Recommended Practice

Progressing Cavity Pump Inspection and Reporting

Version 1.0

PCP Run-Life Improvement JIP

Prepared by
B. T. Wagg, MSc, PEng

Reviewed by
F. J. S. Alhanati, PhD, PEng

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August 2007
Project R004
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FORWORD

The objective of this Recommended Practice on PCP Inspection and Reporting is to achieve consistency in the information gathered during pump inspections conducted by pump Vendors for the operating companies. This will be achieved by recommending practices for conducting inspections and reporting the information. Standardized inspection and reporting procedures will make it easier for Operators to compare pump inspection information gathered by different pump Vendors. In addition, the recommended inspection practices and reports will ensure that the data required for describing pump condition in the PCP Run-Life Improvement JIP will be gathered.

An effort was made to ensure that this Recommended Practice conforms to the following documents:

1) The International Standard ISO 14224: Petroleum and Natural Gas Industries – Collection and Exchange of Reliability and Maintenance Data for Equipment (1996 and 1999);

2) The International Standard ISO 15136.1: Downhole Equipment for Petroleum and Natural Gas Industries – Progressing Cavity Pump Systems for Artificial Lift (2001 and 2003). Note that this International Standard is currently under revision; and

3) The PCP Failure Nomenclature Standard created by C-FER for the PCP Run-Life Improvement Joint Industry Project (v2.1, Feb. 2006).
ACKNOWLEDGEMENTS

C-FER would like to acknowledge the contribution of the PCP Run-Life Improvement JIP Participants in the development of this Recommended Practice:

- Chevron
- ConocoPhillips
- Husky
- Nexen
- Petrobras
- Repsol-YPF
- Shell
- Total

C-FER would also like to acknowledge the contribution of the following pump Vendors in providing information and sharing their pump inspection experience:

- Kudu Industries
- Lifteq
- National Oilwell
- R&M Energy Systems
- Weatherford Artificial Lift
1. SCOPE

This Recommended Practice addresses inspections of progressing cavity pumps. It does not address inspections of other components of a progressing cavity pumping system such as: surface drives, prime movers, tubing strings, or drive strings.

Inspections of progressing cavity pumps are conducted for the following reasons:

- Pre-installation to verify performance;
- Post-pull to determine if the pump can be reused; and
- Post-pull failure analysis to assist in determining root cause of failure.

Inspections may be conducted at the wells site, at the field distribution center, or at the manufacturing facility, depending on the complexity of the inspection and reason for conducting the inspection.

To ensure that consistent information is collected from the various inspections in the different locations by numerous personnel, pump Vendors have developed procedures and forms for guiding the inspector through the inspection and recording the information. While there are some similarities in the inspection procedures and forms among the Vendors, the differences and omissions make it difficult for the Operator to use the information gathered by different Vendors in a consistent manner.

This Recommended Practice covers:

- Designations for different pump Inspection Classes;
- Inspection components included in each Inspection Class; and
- Reporting requirements, including nomenclature, for each inspection component.

Procedures for pump bench testing, while forming an integral part of the inspection process, are not discussed in detail in this Recommended Practice. It is C-FER’s understanding that these will be included in the revised ISO Standard 15136.1 – Petroleum and Natural Gas Industries – Progressing Cavity Pump Systems for Artificial Lift – Part 1: Pumps, which is currently under development.

This Recommended Practice does not provide criteria for designating pumps as “reusable” since these criteria depend on the application and, in some cases, on the Operator’s preference. Instead, it is recommended that whenever a pump is considered to be “not reusable” the inspection report should indicate what criteria was used to reject the pump.
2. DEFINITIONS

For the purpose of this Standard, the following definitions of ISO 14224, with slight modifications, will apply:

**Failure:** The termination of the ability of an item to perform a required function.

**Failure Descriptor:** The apparent, observed effect of failure (of a Failed Item).

**Failure Cause:** The circumstances during design, manufacture, or use which have led to a failure.

**Item:** Any part, component, device, subsystem, functional unit, equipment or system that can be individually considered.

**Required Function:** A function or a combination of functions of an item, which is considered necessary to provide a given service.

