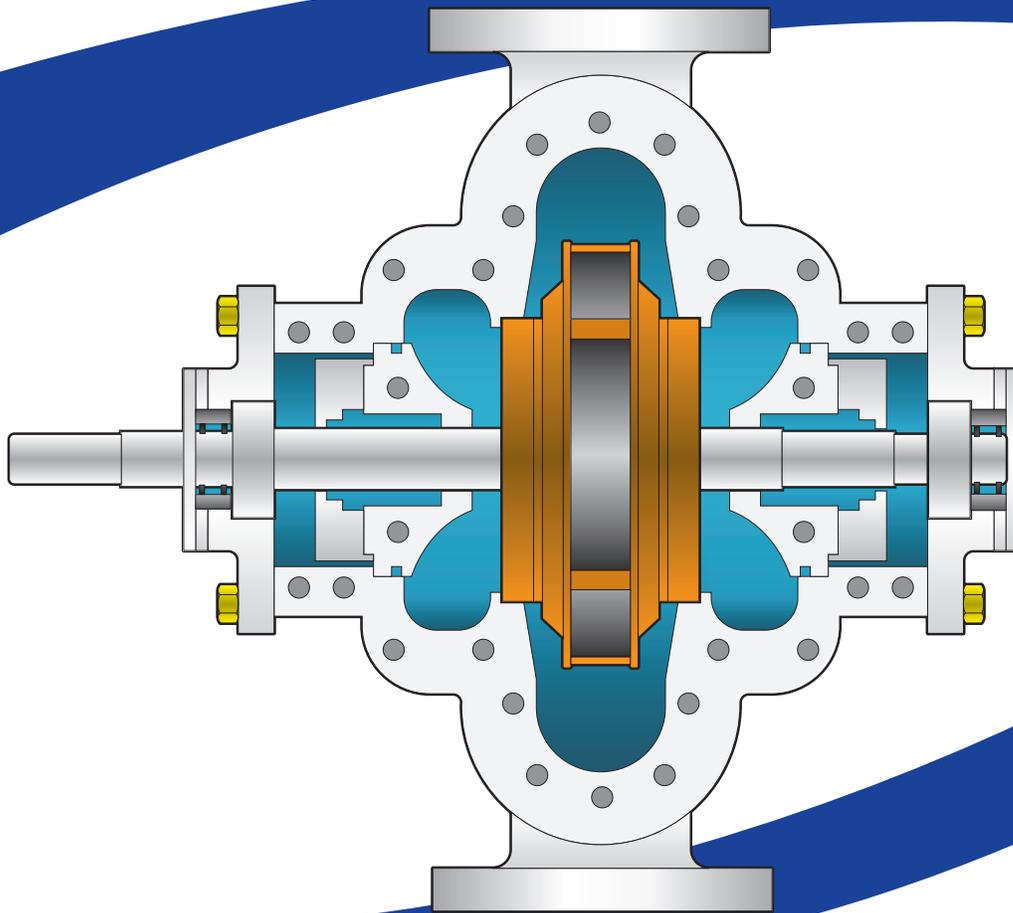


# QUICK GUIDE

## Continuous On-Line Monitoring (COLM): Horizontal Pumps

Horizontal – Single Stage – Double Suction



## COLM Quick Guide Overview

COLM Quick Guides recommend the instrumentation required to Replace, Partially Replace, or Extend Intervals for existing time-based Preventive Maintenance (PM) Tasks identified for a particular asset in EPRI's Preventive Maintenance Basis Database (PMBD). COLM Quick Guides also identify the instrumentation required to provide early detection of equipment degradation to minimize equipment forced outages and reduce corrective maintenance cost.

The COLM Quick Guide development process involves identifying sensors capable of detecting each failure mode (Failure Location/Degradation Mechanism/Degradation Influence) associated with an asset in the PMBD. Sensor Detectability (High, Medium, and Low) is assigned to that sensor for a particular failure mode based on input from Subject Matter Experts (SMEs).

PM Tasks are assessed for a "Replace Task with Online Monitoring," "Replace Task with Online Monitoring and Existing PM Tasks," "Evaluate Task for Interval Extension," or "No Change" recommendation by evaluating the Sensor quantity, Sensor Detectability, PM Task Impact on Failure Mode and Failure Mode Severity Classification for each Failure Mode impacted by the PM Task. A Decision Matrix was developed to classify the minimum quantity of measurement technologies required to address each Failure Mode impacted by the PM Task.

