ELECTRIC POWER
RESEARCH INSTITUTE

PREVENTIVE MAINTENANCE BASIS DATABASE (PMBD)

QUICK REFERENCE GUIDE

March 2021

USE OF THIS REFERENCE GUIDE

This guide is to be used as an initial resource for someone who is new to using EPRI's Preventive Maintenance Basis Database (PMBD) or interested in learning more about its functionality. Although short, it includes enough information to get an individual started in using this web-based tool. After a PMBD user gains proficiency at navigating and using the tool, this guide can also serve as a quick reference for important definitions and terminology.

WHAT IS PMBD?

The Preventive Maintenance Basis Database (PMBD) is a web-based tool developed by EPRI for use by its members in developing and supporting custom maintenance strategies for a variety of plant components. The tool is available directly at https://pmbd.epri.com or by visiting the EPRI Member Center and searching for Product ID 3002005428.

Through a structured expert elicitation process, information needed to complete the PMBD data tables for a specific component is collected from knowledgeable individuals
(consisting of industry experts, vendors, and plant maintenance or engineering personnel). Information that is collected includes a listing of the expected failure modes associated with the component, tasks that can identify and manage the degradation mechanisms associated with those failure modes, along with other important information.

In addition to providing a technical basis for a utility's custom maintenance strategy, PMBD also provides tools to analyze potential changes to that strategy and also serves as a living repository for industry PM experience. This tool is expected to be used in conjunction with a plant's existing operating experience and unique equipment considerations.

Windows from Figure 1 Available from the PMBD Homepage:

- Recent Component Template Changes: Shows templates in PMBD that have been revised or created within 1, 6 or 12 months.
- Recently Viewed Component Templates: Shows the last 5 templates that a user has viewed.
- Component Templates with Sensors: Shows templates that have Continuous Online Monitoring (COLM) Guide information incorporated into the template.
- Component Templates with Industry Documents: Shows templates that have industry documents attached to them, such as Value Based Maintenance (VBM) Component White Papers.

WHAT IS INCLUDED IN THE WEB-BASED PMBD SOFTWARE TOOL?

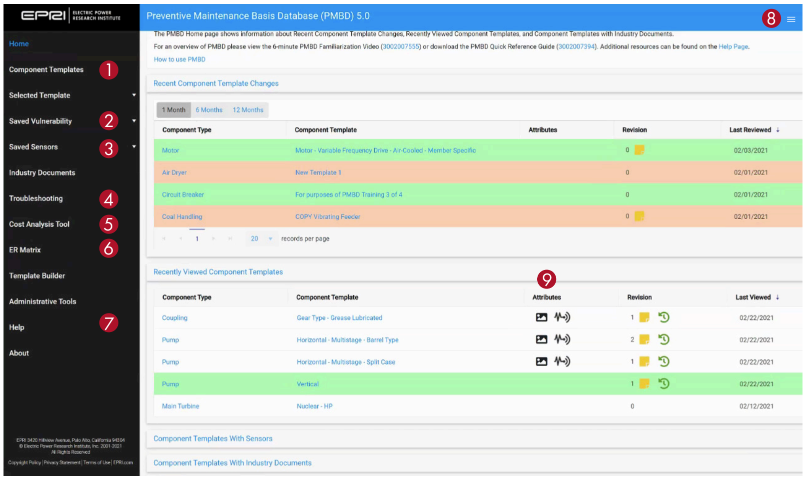


Figure 1 – PMBD Homepage

1. Component Templates: From this tab you can view and select from over 350 specific component templates (including FLEX templates).
2. Saved Vulnerability: This tab houses saved user vulnerability calculations as well as shared vulnerability calculations. Saved vulnerability calculations can be designated as either "private", "company" (available only to members within the user's company), or "public" (available to all PMBD users).
3. Saved Sensors: This tab houses saved sensor calculations as well as shared sensor calculations for a selected component. Designations are similar to the options within Saved Vulnerability.
4. Troubleshooting: From this tab you can filter and search a combined database of all Component Types, Component Names, Failure Locations, Degradation Mechanisms, Degradation Influences and Discovery Methods contained within both the Component Templates in the PMBD Database and the Troubleshooting Knowledge data.
5. Cost Analysis Tool: This provides a link to the Cost Analysis Tool (CAT) for comparing cost and reliability considerations in custom maintenance strategies.
6. ER Matrix: This provides a link to the Equipment Reliability (ER) Matrix, where additional reports providing technical guidance for components of interest can be accessed.
7. Help: This tab provides additional information to answer questions related to either page navigation or specific topic help. It also includes links to training slides and previous webcasts.
8. Minimize or Expand Navigation Menu: Click the ≡ icon to minimize or expand the black navigation menu on the left-hand side of the page.
9. Attributes: Click on the , , symbol to open the component boundary graphic, the component sensor page, or the component industry document page, respectively.

The Preventive Maintenance Basis Database (PMBD) is a web-based tool developed by EPRI for use by its members in developing and supporting custom maintenance strategies for a variety of plant components. Origins of this tool date back to the adaptation of Reliability Centered Maintenance (RCM), processes initially developed for the civil aviation industry back in the 1960s, and then documented and circulated to other industries in the 1970s. Classical RCM is a very involved, time-intensive process of determining the most effective maintenance strategy for a specific component. The philosophy integrates Preventive Maintenance (PM), Predictive Maintenance (PdM), On-line Monitoring Techniques, and Run-to-Maintenance (aka Run-to-Failure) techniques in a method aimed at increasing the probability that a machine or component will function as designed over its lifetime with an acceptable failure rate and an appropriate level of maintenance.

In the 1980s and 1990s, the commercial nuclear power industry adapted RCM methodologies as part of a larger effort to improve equipment reliability while shifting away from a largely Time-Based Maintenance (TBM) strategy. An RCM Users Group was managed by EPRI from 1984 to 1994 to assist in collaboration and information sharing during this initial time period. Along with several participating utilities, EPRI was involved in the early adaptation and application of RCM methodologies from the classical form into one that fit within the power generation industry.

As part of this initial effort, in 1997, a series of 38 small Preventive Maintenance Basis Reports were published by EPRI. Working with panels of industry experts to collect the appropriate information, each of these reports documented a maintenance strategy for common power plant components (such as valves, electric motors, pumps, and HVAC equipment) that could be used as a technical basis for establishing appropriate PM tasks and task intervals. In addition to providing a baseline for PM task intervals, these reports identified expected task content, failure modes, and varying operating environment characteristics for each of these components (this information is very similar to some of the information included in the current web-based PMBD tool).

In 2001, these 38 reports provided the initial data needed to develop EPRI's Preventive Maintenance Basis Database, which was initially mailed to members as a CD with a database that could be downloaded on a specific user's PC. Over the course of the next 12 years, this database would grow to include additional components and the interface would improve, but utility use and adoption of the PMBD was still limited due to challenges associated with installing the CD-based software and learning how to use the tool.