The following additional definitions will also apply:

**Failed Item:** Any item that has failed.

**Reason for Pull:** The motive for the pump being pulled from the well.

**PCP:** The assembly of the rotor and stator of a progressing cavity pump, including items such as the tag bar which are considered part of the pump.

**Primary Failed Item:** The Failed Item within the PCP responsible for initiating the failure of the PCP.

More detailed comments on the above definitions are included in the PCP Failure Nomenclature Standard.
3. **INSPECTION CLASSES**

Pump inspections should be classified according to the reason for the inspection so that both the Operator and Vendor are clear as to the purpose of the inspection and the specific deliverables that will result from each Inspection Class.

Three Inspection Classes are recommended:

- Class 1 – Post-Pull Verification;
- Class 2 – Used Pump Evaluation; and
- Class 3 – Failure Investigation.

The following subsections describe the circumstances where each of these inspections are used and the information that should be provided by the Vendor from each Inspection Class. Figure 1 shows how a stator and rotor combination can proceed through the inspection process.

![Figure 1 Flow Diagram of the Pump Inspection Process](image-url)
3.1 Class 1 Inspection – Post-Pull Verification

3.1.1 Purpose and Initiation

The purpose of the Class 1 Inspection is to determine if there is any significant damage to a pump that was pulled from a well. If no damage is apparent in this inspection, the pump may be rerun.

This inspection is typically initiated by the Operator.

3.1.2 Inspection Location

This inspection is typically conducted at the wellsite or in the Vendor’s field distribution centre. The Vendor personnel responsible for the inspection should be familiar with any special requirements imposed by either the application or the preferences of the Operator.

3.1.3 Inspection Components

The Class 1 Inspection should include the following components:

- Pump Identification;
- Well Description;
- Rotor Inspection;
- Exterior Stator Inspection; and
- Auxiliary Equipment Inspection.

A more detailed description of these inspection components is provided in Section 4.

3.1.4 Reporting

The report should include all of the information gathered in each of the inspection components. This should include a clear indication of whether any damage was identified that would prevent the pump from being reused. If the Primary Failed Item can be identified at this stage of the inspection, it should be identified using descriptors consistent with the PCP Failure Nomenclature Standard.
3.2 Class 2 Inspection – Used Pump Evaluation

3.2.1 Purpose and Initiation

The purpose of the Class 2 Inspection is to determine if a used pump can adequately perform its function within the operating requirements specified by the Operator. Components of the Class 2 Inspection may also be used to assist in determining the scope of the Class 3 Inspection.

A Class 2 Inspection is typically initiated by the Operator to determine if the pump can be reused.

3.2.2 Inspection Location

This inspection is typically conducted in the Vendor’s local distribution shop. The Vendor personnel responsible for the inspection should be familiar with any special requirements imposed by either the application or the preferences of the Operator.

3.2.3 Inspection Components

The Class 2 Inspection should include the following components:

- All components of the Class 1 Inspection – Post-Pull Verification;
- Interior Stator Inspection; and
- Pump Bench Test.

Details of these components are provided in Section 4.

Note that in some cases, the Class 1 Inspection or the Interior Stator Inspection could indicate that the pump damage is severe enough that a pump bench test would provide no additional valuable information regarding the pump condition or that the stator condition would make it impossible to run a pump bench test. In these circumstances, a pump bench test may not be conducted. In addition, the minor diameter of some stators may be too small to allow an interior inspection of the stator using a boroscope. It is the Vendor’s responsibility to indicate on the inspection reports when these tests cannot be conducted.

Operators may also request that the interior inspection be excluded from the Class 2 inspection. It is the Operator’s responsibility to indicate this exclusion to the Vendor prior to the pump inspection.
3.2.4 Reporting

The report should include all of the information gathered in each of the inspection components. The report should clearly state whether the pump is considered to be “reusable” in the intended application, based on the results of the inspection.

