in large machines can cause low frequency circulating currents because of the motor's asymmetrical design and magnetic asymmetries.

Bearing Currents



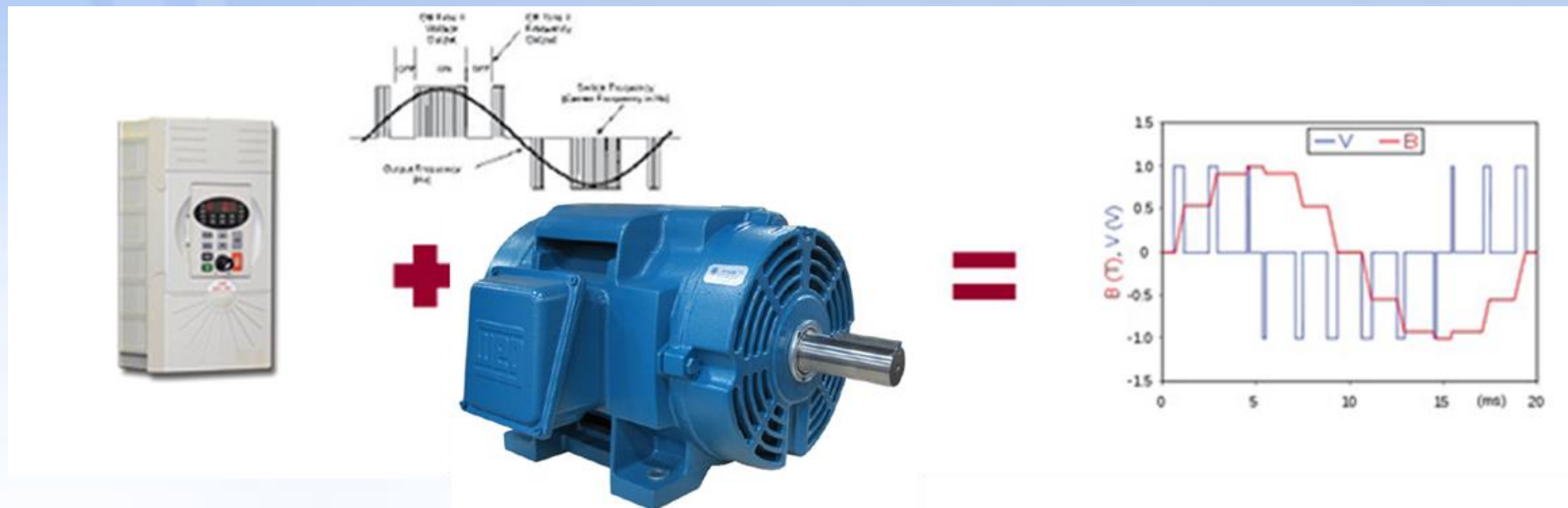
Motor Design



- Electric induction motors designed for operation on 3-phase sine wave power – either 50 or 60 Hz.
- Input power is balanced in frequency, phase (120 degree phase shift) and in amplitude.
- Common mode voltage – the sum of the 3 phases always equal zero volts when properly balanced.

Bearing protection generally not needed except for large frame motors.

Electric Motor Operation by VFD

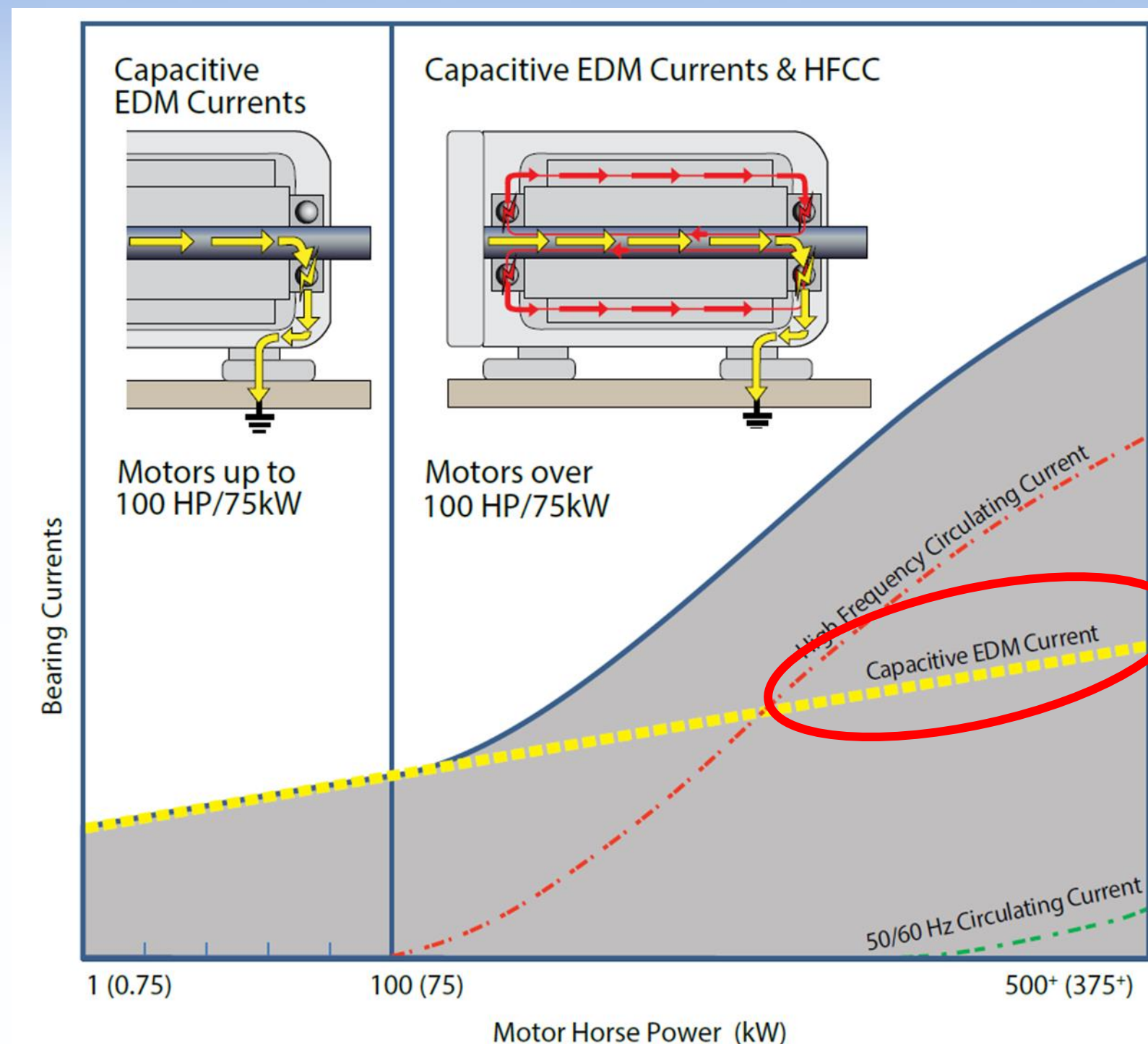


- When operated by VFD, the power to the motor is a series of pulses instead of a smooth sine wave.
- The input voltage is never balanced because the voltage is either 0 volts, positive, or negative with rapid switching between pulses in all three phases
- The common mode voltage is usually a “square wave” or “6 step” voltage wave form.

Bearing protection needed to mitigate electrical discharge machining (EDM) damage in bearings.

EDM Current

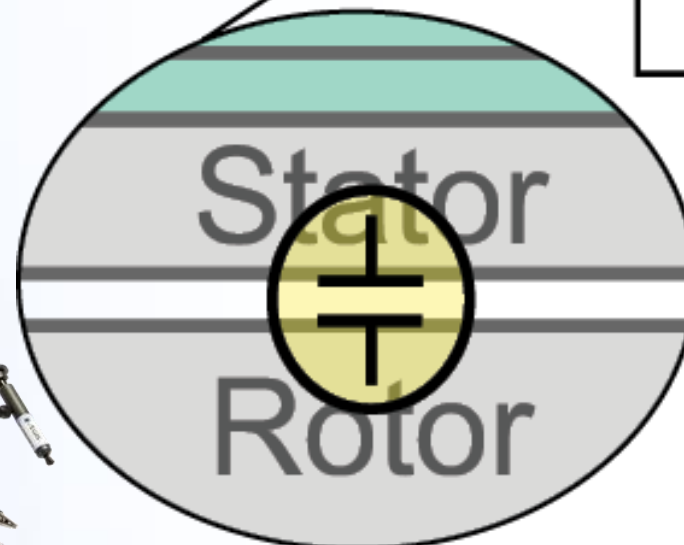
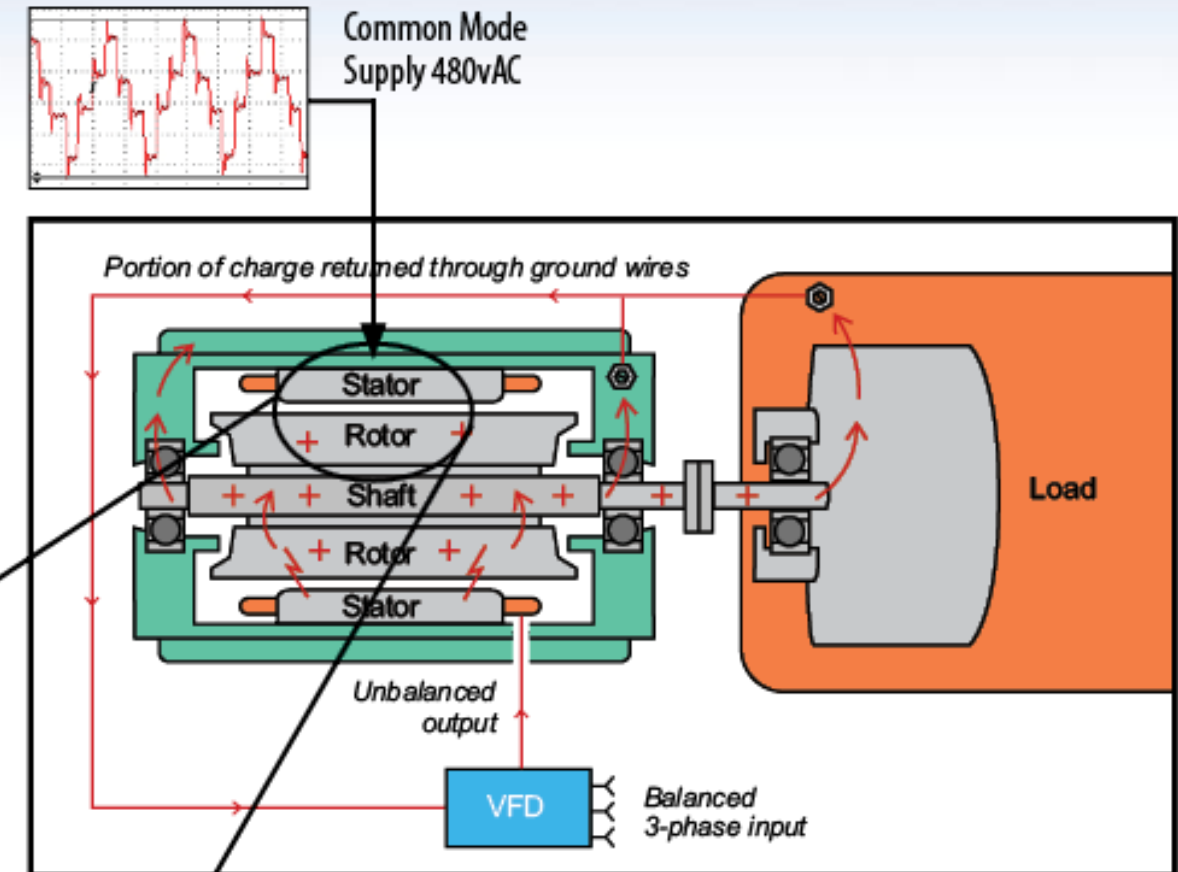
- Capacitive induced shaft voltage discharges through the motor bearings.
- Virtually any motor may have EDM current from this source.