Sensors identified in the Ideal Instrumentation Layout represent an ideal world where sensor cost is negligible and sensors are readily commercially available. Each number representing each sensor is located in its relative position on the graphic representing the ideal location. Sensors located in the System Parameters box are sensors that are not normally installed directly on the equipment, but represent system parameters that may already be collected and can be used as additional insights identified for online monitoring. Sensors are color coded as follows:

- High Value Sensor – Sensors that are required for PM task extension or replacement
- APR Support Sensor – Sensors that are normally utilized for APR model development, but do not directly detect equipment or component parameters
- Secondary Sensor – Supporting sensors with low or medium detectability that can be used directly or collectively to detect a degradation mechanism or influence. These guides are intended for knowledgeable personnel responsible for component programs and/or reliability and should be utilized for sensor selection, installation specifications, and data analysis.

The Normalized Sensor Value chart represents those sensors with the most impact on the PM Task Assessment tables. Sensors with a value of '1' provide the most detection of degradation mechanisms and influences and have the most significant impact on PM tasks and frequencies. Sensors are then sorted by normalized value from left to right aiding utilities in prioritizing the purchase of sensors.

### Usage guidelines:

- Ensure station, code, and regulatory requirements are adhered to.
- Identified sensors were commercially available at the time this report was created.
- EPRI and industry documents should be reviewed and component design, operation, and classification should be considered when applying.
- Sensor selection and installation may not be applicable to all component designs.
- Some sensor installation may require modifications during component refurbishment or manufacturing to achieve proper sensor measurements in the most effective locations.

Advanced Pattern Recognition Technology (APR) can enhance the value obtained from the addition of new sensors for COLM. Recommendations for sensor data points to be included in mechanical, electrical and advanced COLM APR models are included.

## COLM Effectiveness Summary: Horizontal Pump

Horizontal - Single Stage - Double Suction

### Quick Guide Boundary

The boundary of a Single Stage Double Suction Horizontal Pump for the purpose of this Quick Guide is defined per EPRI PMBD as:

#### Included

- Suction and Discharge flanges
- Gear drive oil pump and auxiliary oil pump
- Lube oil cooling heat exchanger
- Internal bearing cooler
- Pump and its foundation
- Detectors, sensors, and alarms

#### Excluded

- Motor/pump coupling
- External Lubrication System (if present)
- Seal Water Injection System (if present)

Asset PMBD Contents

Total Failure Locations	27
Total Degradation Mechanisms	45
Total Degradation Influences	142
Severity Classification 1	42
Severity Classification 2	67
Severity Classification 3	33



Sensor Detectability Assessment

Highest Level of Detectability for Degradation Influences by Severity Classification

		High		Medium		Low		None Identified	
Severity Classification 1	42	34	81%	0	0%	0	0%	8	19%
Severity Classification 2	67	48	72%	5	7%	0	0%	14	21%
Severity Classification 3	33	21	64%	2	6%	0	0%	10	30%

PM Task Assessment Summary

		Total PM Tasks	10
<b>Results of COLM Assessment</b>	Replace		5
	Extend/Partial Elimination		4
	No Change		1

### Ideal Instrumentation Layout

The Ideal Instrumentation Layout provides a list of applicable instrumentation identified for the asset and a graphical representation of sensor locations. Any associated system parameters monitored by sensors not installed directly on the asset are also included.

### PM Task Assessment Table

The PM Task Assessment Table identifies monitoring technology, analysis methods, and sensors recommended for the asset to Replace the time-based PM Task or provide equipment health status information suitable for making a decision to Extend PM Task Intervals.

## Ideal Instrumentation Layout

Sensor Number	Sensor Name	Sensor Technology
1	Suction Pressure	Pressure
2	Suction Temperature	Temperature
3	Suction Flow	Flow
4	Discharge Pressure (Static/Dynamic)	Pressure
5	Discharge Temperature	Temperature
6	Discharge Flow	Flow
7	Triaxial Vibration (Inboard)	Vibration-Absolute
8	Triaxial Vibration (Outboard)	Vibration-Absolute
9	Proximity Probes (Inboard X/Y)	Vibration-Relative
10	Proximity Probes (Outboard X/Y)	Vibration-Relative
11	Bearing Temperature (Inboard)	Temperature
12	Bearing Temperature (Outboard)	Temperature
13	Thrust Probe	Position
14	Thrust Bearing Temperatures	Temperature
15	ESA	Elec. Signature Analysis
16	Lube Oil Supply Pressure	Pressure
17	Lube Oil Supply Temperature	Temperature
18	Oil Viscosity	Oil Analysis
19	Oil Wear Particle Count	Oil Analysis
20	Seal Water Pressure	Pressure
21	Seal Water Temperature	Temperature
22	Acoustic Monitor	Acoustics
23	Speed (Key Phasor)	Speed
24	Unit Mwe	Power
25	Ambient Temperature	Temperature
26	Oil Level	Level