In 2013, EPRI released PMBD Version 3.0, which is a web-based product (available at https://pmbd.epri.com) with an improved user interface. This evolution of PMBD has greatly simplified EPRI member access to the tool and, as a result, has seen a noticeable increase the tool's use. Additional versions with improved features and functionality continue to be issued each year.

HOW PMBD TEMPLATES ARE CREATED – TEMPLATE BUILDER MODULE

PMBD Component Templates are created through a structured process that involves gathering specific information from a group of individuals who have experience with the component in question. The group will typically consist of industry experts (utility individuals with a background in engineering, maintenance, or operations), subject matter experts (SME)s, consultants, and vendor representatives.

This group is led by a facilitator, who asks for specific information from the group, keeps the overall process on track, and drives the group to a consensus (if required) when there is disagreement over specific information.

The 2011 EPRI Report, *Guideline for Expert Elicitation of Equipment Reliability Experiences* (Product ID 1023073), includes much more information on this process. A bubble-chart showing the typical make-up of an elicitation team is shown in Figure 2.

In 2018, a web-based Template Builder tool was developed to allow this structured process of reviewing, revising, and creating templates to be accomplished online using a module within PMBD. Only editors/reviewers who have been assigned access to the Template Builder are able to view a link that appears in the left hand menu on the home page (see Figure 1).

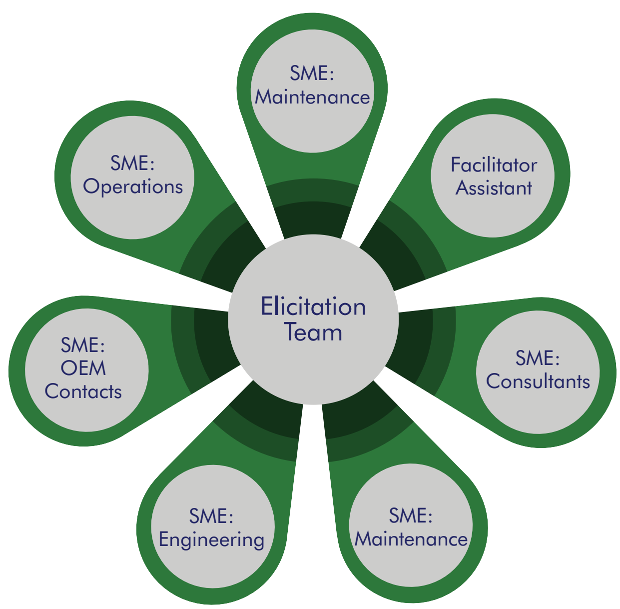


Figure 2 – Typical Members of an Expert Elicitation Team Building Templates in PMBD

Expert Elicitation Process (continued)

A screenshot of the Template Builder dashboard is shown in Figure 3. This web-based tool allows participants to edit information ranging from component boundaries, tasks/task intervals, failure modes, task effectiveness values, and “As Found Condition” checklists. Through interaction with other template editors and reviewers, any updates to templates can be reviewed and released as new revisions to templates following an approval process. User comments are able to be documented within this tool for future reference. This web-based tool has greatly increased the efficiency at which templates can be reviewed, updated, and created.

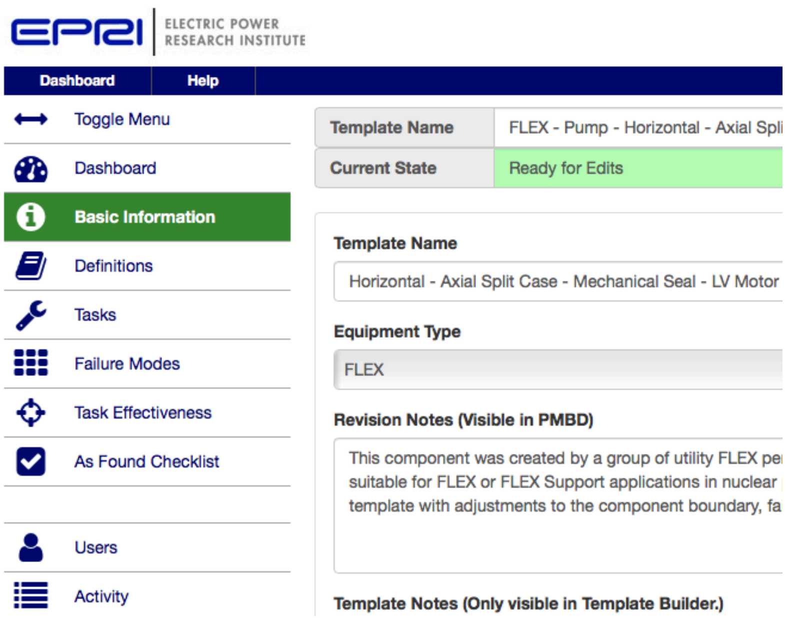


Figure 3 – Template Builder Dashboard

PMBD PAGE NAVIGATION – COMPONENT TEMPLATE TAB

1. Tasks: Specific preventive and predictive maintenance tasks are listed along with baseline task intervals for various categories (e.g., CHS) as identified by the subject matter experts involved in developing the component template. A hyper-link for each task will lead the user to task content.
2. Failure Modes: This tab lists the important information associated with the failure modes for a selected component. Information in this tab for each failure mode is used on the Vulnerability Calculation Page.
3. Vulnerability: This tab directs the user to the Vulnerability Calculation Page associated with that component. Additional information on the Vulnerability Calculation Page is provided further on in this guide.
4. Sensors: If available for the selected component, a Sensors Page will appear, allowing a user to view additional information related to how the component can be monitored using sensors or monitoring parameters.
5. Definitions: Specific definitions for the selected component are listed within this tab. This would include component boundary definition (under attributes shows a graphic representation), common failure causes, and items contributing to the risk of doing maintenance.
6. Industry Documents: Some component templates have additional documents housed within them. One example of these types of documents is the Component White Papers being developed as part of the Value-Based Maintenance (VBM) initiative. Templates with “Industry Documents” also appear in a list at the bottom of the homepage (see Figure 1).
7. Task Details: This section includes specific task information such as the task objective, content, and other information collected during the Expert Elicitation Process.

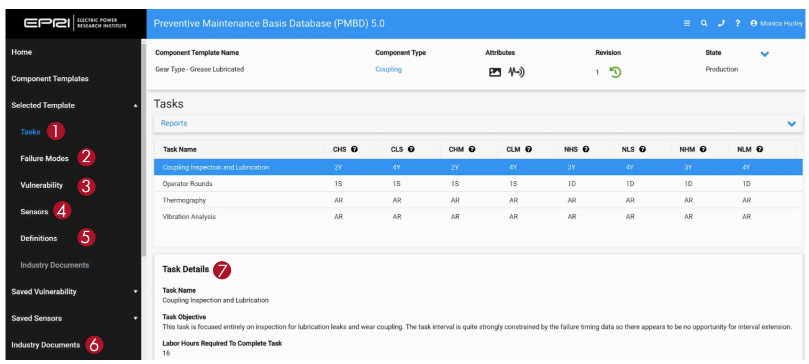
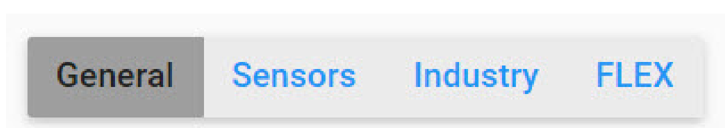


Figure 4 – Component Template Tab

Note: From the component templates page, a user can select templates from four different categories:

1. General: View a wide range of categories of components included in the PMBD.
2. Sensors: View only the component templates that have additional Sensors module data.
3. Industry: View only the component templates that include an industry document.
4. FLEX: View only the component templates that relate to beyond design basis equipment like portable generators, pumps, and compressors.