3.3 Class 3 Inspection – Failure Investigation

3.3.1 Purpose and Initiation

The purpose of the Class 3 Inspection is to collect additional information to assist in a comprehensive failure investigation. These inspections are typically initiated by the Vendor in response to a warranty claim for equipment that the Operator feels failed prematurely. However, Operators may also initiate these investigations to learn more about the circumstances of the failures in their applications.

3.3.2 Inspection Location

This inspection is typically conducted in the Vendor’s manufacturing facility or main service center. This inspection requires specialized measurement equipment and personnel with specialized technical expertise that are not typically available in the local distribution shops.

3.3.3 Inspection Components

A Class 3 Inspection should include the following components:

- All components of a Class 2 Inspection – Used Pump Evaluation;
- Detailed Rotor Inspection;
- Detailed Stator Inspection; and
- Failure Cause Analysis.

Details of these components are described in Section 4.

3.3.4 Reporting

The failure investigation report should include all of the information gathered in each component of the inspection. Unlike the check box format used for the other investigation reports, the failure investigation report should be a written summary of the information (including pictures to illustrate the key damage features identified). In addition to reviewing the information gathered in the pump inspections, the report should provide a comprehensive review of the factors that
Inspection Classes

could have contributed to the failure. This includes an examination of the pump history and manufacturing quality control records.

The report should include a summary of the investigation, in accordance with the PCP Failure Nomenclature Standard, indicating the following items:

- Primary Failed Item and Descriptors; and
- Failure Cause (and any Contributing Cause).
4. INSPECTION COMPONENTS

The following sections describe the information that should be collected in each component of the inspection process. As described in the preceding sections, these inspection components are combined to fulfill the purpose of the different Inspection Classes.

The recommendations focus on the specific information that should be included in the inspection report for each Inspection Class but does not specify the format of the report. This allows the Vendors some freedom in creating their own unique report format to meet their customer’s needs.

4.1 Pump Identification

Information in this section should identify the pump and where it was installed. This information would be used to track the service life of the pump. The following information should be included in this section:

- Well Operator (Company, Division) and contact person;
- Field Name and Well Name (i.e. Unique Well Identifier);
- Pump Vendor and Model Name;
- Date Received by Vendor;
- Date Inspected by Vendor;
- Name of person who performed the inspection;
- Reason for Pull;
- Equipment Accessibility (stator left downhole – stator not inspected, rotor seized in stator – rotor not inspected); and
- Work order number related to further inspection of the pump.

4.2 Well Description

This section describes the general operating conditions in the well prior to the pump being pulled. This information would allow the Operator or Vendor to assess the operating conditions in the well to ensure that the pump model was appropriate for the application. This section should include the following information:

- Date Installed and Pulled;
- Date Production Period Started and Ended;
Inspection Components

- Pump Speed and Average Total Fluid Rate;
- Pump Intake Temperature;
- Wellhead Tubing and Casing Head Pressure;
- Producing Fluid Level and Pump Seating Depth;
- Oil Density (API gravity), Aromatics Content, Water Cut and Gas-Oil Ratio of produced fluids;
- CO₂ and H₂S content of gas; and
- Sand Cut.

**4.3 Rotor Inspection**

This inspection component collects information to describe the condition of the rotor based on a visual inspection. The result of this component of the inspection should be a decision whether the rotor is reusable as-is or is not reusable. The following information should be recorded:

- Rotor Serial Number;
- Rotor Coating Type (e.g. chrome, boron, etc.);
- Pull Descriptors for Rotor Components (using descriptors in Table 1 which is based on the PCP Failure Nomenclature Standard) including severity and location of the observations;
- Rotor Pull Condition (i.e. reusable or not reusable); and
- Criteria used to reject the rotor if it is designated as “not reusable”.

Note that a “not reusable” rotor may be repaired (e.g. recoated, threads redressed) to return it to full serviceability but it is given a new serial number and is treated as a “new” rotor in the next installation.

Pictures of damaged rotors that correspond to the descriptors are presented in Appendix A.

**4.4 Exterior Stator Inspection**

This component of the inspection collects information to describe the condition of the stator. In some cases, only the rotor may be pulled to surface, leaving the stator downhole where it cannot be inspected. In these cases, the inspection report should indicate that the stator was left downhole, rather than simply leaving the stator inspection section blank.

