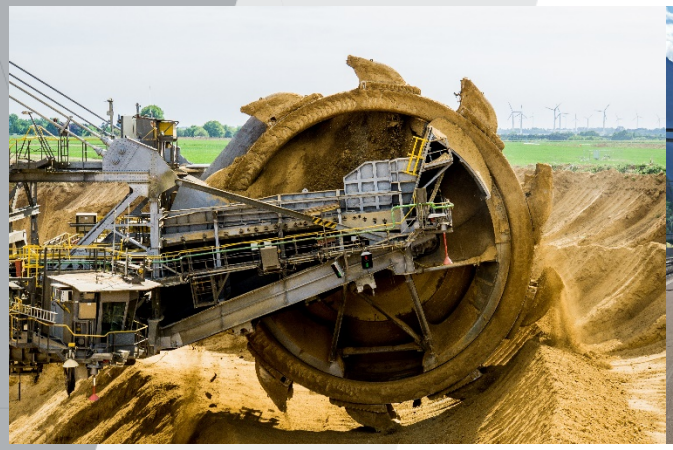

TRANSCAT®

Motor Predictive Maintenance Test Technologies & Case Studies

Paul Knock

Megger Baker Instruments

Megger®

Power on

Electric motor monitoring

- BAKER Instruments electric motor health and predictive evaluation checks
- Electric motors are the most common rotating machinery found in industry - driving Pumps, Fans, Gearboxes, Thrusters, Compressors, Mixers, Conveyors etc, etc.
- Prevent unscheduled electrical breakdown – No other testing can deliver predictive motor and generator predictive maintenance
- Can be offered as part of the planned maintenance to build and track the electric motor condition

Generators

Motors

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Electric motor monitoring – Options

- Electric motor monitoring gives early warning of developing issues in the electric motor and gives the customer time to act and plan maintenance avoiding breakdown.

- Static monitoring monitors insulation degradation – 80% of all electrical motor failures route cause is turn insulation failure.
  - Faults also detected include loose or corroded connections & Low Mohm levels.

- The dynamic monitoring looks at the total system performance identifying many parameters such as power supply, motor condition and load problems that limits the life of the motor.

Static Motor Analyzer

Dynamic Motor Analyzers

On-line Motor Analyzer

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Complimentary Strategies

Strategy 1:

Limit unplanned downtime by averting motor failures caused by insulation breakdown. Perform quality control on rebuilds & repairs

Strategy 2:

Maximize the lives of motors by correcting problems found in the operating machine systems (power, motor, or load conditions

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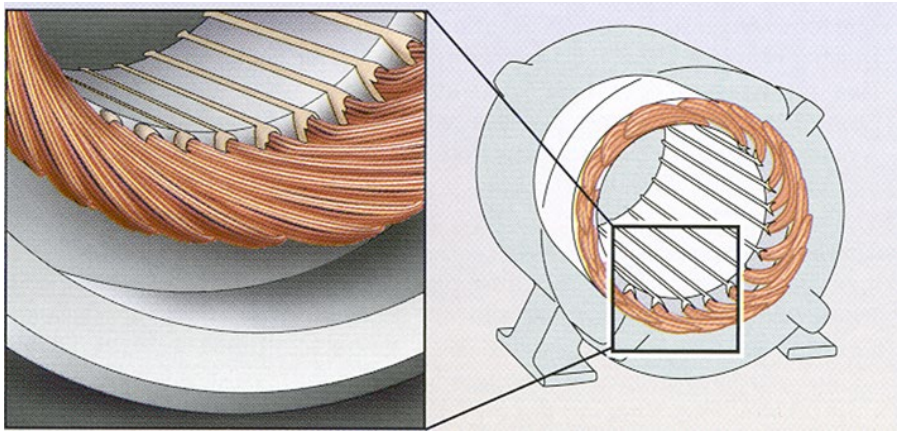
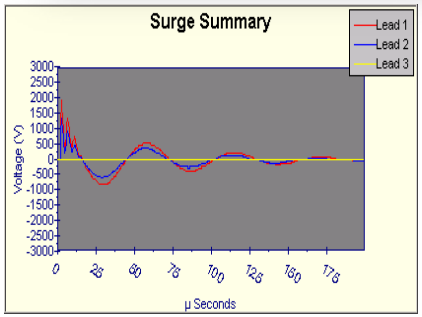
Service & Reporting – Static Motor Analysis

Results Summary		Test Date/Time 12/4/2008 10:25:16am	
Test ID:	415V W/Rotor	Repair/Job #	
Tested By	Paul Knock	Tested For	A Mann
Room #		MCC	Yes
Location	Main Drive	Building	
Temp Status	**Tested**	**PI Status**	**PASS**
Temp	20.0°C 68.0°F	Volts (V)	510
Resist Status	**PASS**	DA Ratio	2.7
L1-L2 (Ohms)	0.0275 Corr: 0.0280	PI Ratio	DA Only
L2-L3 (Ohms)	0.0276 Corr: 0.0282	**Step-Voltage**	**MIN MEGOHM**
L3-L1 (Ohms)	0.0276 Corr: 0.0282	Volts (V)	2000
Max Delta R %	0.533%	Current(µA)	423.00
Coil 1 (Ohms)	0.0138 Corr: 0.0140	Resist (Mohm)	5 At 40°C 1
Coil 2 (Ohms)	0.0137 Corr: 0.0140	**Surge Status**	**ppEAR LIMIT**
Coil 3 (Ohms)	0.0139 Corr: 0.0142	Peak Volt(V) L1	2000
Megohm Status	**PASS**	Peak Volt(V) L2	1240 Failed
Volts (V)	510	Peak Volt(V) L3	0
Current(µA)	4.10	Max P-P EAR%	6.8%,10.7%,--
Resist (Mohm)	124 At 40°C 31	EAR 1-2,2-3,3-1	30%,--,--



Comment:
Surge test failed at 1240V.
Turn to Turn insulation is showing deterioration.
Stepped High Voltage test also showed weak insulation to earth.

Action: Overhaul unit at next planned outage.



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On-Line (Dynamic) Test Equipment!

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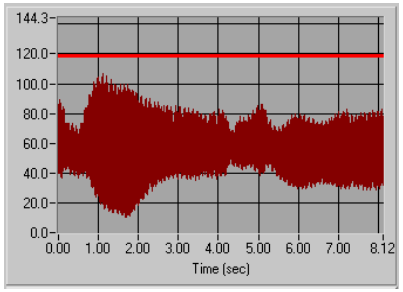
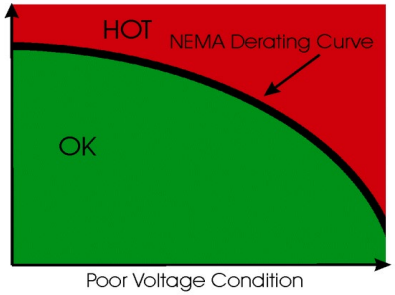
Examples of tests performed

Rotor bar

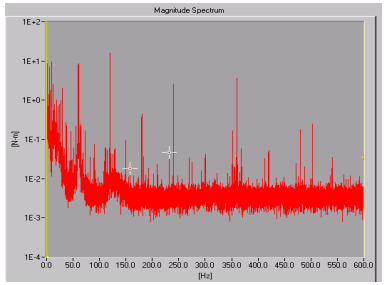


Instantaneous torque

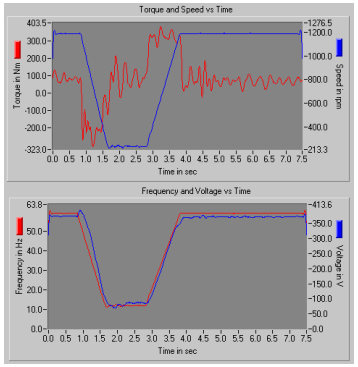


Thermal condition

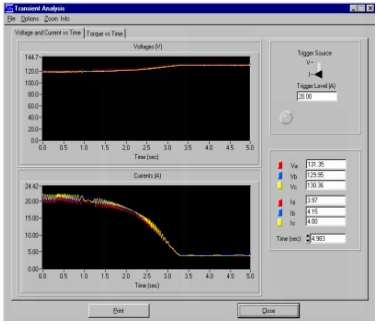
Continuous Monitoring



Voltage, current, and torque spectrums



- **VFD**
- **Torque vs. speed**
- **Freq. vs. voltage**



- **Start-up transients**
- **Voltage, current, and torque over time**

Power Quality

Efficiency Estimation

Power and efficiency

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Motor Monitoring Made Easy

- **Monitor Machine Systems 24/7 From Anywhere**
- Get more out of your machine systems with a performance monitoring product that continuously monitors plant.

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Why Test Motors?