1. **Save Calculation:** This area allows the user to save custom vulnerability calculations for either future documentation or reference. After saving a calculation the user also has the option of exporting that report to
2. a .pdf or .xml file. Reports: Use this tab to export results from a vulnerability calculation to .pdf or .xml.
3. **Task Importance:** Provides some additional information to help the user understand which tasks are more and less important when it comes to their impact on failure rates in a vulnerability calculation.
4. **Failure Mode Exclusions:** This section allows a user to view all of the failure modes associated with the component being evaluated. Specific failure modes can be excluded from the analysis along with groups of failure modes (e.g., excluding all "minor" severity classification failure modes.

VULNERABILITY CALCULATION INPUTS

5. **Task Interval Comparison:** This module within the Vulnerability Calculation Tab allows the user to input specific task intervals and compare them to a baseline set of intervals in order to run vulnerability calculations and analyze results. This is the most commonly used and default module when running calculations. Additional information on this module is provided in the "How to Run a Vulnerability Calculation" section.
6. **Task Interval Optimization:** This vulnerability module allows the user to select a specific task within a component template and then analyze the impact of up to 10 different task intervals on the "Annual Failure Rate" values associated with that component. This impact is represented by a chart and table.

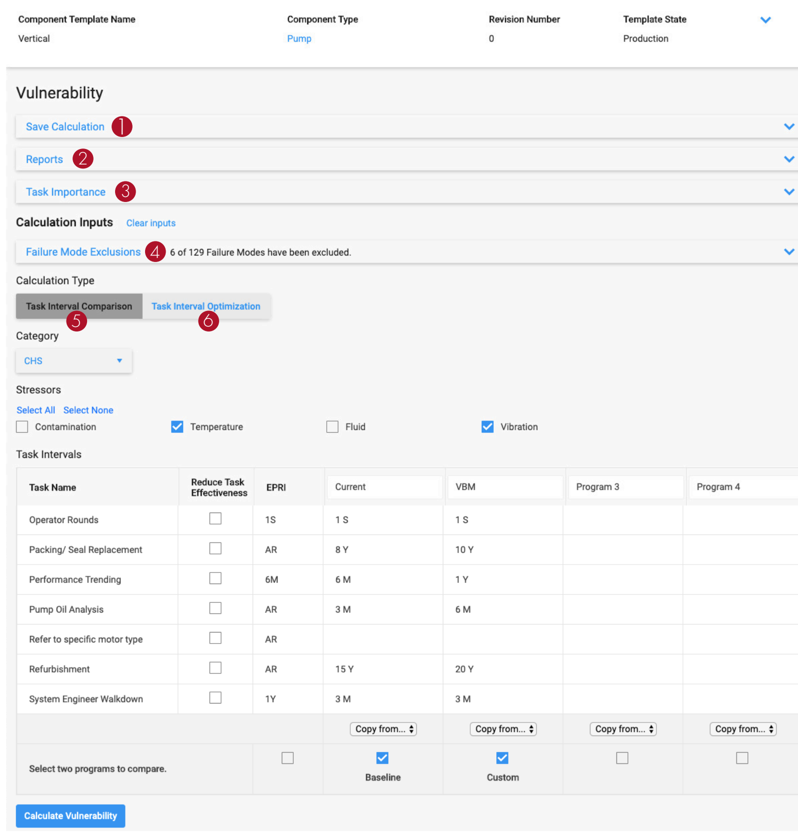


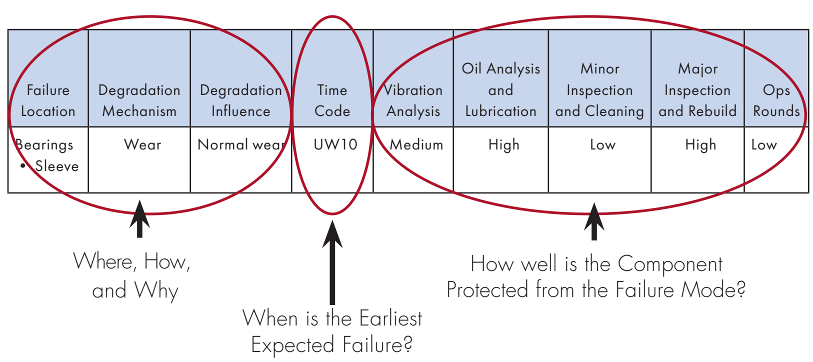
Figure 5 – Vulnerability Tab

IMPORTANT PMBD TERMINOLOGY

Failure Mode: Defined as a component or part of a component not operating within its design basis (aka how it was intended to operate). Failures can vary in severity from oil degradation or wear of a part up to more significant functional failures which could prevent the component from operating. Figure 6 gives an example of the type of information that is collected during an expert elicitation session as each failure mode is developed for the component of interest. The level of severity for each failure mode is given a more quantitative ranking based on the severity classification assigned to it (severe, significant, or minor). Figure 21 gives an explanation of severity classification.

The Failure Mode tab shown in Figure 6 is available within each component template. This tab lists all of the failure modes developed for that component and the list can be filtered and exported into an Excel file.

Within each component template there are anywhere from tens to hundreds of unique failure modes which can impact the component.



Export to Excel

Failure Location	Degradation Mechanism	Degradation Influence	Discovery Methods	Time Code	Impact	Repair Time	Severity
Baffles	Loose Hardware	Manufacturing defect	Inspection	R	Design	8	Significant
Baffles	Loose Hardware	Personnel error	Inspection	R	Maintenance	8	Significant

Figure 6 – Elements that make-up a Failure Mode within PMBD

Important PMBD Terminology (continued)

Time Codes Definition: Time codes for each failure mode represent the expected time to earliest failure for the specific failure mode if it was left to progress on its own. It is important to note that this is not the Mean Time Between Failures (MTBF), since MTBF requires significant statistical data collected on a specific component. The time codes used within PMBD are developed during the expert elicitation session based on the experiences/knowledge of the experts, along with any available industry failure rate information. When there isn't enough consensus to agree on a specific value, a range will be applied to a time code (e.g., UW5_7 or W10_15). All numbers in the time codes represent years.

