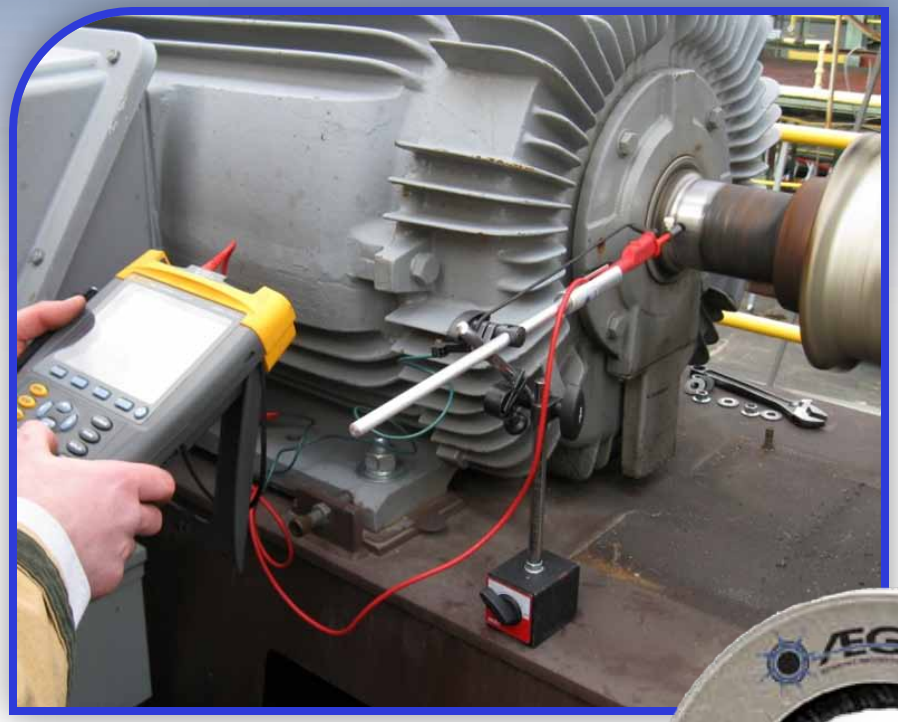
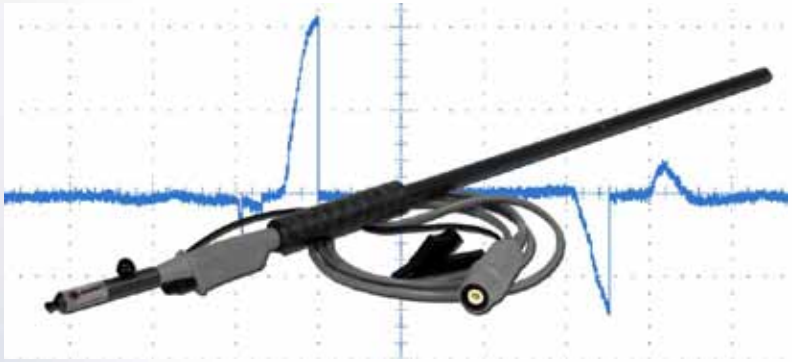
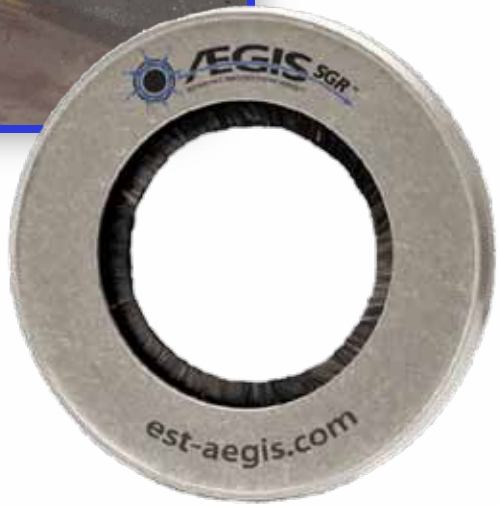
Testing Procedure for Shaft Voltage and Discharges using a Fluke 190 Series II ScopeMeter®







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AEGIS™ BEARING PROTECTION RING

Why Test for Shaft Voltages…

- Unexpected production down time due to a failed motor is costly.
- Air conditioning failure in a commercial building is unacceptable.
- A stopped train during rush hour is avoidable.

AEGIS™ BEARING PROTECTION RING

Why Test for Shaft Voltages…

…because bearing failures are costly

Typical Bearing Failure Cost:	Small Motor 10 HP/215T	Large Motor 300 HP/449T
Rigging/Removal and Replacement	$1,000	$2,000
Motor Repair	$990	$13,200
Production Downtime	$10,000	$100,000
Total	$11,990	$115,200
Cost of AEGIS™ installed on Marathon motor to Prevent Bearing Fluting Failure	$456	$1,327
Return on Investment	2629%	8681%

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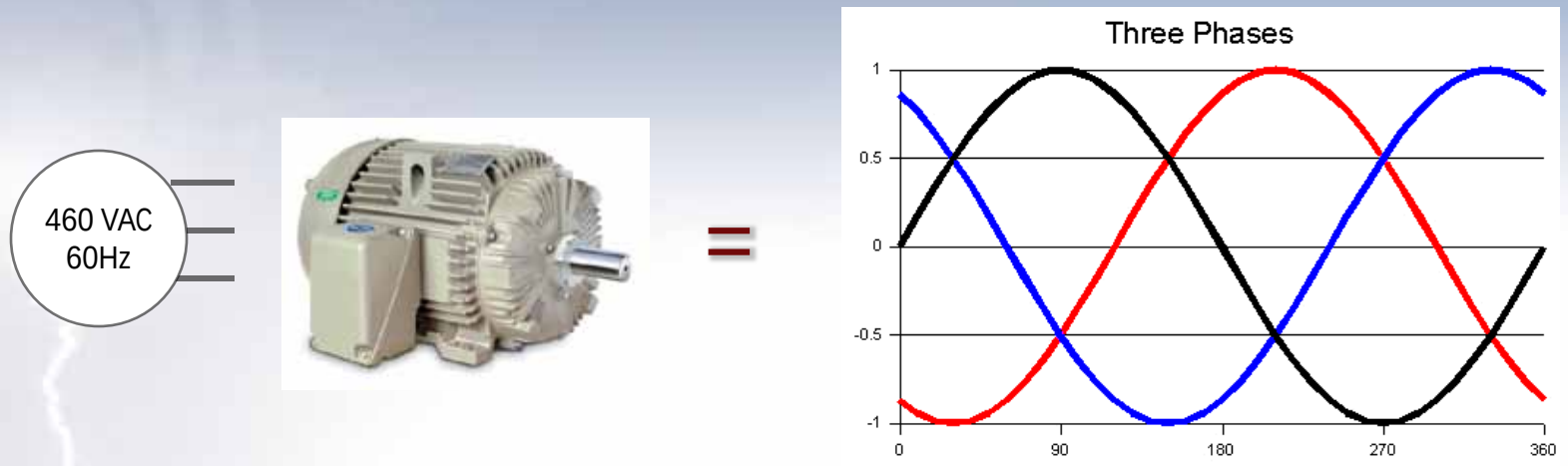
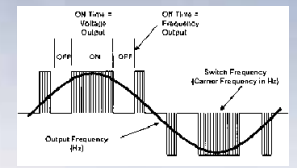
Electric Motor Design



- Most electric induction motors were designed for operation on 3 phase sign wave power – either 50 or 60 Hz.
- The input power was balanced in frequency, phase (120 degrees apart) and in amplitude.
- Common mode voltage – the sum of the 3 phases would always equal zero volts.