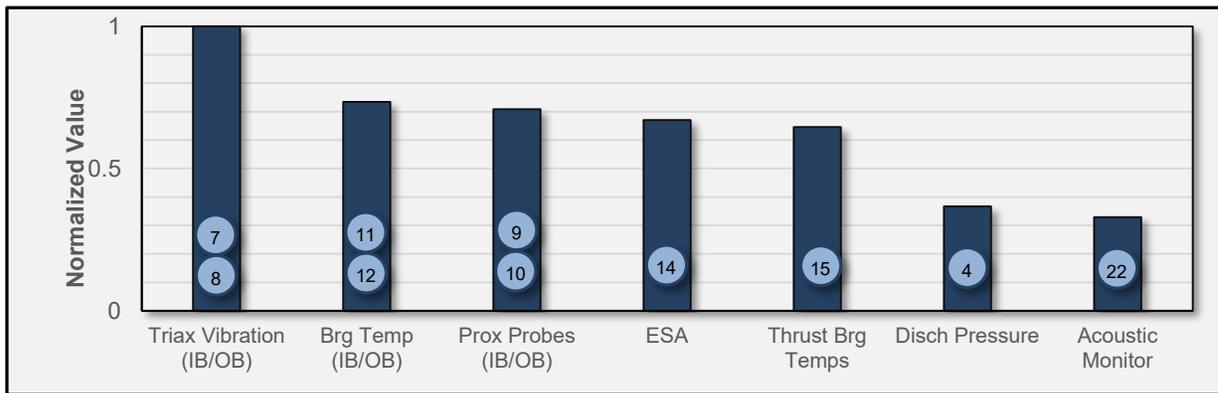
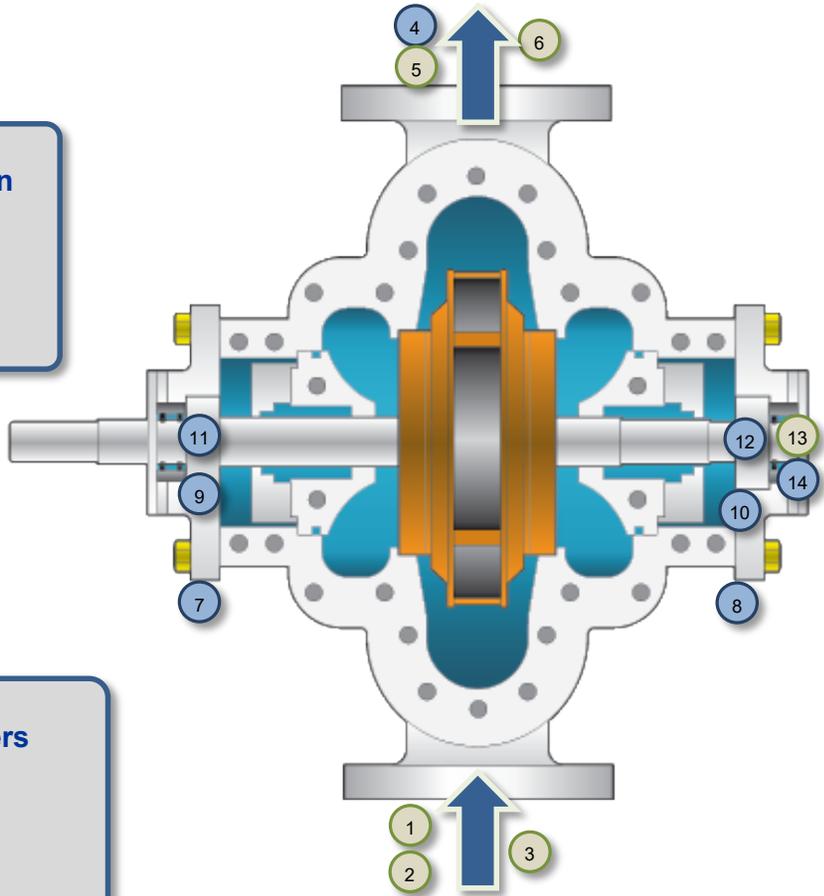
### Sensor Designation