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Why Is Motor Testing Important?
3 Key Points Should be considered

Unscheduled Electrical motor breakdown is one of the most costly issues maintenance teams face!

Electric motors are the most common Rotating Plant in any Industry

Electric Motors are the biggest energy users in industry today!

(65% on average of any Ind facility)

Field Predictive Maintenance

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Motor Failures

Motor Problems

Electrical

No Warning - $$$$

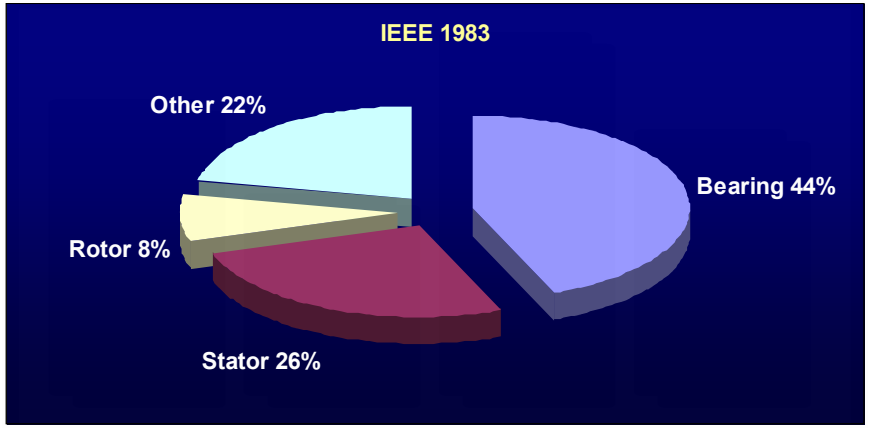
25% - 35%

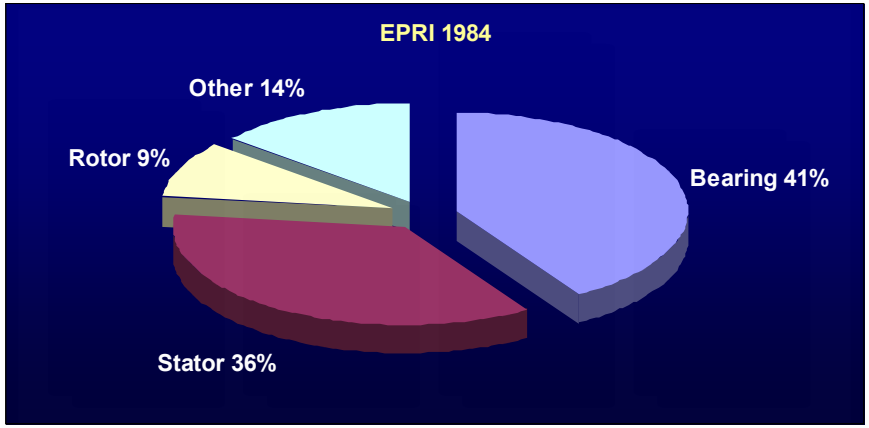
Mechanical

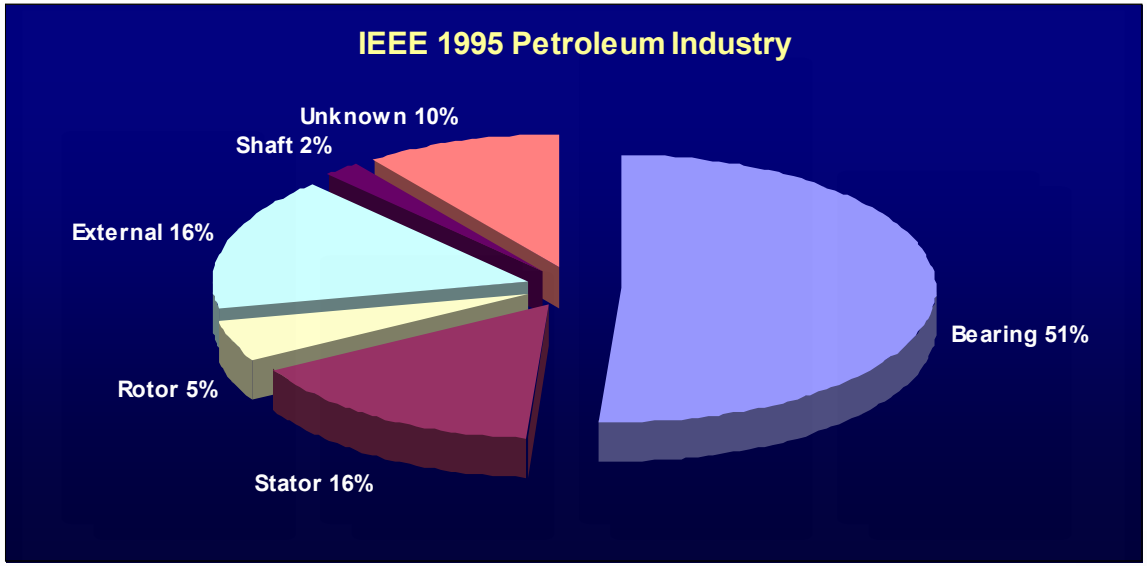
Warning Signs – Heat & Noise

65% - 75%

Motor Failure Studies







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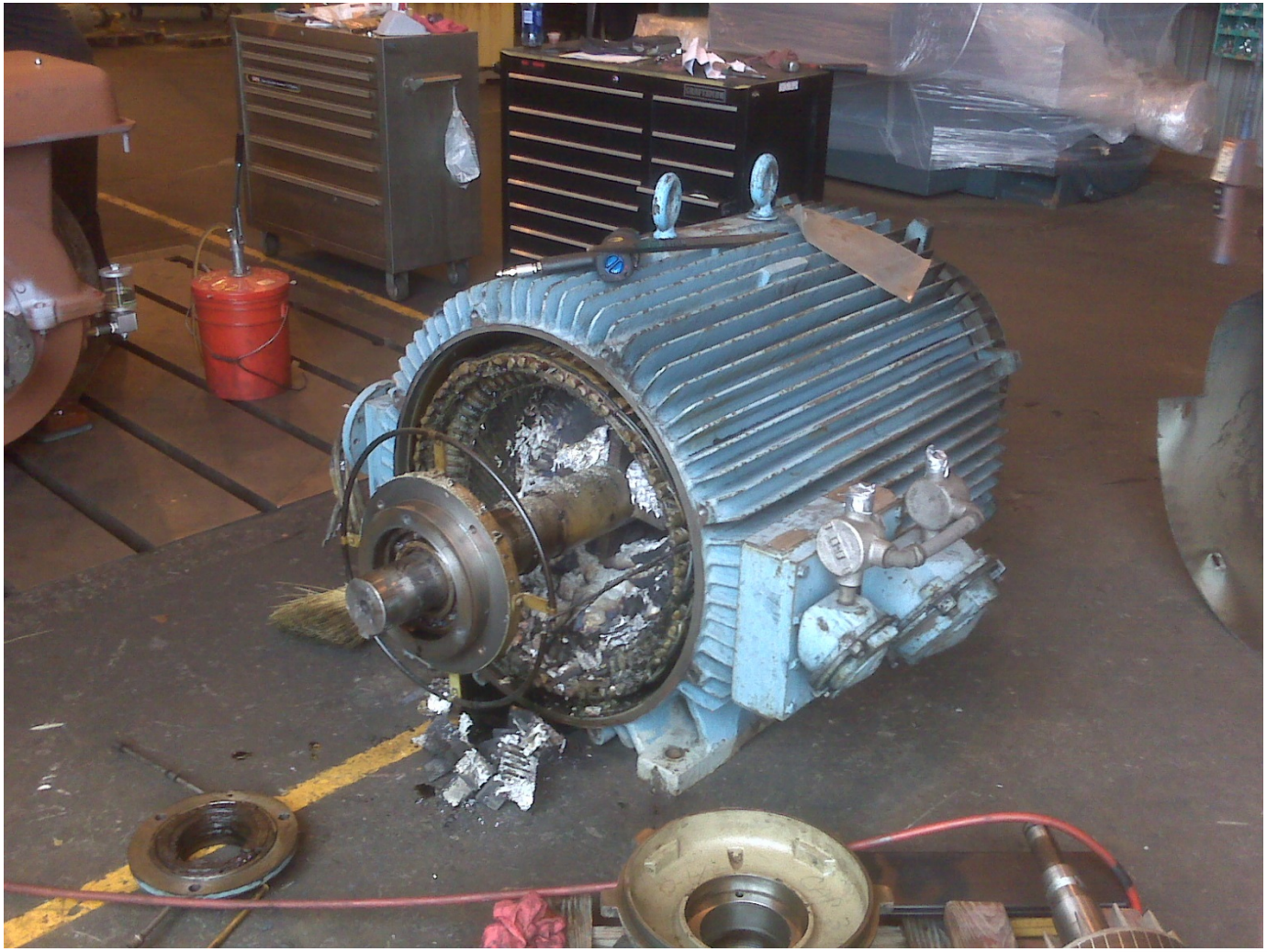
Electrical Motor Faults

- What If you could prevent premature motor failures by identifying motor fault areas in advance?