Electric Motor Operation by VFD



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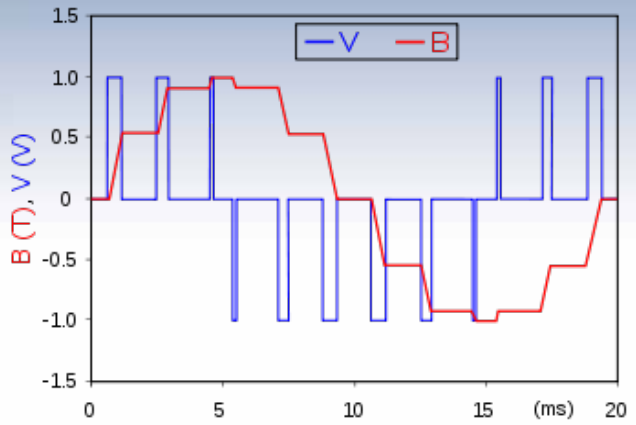
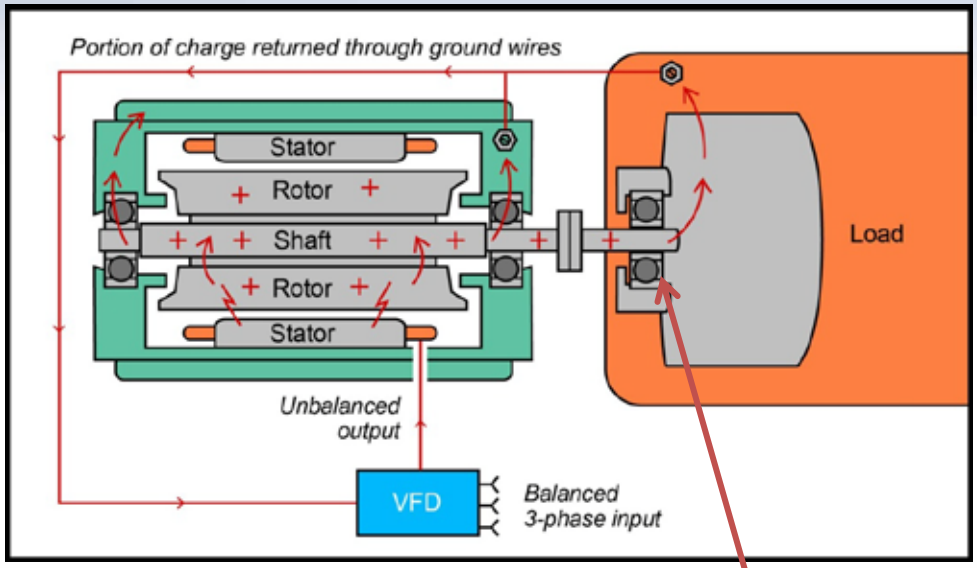
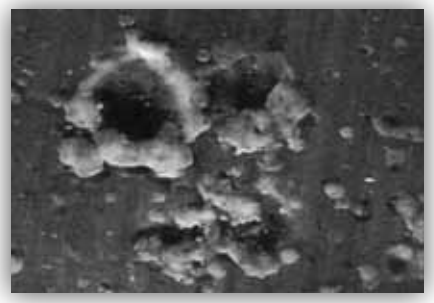


- When operated by VFD, the power to the motor is a series of pulses instead of a smooth sign wave.
- The input power is never balanced because the voltage is either 0 volts, positive, or negative with rapid switching between pulses.
- The Three phases of voltage pulses ensures that the common mode voltage is never equal to zero and instead is a “square wave” or “6 step” voltage.

An Electric Motor acts like a Capacitor

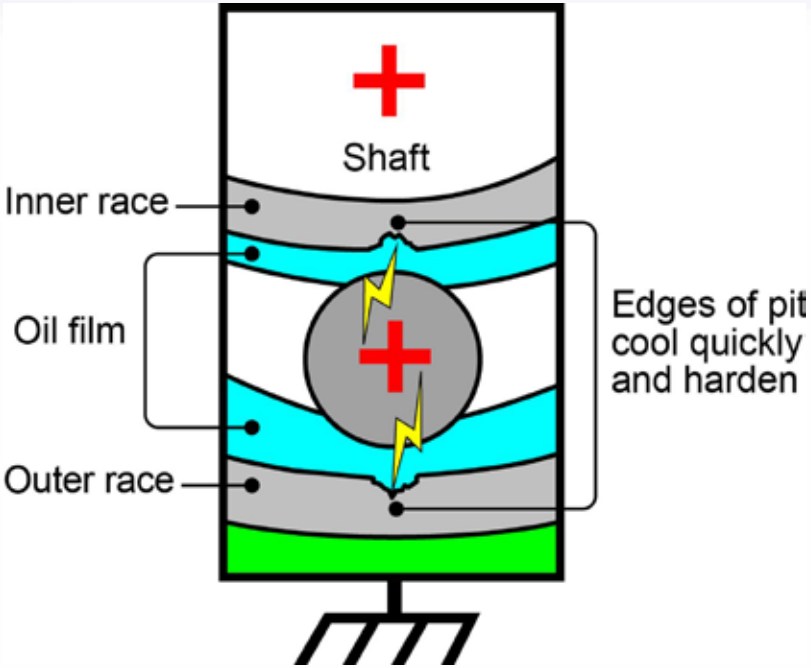
- The pulses to the motor from the VFD create a capacitively coupled common mode voltage on the motor shaft.
- The voltage looks for a path to ground and breaks down the dielectric in the bearing.
- The resulting discharge creates a pit in the bearing race. This occurs multiple times a second and overtime the bearing may fail.





Voltage arcs through the bearing

- Voltage arcs through bearing, and electrical discharge machining (EDM) produces thousands of pits
- Eventually, the rolling element causes fluting damage to race
- Bearings degrade and lose their function resulting in bearing and motor failure