- # High Value Sensor
- # APR Support Sensor
- # Secondary Sensor

### System Parameters

15 16 17 18  
19 20 21 22  
23 24 25 26

Sensors not installed directly on the pump but have been identified for online monitoring



### NOTES

**Normalized Value** is determined from the quantity of *Degradation Influences* in PMBD detected and the *Detectability* (High/Medium/Low) for each of those *Degradation Influences*.

**ESA** requires measurement of each motor phase voltages and currents. Not applicable for turbine-driven pumps.

**Proximity Probes** are only applicable for pumps equipped with sleeve bearings.

**Thrust Probes** are only applicable for pumps equipped with Kingsbury type thrust bearings

Current Recommended PM Task per PMBD	Monitoring Methods	Analysis Methods	Required Sensors	Monitoring Result	Notes
<b>Functional Testing</b>	<p><b>Suct./Disch. Pressure</b>  <b>Suct./Disch. Flow</b>  <b>Suct./Disch. Temperature</b>  <b>Bearing Temperatures</b></p> <p><b>Vibration Analysis</b></p> <p><b>Electrical Signature Analysis (ESA)</b></p> <p><b>Acoustic Monitor</b></p> <p><u>Alternate PM Tasks:</u>                      Operator Rounds                      System Engineer Walkdowns</p>	<p><b>Pressure/Flow/Temperature</b>                      Trend Analysis</p> <p><b>Vibration</b>                      Time Waveform Analysis                      Spectrum Analysis                      Frequency Band Filtering                      Phase Analysis                      Enveloping                      Trend Analysis</p> <p><b>ESA</b>                      Time Waveform Analysis                      Spectrum Analysis                      Trend Analysis                      Wavelet Analysis                      Park's Transformation</p> <p><b>Acoustics</b>                      Trend Analysis                      Octave Band Analysis</p>	<p>1,2,3,4,5,6                      11,12,14                      16,17</p> <p>(7,8 or 9,10),23</p> <p>15</p> <p>22</p>	<p>Replace Task with Online Monitoring</p>	<p>Online monitoring methods allow for this time based task to become condition based.</p> <p>ESA requires individual motor phase voltage and current measurements for motor driven pumps.</p> <p>Only one flow measurement (3 or 6) is required.</p>
<b>Oil Filter Change, Clean and Inspect</b>	<b>Bearing Temperatures</b> <b>Lube Oil Supply Temperature</b>	<b>Temperature/Pressure</b> Trend Analysis	11,12,14,17	Replace Task with Online Monitoring	This time based PM Task may be replaced with online monitoring.

Current Recommended PM Task per PMBD	Monitoring Methods	Analysis Methods	Required Sensors	Monitoring Result	Notes
<p><b>Performance Trending</b></p>	<p><b>Suction/Discharge Pressure</b>  <b>Suction/Discharge Flow</b>  <b>Temperature</b>  <b>Bearing Temperatures</b></p> <p><b>Vibration Analysis</b></p> <p><b>Electrical Signature Analysis (ESA)</b></p> <p><u>Alternate PM Tasks:</u>                      Operator Rounds                      System Engineer Walkdowns</p>	<p><b>Pressure/Flow/Temperature</b>                      Trend Analysis</p> <p><b>Vibration</b>                      Time Waveform Analysis                      Spectrum Analysis                      Frequency Band Filtering                      Phase Analysis                      Enveloping                      Trend Analysis</p> <p><b>ESA</b>                      Time Waveform Analysis                      Spectrum Analysis                      Trend Analysis                      Wavelet Analysis                      Park's Transformation</p>	<p>1,2,3,4,5,6                      11,12,14</p> <p>(7,8 or 9,10),23</p> <p>15</p>	<p>Replace Task with Online Monitoring</p>	<p>This time based PM Task may be replaced with a combination of online monitoring and other PM Tasks. May also be evaluated for interval extension where all recommended online monitoring tools are not implemented.</p> <p>ESA requires individual motor phase voltage and current measurements for motor driven pumps.</p> <p>Only one flow measurement (3 or 6) is required.</p>
<p><b>Acoustic Monitoring</b></p>	<p><b>Bearing Temperatures</b>                      Vibration Analysis</p> <p><b>Acoustic Monitor</b></p>	<p><b>Temperatures</b>                      Trend Analysis</p> <p><b>Vibration</b>                      Time Waveform Analysis                      Spectrum Analysis                      Frequency Band Filtering                      Phase Analysis                      Enveloping                      Trend Analysis</p> <p><b>Acoustics</b>                      Trend Analysis                      Octave Band Analysis</p>	<p>11,12,14</p> <p>(7,8 or 9,10),23</p> <p>22</p>	<p>Replace Task with Online Monitoring</p>	<p>This PM Task can be replaced with online monitoring.</p>