The result of this component of the inspection should be a decision whether the stator appears to be reusable as-is or is not reusable. The following information should be recorded:
Inspection Components

- Stator Serial Number;
- Elastomer Type;
- Foreign material found in stator (i.e. sand, paraffin, etc.), if any;
- Pull Descriptors for Stator Components (using descriptors in Table 2 which is based on the PCP Failure Nomenclature Standard) including severity and location of the observations;
- Amount of elastomer swell measured using plug gauges or other device to measure minor diameter near each end of the stator;
- Stator Pull Condition (e.g. reusable or not reusable); and
- Criteria used to reject the stator if it is designated as “not reusable”.

When using the condition descriptors in Table 2, the inspector should indicate that observations of the condition of the mid-section of the stator were not available (N/A) in the exterior inspection rather than leaving those boxes blank.

If the stator appears to be reusable, the Operator may elect to perform a Class 2 inspection to verify that the pump is reusable.

4.5 Interior Stator Inspection

This component of the inspection collects information to describe the condition of the stator elastomer along the entire length of the stator. This inspection should be performed using a boroscope or similar tool to visually inspect the interior surface of the stator elastomer. The boroscope tool should be run once from each end of the stator along its full length to allow inspection of the complete helical elastomer surface. The entire inspection should be recorded so that it may be reviewed later should the pump be reused but not meet performance expectations.

The descriptors listed in Table 2 should be used to report the condition of the stator. These descriptors should be added to the information already collected in the Exterior Stator Inspection. The result of this component of the inspection should be a decision whether the stator is in adequate condition for a pump bench test or is not reusable (discarded). The inspection report should also indicate the criteria used to reject the stator if it is designated as “not reusable”.

The interior inspection may also include measurement of the stator elastomer dimensions along the full length of the stator using a specially designed electronic internal caliper tool. These tools are not currently in common use, but they should be considered an optional component of a pump inspection.


4.6 Auxiliary Equipment Inspection

PCP installations can include various auxiliary equipment such as tag bars, no turn tools and gas separators. The result of this section of the inspection should be a decision whether the auxiliary is reusable as-is, or is not reusable. The following information should be recorded in this phase of the inspection.

- Auxiliary equipment type, manufacturer and model;
- Pull Descriptor (using descriptors in the PCP Failure Nomenclature Standard);
- Pull Condition (i.e. reusable or not reusable); and
- Criteria used to reject equipment if it is designated as “not reusable”.

Note that “reusable” auxiliary equipment may require some minor repair (e.g. thread redressing, fitting replacement, painting) to return the equipment to full serviceability.

4.7 Pump Bench Test

A pump bench test may be used to assess the performance of a stator-rotor combination that is deemed to be reusable. Consistent testing procedures should be used to allow comparison of the results of the bench test to any pre-installation bench test data that may be available. This includes ensuring that all aspects of the test setup, measuring techniques, test fluids, test temperatures, test speeds, discharge pressures and test durations are the same. The results of the re-test should be plotted on the same graph as the pre-installation test (if available) to allow direct comparison of the two tests.

The result of this component of the inspection should be a decision whether the stator is reusable as-is or is not reusable. The inspection report should also indicate the criteria used to reject the pump if it is designated as “not reusable”.

Specification of the details for pump bench testing are beyond the scope of this document. It is C-FER’s understanding that this will be addressed in the revised version of ISO 15136.1 – Petroleum and Natural Gas Industries – Progressing Cavity Pump Systems for Artificial Lift – Part 1: Pumps. Until such time as this revised standard is available, the pump bench test report should be accompanied by a brief description of the bench test setup and testing procedures.

This bench test procedure description should include the following:

- Measurement method, accuracy, precision, calibration method and measurement location for each of the following measurements:
  - Discharge Pressure;
  - Speed;
Inspection Components

- Friction Torque;
- Test Fluid Temperature;
- Flow Rate;
- Basis for specifying the matrix of speeds and differential pressures to be tested;
- Criteria used to determine duration of operation at a given test speed and differential pressure; and
- Method for calculating pump efficiency.