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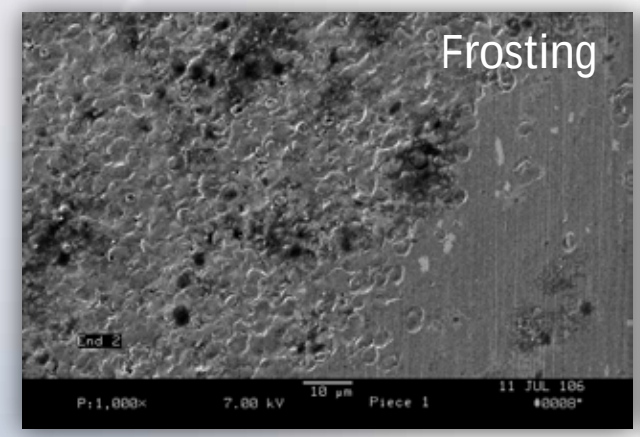
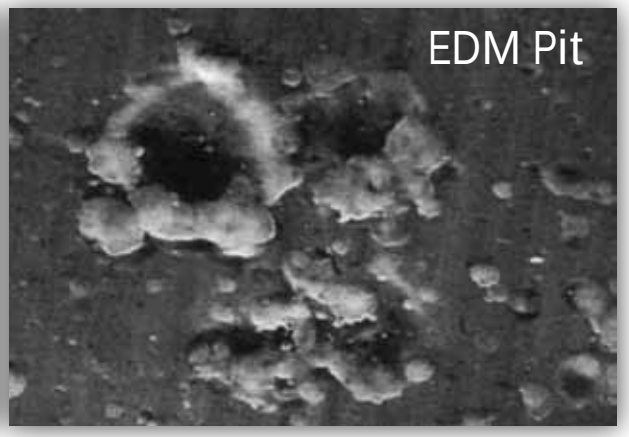
Bearing from a Failed Motor

Destructive shaft voltages discharge through electric motor bearings causing electrical pitting damage, bearing lubrication degradation and catastrophic “fluting” damage in the motor’s bearings.





Pitting due to electrical discharge machining as seen under a Scanning Electron Microscope

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Recommended Testing Equipment

- Oscilloscope with a 10:1 probe. We recommend a minimum 100MHz bandwidth to accurately measure the waveform. The Fluke 190 Series II ScopeMeter® 2 channel also has an Ohm meter function which can be used to measure the resistivity of the shaft. (Fluke 190 Series II ScopeMeter® 4 Channel shown)
- AEGIS™ SVP KIT (**S**haft **V**oltage **P**robe)
- Magnetic base to fit the 3/8" (9.5mm) probe extension rod.

Installing the AEGIS™ SVP Tip

10:1 probe

1. Remove the protective cap

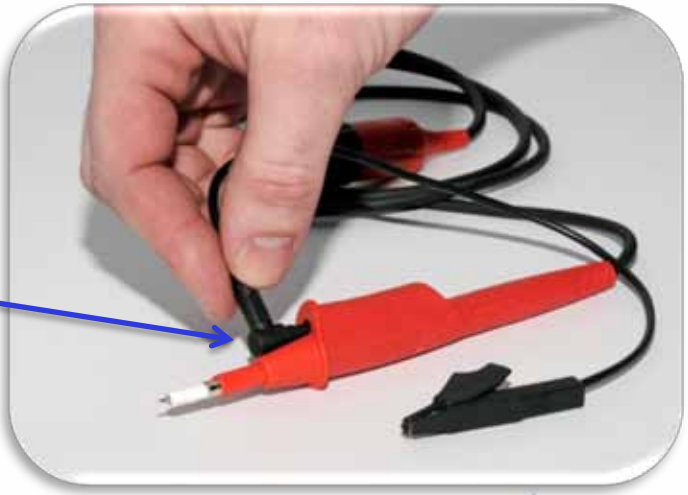
2. Remove the plastic sleeve

AEGIS™ BEARING PROTECTION RING

Installing the AEGIS™ SVP Tip

3. Probe with sleeve removed

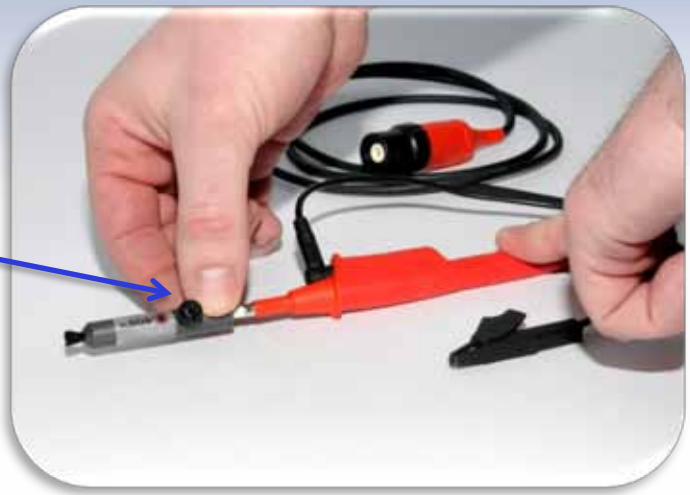
4. Attach ground lead



AEGIS™ BEARING PROTECTION RING

Installing the AEGIS™ SVP Tip

5. Install the AEGIS™ SVP tip over the probe tip



6. Secure the tip to the probe using the thumb screw. Be careful not to over tighten.

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Setting the ScopeMeter® Parameters

The following pages describe the parameters we use to capture shaft voltages. Although not all meters have the same options, the basic concept is the same.

To demonstrate, we will use the Fluke 190-204 ScopeMeter®.

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ScopeMeter Parameters *Set Readings "ON"*

Press the **A** button for channel A.

A menu will appear at the bottom.

Press **SCOPE**

Press **F1** to toggle **ON**

Press **CLEAR** to clear menu

Instructions are specific to the Fluke 190-204 ScopeMeter. Refer to your owner's manual for a different meter.

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ScopeMeter Parameters *DC Coupling*

Press the **A** button for channel A.
A menu will appear at the bottom.

Press **F2 COUPLING** to toggle between the DC and AC Coupling.
Choose **DC** and press **ENTER**.
Press **CLEAR** to clear menu.

DC Coupling will pick up DC and AC voltages.

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ScopeMeter Parameters *Set Voltage Peak-Peak*

Press the **SCOPE** button. A menu will appear at the bottom.

Press **F2 READING**. Move cursor to desired channel and press **ENTER**.

Note: VPS410 should be connected to the ScopeMeter; preferably Channel A.

Use up/down arrows to choose **Peak** and press **ENTER**.

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ScopeMeter Parameters *Set Voltage peak-peak*

Choose **Peak to Peak** and press **ENTER**.

Press **CLEAR** to remove the menu bar.

Voltage **Peak to Peak** is now set.

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ScopeMeter Parameters *Set Polarity and Bandwidth*

Press the **A** button. A menu will appear at the bottom.

Press **F4 INPUT A OPTIONS**.

Column 1 choose **Normal** and press **ENTER**

Column 2 choose **Full** and press **ENTER**

Press **CLEAR** to clear the menu

Instructions are specific to the Fluke 190-204 ScopeMeter. Refer to your owner's manual for a different meter.

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Set Waveform Averages "OFF" and Waveform "Normal"

To show specific voltage measurements instead of averages:

Press the **SCOPE** button.

Press **F4 WAVEFORM OPTIONS**

Move cursor to 3rd column using arrow buttons.