Best Practice: Ground the motor shaft

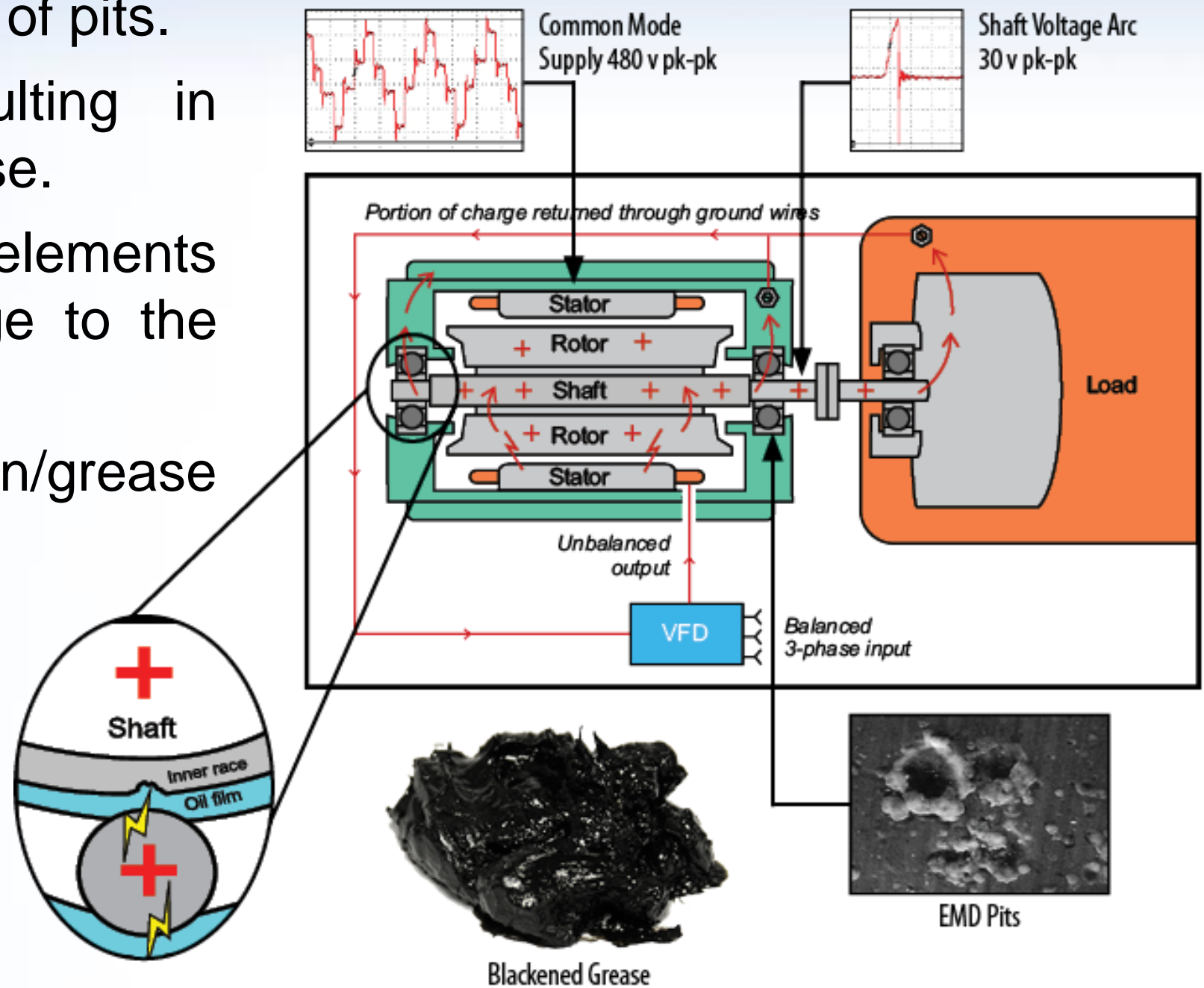
An Electric Motor looks like a Capacitor

- The Pulses to the motor from the VFD create a capacitive coupled common mode voltage on the motor shaft.
- Voltages are measurable with an oscilloscope and AEGIS® SVP Shaft Voltage Probe Tip.
- Creates electrical bearing discharge currents.



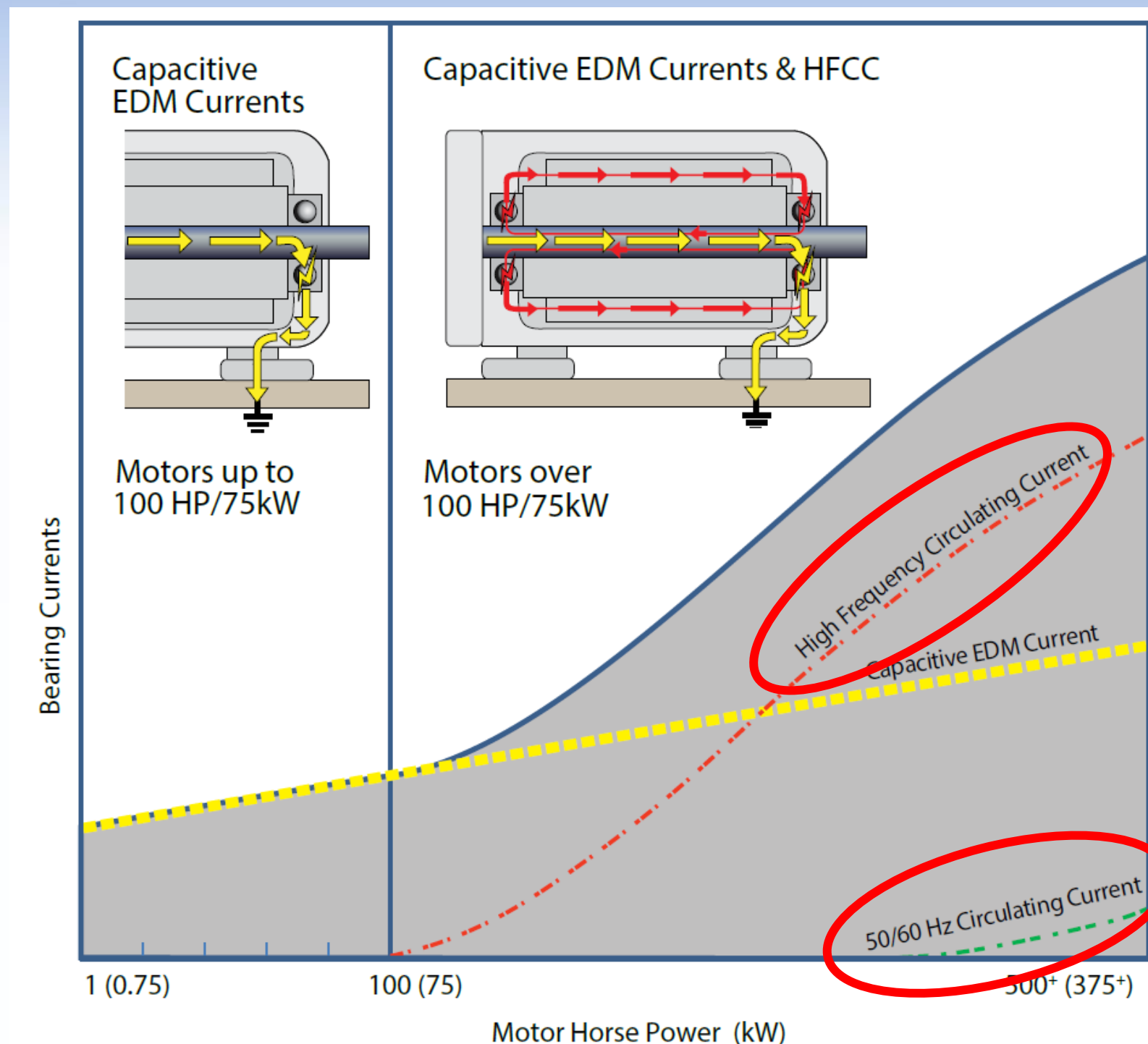
What effect does this have on the bearings?