- Well, you can!!!

- How? By adding motor testing to your PdM program.

Electric Motor Deconstruction



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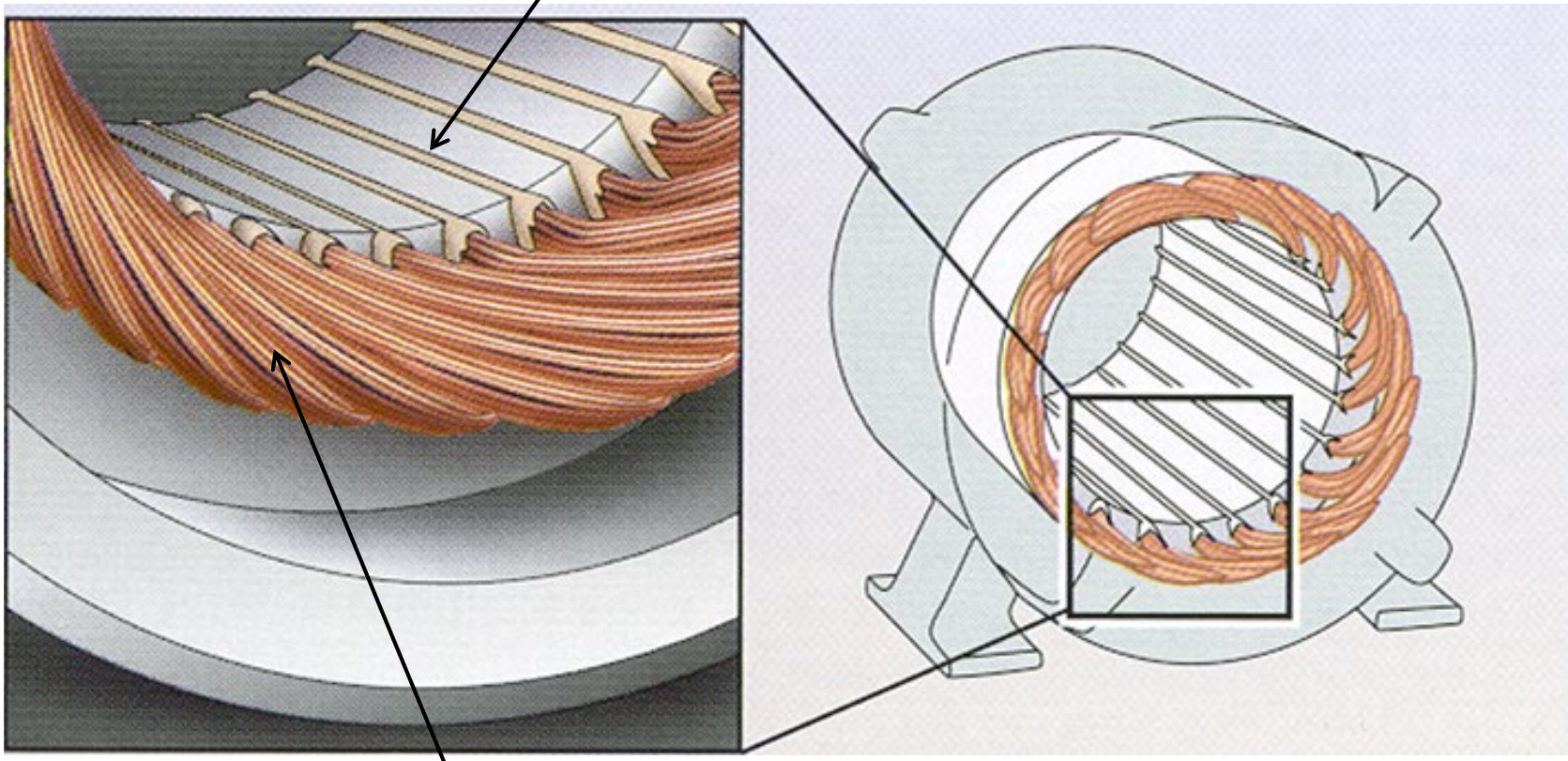
Why implement motor testing to Pdm

The Question Is Not *IF* A Motor Will Fail Electrically

The Question Is *WHEN* Will The Motor Fail Electrically

Motor Insulation Components

Ground Wall Insulation – Copper-to-Earth



Turn Insulation – Copper-to-Copper

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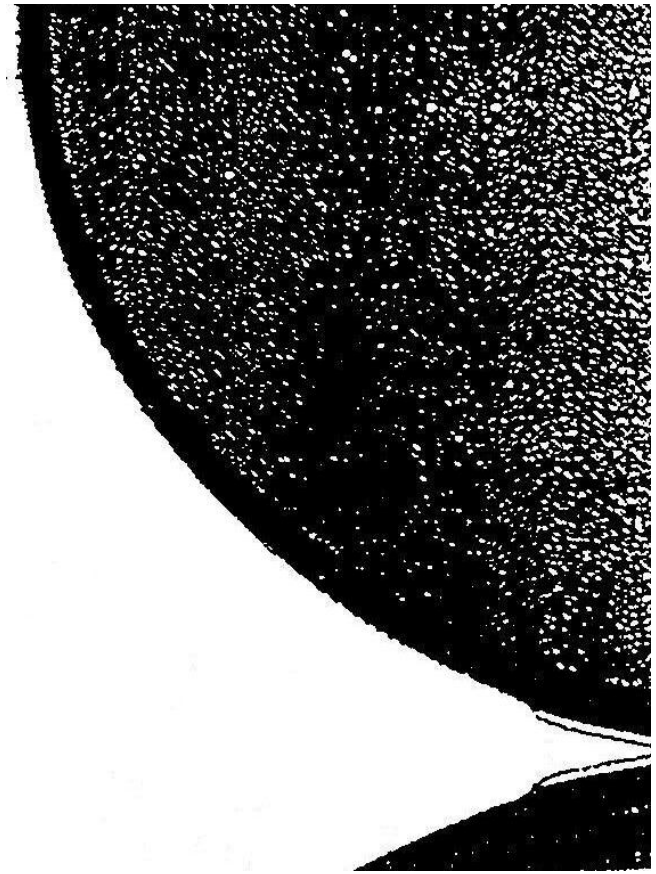
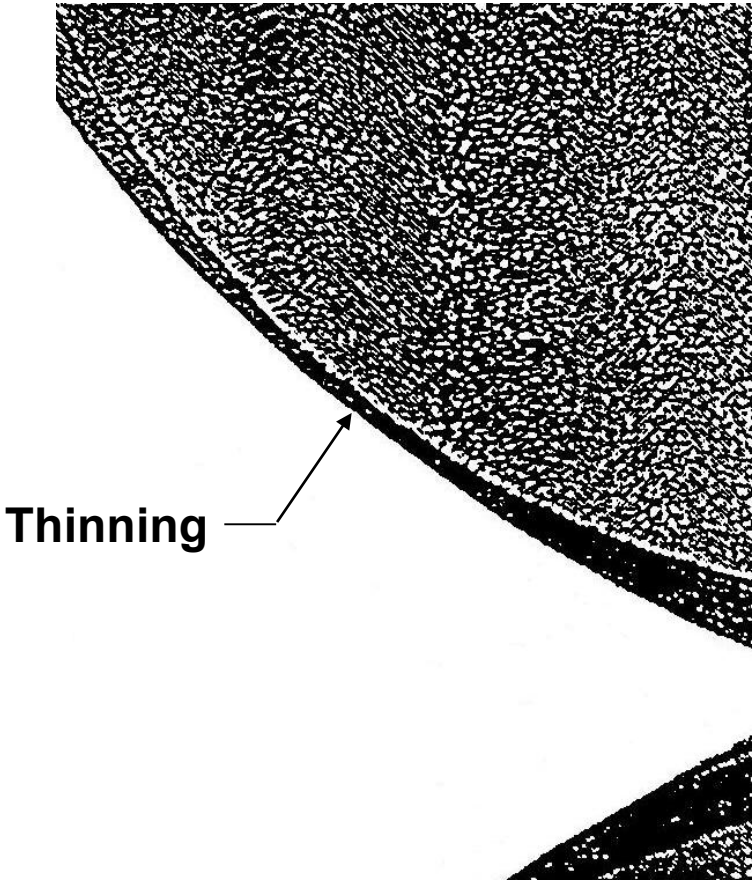
Corona Caused Insulation Degradation