Time	Code	Categories
R	Random	Failure modes with a Random (R) time code associated with them are assumed to occur at random during the operational life of the component. Within the PMBD calculations, they are assigned a constant, low probability of occurrence.
UW	Unconditional Wearout	Unconditional Wearout (UW) time codes are assigned to failure modes that occur regardless of specific stressors that may impact the component. As an example, UW5 would represent a failure mode whose expected time to earliest failure would be 5 years. If a stressor is selected during a vulnerability calculation, it will cause a UW failure mode to happen earlier.
W	Wearout	Wearout (W) time codes are assigned to failure modes that are initiated/aggravated by specific stressors, such as temperature, vibration, or contamination. As an example, for W7_10, the expected time to earliest failure if the aggravating stressor is present would be between 7 to 10 years. If the aggravating stressor is not present, W time codes are treated as R time codes in a vulnerability calculation.

Impact Definition: Impact provides enhancement to the definition of Random failure codes by identifying the primary influence of random failure modes.

Impact	Categories
Maintenance	Designates a random time code "R" that is influenced primarily from maintenance-related or intrusive activities (e.g. alignment, installation, or other improper maintenance actions). This impact will have a larger weighting in the component failure rate as major and minor intrusive maintenance tasks are performed more often.
Design	Designates a random time "R" that is influenced primarily from design related factors (e.g. manufacturing defects or improper material). This failure typically presents itself as 'early-in-component-life' failure, and a maintenance strategy would have difficulty protecting against it.
Operational	Designates a random time code "R" that is influenced primarily from plant or component operational conditions or parameters (e.g. improper operation, poor chemistry, Off-BEP operation, or inadvertent operation). There is some ability to avoid or mitigate this failure mode based on the way in which the plant or component is being operated.

Task Effectiveness Definition: The probability that a specific task will identify degradation associated with a failure mode prior to its actual occurrence.

Task Effectiveness	Value	Notes
High (H)	97%	When performed correctly, the results of this task will properly signal plant staff to a degradation mode
Medium (M)	80%	When performed correctly, the results of this task will properly signal plant staff to a degradation mode at least 4 out of 5 times
Low (L)	50%	When performed correctly, the results of this task will properly signal plant staff to a degradation mode more than 50% of the time
None	0%	When performed correctly, the results of this task will not properly signal plant staff to a degradation mode or will do so less than 50% of the time

Important PMBD Terminology (continued)

Program Effectiveness: Links tasks to individual failure modes and provides a color rating as to how well a custom maintenance program is protected against a specific failure mode. Each failure mode within a component template will have a Program Effectiveness Rating assigned to it.

Program Effectiveness Color Rating	Description/Characteristics of Color Ranking Scheme
No Protection	PMs provide no protection • Tasks with no effectiveness at identifying degradation related to the selected failure mode • Cumulative protection against failure mode in question (around 0%)
Low Protection	PMs provide low protection • Any number of L tasks • Cumulative protection against failure mode in question (around 50%)
Moderate Protection	PMs provide moderate protection • At least one M task (any number of L & M tasks) • Cumulative protection against failure mode in question (around 80%)
Good Protection	PMs provide good protection • No more than one H task (any number of L & M tasks) • Cumulative protection against failure mode in question (at least 97%)
Excellent Protection	PMs provide excellent protection • At least two H tasks (any number of L & M tasks) • Cumulative protection against failure mode in question (at least 99.5%)

Component Categories: Task intervals associated with each component template are divided into different categories depending on 1) Equipment Criticality, 2) Equipment Duty Cycle, and 3) Equipment Service Conditions. Specific definitions for each of these categories are provided in the "Definitions" Tab within that component's template. This results in 8 different categories represented within each component template (see table to the right).

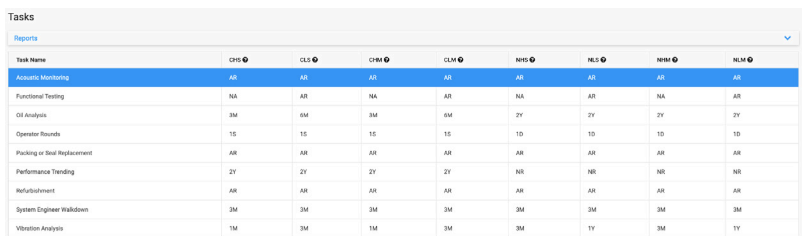
Using the example shown in Figure 7 (Example of Baseline Task Intervals from Horizontal - Single Stage - Single Suction Pump Component Template), different baseline intervals are indicated for each of the 8 categories.

Note: AR = As Required intervals, based on the condition of the equipment and usually determined from other tasks or requirements (e.g., regulatory or code-driven).
NR = Not Required
NA = Not Applicable for the given category.
S = Shift
Y = Year
M = Month

Shifting Task Effectiveness: The intrinsic effectiveness of a task at being able to identify or protect against a specific failure mode prior to its occurrence is influenced by when it is performed as compared to the expected earliest failure time. Figure 8 indicates how a Highly Effective (H) Task can turn into a Medium (hM) or Low (hL) or No (hN) Effectiveness Task if performed after the expected earliest failure time.

Categories in PM Basis – Service Conditions

Critically	Critical				Non-Critical			
Duty Cycle	HI	LO	HI	LO	HI	LO	HI	LO
Service Conditions	Severe		Mild		Severe		Mild	



Tasks

Reports

Task Name	CHS	CLS	CHM	CLM	NHS	NLS	NHM	NLM
Acoustic Monitoring	AR	AR	AR	AR	AR	AR	AR	AR
Functional Testing	NA	AR	NA	AR	NA	AR	NA	AR
Oil Analysis	3M	6M	3M	6M	2Y	2Y	2Y	2Y
Operator Rounds	1S	1S	1S	1S	1D	1D	1D	1D
Packing or Seal Replacement	AR	AR	AR	AR	AR	AR	AR	AR
Performance Trending	2Y	2Y	2Y	2Y	NR	NR	NR	NR
Refurbishment	AR	AR	AR	AR	AR	AR	AR	AR
System Engineer Walkdown	3M	3M	3M	3M	3M	3M	3M	3M
Vibration Analysis	1M	3M	1M	3M	3M	1Y	3M	1Y

Figure 7 – Example of Baseline Task Intervals from Horizontal - Single Stage - Single Suction Pump Component Template