Current Recommended PM Task per PMBD	Monitoring Methods	Analysis Methods	Required Sensors	Monitoring Result	Notes
Vibration Analysis	Bearing Temperatures  Electrical Signature Analysis (ESA)  Vibration Analysis	<b>Temperatures</b> Trend Analysis  <b>ESA</b> Time Waveform Analysis Spectrum Analysis Trend Analysis Wavelet Analysis Park's Transformation <b>Vibration</b> Time Waveform Analysis Spectrum Analysis Frequency Band Filtering Phase Analysis Enveloping Trend Analysis	11,12,14  15  (7,8 or 9,10),23	Replace Task with Online Monitoring	This task can be replaced with online monitoring.  ESA requires individual motor phase voltage and current measurements for motor driven pumps.
Operator Rounds	Various Process Parameters	Monitor	Varies	Evaluate Task for Partial Elimination	Multiple degradation mechanisms associated with this PM Task could not be mitigated with available online monitoring technology. The scope of the PM Task may be reduced based on available online monitoring tools deployed.
System Engineer Walkdown	Various Process Parameter	Monitor/Trend	Varies	Evaluate Task for Partial Elimination	Multiple degradation mechanisms associated with this PM Task could not be mitigated with available online monitoring technology. The scope of the PM Task may be reduced based on available online monitoring tools deployed.
Packing or Seal Replacement	Seal Water Pressure Seal Water Temperature  Vibration Analysis  <u>Alternate PM Tasks:</u> Operator Rounds System Engineer Walkdowns	<b>Temperature/Pressure</b> Trend Analysis  <b>Vibration</b> Time Waveform Analysis Spectrum Analysis Frequency Band Filtering Phase Analysis Enveloping Trend Analysis	20,21  (7,8 or 9,10),23	Evaluate Task for Interval Extension	If this task is currently time based, it can be evaluated for interval extension based on available online monitoring tools.

Current Recommended PM Task per PMBD	Monitoring Methods	Analysis Methods	Required Sensors	Monitoring Result	Notes
<p><b>Refurbishment</b></p>	<p><b>Suct/Disch Pressure/Flow Temp</b>  <b>Bearing Temperatures</b>  <b>Thrust Position</b>  <b>Lube Oil Supply</b>  <b>Pressure/Temp</b>  <b>Oil Viscosity</b>  <b>Oil Wear Particle Count</b>  <b>Seal Water Pressure/Temp</b></p> <p><b>Vibration Analysis</b></p> <p><b>Electrical Signature Analysis (ESA)</b></p> <p><b>Acoustic Monitoring</b></p> <p><b>Alternate PM Tasks:</b>                      Operator Rounds                      System Engineer Walkdowns</p>	<p><b>Pressure/Flow/Temperature /Viscosity/Wear Particle</b>                      Trend Analysis</p> <p><b>Vibration</b>                      Time Waveform Analysis                      Spectrum Analysis                      Frequency Band Filtering                      Phase Analysis                      Enveloping                      Trend Analysis</p> <p><b>ESA</b>                      Time Waveform Analysis                      Spectrum Analysis                      Trend Analysis                      Wavelet Analysis                      Park's Transformation</p> <p><b>Acoustics</b>                      Trend Analysis                      Octave Band Analysis</p>	<p>1,2,3,4,5,6                      10,11,12,13,14                      16,17,18,19                      20,21</p> <p>(7,8 or 9,10),23</p> <p>15</p> <p>22</p>	<p>Evaluate Task for Interval Extension</p>	<p>While it is not possible or practical to use online monitoring to completely replace a full refurbishment, the task interval may be extended based on the online monitoring tools deployed and the equipment history.</p> <p>Only one flow measurement (3 or 6) is required.</p>
<p><b>Oil Analysis</b></p>				<p>No Change</p>	<p>Online monitoring tools are not available to match the Task Impact of the Oil Analysis PM. However, it may be suitable to extend the PM Task Interval where online monitoring tools are deployed.</p>

## Typical or Traditional APR Model Configurations

APR models for horizontal pumps and motors are usually built with signals grouped for Mechanical, Electrical and where advanced instrumentation exists, Vibration, current and voltage related faults. The differences between the available commercial APR tool functionality can influence whether a few models with many related parameters or many models with few related parameters provide the most effective anomaly detection. Each APR model should contain a process data point that gives an indication of how the equipment is loaded, like motor amps or pump discharge flow.