New Insulated Wire Cross-Section



Insulated Wire After Life Testing



Photos courtesy of Phelps Dodge

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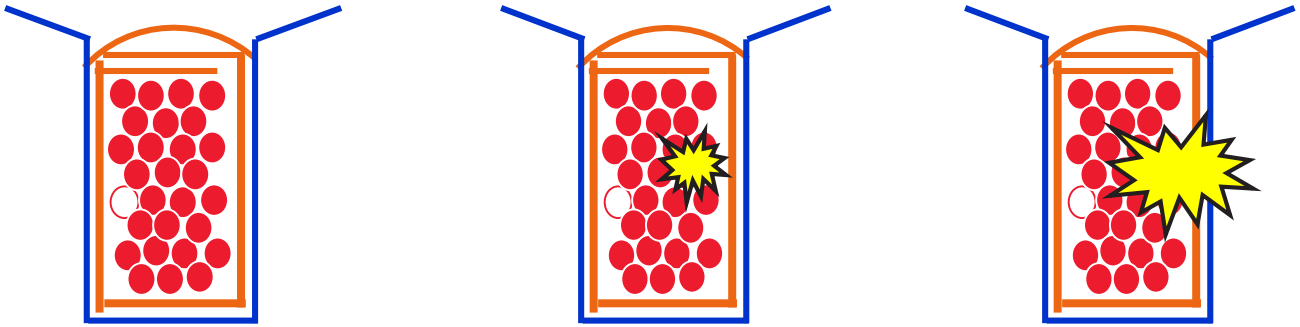
Turn to Turn Failure

- At least **80%** of electrical stator failures start as turn-to-turn fault!

- *Most will fail to ground in the slot, but the root cause will be turn to turn failure*



General Electric Paper

Megger
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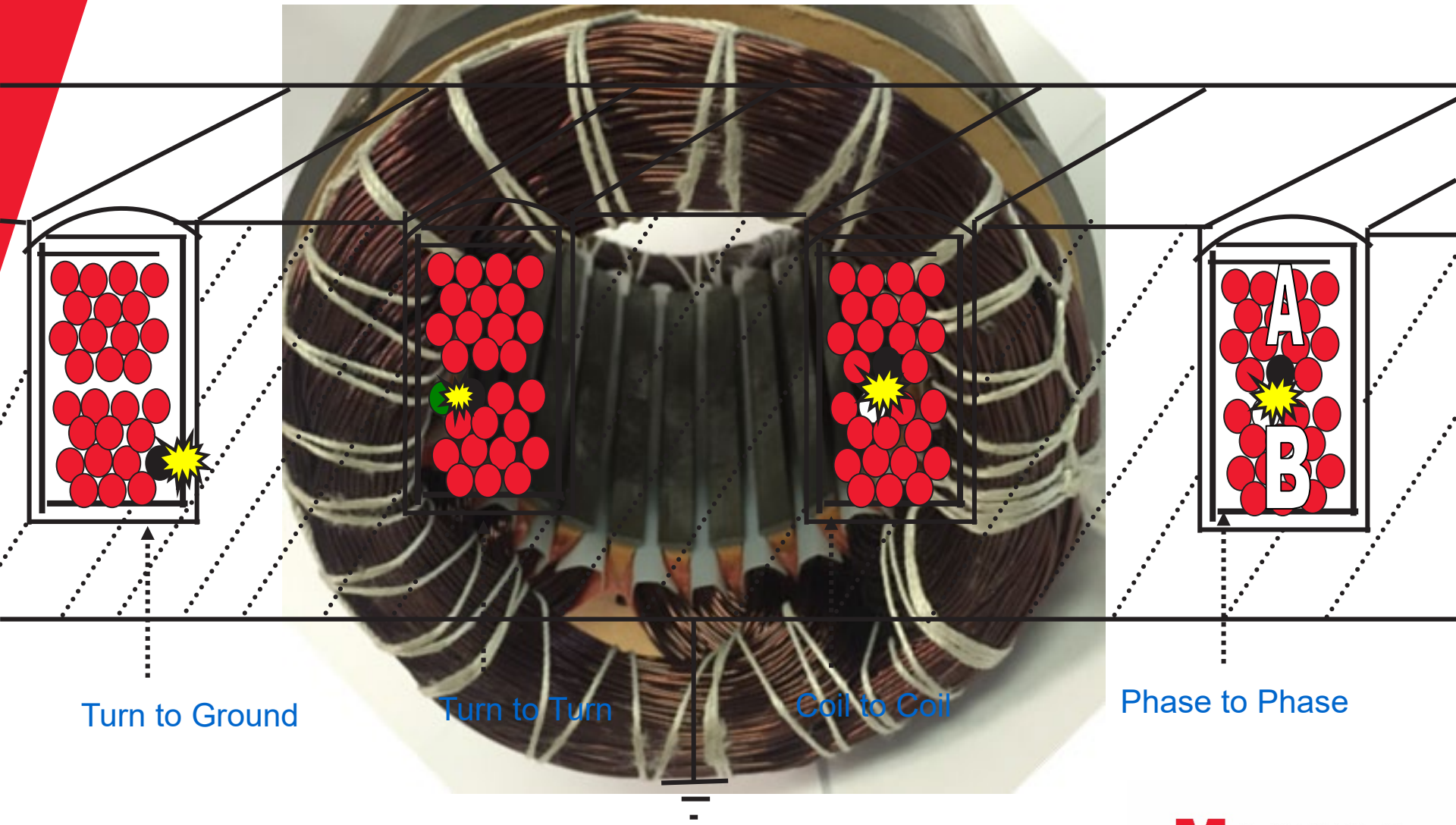
Stator Insulation Failure Modes



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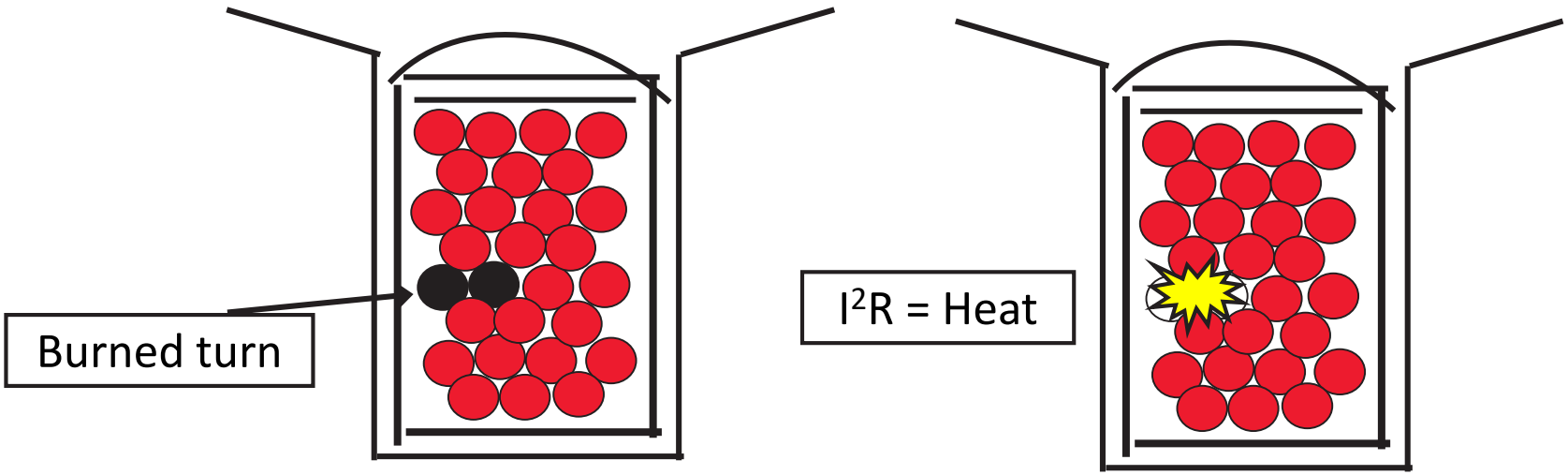
Power on