- Electrical discharge machining (EDM) creates thousands of pits.
- Bearings degrade, resulting in increased friction and noise.
- Eventually, the rolling elements can cause fluting damage to the bearing races.
- Bearing lubrication/grease deteriorates/burns.
- Potential for costly unplanned downtime



Circulating Currents

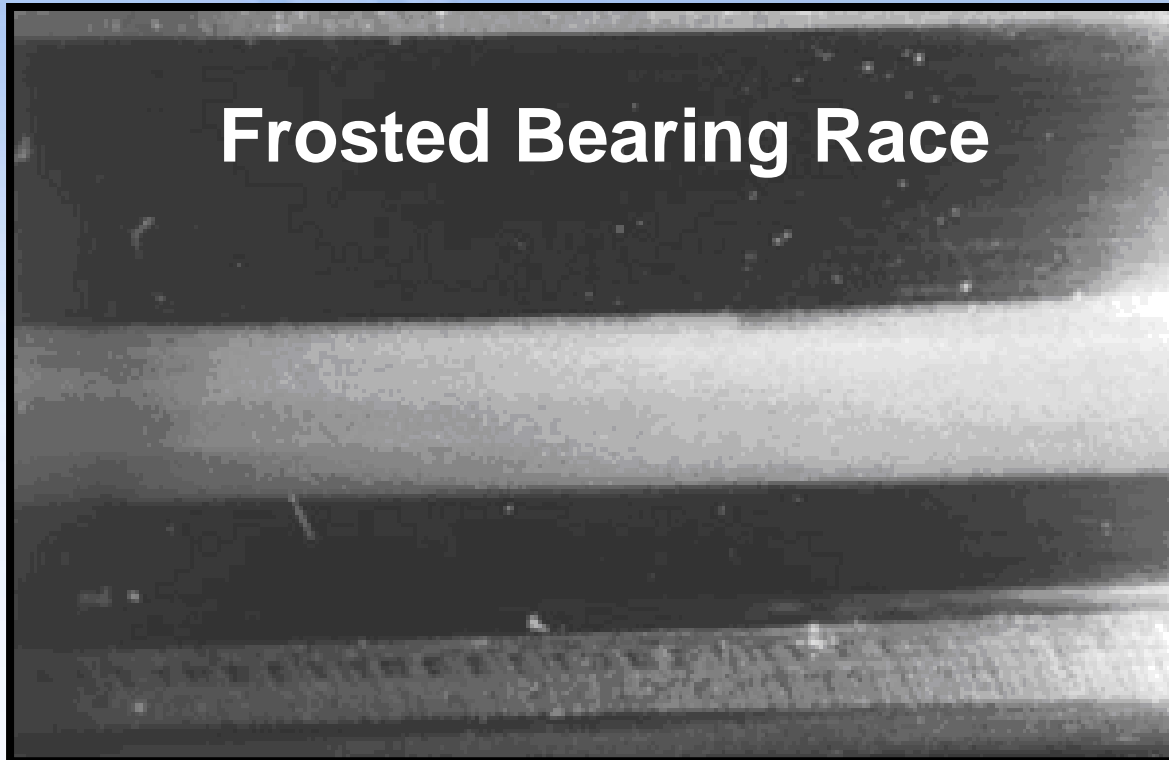
- High frequency circulating currents may flow due to a high-frequency flux produced by common-mode currents in KHz or MHz frequencies.
- Usually present in motors above 75 kW.
- Circulate through the motor bearings, shaft to frame