Averages: **Off**

Press **ENTER**

In column 4

Waveform: **Normal**

Press **ENTER**

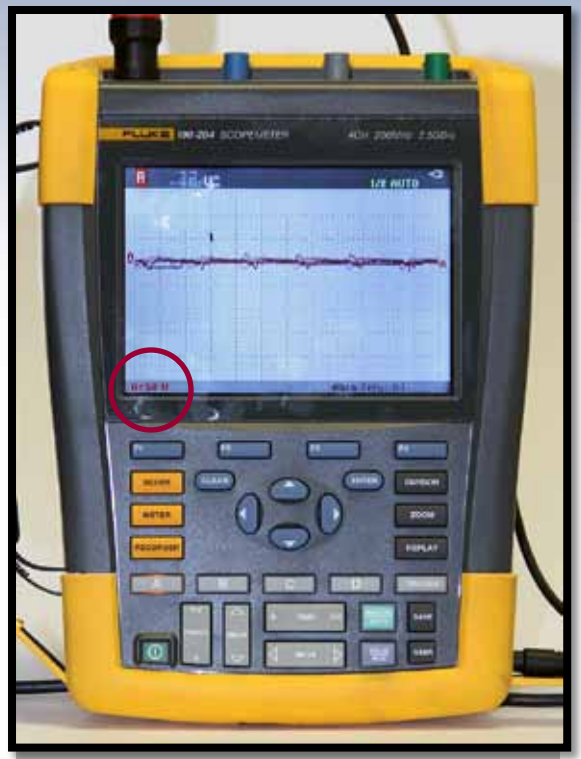
Press **CLEAR** to clear the menu

AEGIS™ BEARING PROTECTION RING

ScopeMeter Parameters *Set Voltage Amplitude*

Amplitude will need to be adjusted according to the conditions.

Set to show complete sign wave from top peak to bottom peak using the **RANGE** button.



In this example the amplitude is too small. Increase **RANGE** to show more detail.

In this example the amplitude is too large. Decrease **RANGE** to show top and bottom peaks.

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ScopeMeter Parameters *Set Time Period*

An EDM discharge pattern will show a climb in voltage and then a sharp vertical line. The sharp vertical line shows the moment of discharge to ground.

To show this detail, adjust the **TIME**.

Setting the time period to 10µs (microseconds) is a good place to start and then you can adjust the **TIME** based on the conditions of the reading.

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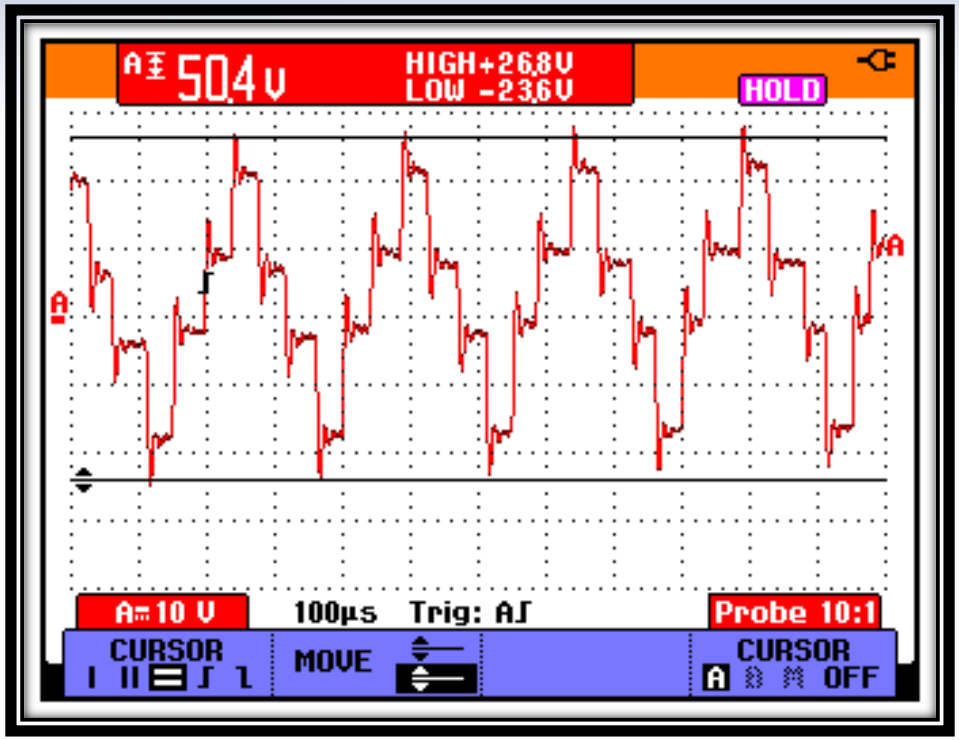
ScopeMeter Parameters *Time Period*

This is an example of a Time period set to 100 microseconds. It is a 6 step pattern in the wave form. 4 full cycles of the pattern are shown.



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Safety

- Wear safety glasses and hearing protection before carrying out a measurement
- Power down the motor, install testing equipment and restart motor
- Use the magnetic base when taking shaft voltage readings
- Ensure all wires are away from rotating equipment

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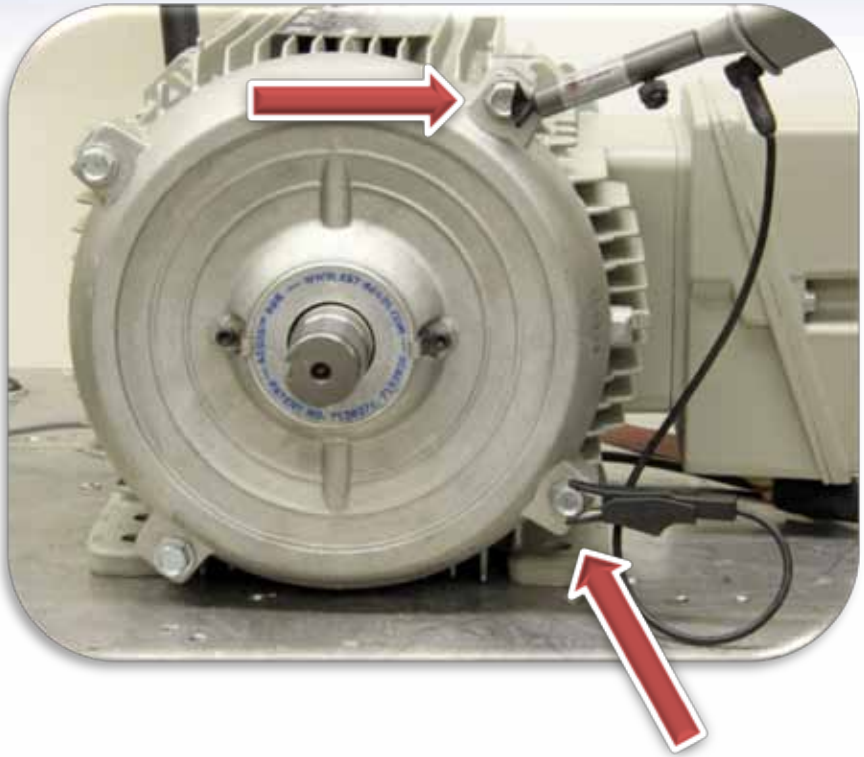
Taking the Measurements

Ground Reference Reading: EMI

1. The reading displays ground noise or EMI being produced by the motor system.
2. Find 2 ground points on the motor. Must be bare metal and conductive.
3. Place the SVP on one of the points and the probe grounding clip on the other point.
4. Measurements will vary depending on the motor size and conditions.