The bench test report should include the following:

- Pump Model, Rotor and Stator Serial Numbers;
- Test Date, Bench Operator;
- Reason for Test (e.g. rotor sizing, used pump assessment, other);
- Lubricant used to insert rotor into stator;
- Test Liquid Type; and
- Pump warm up description including Time, Speed, Differential Pressure, Initial and Final Liquid Temperatures.

The following should be included for each test point in the bench test:

- Speed;
- Differential Pressure;
- Duration;
- Maximum Total Torque;
- Maximum Flow Rate;
- Maximum Liquid Temperature;
- Volumetric Efficiency; and
- Shaft Power.

The pump test report must identify which of the following two methods was used to calculate the efficiency:

- Nominal Efficiency: ratio of the measured flow rate to the calculated flow rate based on the nominal pump displacement.
Inspection Components

- Actual Efficiency: ratio of the measured flow rate to the calculated flow rate based on the measured pump displacement at zero differential pressure.

The pump test report should also include plots of pump efficiency (indicating nominal or actual as appropriate) and total torque versus differential pressure.

4.8 Detailed Stator Inspection

It is generally necessary to cut a stator open to perform a detailed stator inspection and therefore this inspection component is only used as part of a Failure Investigation. Typically the entire stator does not have to be subjected to the detailed inspection but sections measuring approximately 0.5 m long should be cut from the top, middle and bottom of the stator. This selection of specimens may be modified if other evidence such as a boroscope inspection indicates that significant problems exist in other sections of the stator. Each specimen is cut longitudinally (slabbed) to expose the elastomer. The following information should be collected:

- Description of the elastomer condition in each section using the descriptors provided in Table 2.
- Photographs of any features with detailed description of the location of the feature in the stator.
- Measurements of elastomer hardness (Shore A) on the cut surface, seal lines and major diameters with at least three measurements on each slabbed section. (These measurements should be compared to the nominal material parameters for the specific elastomer type.)
- Measurements of the major and minor diameters in at least three locations in each slabbed section to determine the degree of elastomer swell present.
- Measurements of the minimum elastomer thickness around the circumference of the slabbed stator housing to determine the degree of centralization of the stator cavity in the stator housing. (These measurements should be compared to the manufacturing tolerances for core centralization.)

Selected pictures of damaged stator elastomers that correspond to the descriptors are presented in Appendix B.

The detailed inspection may also include measurements of the specific gravity, hardness, bond strength, tensile strength and elongation of specimens removed from the stator elastomer. These properties should be compared to the nominal material parameters for the specific elastomer type.

4.9 Detailed Rotor Inspection

A detailed rotor inspection should collect the following information:
Inspection Components

- Photographs of any features with a detailed description of the location of the feature on the rotor.

- Measurements of the major and minor diameter of the rotor with three measurements of each parameter in each segment of the rotor—top, middle, bottom plus any segment showing damage to the rotor coating. (The average of the three major and minor diameter measurements should be reported for each segment.)

- Measurements of the hardness (Rockwell C) of the coating with three measurements of each parameter in each segment of the rotor—top, middle, bottom plus any segment showing damage to the rotor coating. (The average of the three hardness measurements should be reported for each segment.)

- Measurement of the hardness (Rockwell C) of the base metal if it is exposed by wear or a rotor break. (Three readings should be made and the average reported.)

If the rotor is broken, the detailed inspection may also include metallographic analysis which may include micrographs of the failure surface, microhardness measurements, and analysis of corrosion products and features.

4.10 Failure Cause Analysis

The intent of conducting a Failure Cause Analysis is to identify the circumstances that led to the failure. The Failure Cause should be specified using the PCP Failure Nomenclature Standard.

It may not be possible to determine the Failure Cause from the information in the Pump Inspection Reports. To determine the Failure Cause, the information collected during the pump inspection should be augmented by a comprehensive review of the pump operating history and the quality control documentation from the manufacturing process. The following sections describe what information should be collected as part of the Failure Cause Analysis.