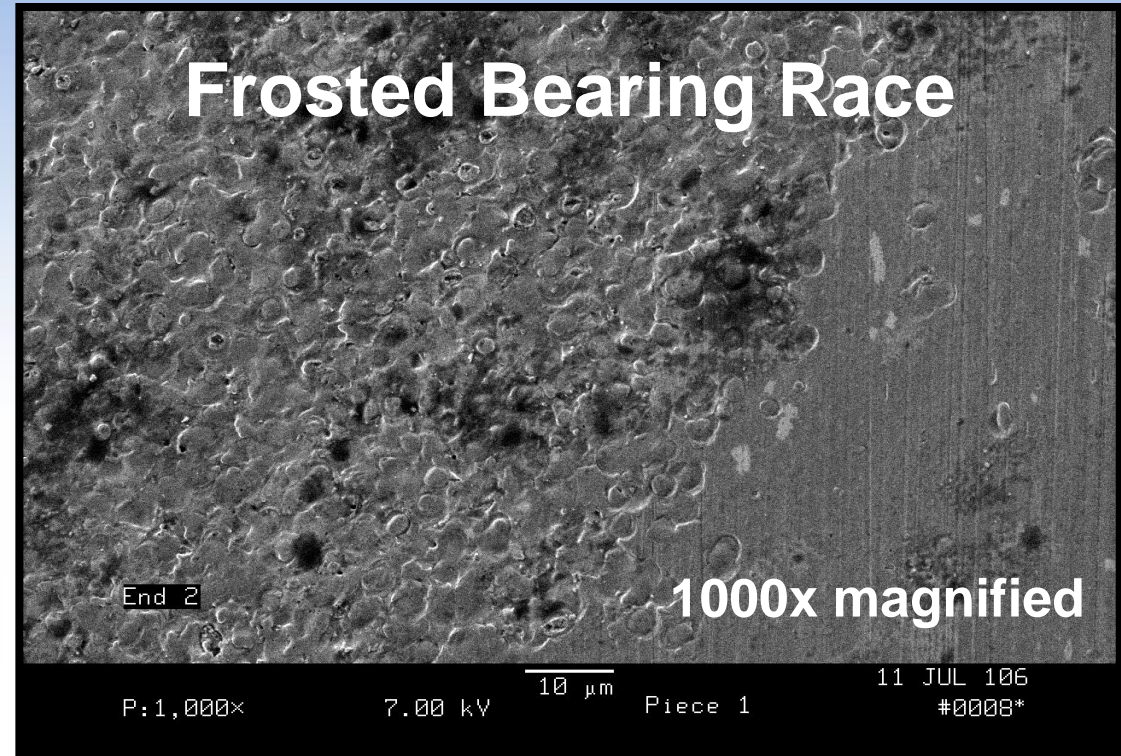
Best Practice: Interrupt the circuit

Bearing Damages

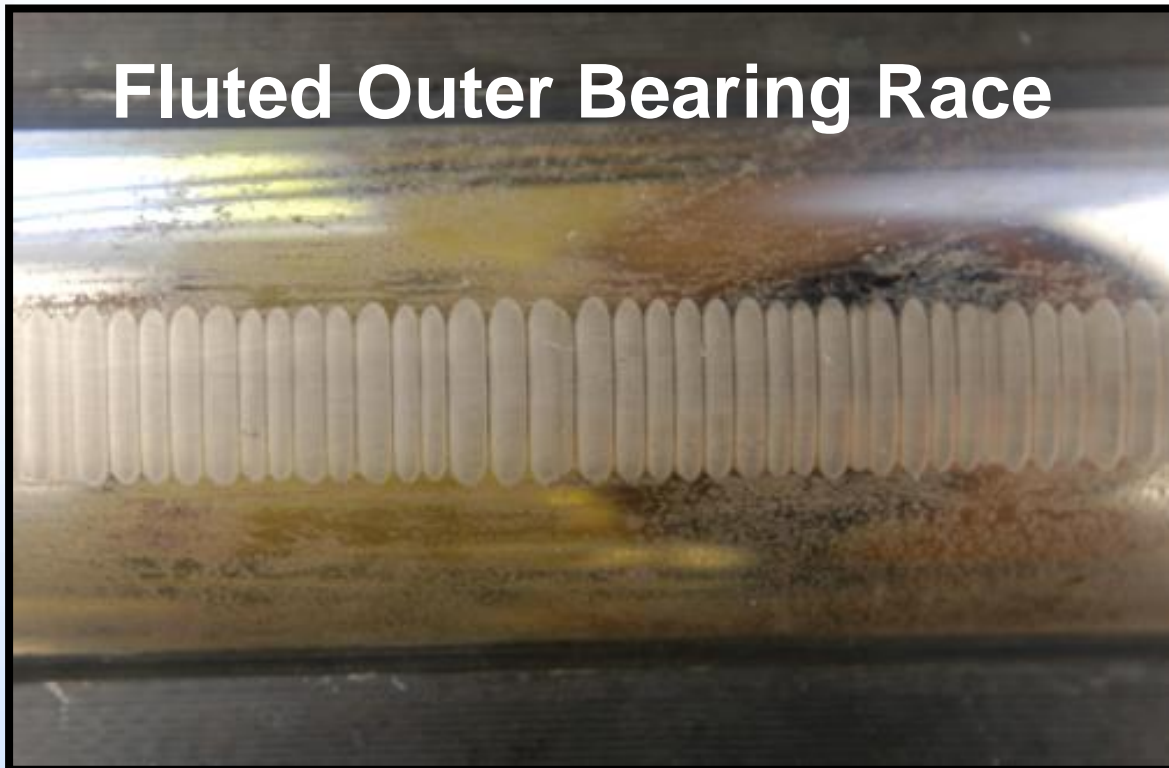
Frosted Bearing Race



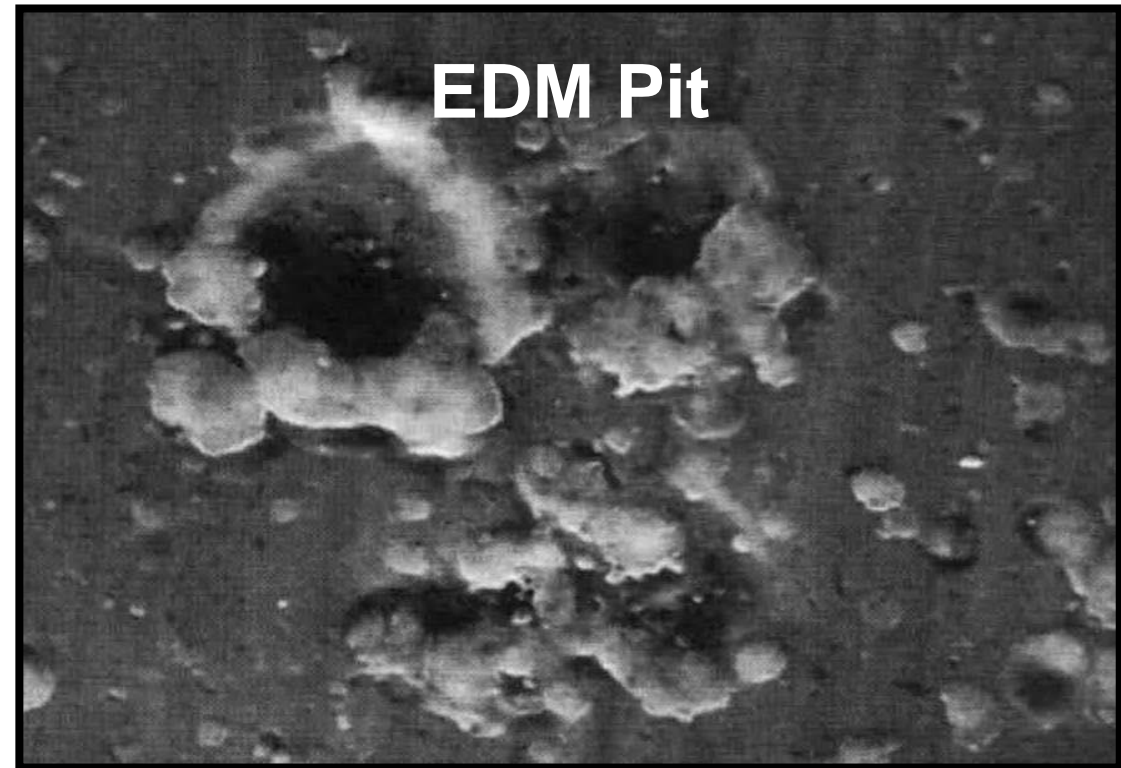
Frosted Bearing Race



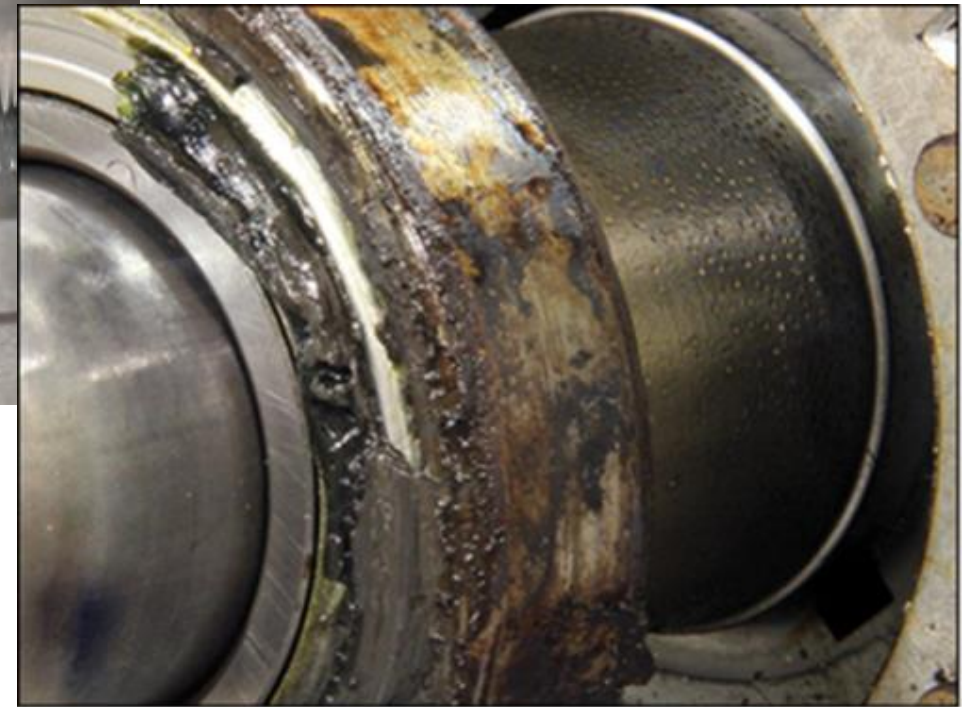
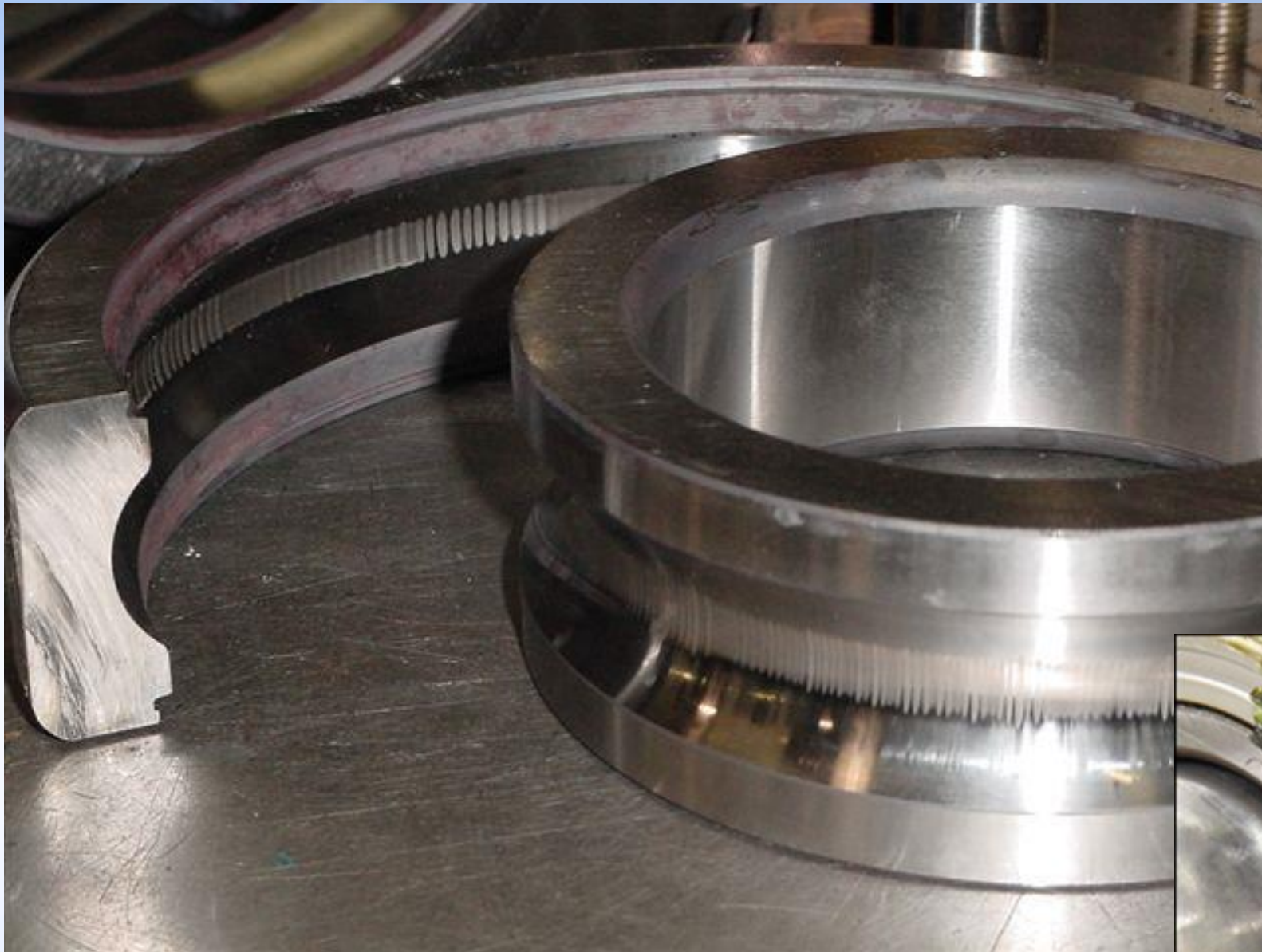
Fluted Outer Bearing Race



EDM Pit



Bearing Damages



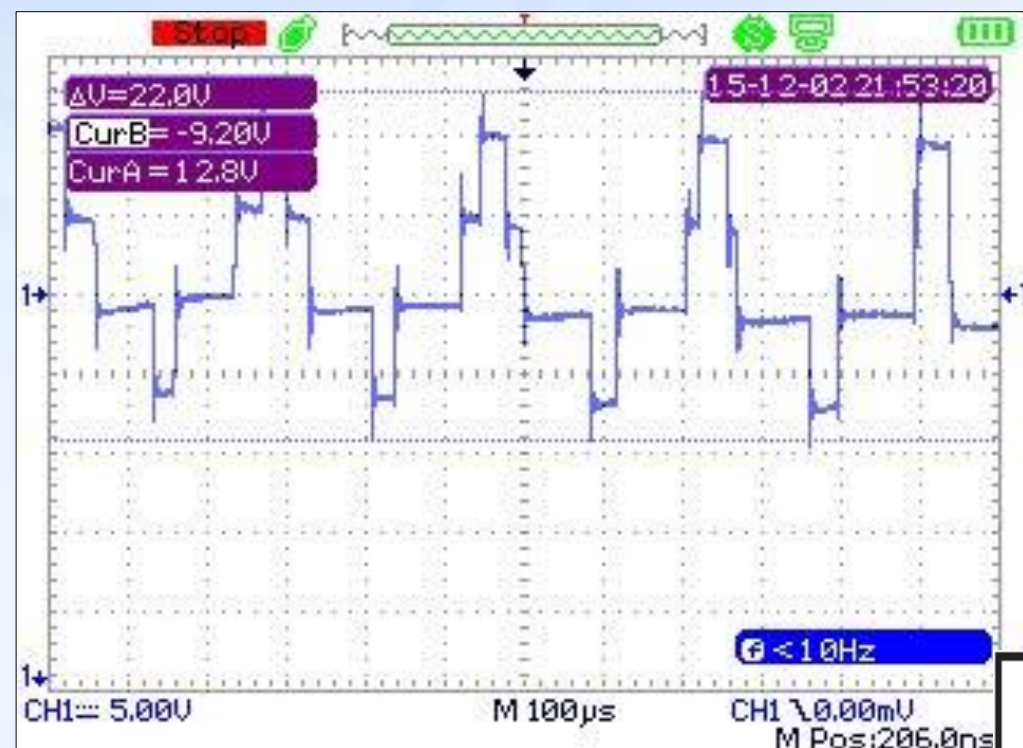
Taking the Measurements Shaft Voltage

- AEGIS® Shaft Voltage Tester with 100MHz bandwidth
- AEGIS® Shaft Voltage Probe Tips to contact the running shaft
- Magnetic base and probe holder