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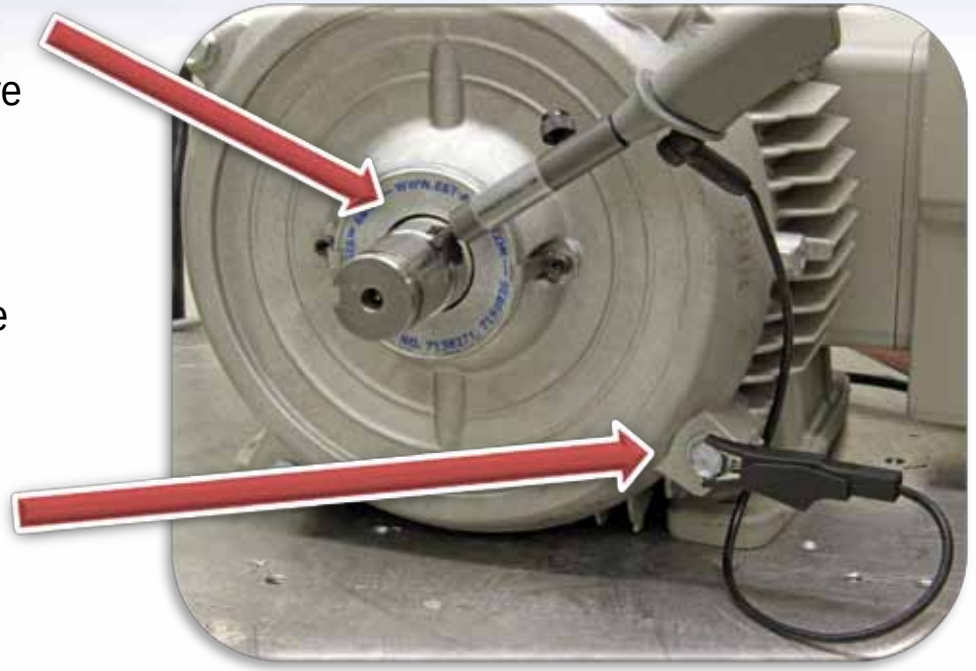
Taking the Measurements

Shaft Voltage Reading

1. Shaft must be clean & free of any coatings, paint or other nonconductive material.
2. Secure the probe in place with magnetic base.
3. Align AEGIS™ SVP on shaft end or side ensuring continuous contact. Avoid keyway if possible.
4. Place oscilloscope grounding lead on bare metal of motor ensuring conductive path to ground.



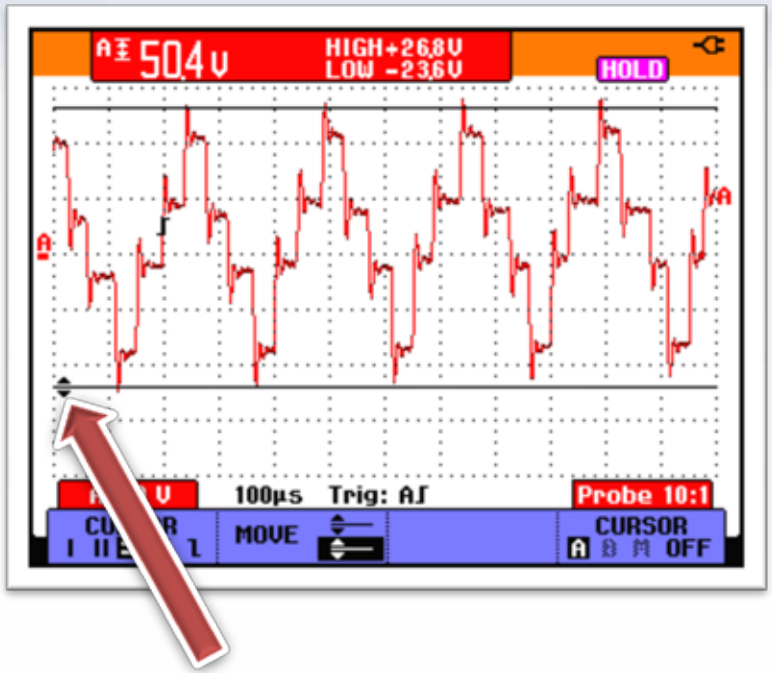
AEGIS™ BEARING PROTECTION RING

Examples of Shaft Voltage Readings

High Peak to Peak common mode voltage –

Typically 20 to 120 volts peak to peak. The waveform image shows the capacitive coupled common mode voltage on the shaft of the motor. The "six-step" wave form is the result of the 3 phases of pulses from the VFD. The timing of the pulse width modulation (PWM) pulses to the motor from the drive determines what the wave form looks like. Sometimes it will look like a square wave.

Important note: This six-step or square wave is what is seen when there is no bearing discharge and the peak to peak shaft voltage is at it's maximum level. The voltage may eventually overcome the dielectric in most bearings and begin discharging.



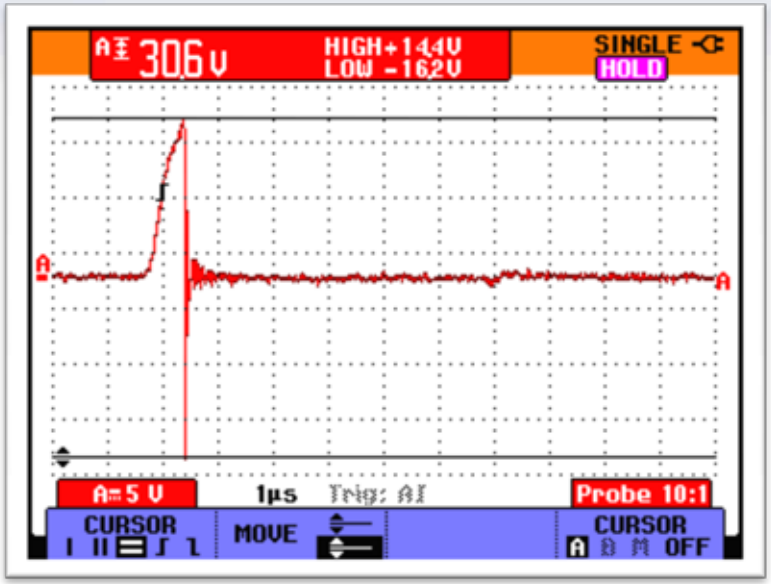
The use of cursors is handy to determine voltages at a specific spot in the reading.

AEGIS™ BEARING PROTECTION RING

Examples of Shaft Voltage Readings

High amplitude EDM discharge pattern –

Typically EDM discharges can occur from 6 volts peak to 80 volts peak depending on the motor, the type of bearing, the age of the bearing, and other factors. The waveform image shows an increase in voltage on the shaft and then a sharp vertical line indicating a voltage discharge. This can occur thousands of times in a second, based on the carrier frequency of the drive. The sharp vertical discharge at the trailing edge of the voltage is an ultra high frequency dv/dt with a typical "discharge frequency" of 1 to 125 MHz (based on testing results in many applications).