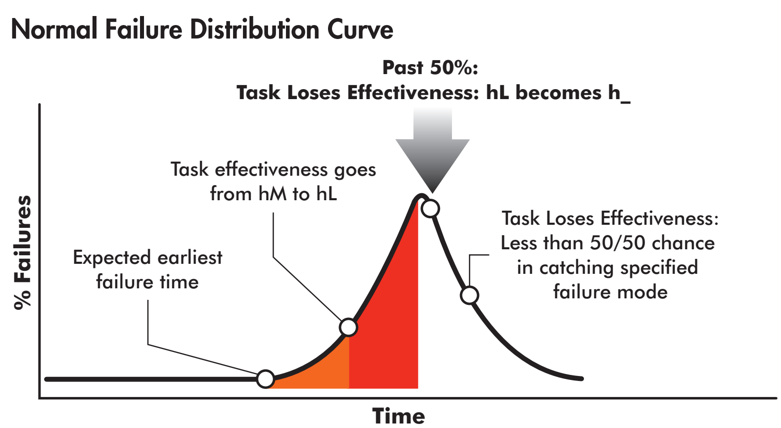


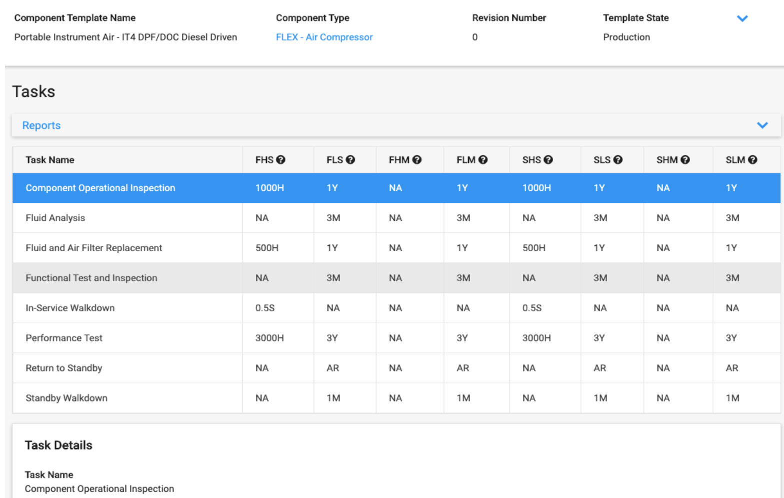
Figure 8 – Representation of How an Intrinsically High (H) Effectiveness Task Can Have Reduced Effectiveness if Performed After the Expected Earliest Failure Time

Important PMBD Terminology (continued)

FLEX-Specific Definitions: Several FLEX templates are included within PMBD and provide information to assist EPRI members in developing maintenance strategies for beyond design basis equipment such as portable emergency generators, pumps, and compressors. F and S designations are used in FLEX-specific component templates. They have the following meanings:

F = Functional Importance
S = Support

Because all FLEX component types were classified as Non-Critical (INPO AP-913, Revision 4, October 2013), the PMBD treats Functional Importance for FLEX components as simply a place-holder that differentiates FLEX Equipment that has N+1 redundancy as compared to FLEX Support Equipment. Internally in the database, the N+1 FLEX Equipment continues to use the existing Critical data fields although the software displays them as FHS, FLM, etc. The FLEX Support category is displayed as SHS, SLM, etc.



Component Template Name	Component Type	Revision Number	Template State
Portable Instrument Air - IT4 DPF/DOC Diesel Driven	FLEX - Air Compressor	0	Production

Tasks

Reports

Task Name	FHS	FLS	FHM	FLM	SHS	SLS	SHM	SLM
Component Operational Inspection	1000H	1Y	NA	1Y	1000H	1Y	NA	1Y
Fluid Analysis	NA	3M	NA	3M	NA	3M	NA	3M
Fluid and Air Filter Replacement	500H	1Y	NA	1Y	500H	1Y	NA	1Y
Functional Test and Inspection	NA	3M	NA	3M	NA	3M	NA	3M
In-Service Walkdown	0.5S	NA	NA	NA	0.5S	NA	NA	NA
Performance Test	3000H	3Y	NA	3Y	3000H	3Y	NA	3Y
Return to Standby	NA	AR	NA	AR	NA	AR	NA	AR
Standby Walkdown	NA	1M	NA	1M	NA	1M	NA	1M

Task Details

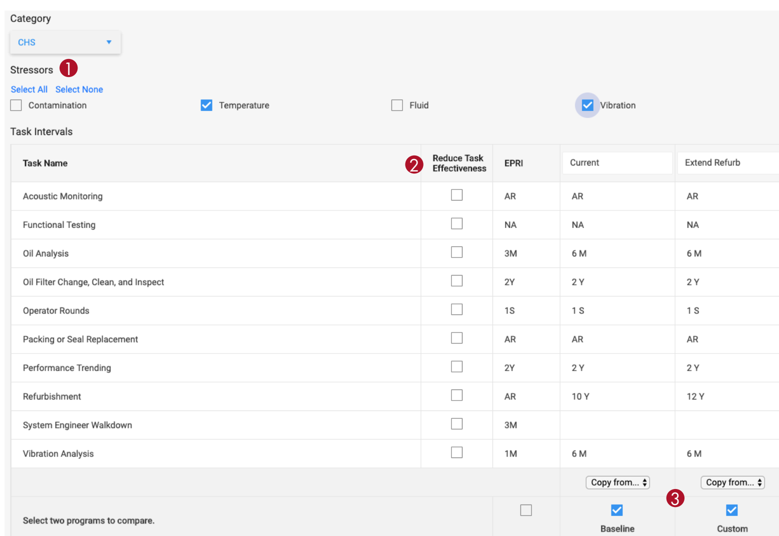
Task Name
Component Operational Inspection

Figure 9 – Example FLEX Component Template - Air Compressor

HOW TO RUN A VULNERABILITY CALCULATION

The following section gives an overview of the inputs and results associated with a PMBD Vulnerability Calculation. Prior to providing these inputs, a user also has the ability to filter/exclude specific failure modes or groups of failure modes that may not apply to their type of equipment. This can be accomplished from the "Failure Mode Exclusions" area directly above the area shown in Figure 10. Failure Mode Exclusions are shown in Figure 5.

1. Assign Stressors: If a "severe" (S) environment is selected as the category, stressors appear within the tool to trigger or aggravate existing failure modes that are impacted by specific "severe" environmental conditions like excessive temperature, humidity, or contamination.
   Specific stressors can be selected prior to calculating vulnerability to account for unique conditions a user's equipment may be exposed to. Available Stressors within the database are listed in Figure 11.
   Note: High Duty Cycle is also treated as a stressor.
2. Reduced Task Effectiveness Option: When selected this reduces the task effectiveness by 1 level at protecting against all failure modes it is intended to protect against (e.g., a task with H effectiveness will be lowered to M).
3. Select Programs to Compare: Select the two programs to use in the vulnerability calculation. This can be either a comparison against the EPRI baseline intervals or between 2 custom programs.
   Note: Vulnerability calculations do not have to use the EPRI intervals (i.e., a plants existing component maintenance strategy can be used as a baseline to examine the impact of proposed changes).