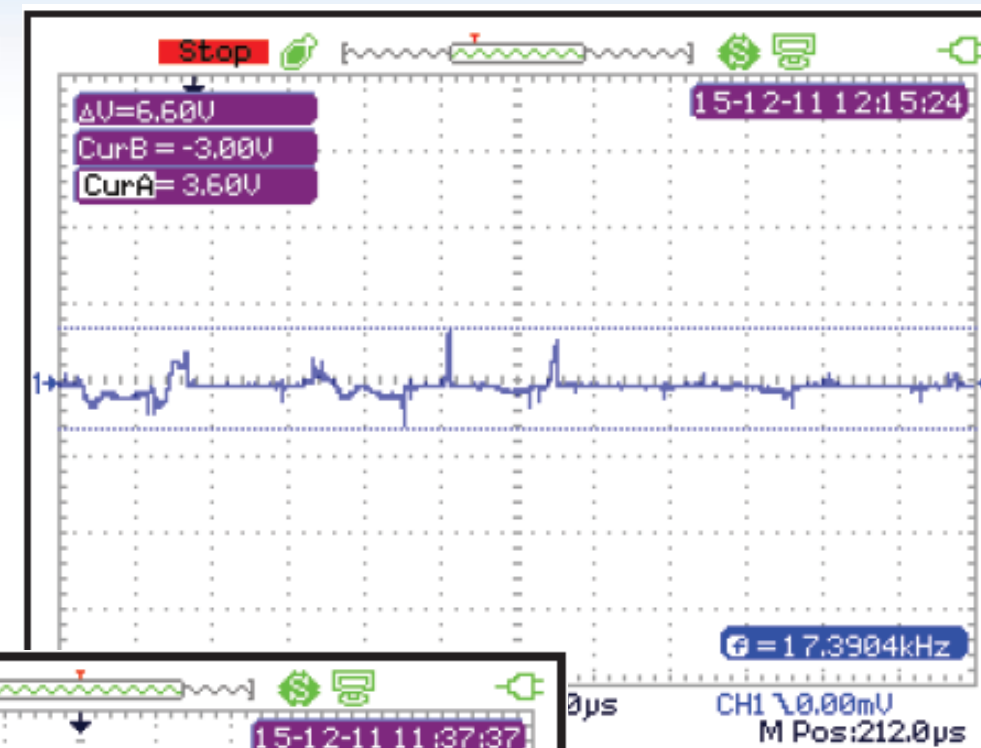


Examples of Shaft Voltage Readings

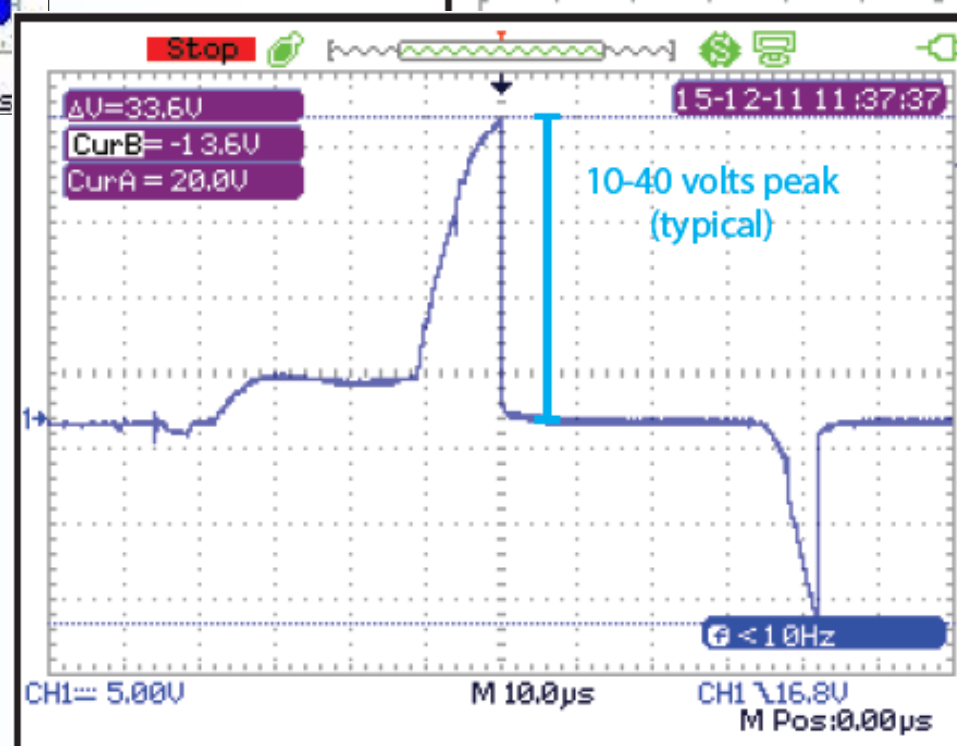
High Peak to Peak Common Mode Voltage



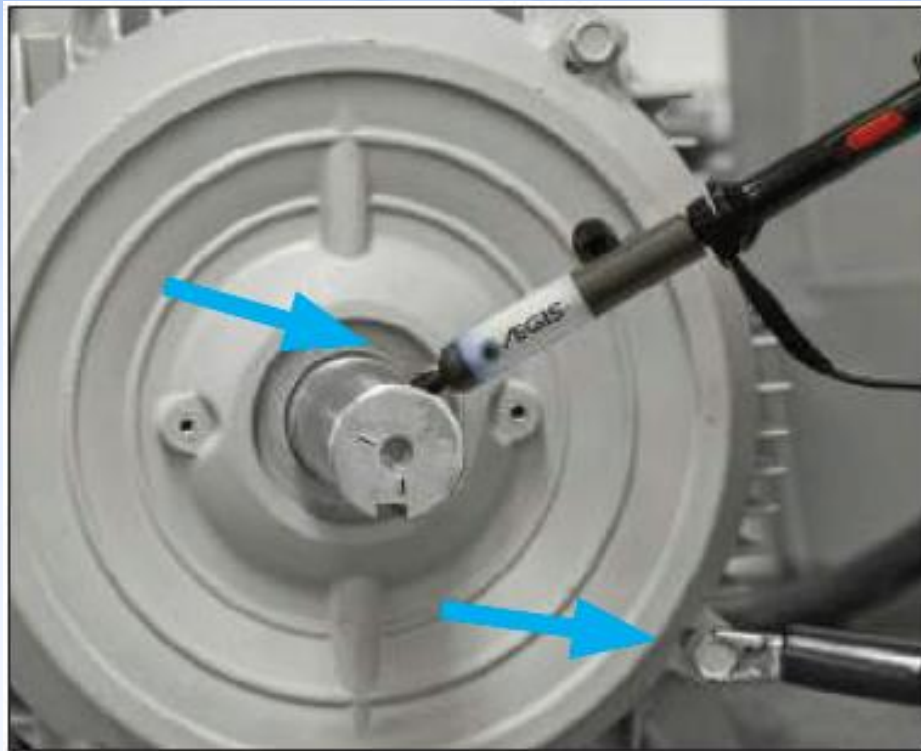
Low amplitude voltage discharge pattern



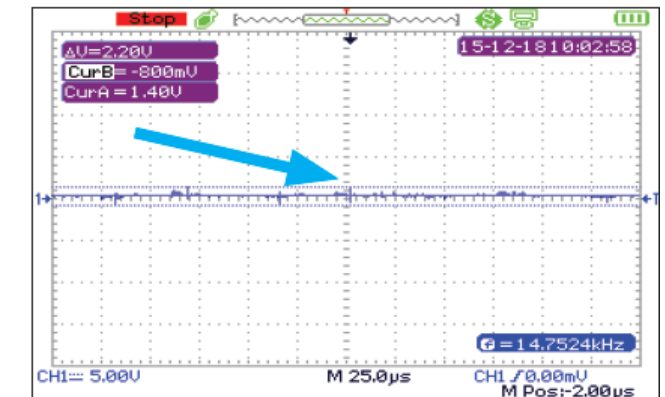
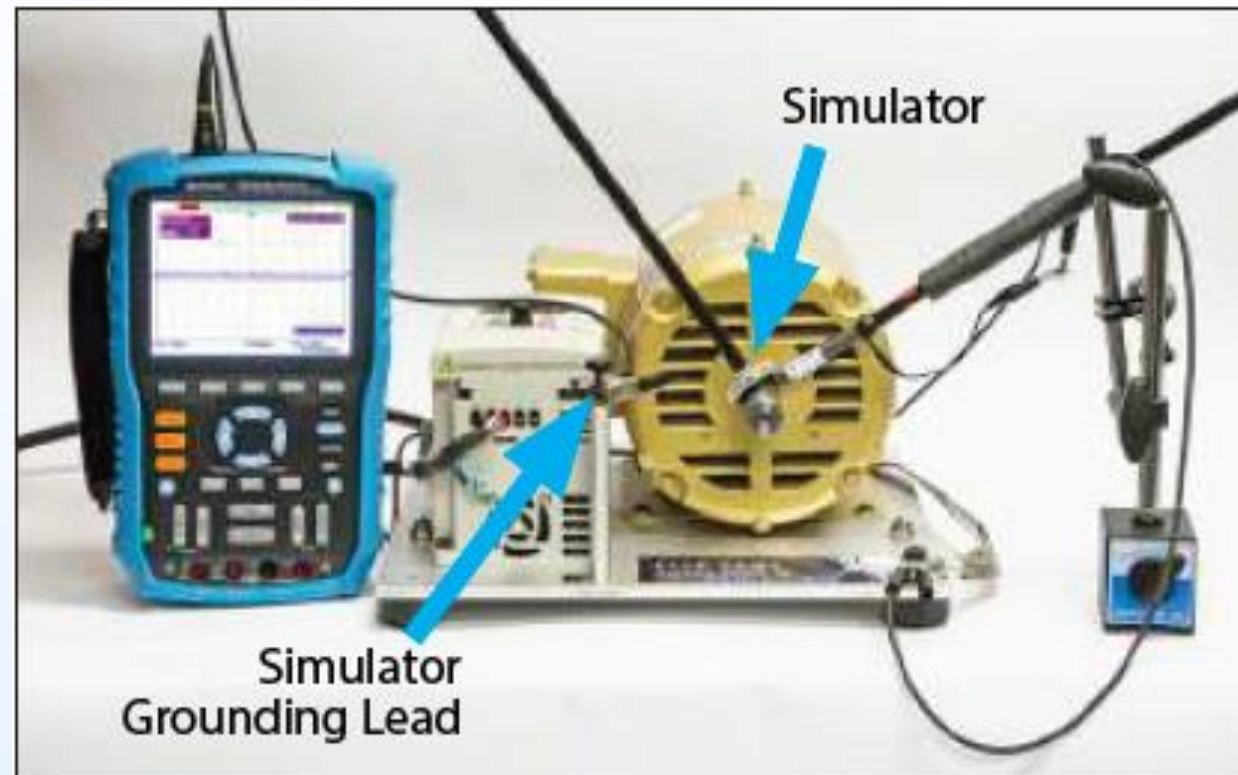
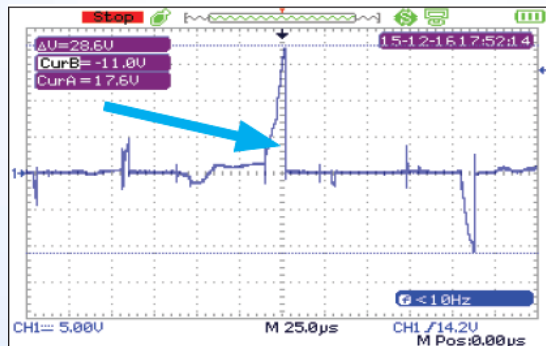
Electrical Discharge Machining (EDM)