4.10.1 Pump History

The report should summarize the installation history for both the rotor and stator including any installations prior to the installation in which the failure occurred. This should include the following: a brief description of the well geometry and completion configuration, any auxiliary equipment that was run with the pump and the operating conditions during the period the pump was in the well.

4.10.2 Pump Quality Control Documentation

The manufacturing and quality control records for the rotor and stator should be reviewed to identify any irregularities. This should include identifying any circumstances where the manufacturing procedures used for the pump in question vary from the allowable tolerances...
Inspection Components

described in the standard manufacturing procedures used by the Vendor. Further, one should determine if the initial material properties and dimensions of the product recorded prior to sale of the product were within the acceptable tolerances used by the Vendor.
## Table 1 Rotor Condition Descriptors

<table>
<thead>
<tr>
<th>Rotor Component</th>
<th>OK</th>
<th>N/A</th>
<th>Descriptor</th>
<th>Top</th>
<th>Middle</th>
<th>Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minor   Moderate    Severe</td>
<td>Minor</td>
<td>Moderate</td>
<td>Severe</td>
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<tr>
<td>Body</td>
<td></td>
<td></td>
<td>Bent</td>
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<td></td>
<td></td>
<td></td>
<td>Broken/Fractured</td>
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<td></td>
<td></td>
<td></td>
<td>Base Metal Worn</td>
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<tr>
<td>Coating</td>
<td></td>
<td></td>
<td>Cracked/Heat Cracked</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Pitted</td>
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<td></td>
<td></td>
<td></td>
<td>Worn</td>
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<td></td>
<td></td>
<td>Discoloured</td>
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<td>Burn/Overheated</td>
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<td>Corroded</td>
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<td></td>
<td></td>
<td></td>
<td>Scratched/Grooved</td>
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<tr>
<td>Coupling</td>
<td></td>
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<td>Damaged</td>
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<tr>
<td>Weld</td>
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<td>Broken/Fractured</td>
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<td></td>
<td></td>
<td></td>
<td>Cracked/Heat Cracked</td>
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<tr>
<td>Base Metal</td>
<td></td>
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<td>Worn</td>
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### Table 2 Stator Condition Descriptors

<table>
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<tr>
<th>Stator Component</th>
<th>OK</th>
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<th>Descriptor</th>
<th>Top</th>
<th>Middle</th>
<th>Bottom</th>
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<tbody>
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<td>Housing</td>
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<td></td>
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<td></td>
<td>Broken/Fractured</td>
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<td></td>
<td></td>
<td>Corroded</td>
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<tr>
<td>Elastomer</td>
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<td>Burnt</td>
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<td>Brittle</td>
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<td>Eroded/Pressure Washed</td>
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<td></td>
<td>Scratched/Grooved</td>
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<td></td>
<td></td>
<td>Worn</td>
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5. REFERENCES


APPENDIX A  PHOTOGRAPHS OF DAMAGED ROTORS WITH CORRESPONDING DESCRIPTORS FROM THE PCP FAILURE NOMENCLATURE STANDARD
Appendix A  Photographs of Damaged Rotors

Figure A.1  Worn

Figure A.2  Cracked/Heat Cracked
Appendix A  Photographs of Damaged Rotors

Figure A.3  Pitted
APPENDIX B  PHOTOGRAPHS OF DAMAGED STATOR ELASTOMERS WITH CORRESPONDING DESCRIPTORS FROM THE PCP FAILURE NOMENCLATURE STANDARD
Appendix B  Photographs of Damaged Stator Elastomers

Figure B.1  Blistered

Figure B.2  Burn/Overheated
Appendix B  Photographs of Damaged Stator Elastomers

![Eroded/Pressure Washed](image1)

**Figure B.3** Eroded/Pressure Washed

![De-bonded](image2)

**Figure B.4** De-bonded
Appendix B  Photographs of Damaged Stator Elastomers

Figure B.5 Scratched/Grooved

Figure B.6 Torn
Appendix B  Photographs of Damaged Stator Elastomers

Figure B.7 Contaminate/Foreign Material

Figure B.8 Torn
Appendix B  Photographs of Damaged Stator Elastomers

Figure B.9  Worn