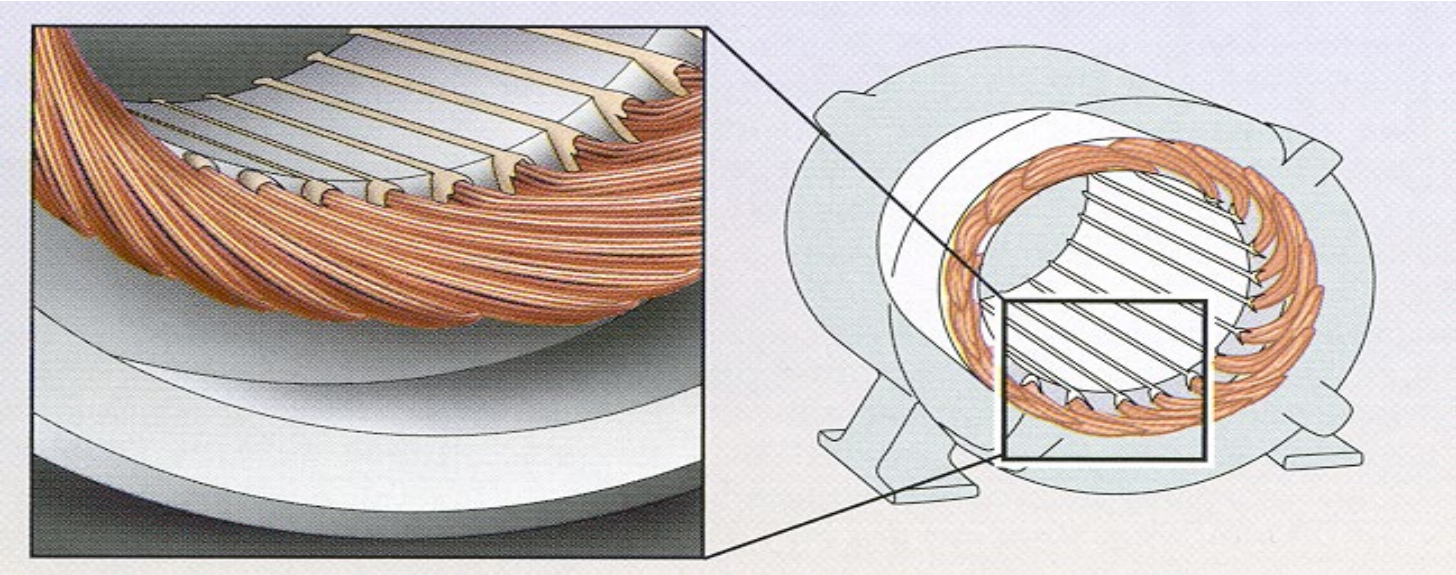
Fused Shorted Turns

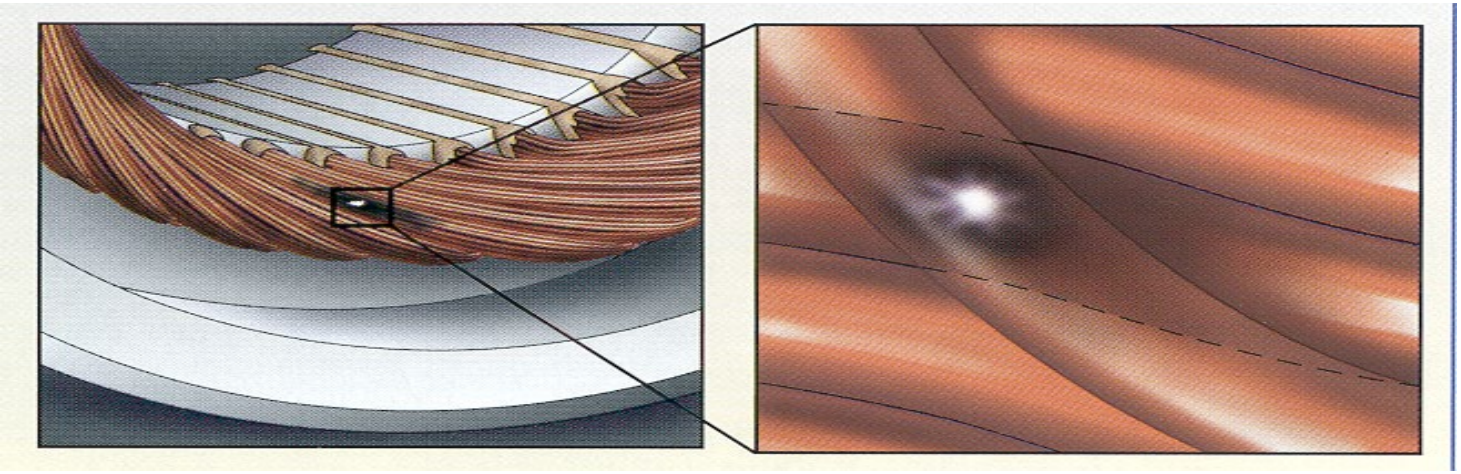
- Initial shorting of the turns is often in the extension
- Failure to ground will be in the slots
- When the dielectric strength falls below the operating voltage the turns will fuse together



According to IEEE the welded faulted turns will burn through the slot cell liner to ground within 15 minutes.

Turn to Turn





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Turn to Turn Insulation Failure

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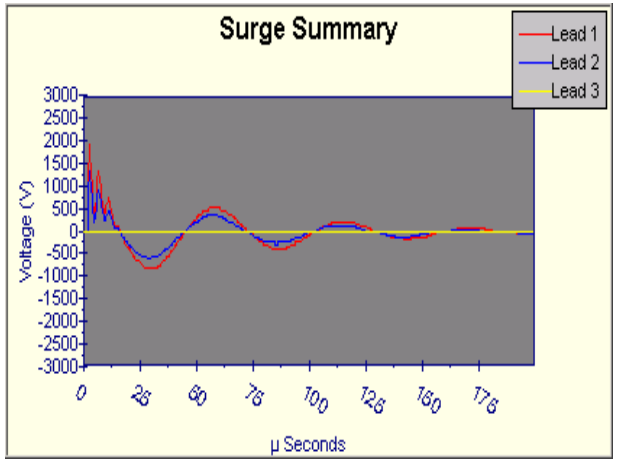
On Site Testing

Megger
Power on

Service Work & Reporting – Motor Analysis

Results Summary		Test Date/Time 12/4/2008 10:25:16am	
Test ID:	415V W/Rotor	Repair/Job #	
Tested By	Paul Knock	Tested For	A Mann
Room #		MCC	Yes
Location	Main Drive	Building	
Temp Status	**Tested**	**PI Status**	**PASS**
Temp	20.0°C 68.0°F	Volts (V)	510
Resist Status	**PASS**	DA Ratio	2.7
L1-L2 (Ohms)	0.0275 Corr: 0.0280	PI Ratio	DA Only
L2-L3 (Ohms)	0.0276 Corr: 0.0282	**Step-Voltage**	**MIN MEGOHM**
L3-L1 (Ohms)	0.0276 Corr: 0.0282	Volts (V)	2000
Max Delta R %	0.533%	Current(µA)	423.00
Coil 1 (Ohms)	0.0138 Corr: 0.0140	Resist (Mohm)	5 At 40°C 1
Coil 2 (Ohms)	0.0137 Corr: 0.0140	**Surge Status**	**ppEAR LIMIT**
Coil 3 (Ohms)	0.0139 Corr: 0.0142	Peak Volt(V) L1	2000
Megohm Status	**PASS**	Peak Volt(V) L2	1240 Failed
Volts (V)	510	Peak Volt(V) L3	0
Current(µA)	4.10	Max P-P EAR%	6.8%,10.7%,--
Resist (Mohm)	124 At 40°C 31	EAR 1-2,2-3,3-1	30%,--,--



Comment:
Surge test failed at 1240V.
Turn to Turn insulation is showing deterioration.
Stepped High Voltage test also showed weak insulation to earth.

Action: Overhaul unit at next planned outage.

Next Test: 1 Month

Megger
Power on

Case Study #1

Client: Marine

Client runs two of four vessels travelling between Australia and NZ that shifts cargo between the two states. The vessels run 6 days a week and can not have any down time.

The motor tested was a Bow thruster, this motor is used to assist in arriving and leaving the dock. If not working the vessel has to hire a tug and each time they come into port - the cost is $15K each trip.