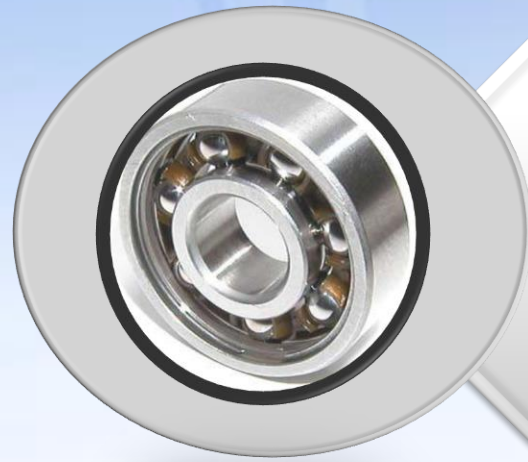
Taking the measurements



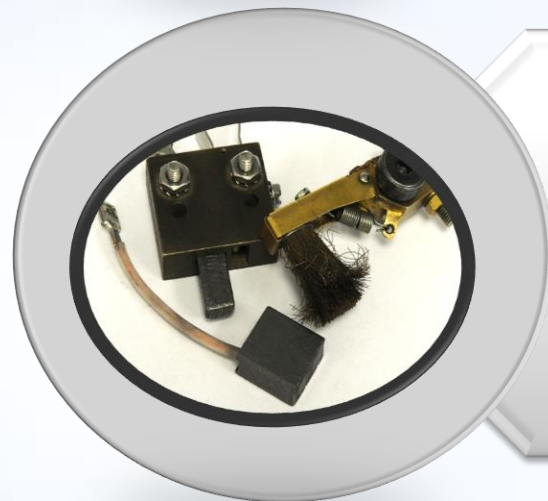
AEGIS®
Grounding Simulator



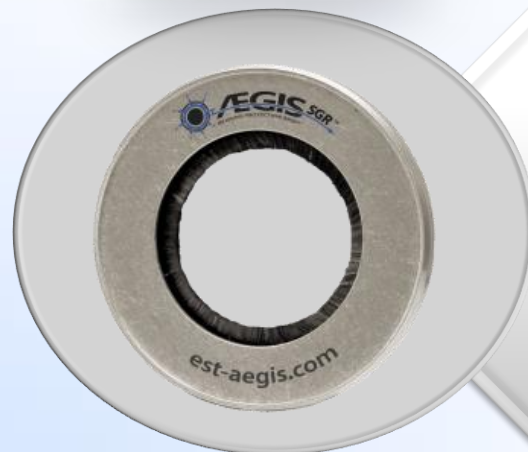
Mitigation Strategies



Insolate the shaft from the frame of the motor

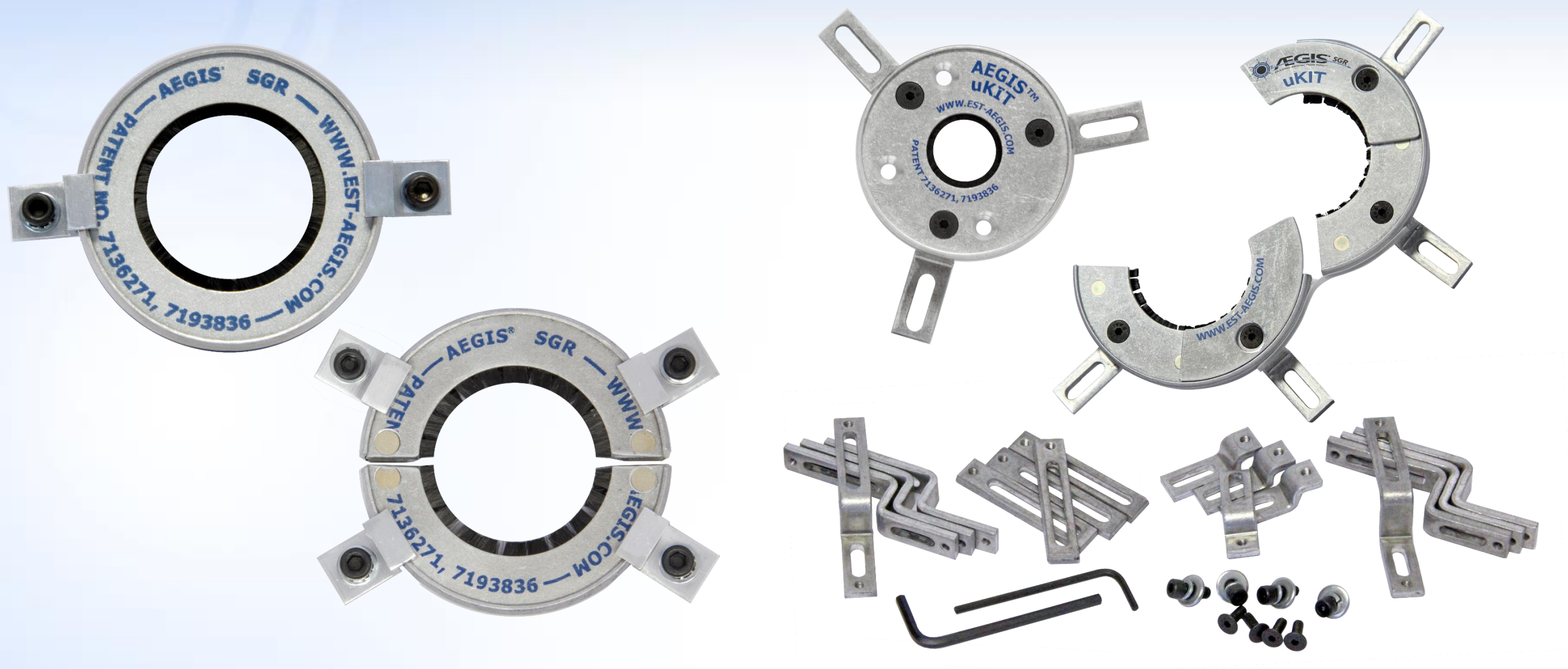


Brush Technology



AEGIS® Shaft Grounding Ring Technology

AEGIS® SGR Technology



New Conductive Microfiber Shaft Grounding Technology

Design Difference

100%

- Full 360° degrees around shaft
- Designed for VFD currents
- Larger Shaft = more current capability
- Contact and Nanogap Contact

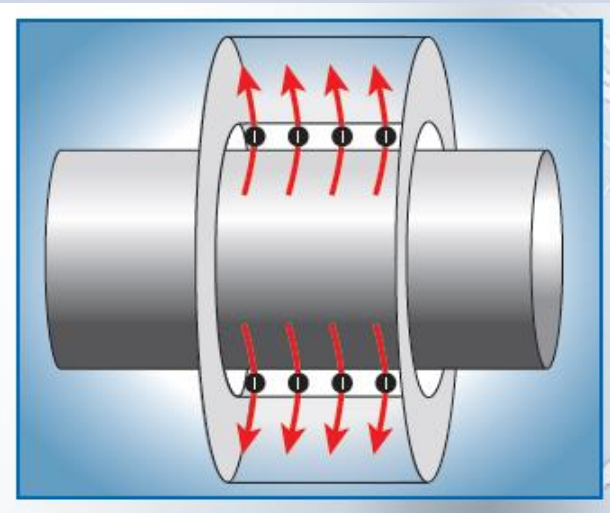
Only 4%

- Limited shaft coverage
- Small contact area
- Friction contact only
- Wear and replacement
- Not suitable for VFD currents