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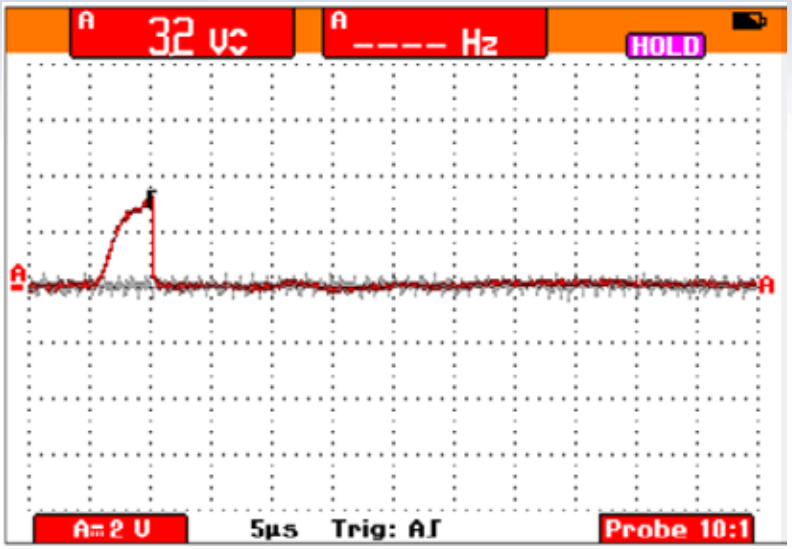
Examples of Shaft Voltage Readings

Low amplitude EDM discharge pattern –

Even though the voltage peak to peak waveform shows a small change (3.2V pk-pk in this case) the bearing is still experiencing arcing thousands of times in a second.

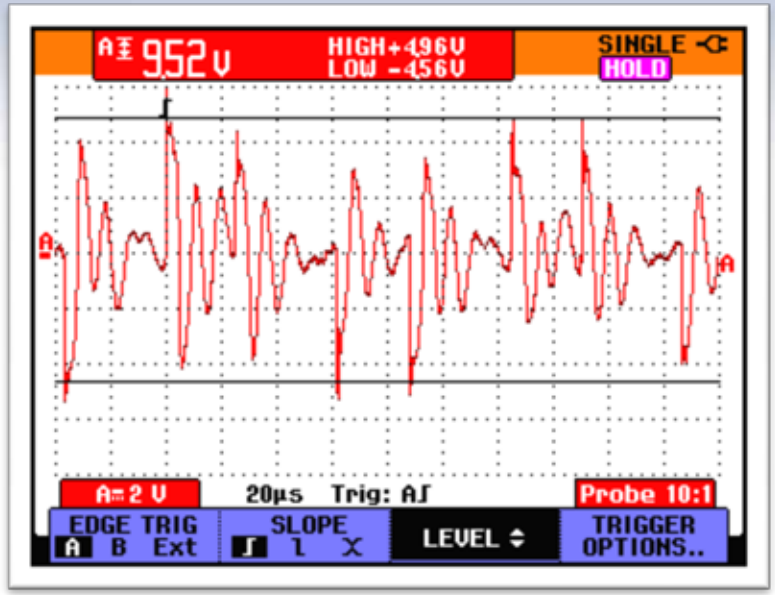


AEGIS™ BEARING PROTECTION RING

Examples of Shaft Voltage Readings

Low amplitude voltage discharge pattern –

Typically the peak to peak voltages are 4 to 15 volts peak to peak. The waveform image shows a more continuous discharge pattern with lower dv/dt frequencies between 30 KHz to 1 MHz. The lower voltage is because of greater current flow in the bearings which are the result of the bearing lubrication becoming conductive. As discharges occur in the bearings the lubrication can become contaminated with carbon and metal particles, At this stage the grease usually is black in color from the contamination and has a lower impedance to the shaft voltages resulting in lower peak to peak voltages. This condition is usually found in motors that have run for many months or years.



new grease vs burnt grease

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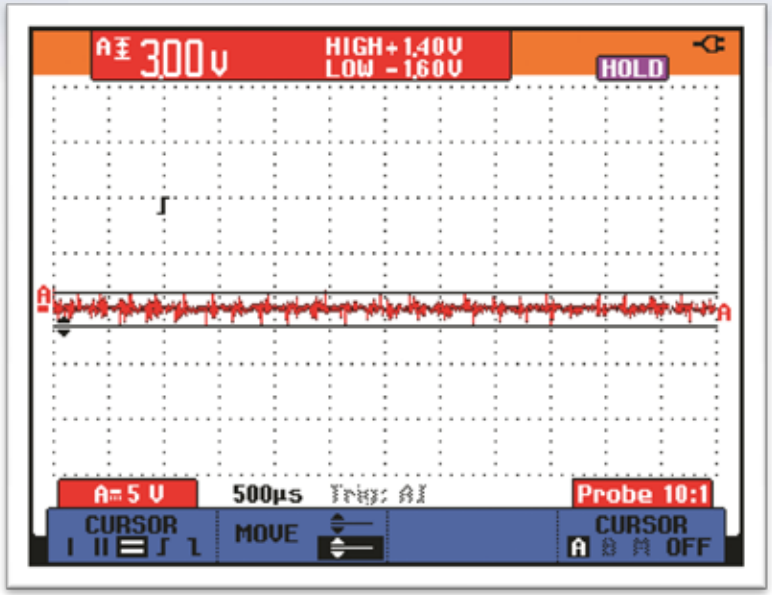
Examples of Shaft Voltage Readings

Peak to Peak voltage with AEGIS™ ring installed –

With the AEGIS™ ring installed, you will typically see discharge voltage peaks around 2 to 3 volts on a bare steel shaft surface. The voltage readings may be decreased with the application of AEGIS™ Colloidal Silver Shaft Coating which allows for a more efficient electron transfer to the conductive micro fiber tips. The waveform image shows the low peak to peak waveform of a motor with AEGIS™ SGR discharging the shaft voltages.



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ScopeMeter *Saving Images as .BMP on USB*

1. Plug in USB drive
2. Saving images as .BMP allow you to view your file without using the Fluke software on your computer.
3. You will not be able to change the file name as you are saving it but you can change it later.
4. Hold Image on screen
5. Save
6. F1 Save
7. F1 again to change from INT to USB
8. F4 Close
9. F3 to save to USB
10. Press Clear to Clear menu
11. To view files saved to USB, use a computer.

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Shaft Voltage Test Reports

After taking voltage readings, it can be very useful to prepare a report with the readings. These reports can then be given to the facility manager for evaluation.