Pump and Motor – Mechanical APR Models	Pump and Motor – Electrical APR Models	Pump and Motor – Vibration APR Models
Motor Amps	Motor Amps	Motor Amps
Pump Speed	Pump Speed	Pump Speed
Pump Suction/Discharge Flow	Pump Suction/Discharge Flow	Pump Suction/Discharge Flow
Pump Discharge Pressure	Pump Discharge Pressure	Pump Discharge Pressure
Motor Inboard Bearing Temp	Motor Winding Temperatures – (use as many as are available)	Motor Inboard Bearing Vibration
Motor Outboard Bearing Temp	Motor Phase Current – (Use all 3 phases if available)	Motor Outboard Bearing Vibration
Pump Inboard Bearing Temp	Motor Voltage - (Use A-B, B-C and C-A if available)	Pump Inboard Bearing Vibration
Pump Outboard Bearing Temp	Ambient Temperature	Pump Outboard Bearing Vibration
Pump Thrust Bearing Temp	Humidity	
Lube Oil Temperature		
Ambient Temperature	<i>NOTE. Other parameters, such as system gross load, total feedwater flow, and steam flow trend components changes when system demand does not.</i>	<i>NOTE: Vibration tags can be Overall vibration levels, Proximity Probes in the X and Y directions, Casing Vibration levels or other vibration data available.</i>

## Advanced APR Models using New Sensor Diagnostic Features

By adding new diagnostic sensors and signal conditioning that can extract key features from vibration and motor current/voltage frequency spectrums, more insightful models can be built to detect specific failure mechanisms.

Example: Monitored Vibration Feature	Example: Equipment Anomaly Indication
Magnitude and Phase of once per revolution Vibration	Can indicate unbalance related problems or misalignment issues, or accelerated wear of mechanical or bearing surfaces.
2X times running speed vibration	Motor, Coupling and other related problems such as misalignment or motor stator eccentricity.
Sub synchronous (below running speed) Band vibration	Used to find Oil related problems in Sleeve Bearings, detects excessive bearing clearances or looseness of rotor restraining components.
Gap Voltage – Proximity Probes Only	Indicates changes in the gap between shaft & proximity probe, shows rotor rise on oil film, indicates bearing surface geometry changes from wear or wiping. Allows for development of Shaft Centerline plots for detecting changes in bearing geometry.
Orbit Plots (Lissajous Patterns of Time Domain Signals)	Greatly aids in the identification of the true root cause of a vibration event. Orbits can identify misalignments, unbalance conditions, changes in critical speed responses, rubs, bearing instabilities, thermal rotor bows and others. Orbit Plots coupled with the Shaft Center Line Plots are the two most powerful features used for event root cause determination.
<b><i>Other features can be extracted and trended depending on equipment and bearing type.</i></b>	

Example: MS SA Feature Trends	Example: Equipment Anomaly Detection
Startup Peak Amps	Max Amperage drawn by Motor during startup
Startup Time	Time taken for Motor to reach Full Speed
RPM	Speed of the Motor when in operation
Rotor Bar Side Band	Utilized to assess condition of rotor assembly including bars and end rings.
Load	Kilowatt or Horsepower of Motor when operating
Current Unbalance	Largest Current unbalance between the 3 phases
Percent Full Load Amps	Indicates Full Load amps
DCS Amps	Indicators used to corroborate MCSA Values
Driven Equipment Output Indication	Can be pump flow, speed or other indicators of loading
Driven Equipment Inlet/Outlet Control Valve Indication	Very useful for Startup, lack of driven equip Isolation will increase startup time and high-amperage levels

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### Electric Power Research Institute

3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA  
800.313.3774 • 650.855.2121 • [askepri@epri.com](mailto:askepri@epri.com) • [www.epri.com](http://www.epri.com)