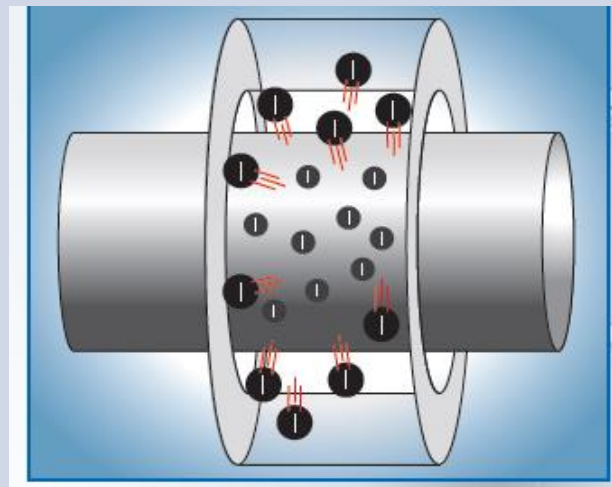


Patented AEGIS® NanoGap Contact Technology

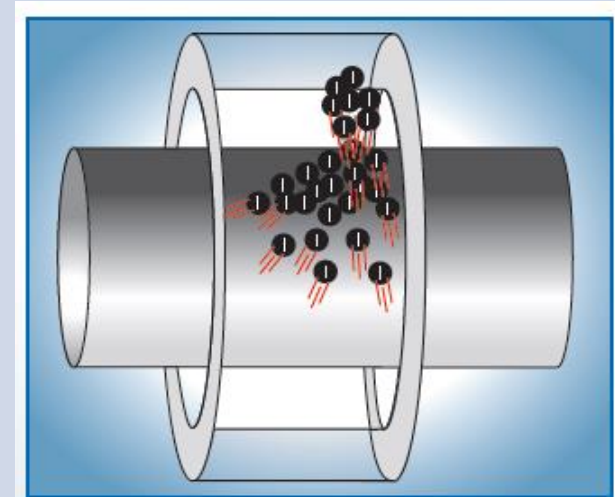
**Tunneling of
Electrons when
Fibers are $<2\text{nm}$**



**Field Emissions of
Electrons when
Fibers are $2\text{nm} - 5\mu\text{m}$**



**Townsend Avalanche of
Gaseous Ions when
Fibers are $>5\mu\text{m}$**

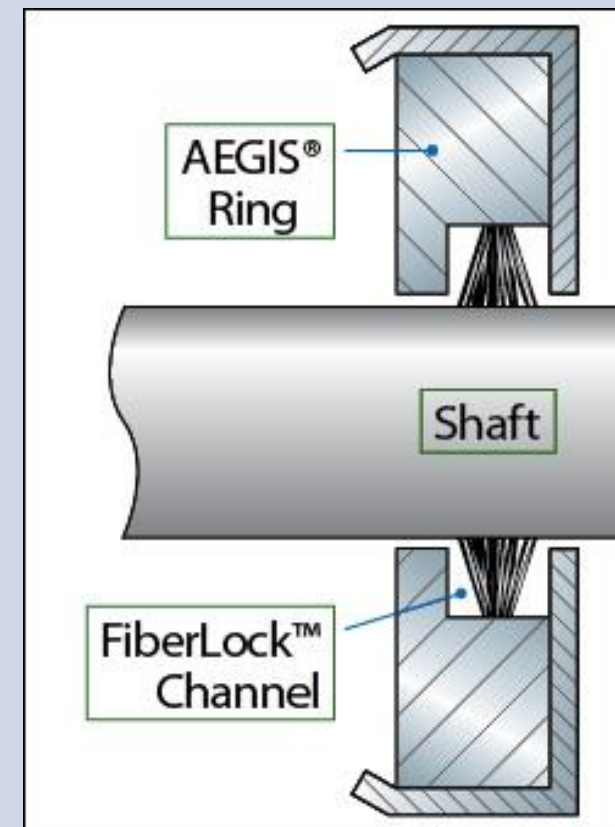
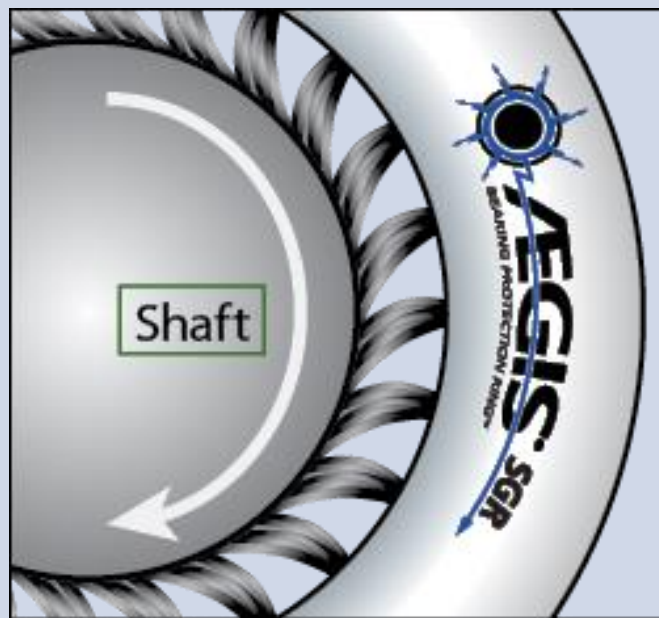


“NanoGap Electron Transfer”

Patented AEGIS® Ring Design

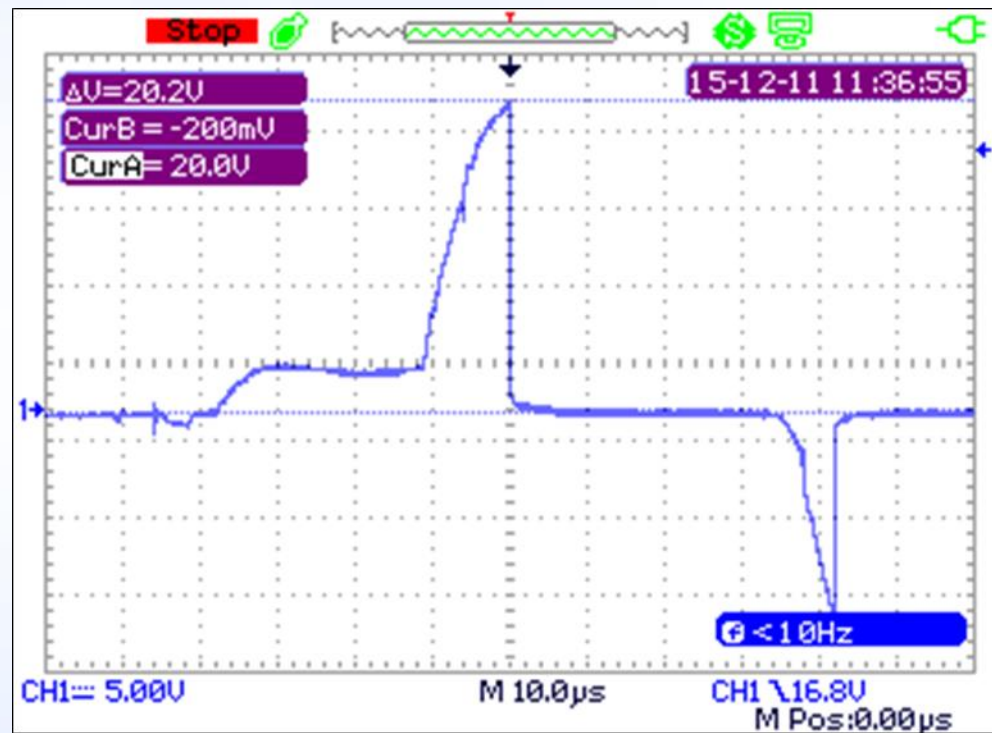
**Specially Designed Microfibers
Flex Without Breaking – Ultra
Low Friction**