The size of the motor tested:

425KW (duty cycle S2, 30mins)

1487 RPM

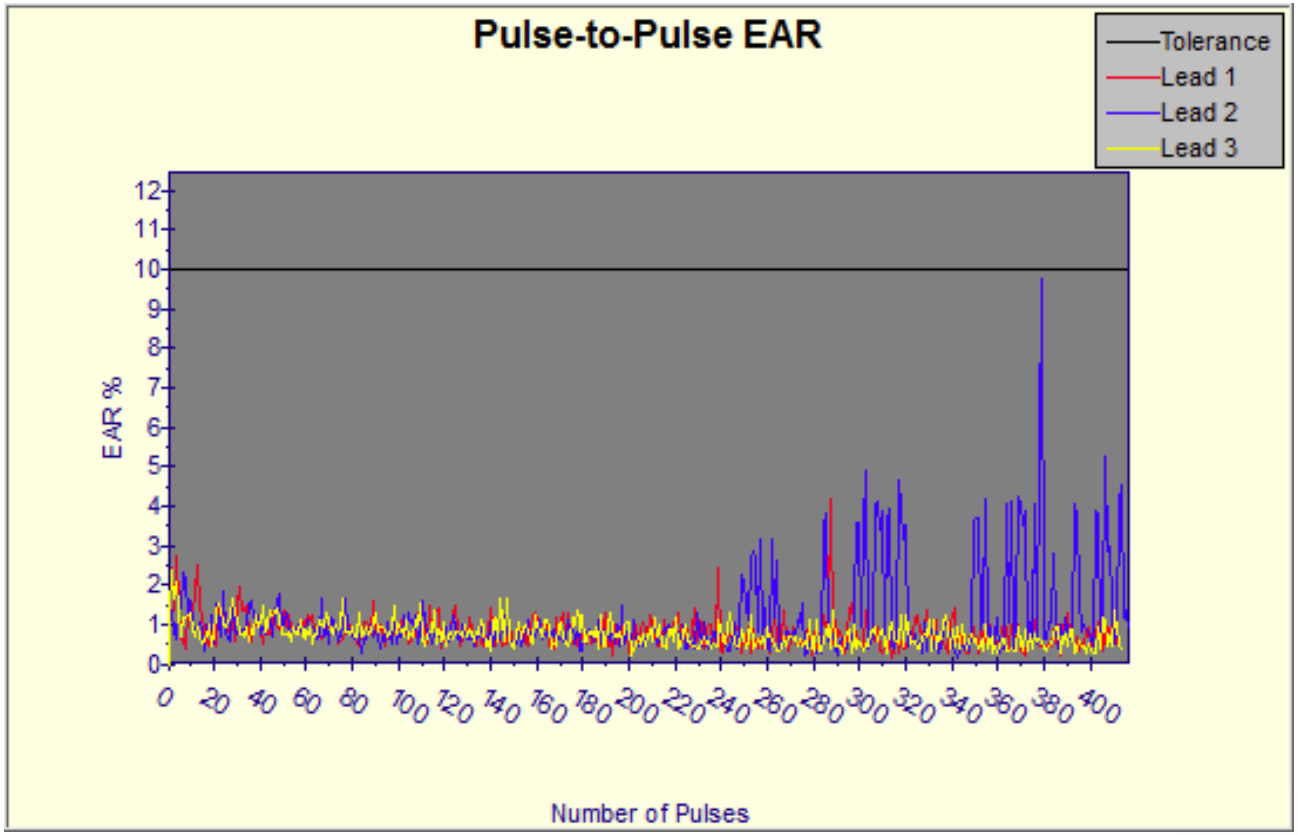
440V

60Htz

Megger.
Power on

Case Study: 1 Cont'd

On looking at the initial test results the motor passed all test, but at closer inspection the Pulse to Pulse EAR is showing insulation breakdown.



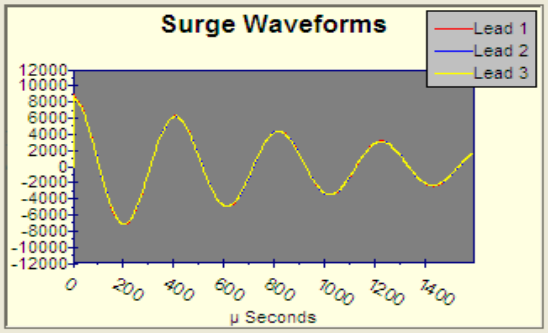
Megger
Power on

Case Study 1

701785 | 1

Data | Tests | Trending

Time	Test ID	Temp	Re...	Mohm	PI	DC	Surge
11/5/2007 12:0...	4160V w/...	PASS	PASS	PASS	FAIL	PASS	PASS



PASS

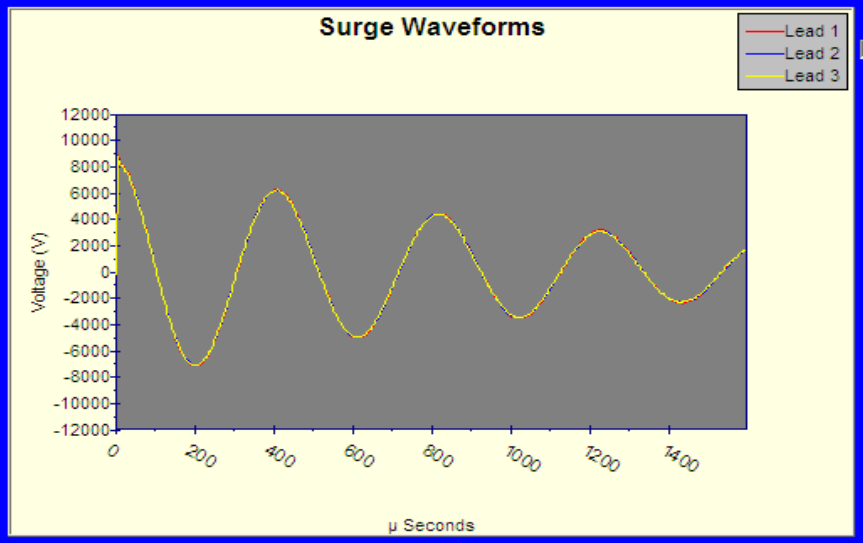
Enlarge | P-P EAR

	Peak Voltage	Max P-P EAR
Lead 1:	9360	6.0%
Lead 2:	9360	6.0%
Lead 3:	9360	6.0%

L-L EAR	
1-2:	1%
2-3:	1%
3-1:	1%

Nameplate | Application | Results Summary | Surge | PI | Step/Ramp-Voltage

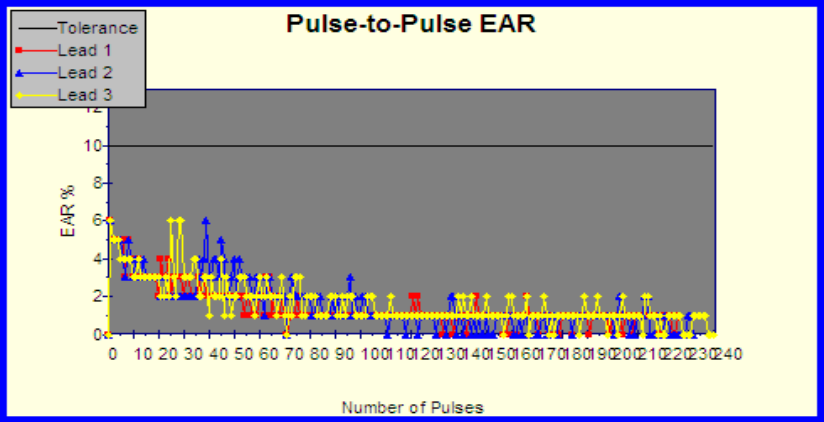
View Surge Waveforms



Close

- View Nested
- Lead 1
- Lead 2
- Lead 3
- Failed Wave

Pulse-to-Pulse EAR



Close

	Max P-P EAR
Lead 1	6.0%
Lead 2	6.0%
Lead 3	6.0%

- Marker

Case Study #1

Conclusion:

The vessel had a schedule dry dock and the motor was removed, when the motor was opened for a rewind and overhaul, there was a section of the motor where the insulation had started to breakdown. The motor was repaired within the scheduled dry dock period and the vessel is currently in service.

If this was not detected and the motor failed during its normal service period it was estimated that the additional costs to the company would have been in the vicinity of $ 240K, (This doesn't take into account the cost lost due to employees having to deal with the break down and the loss of work that they would normally be doing.)

This example not only created revenue for service work but also led to the rewind of 425KW motor. The client was still happy as the entire cost was considerably less than breakdown repair.