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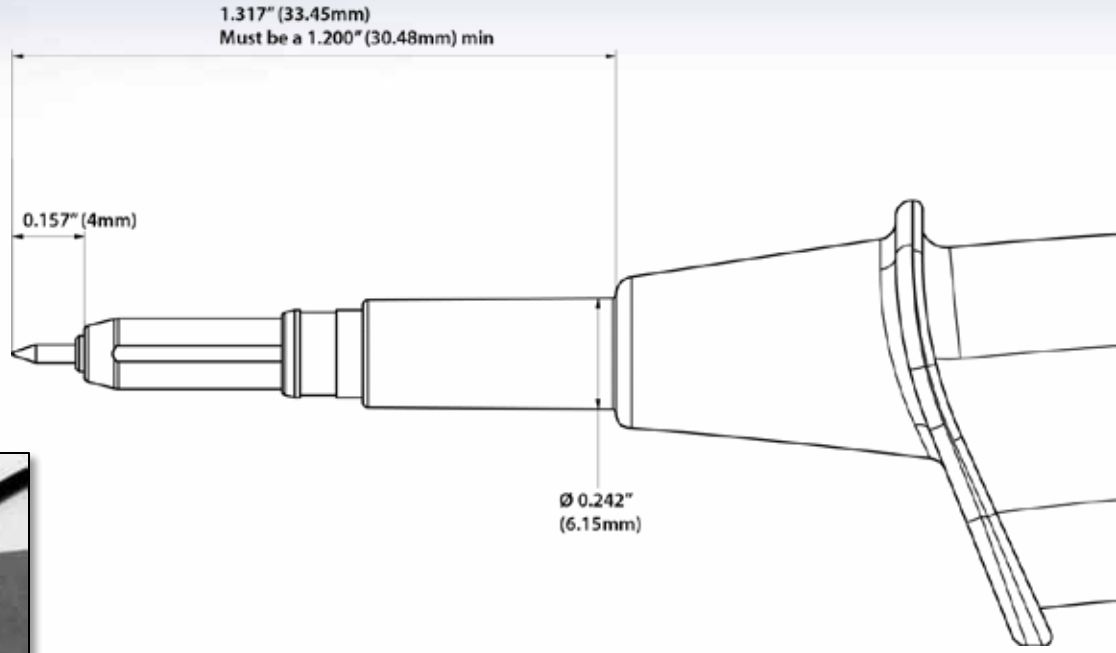
SVP Tip Specifications

The AEGIS™ SVP-KIT-3000 and SVP-TIP-3000 is designed to fit the following Fluke 10:1 probes:

- Ø Fluke VPS200
- Ø Fluke VPS410



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AEGIS™ BEARING PROTECTION RING

AEGIS™ SVP Shaft Voltage Probes

The AEGIS™ SVP-KIT-3000 includes 3 SVP tips, probe holder with two piece extension rod (total length of probe holder with extension rod is 18 inches. Fits 3/8” magnetic base (base not included).

The AEGIS™ SVP-TIP-3000 includes 3 SVP tips only

The AEGIS™ SVP-KIT-3000 and SVP-TIP-3000 is designed to fit the following Fluke 10:1 probes:

- Ø Fluke VPS200
- Ø Fluke VPS410

Tips for other probe styles are available. See website for details.

When Destructive Shaft Voltages are Present

Damaging shaft voltages can cause bearing failure.

SOLUTION:

Install an AEGIS™ Shaft Grounding Ring to protect motor bearings from harmful shaft voltages.

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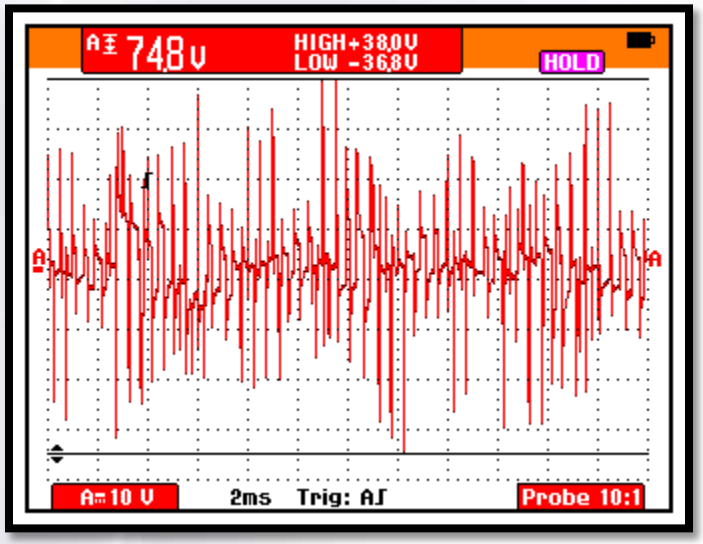
AEGIS™ BEARING PROTECTION RING

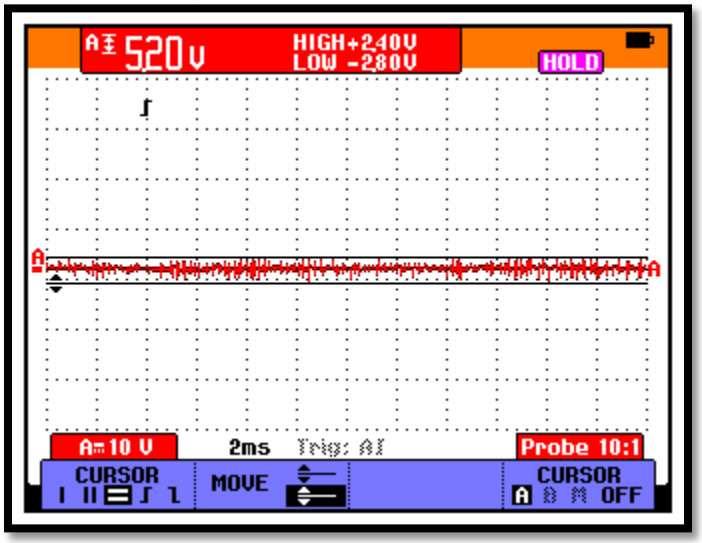
When Destructive Shaft Voltages are Present

SHAFT VOLTAGE READING
WITHOUT AEGIS™ SGR :



PROBLEM

SHAFT VOLTAGE READING
WITH AEGIS™ SGR:



SOLUTION

Readings taken on a conveyor motor

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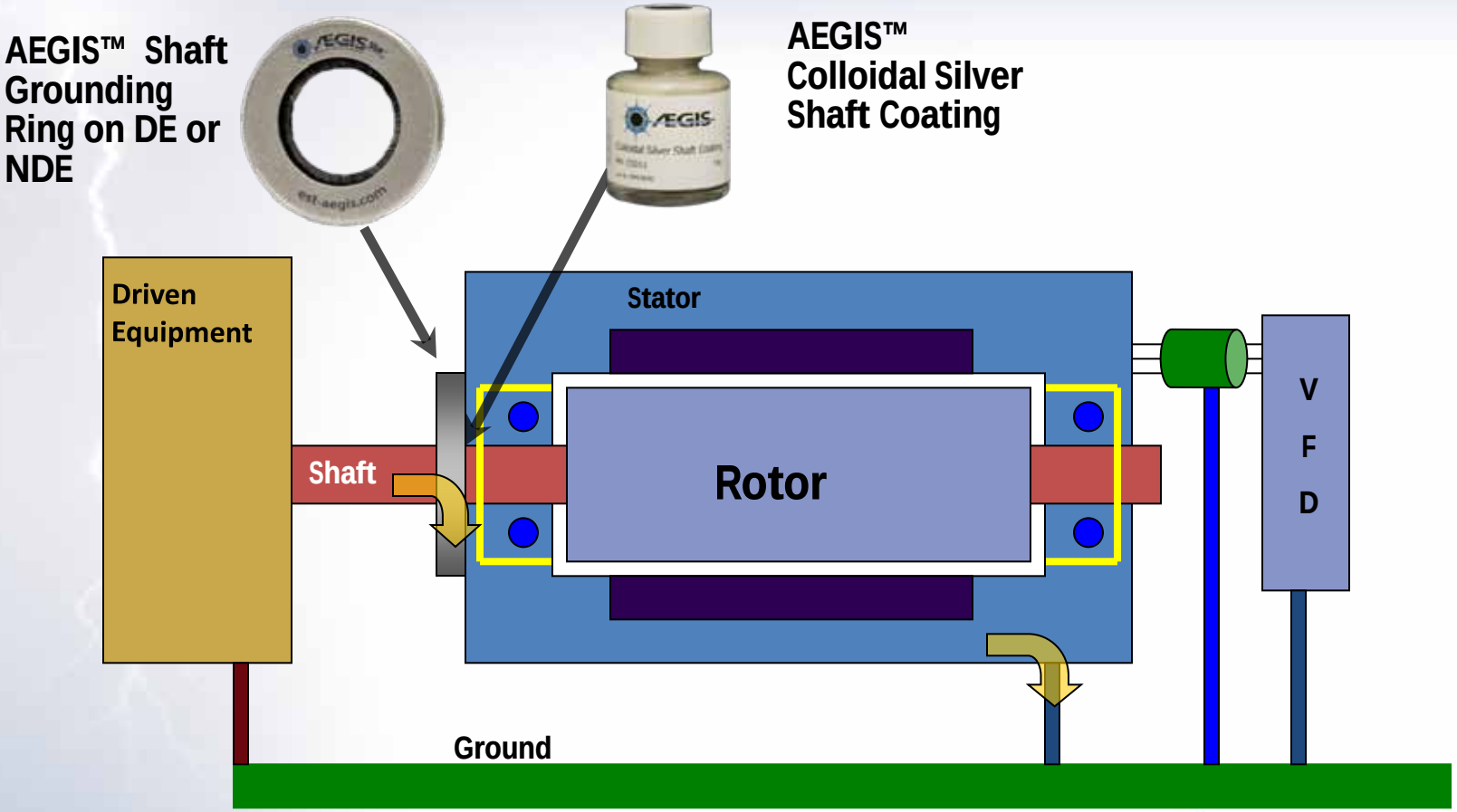
When Destructive Shaft Voltages are Present