**Patented FiberLock™ Channel
Secures and Protects Fibers**

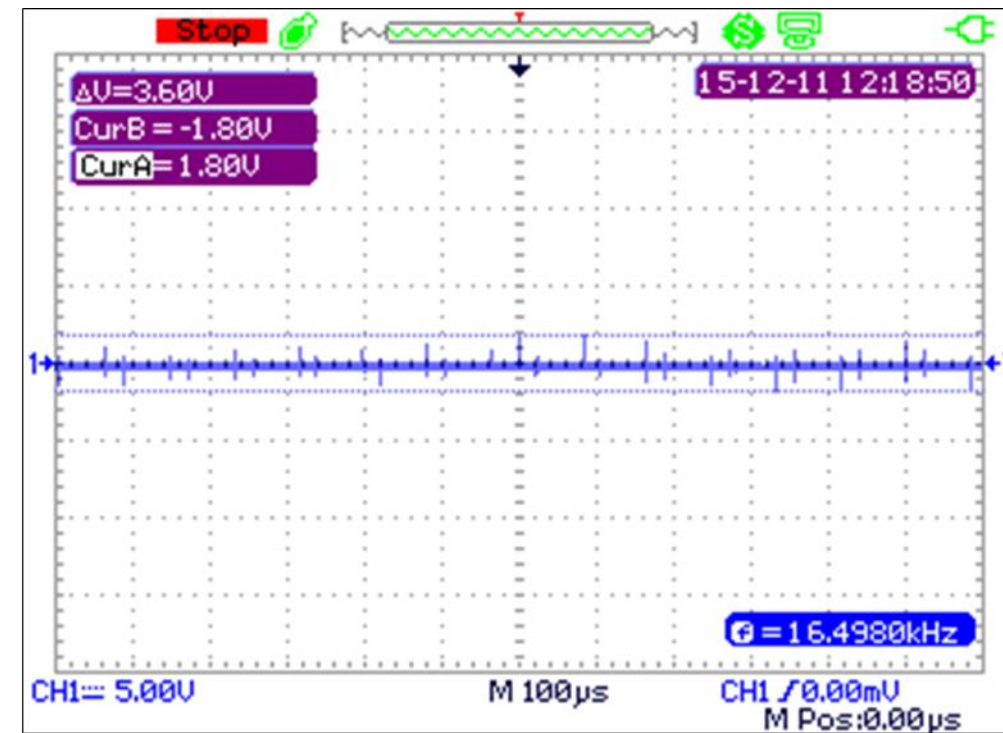


Typical Shaft Voltage Readings

Shaft Voltage without AEGIS® Ring

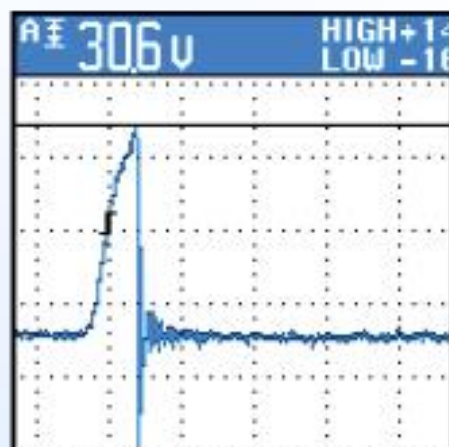


Shaft Voltage with AEGIS® Ring



Bearing Protection Best Practices

www.est-aegis.com



**Edition 3
metric**

AEGIS®

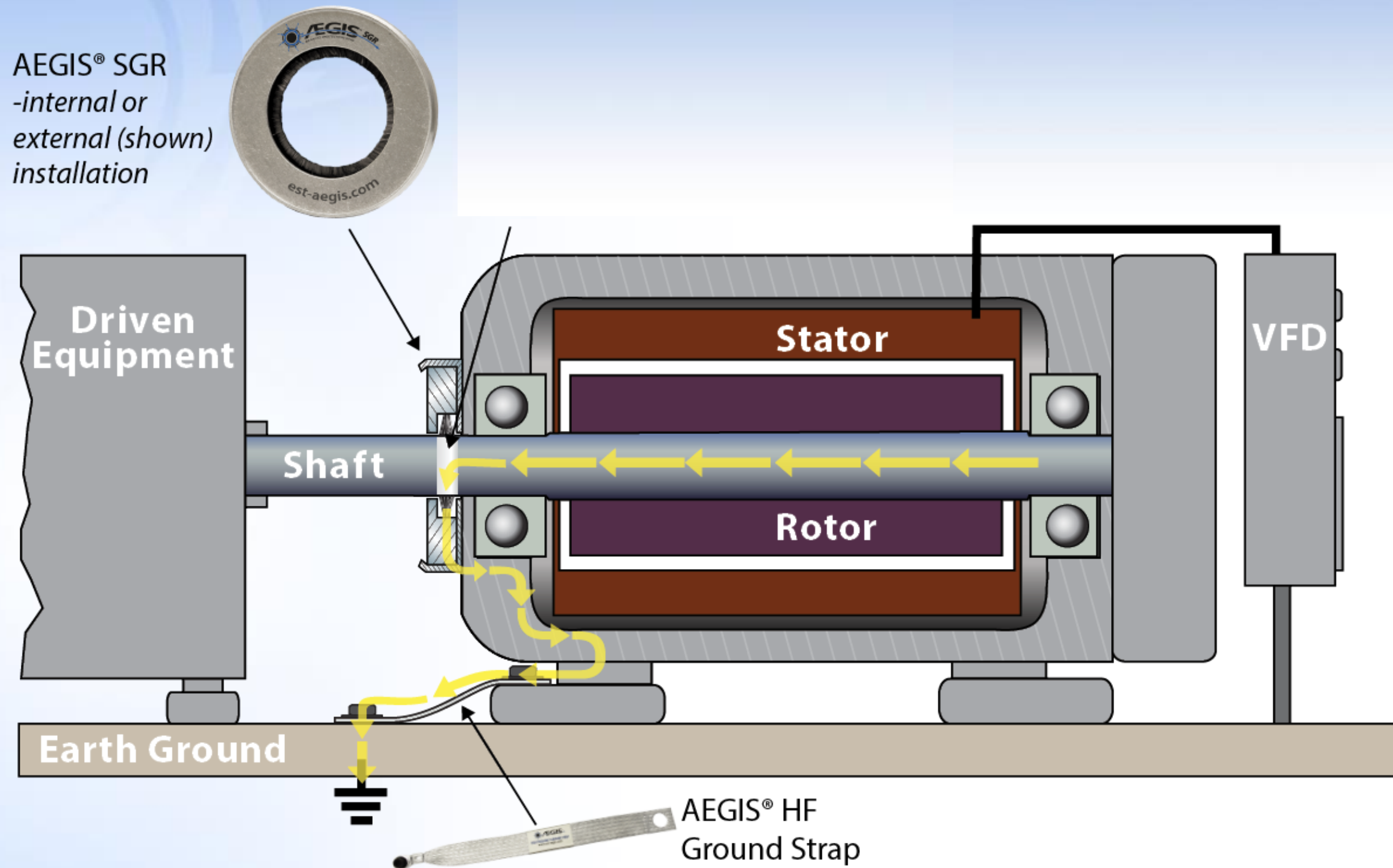
Bearing Protection Handbook

Best Practices for Bearing Protection in New and Repaired Motors,
Testing In-Service Motors, and Inspecting Damaged Motor Bearings

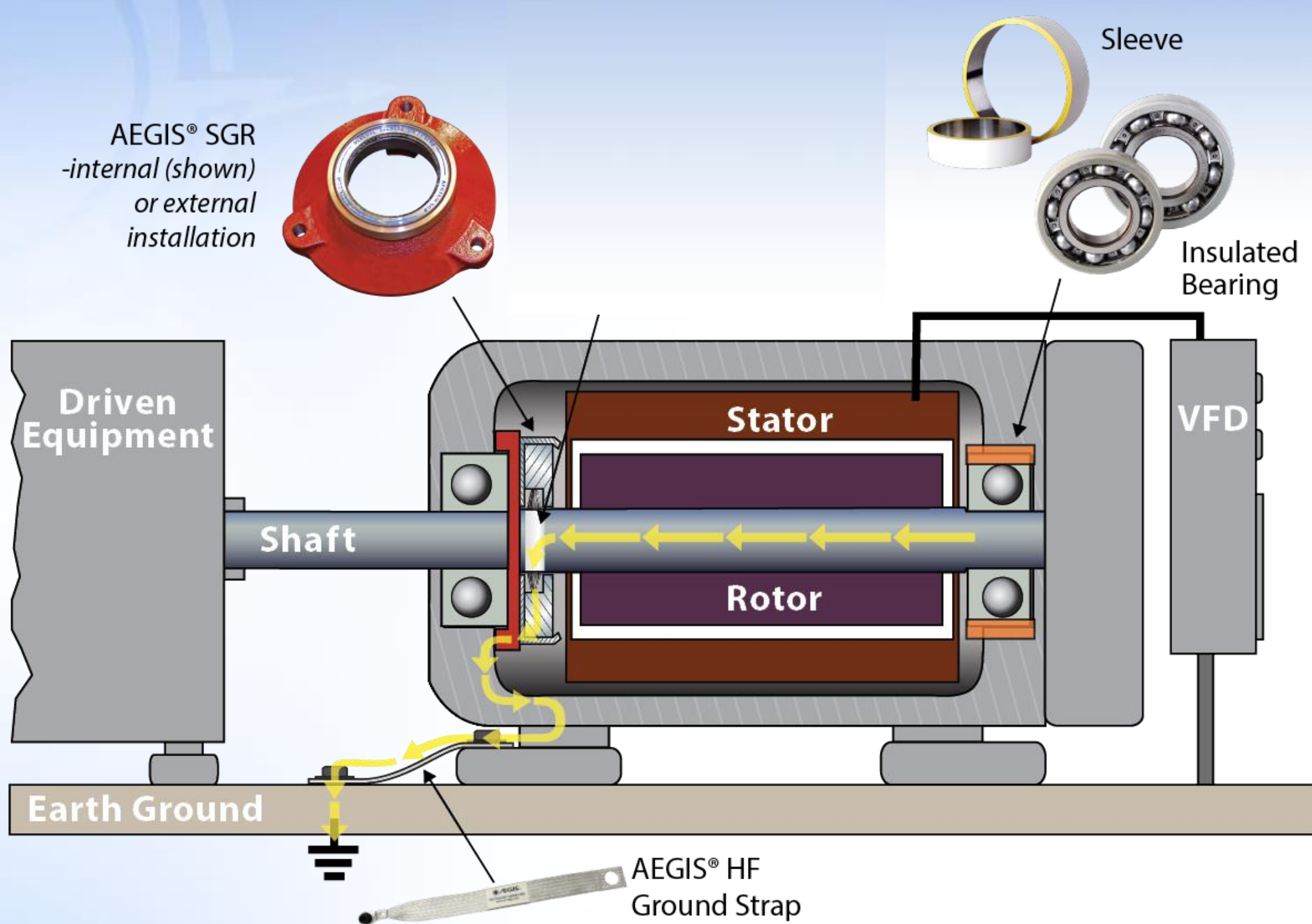
Electro Static Technology™
An ITW Company

"Sustainable Technology for True Inverter Duty Motors"

Motors up to around 75 kW



Motors above around 75 kW



AEGIS® PRO rings for high current application

50 to 800 mm shaft diameter

6 rows of fibers for to discharge up to 120 A

Split version possible

Customized design possible



Application areas

- Medium voltage motors
- AC and DC motors
- Generators

AEGIS® Shaft Voltage Tester

2-channel, 100 MHz
Digital-Oscilloscope

Including 3 Probe Tips,
AEGIS® Grounding
Simulator, magnetic
base and holder.



Application Areas for AEGIS[®] SGRs



Where to buy

- **ABB, EU**
- **ATB Group, EU** - for large drives, AEGIS for serial demand
- **Baldor, US** – Super E Series
- **Baumüller, DE** - serial demand for two motor types
- **EMOD, DE** - serial demand for motors >110 kW
- **GE Converteam, FR** - AEGIS® for special drives
- **GE, US** – A\$D Ultra Series
- **Leroy Somers, FR** - Motors for electrical cars
- **Oswald, DE** - AEGIS® for special drives (Motor test rigs)
- **Regal, US** – Marathon Motors
- **Siemens, EU**
- **TES, CZ**
- **TSA, AT** – serial demand for traction motors
- **T-T Electric, FR** - Serial demand for all motor types
- **WEG, Mexico and PT** - serial demand for some motor types
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Thank You



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