Case study #2 Stored Motor

Megger
Power on

FREEPORT-MCMORAN COPPER & GOLD

Spare Auto Mill Motor
Static Motor Testing

- Testing 4000Hp AC
- Wound Rotor Motor

- **Mike Draper**
- **Certified Diagnostic Electrician**

Megger
Power on

Description

Important change out coming up for key motor on site.
Decided to test stored motor prior to proposed installation
June 17th 2012 (3 years in storage)

Megger
Power on

Test Results

Results Summary		Test Date/Time 5/31/2012 3:28:48 PM	
Test ID:	4160V w/ Rotor HiPot	Repair/Job #	
Tested By	Mike Draper	Tested For	Mill Electric
Room #		MCC	
Location	Auto Mill Motors	Building	Concentrator
Temp Status		**PI Status**	
Temp	36.7°C 98.0°F	Volts (V)	5000
Resist Status		DA Ratio	4.0
L1-L2 (Ohms)	0.067 Corr: 0.064	PI Ratio	7.5
L2-L3 (Ohms)	0.067 Corr: 0.064	**HiPot**	
L3-L1 (Ohms)	0.069 Corr: 0.066	Volts (V)	9360
Max Delta R %	3.562%	Current(µA)	0.70
Coil 1 (Ohms)	0.035 Corr: 0.033	Resist (Mohm)	13371 At 40°C 8105
Coil 2 (Ohms)	0.032 Corr: 0.031	**Surge Status**	
Coil 3 (Ohms)	0.034 Corr: 0.033	Peak Volt(V) L1	9360
Megohm Status		Peak Volt(V) L2	4320 Failed
Volts (V)	5000	Peak Volt(V) L3	9360
Current(µA)	0.60	Max P-P EAR%	3.7%,13.3%,3.6%,
Resist (Mohm)	8333 At 40°C 5051	EAR 1-2,2-3,3-1	39%,63%,0%

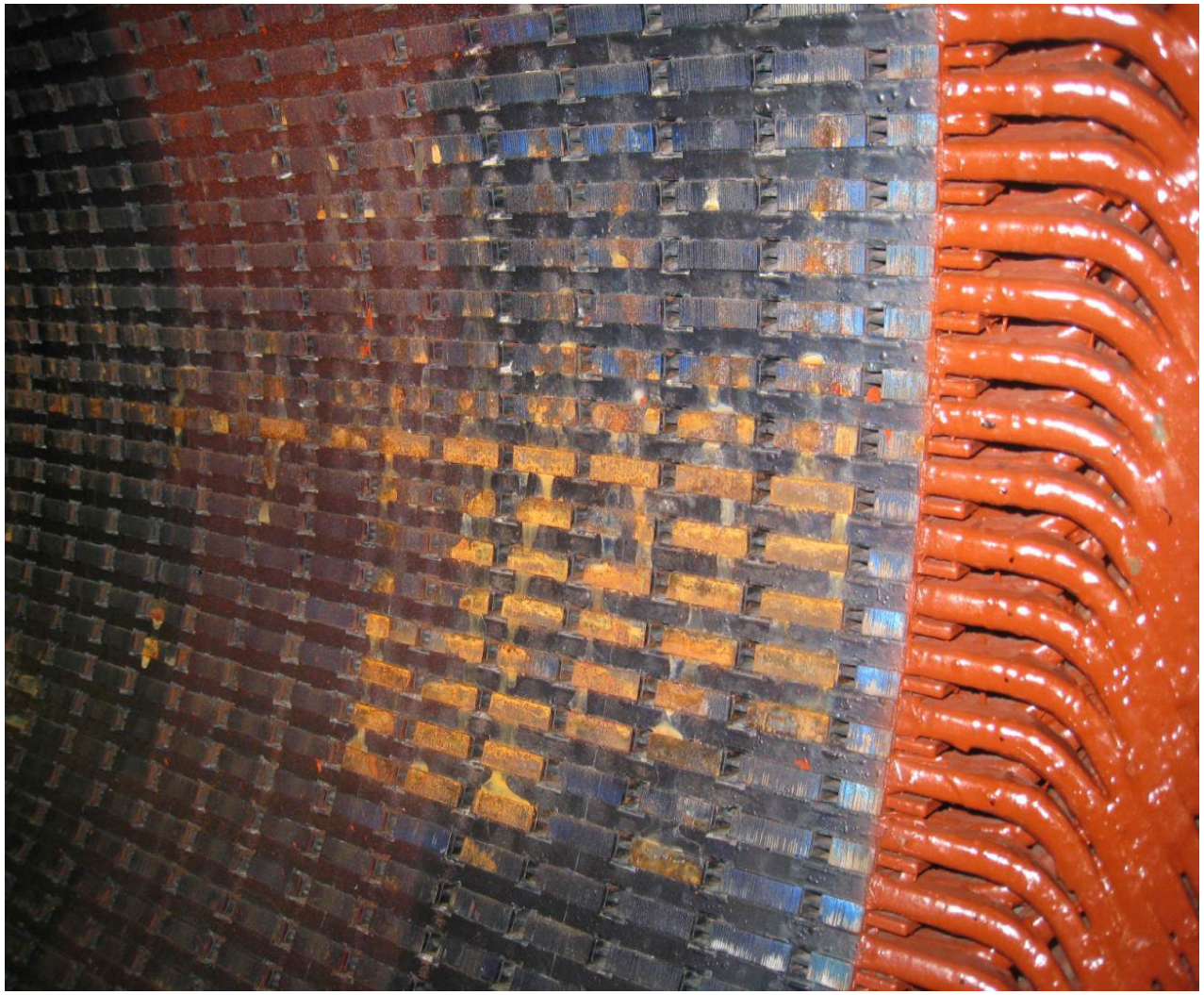
Megger
Power on

Findings After Dismantle

Recommendation

- 05/31/2012 My recommendation was to send to a motor repair facility for further analysis. The testing shows the Stator had Failed the “Surge Test”

Stator Bore – signs of corrosion



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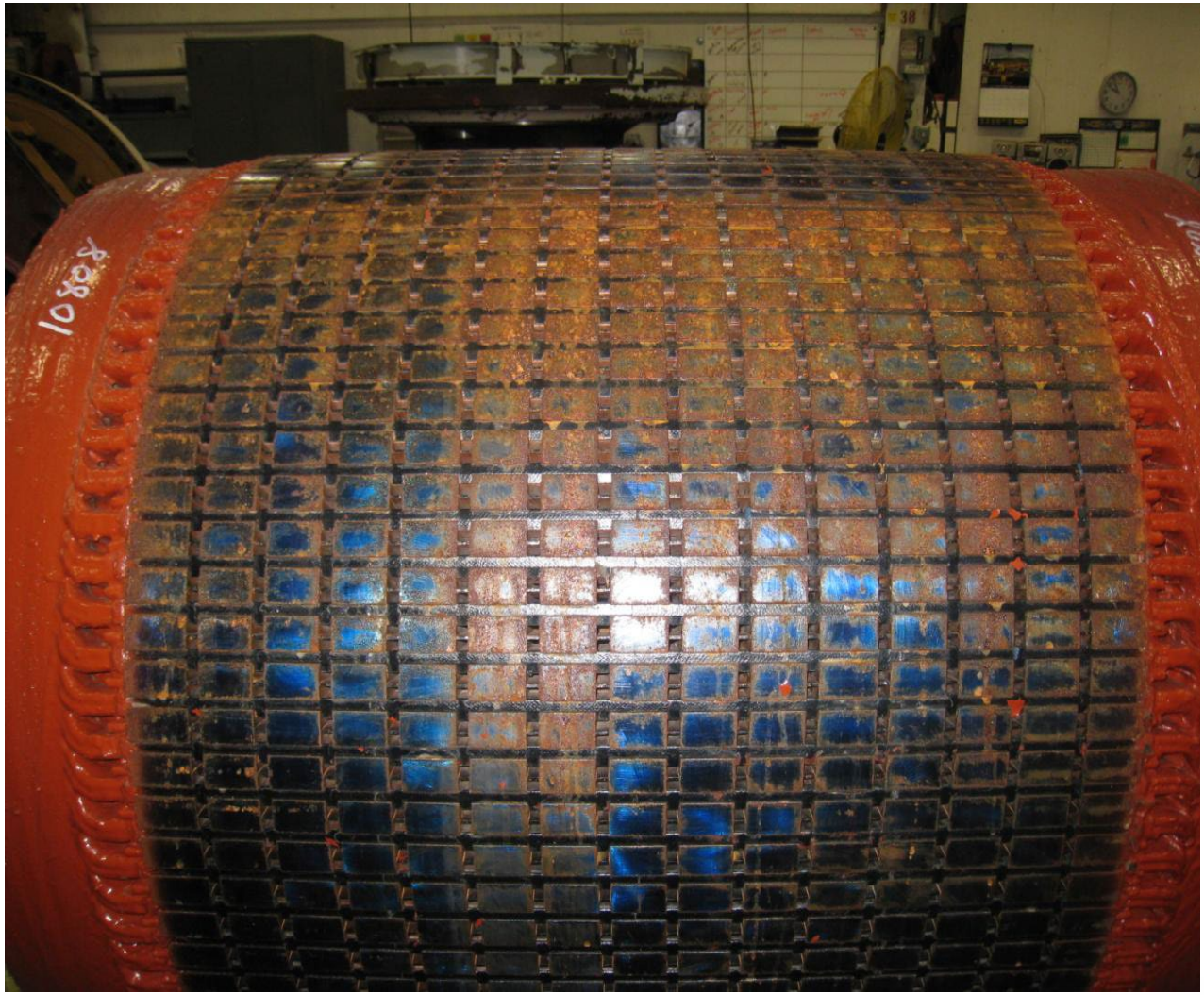
Power on

Rotor Condition



Megger
Power on

Assembled View

Megger
Power on

Conclusion

I was able to identify this motor could potentially fail at start-up.

The plan was to install this motor at the next scheduled outage .