BEST PRACTICES FOR SHAFT GROUNDING MITIGATION –MOTORS TO 100 HP



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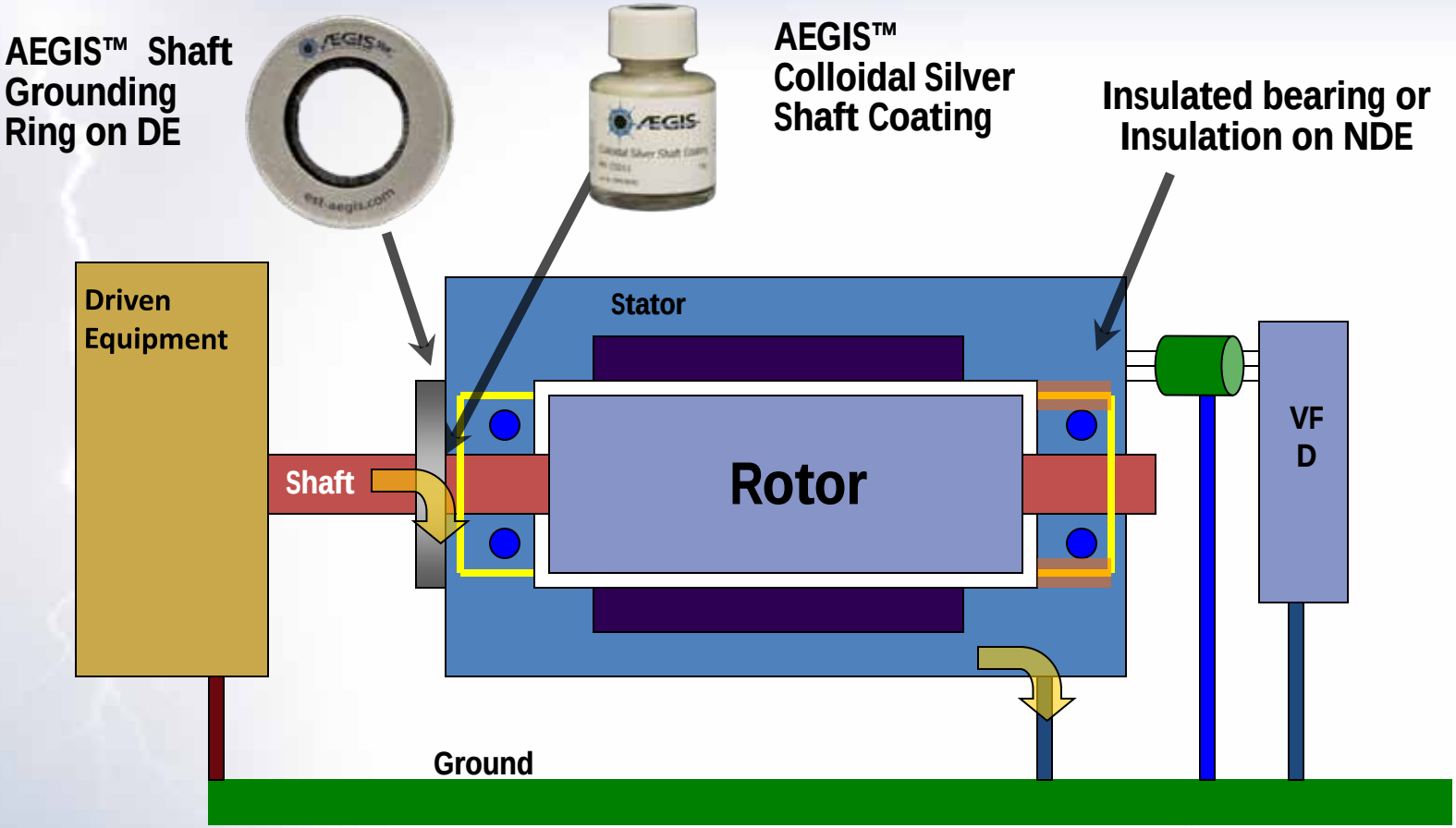
When Destructive Shaft Voltages are Present

BEST PRACTICES FOR SHAFT GROUNDING MITIGATION –LARGE LOW AND MEDIUM VOLTAGE MOTORS OVER 100 HP TO ABOVE NEMA FRAMES



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Typical Installations on a motor

AEGIS™ uKIT

AEGIS™ uKIT

AEGIS™ SGR with Conductive Epoxy

AEGIS™ SGR Split Ring with Conductive Epoxy

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Conclusions

- VFD driven motors have shaft voltages that may discharge in the motor bearings.
- Bearing discharges cause pitting and “fluting” damage and catastrophic bearing failure.
- Protecting motor bearings is essential in ensuring reliability and up-time.
- AEGIS™ rings protect bearings by providing a less resistant path to earth ground than the motor’s bearings.

This procedures manual is intended as a general guidance to assist with proper testing and application of the AEGIS™ SGR Bearing Protection Ring to protect motor bearings. All statements and technical information contained in this procedure manual are rendered in good faith. User must assume responsibility to determine suitability of the product for its intended use. The manufacturer shall not be liable for any injury, loss or damage, direct or consequential arising out of the use, or attempt to use the product.

AEGIS™ BEARING PROTECTION RING

Thank You for Your Business

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Electro Static Technology™
An ITW Company

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