Task Name	Reduce Task Effectiveness	EPRI	Current	Extend Refurb
Acoustic Monitoring		AR	AR	AR
Functional Testing		NA	NA	NA
Oil Analysis		3M	6 M	6 M
Oil Filter Change, Clean, and Inspect		2Y	2 Y	2 Y
Operator Rounds		1S	1 S	1 S
Packing or Seal Replacement		AR	AR	AR
Performance Trending		2Y	2 Y	2 Y
Refurbishment		AR	10 Y	12 Y
System Engineer Walkdown		3M		
Vibration Analysis		1M	6 M	6 M

Figure 10 – Running a Vulnerability Calculation

Available Custom Stressors in PMBD
Duty Cycle (i.e. CHM instead of CLM)
Temperature
Humidity/Moisture
Vibration/Flow Oscillations/Fluid Quantity/Biological
Contamination/Dirt/Debris

Figure 11 – Values Used for Stressors Within the PMBD

HOW TO INTERPRET RESULTS OF A VULNERABILITY CALCULATION

After entering the required information to run a vulnerability calculation, after the "Calculate Vulnerability" button is selected, results will appear below the user inputs. The default display shows the Failure Mode Summary, Most Likely Causes of Failure, and Failure Modes Impacted by Custom Interval Modules. Selecting the Additional Results button will open up 4 additional modules. All 7 modules are discussed below.

Failure Modes Summary: Provides a numerical tally of program effectiveness (color coded) at addressing all failure modes for a component (Provides a good summary of Baseline vs. Custom comparison). Click on the "View" link next to each row to see a list of the failure modes covered by the associated program effectiveness level.

All vulnerability modules within PMBD can be exported in Excel.

Most Likely Causes of Failure: Provides a list of the top potential failures that will occur based on PM intervals and the program effectiveness at addressing those failures (use this module to determine which failure modes have the highest probability of occurrence). See Figure 13.

Failure Modes Impacted by Custom Intervals: Powerful module for identifying new risks or improved risks by comparing baseline to custom intervals. See Figure 14.

Component Degradation: Provides additional information on failure modes and their impact on custom PM programs (used for more advanced analysis). The module (along with all the others) can be exported to Excel (click on "Export to Excel"). Keep in mind that a simplified listing of failure modes can also be filtered and exported from the "Failure Modes" tab for each component (see Figure 6).

Failure Mode Summary

Export to Excel

	Program Effectiveness	Baseline	Custom	Description
View	None	6	12	Failure Modes with No Effective Tasks
View	Low	6	9	Failure Modes with only Low Effective Tasks
View	Moderate	56	53	Failure Modes with No Better than Medium Effective Tasks
View	Good	34	55	Failure Modes with One Highly Effective Task
View	Excellent	41	14	Failure Modes with At Least Two Highly Effective Tasks

Figure 12 - Interpreting Results of Vulnerability Calculation: Failure Modes Summary Module

Most Likely Causes Of Failure

Export to Excel

Severity	Failure Location	Degradation Mechanism	Degradation Influence ↑	% of Potential Failures	Program Effectiveness
Significant	Lube Oil System	Auxiliary Oil Pump Pressure Switch	Drift	48.1	None
Minor	Seal - Packing	Excessive leakage	Normal wear	6.8	Moderate
Significant	Diffusers, Volutes & Channel Rings	Leak in balancing leakoff line	Vibration	7.3	Low
Significant	Diffusers, Volutes & Channel Rings	Erosion of interstage sealing	Warping from thermal shock	5.3	Low

Figure 13 – Interpreting Results of Vulnerability Calculation: Most Likely Cause of Failure Module

Failure Modes Impacted By Custom Intervals

New Risks

Export to Excel

Baseline Program Effectiveness	Custom Program Effectiveness	Severity	Failure Location ↑	Degradation Mechanism ↑	Degradation Influence ↑	Time Code	Impact
Excellent	Moderate	Severe	Automatic Oilers	Improper oil flow	Misadjusted, improper installation	R	Maintenance
Good	Moderate	Significant	Balancing Device	Wear	Distortion due to improper pump startup	R	Operational
Good	Moderate	Severe	Balancing Device	Wear	Improper assembly, materials, or operation	R	Maintenance
Good	Moderate	Significant	Bearing Seals - Labrynth	Wear	Imbalance or misalignment of shaft	R	Maintenance
Good	Moderate	Severe	Bearing Seals - Labrynth	Wear	Improper installation or material defect	R	Maintenance
Excellent	Moderate	Significant	Bearings - Antifriction (radial and thrust)	Wear - fatigue	Degraded lubricant - contamination, e.g. water	R	

Figure 14 – Failure Modes Impacted by Custom Intervals Module

Component Degradation

Export to Ex

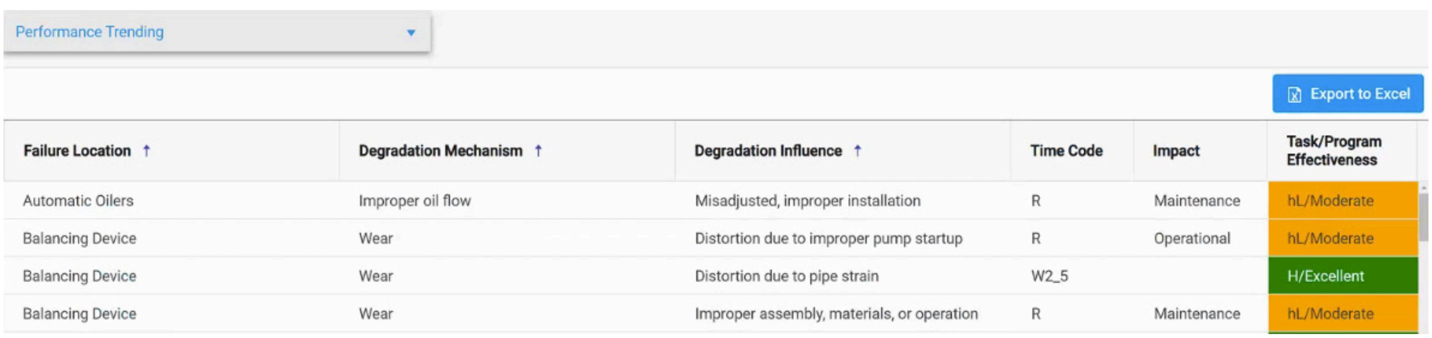
Program Effectiveness	Failure Location ↑	Degradation Mechanism ↑	Degradation Influence ↑	Repair Time (hrs)	Time Code	Impact	Discovery Methods	Improved Vulnerability	Severity	Strength	Fail Weight	Duty Stressor	Service Stressor
Moderate	Automatic Oilers	Improper oil flow	Misadjusted, improper installation	4	R	Maintenance	Oil level, oil temperature, inspection		Severe	0.02	0.00		
Moderate	Balancing Device	Wear	Distortion due to improper pump startup	24	R	Operational	Thrust bearing temperature Balance line leakoff pressure or flow Vibration Inspection		Significant	1.50	0.18	✓	
Excellent	Balancing Device	Wear	Distortion due to pipe strain	24	W2_5		Thrust bearing temperature Balance line leakoff pressure or flow Vibration Inspection		Significant	0.02	0.00		