The scheduled down time was 24hrs to remove and install this motor. Had the motor been installed in its degraded condition it could have failed catastrophically.

As this motor was the only spare, this potential failure would have resulted in many more hours of down time and production loss.

Financial Impact: $44,000 per hour unscheduled breakdown costs.

Mike Draper

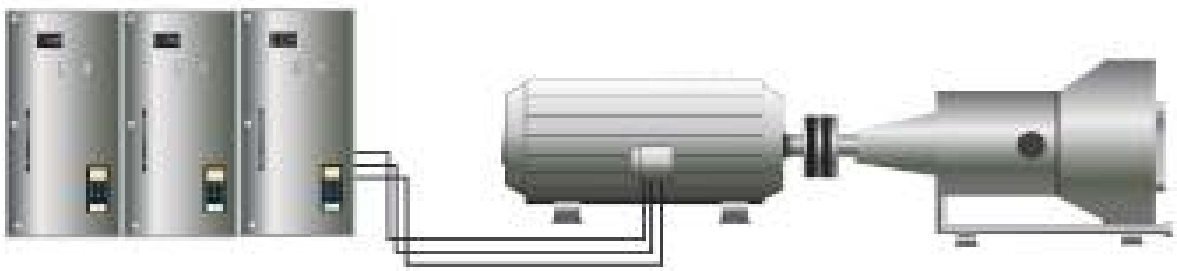
On Line: Dynamic Testing

Megger
Power on

SKF Dynamic Motor Testing

EXP4000 portable motor analyzer

NetEP stationary on-line (networked) motor monitoring system



Power

- Voltage level
- Voltage Unbalance
- Harmonic Distortion
- Total Distortion
- Harmonics
- VFD Details

Motor

- Load%
- Rotor Bar
- Current level
- Current Unbalance
- Effective Service Factor
- Operating Condition
- Power Factor
- Efficiency

Load

- Torque
- Speed
- Over current
- Load unbalance
- Load variance

- Get visibility into the *entire* motor machine system: Power, Motor, Load
- Detect and correct operating point problems before they cause failures
- Safe, easy to use
- Clear diagnostics
- Unique instantaneous load torque measurement
- Portable and networked solutions available
- Separate electrical from mechanical problems
- VFD capable
- World Wide Support

The entire motor machine system is “visible” !

Megger
Power on

Results Summary

Explorer

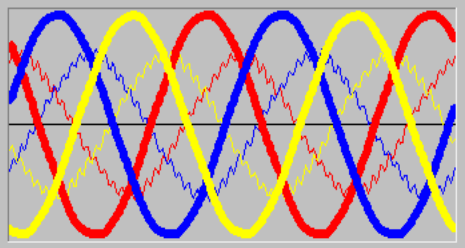
File Machine Thresholds Tools Options Help

Machine	Dumpchest Pump 1037	NP Speed	1485	Volts	380	Elec. Model	default elec
Database	PT. Surya Pamenang	kW	93.25	Amps	157.00	Vibr. Model	

PHASES	A	B	C	Ave/Sum
Volt [V]	229.8	229.5	227.7	396.7
Curr [A]	77.6	79.2	78.7	78.5
Pow [kW]				31.1
pf				0.58
NEMA Volt Unbalance [%]				0.12
NEMA Derating Factor				1.00

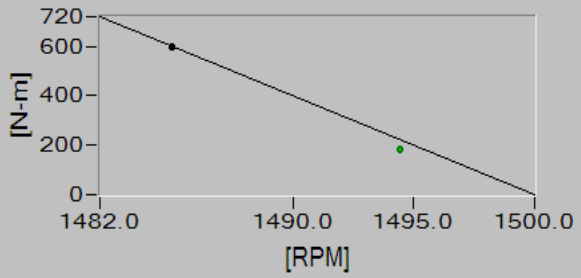
Avg Freq [Hz] 50.0

Waveforms



Speed	[RPM]	1494.4
Torque	[N-m]	182.0
Load	[kW]	28.5
% Load		30.5
% Efficiency		91.7

Torque - Speed



Power Quality

Machine Perf.

Current

Spectrum

Torque

Connection

VFD Details

Autophase: Yes / No

Sensors: Portable / EP

CT Selection: 3000 A / 1000 A / 150 A / 10 A

Run Electrical

Run Vibration

Exit

| < < 07/03/2008 04:54:49 PM elec > > |

Using Torque Ripple to Diagnose Mechanical Problems

Pump Case Study:

Megger
Power on

Power Plant Pump Issue

Problem: Reduced flow of cooling water

- **3 x** 1250HP Identical Vertical Pumps Feeding a Manifold
- All theories were unable to be prove conclusively which or any of the pumps were faulty by mechanical & electrical dept's….. Blockages, Motor Faults all considered
- Plan was to pull all 3 pumps for service and investigation.
- After on-line testing:
  - One Pump pulling only 28,000Nm from motor.
  - Pumps designed to pull 32,000Nm from motor.

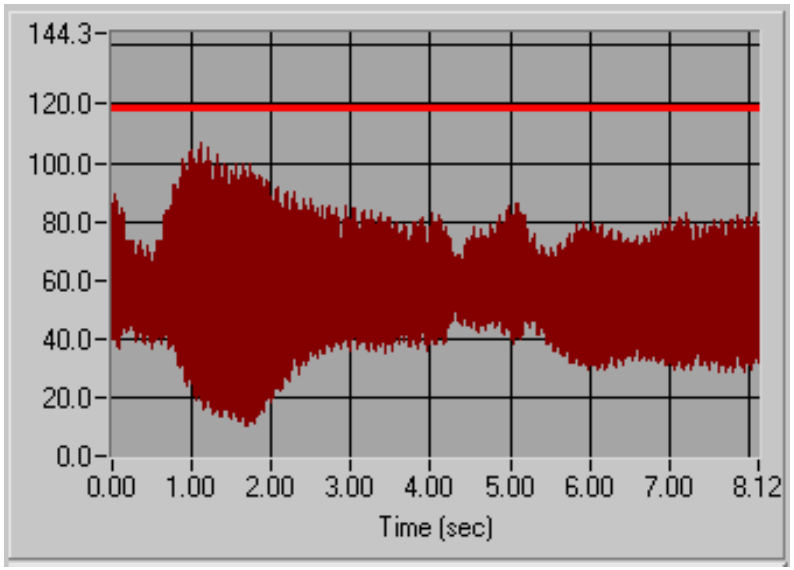
Test Findings

- Problem found in the pump – not the motor:
  - First pump would only run at 28,000Nm
  - Pump showed fluctuating torque against time graph
- The utility wanted higher cooling capacity for summer months - pump pulled for repair Pump 1 Repair cost $180,000
  - Saving $ On Pumps 2 & 3 Repair & removal costs.

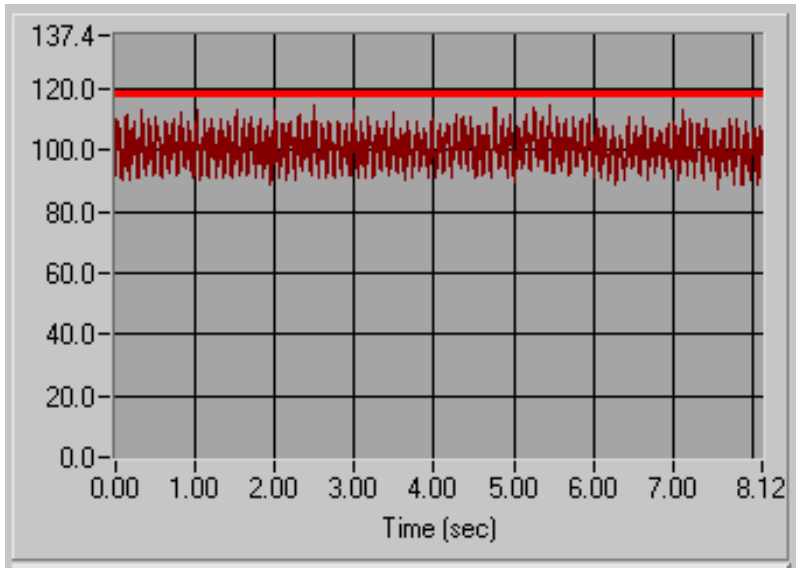
Megger
Power on

Torque Signature

Pump # 1



Typical - Pump # 2 & 3



Summary

- It is Possible to “Predict” a Motor’s Condition with a great deal of accuracy provided you have the “right tools”.
- Motor Testing and Trending properly performed provides valuable information allowing YOU to determine when a motor needs attention.
- Adding these tests to your present PdM program extends your capabilities and diagnostic successes!
- Save Down time …. $$$$$ Reduce Repair Costs …. $$$$$

THANK YOU!

Questions?

Megger.
Power on