Figure 15 – Component Degradation Module

Component Degradation Table Definitions

Field	Description
Failure Location	Subpart of the component where degradation is occurring
Degradation Mechanism	What the degradation process is
Degradation Influence	Influences which initiate, drive, accelerate, or slow the degradation
Repair Time	The wrench time for repair in hours
Time Code	The failure timing (either R, W, or UW)
Impact	Primary influence of Random failure modes
Discovery Methods	Methods of detecting the presence of the degradation mechanism (these do not impact vulnerability calculation results)
Improved Vulnerability	Indicates a check mark if the Program Effectiveness for the Failure Mode has been improved as a result of custom intervals
Functional Failure Mode	Identifies the Severity Classification for a failure mode. See Figure 21 for more information.
Severity	Another representation of the Functional Failure Mode (Severe = 1, Significant = 2, or Minor = 3)
Strength	Absolute value of the expected number failures from a degradation mechanism over 40 years when "Run-to-Failure" applies
Fail Weight	Calculated value of the number of times a degradation mechanism could be detected over 40 years when the "Custom PM Program" is applied. Divide by 40 years to get the annual failure rate. **Note:** Additional columns appear if the user scrolls to the right within the table.
Duty Stressor and Service Stressor	A check mark appears in these columns if the associated failure mode is impacted by duty cycle or another stressor

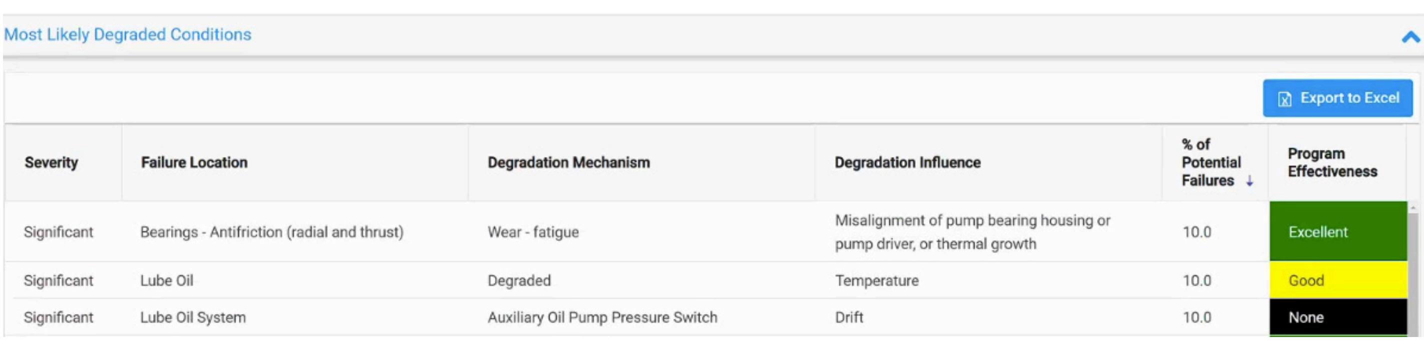
Task Effectiveness: Allows a user to evaluate all of the failure modes impacted by a specific task and the overall program effectiveness at addressing each failure mode. All vulnerability modules within PMBD can be exported in Excel.



Failure Location	Degradation Mechanism	Degradation Influence	Time Code	Impact	Task/Program Effectiveness
Automatic Oilers	Improper oil flow	Misadjusted, improper installation	R	Maintenance	hL/Moderate
Balancing Device	Wear	Distortion due to improper pump startup	R	Operational	hL/Moderate
Balancing Device	Wear	Distortion due to pipe strain	W2_5		H/Excellent
Balancing Device	Wear	Improper assembly, materials, or operation	R	Maintenance	hL/Moderate

Figure 16 – Task Effectiveness Module

Most Likely Degraded Conditions: Identifies the highest % degradation mechanisms that are likely to occur based on PM program being examined (should be examined in conjunction with "Most Likely Causes of Failure" Module to determine vulnerabilities).



Severity	Failure Location	Degradation Mechanism	Degradation Influence	% of Potential Failures	Program Effectiveness
Significant	Bearings - Antifriction (radial and thrust)	Wear - fatigue	Misalignment of pump bearing housing or pump driver, or thermal growth	10.0	Excellent
Significant	Lube Oil	Degraded	Temperature	10.0	Good
Significant	Lube Oil System	Auxiliary Oil Pump Pressure Switch	Drift	10.0	None

Figure 17 – Most Likely Degraded Conditions Module

Calculated Values: Provides a numerical representation of the impact of custom PM programs on failure rates and repair hours.

Caution: Don't get too focused on the number values – examine other modules as well when using the PMBD to justify changes to a maintenance strategy).

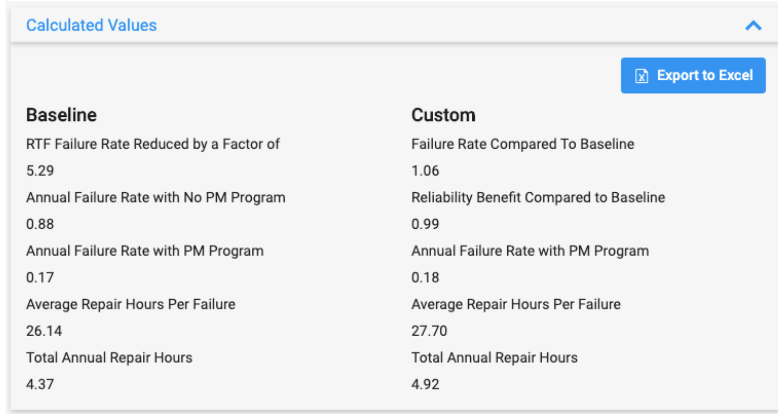


Figure 18 – Calculated Values Module

These figures show the specific formulas associated with the Calculated Values Module that appears as one of several output modules. The results from these calculations can be used to identify a relative change in one maintenance strategy vs. another, but using these values to make a "go/no-go" maintenance strategy decision without consulting other vulnerability modules is not recommended

Baseline Program Calculations

Name	Calculation
RTF Failure Rate Reduction (RTF is "Run to Failure")	= Annual Failure Rate: No Program/Annual Failure Rate with PM Program (Baseline)
Annual Failure Rate with No PM Program	= (Sum of Strength Values in Component Degradation Table)/ 40
Annual Failure Rate with PM Program	= (Sum of FailWeight Values in Component Degradation Table for Baseline)/40
Total Annual Repair Hours	= (Sum of Individual Baseline [FailWeight * Repair Hours])/ 40
Average Annual Repair Hours	= Total Annual Repair Hours/Annual Failure Rate with PM Program (Baseline)

Custom Program Calculations

Name	Calculation
Annual Failure Rate with PM Program	= (Sum of FailWeight Values in Component Degradation Table for Custom)/40
Failure Rate Compared to Baseline	= Annual Failure Rate with PM Program (Custom)/Annual Failure Rate with PM Program (Baseline)
Reliability Benefit Compared to Baseline	= 1 – ([Custom Failure Rate – Baseline Failure Rate]/[No PM Program Failure – Baseline Failure Rate])
Total Annual Repair Hours	= (Sum of Individual Custom [FailWeight * Repair Hours])/40
Average Annual Repair Hours	= Total Annual Repair Hours /Annual Failure Rate with PM Program (Custom)

Figures 19 and 20 – Baseline and Custom Program Calculations Module

Severity Classifications: Severity classifications are assigned to each failure mode for a component to provide a better measure of the direct consequences resulting from the degradation associated with the components identified failure modes listed in the PMBD. They are developed as part of the expert elicitation process and are intended to assist PMBD users in better interpreting vulnerability results. Definitions for each of the 3 classification levels are provided in Figure 21. They can be found in the following Vulnerability Modules that were explained above:

- Component Degradation
- Most Likely Degraded Conditions
- Most Likely Causes of Failure
- Failure Modes Impacted by Custom Intervals

Functional Failure Mode	Severity Classification Category	Definition
1	Severe	The degradation mechanism (failure mode) and its influence would produce an equipment functional failure in a very short time if not immediately addressed.
2	Significant	The degradation mechanism (failure mode) and its influence would produce an equipment functional failure with trendable degradation after a much longer than that of a Level 1 if not addressed (e.g. Emergent maintenance activity required to address).
3	Minor	The degradation mechanism (failure mode) and its influence results in a long term unacceptable or undesirable operating condition (e.g. Can wait until next available and open system work window to address).

Figure 21 – Severity Classification Categories and Definitions

SENSORS: CONTINUOUS ONLINE MONITORING

Several Continuous Online Monitoring (COLM) Guides have been integrated into their corresponding templates in the PMBD. These specific templates are accessible from the PMBD home page, or from the "Sensors" link inside templates which have them. They are also designated with a specific icon in the Attributes associated with PMBD templates.

The Sensors module is intended to be used by members to help them examine the contribution that sensors and monitoring parameters can have on their component maintenance strategies, specifically when it comes to failure mode coverage. After selecting existing sensors and monitoring parameters
as part of the Calculation Inputs (along with Continued Tasks and Failure Mode Exclusions), a user can run an analysis and examine tables and charts as part of their results that are broken up into the 4 following categories:

1. PM Task Assessment
2. Sensor Detectability of Failure Modes
3. Sensors that can Detect Failure Modes Not Covered
4. Tasks that can Detect Failure Modes Not Covered

Each of these results is further explained above the calculation results that appear in the module. In terms of how the results are determined, as part of the data gathered to build a Sensor Module for a given component, each sensor is assigned a "Detectability" level, ranging from High, Medium, Low, or No Detectability for each failure mode.

This detectability level relates to how well a given sensor or monitoring parameter would be at identifying degradation related to a specific failure mode.

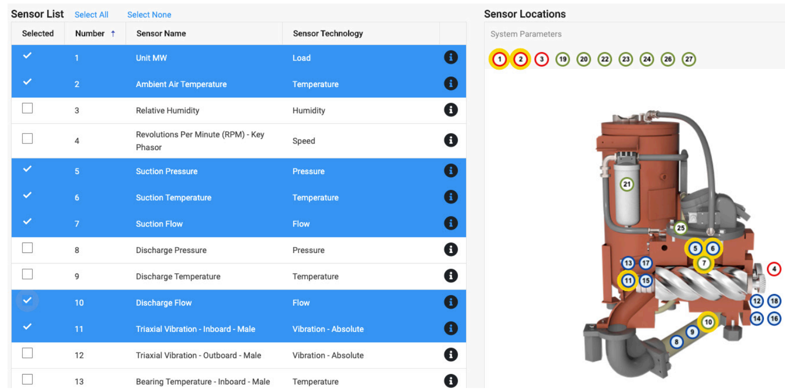


Figure 22 – Sensor List and Sensor Locations Example - Rotary Screw Compressor

The Detectability level is modeled after the Task Effectiveness values in PMBD, and relates to a confidence value that the sensor would identify degradation:

- High = 97% confidence
- Medium = 80% confidence
- Low = 50% confidence
- None = 0% confidence

Figure 22 shows how a customized list of sensors and monitoring parameters can be selected from the "Sensor List" or "Sensor Locations" for a selected template. More information on the Sensors module is available from the PMBD Help Page.

TROUBLESHOOTING

A Troubleshooting feature was added to the PMBD in version 5.0 referred to as the PMBD Troubleshooting Knowledgebase. This allows members to filter and search a combined database of all Component Types, Component Names, Failure Locations, Degradation Mechanisms, Degradation Influences and Discovery Methods contained within the Component Templates in the PMBD Database.

The Troubleshooting Knowledgebase also contains data that has been shared with EPRI by members from troubleshooting efforts, referred to as "Troubleshooting Knowledgebase data." This data has yet to be integrated into the PMBD templates and will be evaluated for entry as it is added.

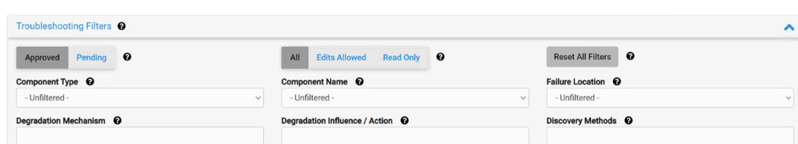


Figure 23 – Troubleshooting Filters

The majority of the Troubleshooting Knowledgebase data contains Corrective Actions in the Degradation Influence Column to help members develop investigative and corrective actions useful during the troubleshooting process at their facility.

Troubleshooting Knowledgebase tool is intended to provide members with a starting point in the troubleshooting process, specifically in their fault table, support/refute matrix, or failure modes and effect analysis development.
The database can be filtered by Component Type, Component Name and Failure Location, and further refined by searching for terms based on the indications presented during an equipment event (for example, high vibrations, leaks, high temperature, noise, etc.) in the Degradation Mechanism, Degradation Influence, and Discovery Methods fields.

Once the user has reduced the data to that applicable to the Troubleshooting Effort, the data can be exported to a Microsoft Excel format that can then be used to create the fault tables, support/refute matrix, or failure modes and effect analysis in their troubleshooting document.

The entire Troubleshooting Knowledgebase can also be exported to Excel if the member wishes to integrate the data into a company owned Troubleshooting tool.

Members also have the ability to add and edit rows in the Troubleshooting Knowledgebase data. This allows member feedback and input to happen immediately.

Members are also encouraged to contact EPRI NMAC via nmachotline@epri.com if they are willing to share troubleshooting reports from past troubleshooting events at their fleet or station. EPRI will process the data and add
it into the Troubleshooting Database. This allows the Troubleshooting Database to continue to grow and add helpful troubleshooting information to other members as well as providing material for EPRI to evaluate adding into new or existing PMBD component templates.

The Troubleshooting feature of PMBD is accessible from the PMBD home page via the "Troubleshooting" Tab on the Navigation menu.

For more information on the Troubleshooting feature and for case studies, please see Appendix J of the EPRI Guide 3002018211, S*ystem and Equipment Troubleshooting Guide*.

AS FOUND CHECKLIST

As Found Checklists are developed for each task defined within a component template. They provide a listing of all the potential failure locations that can be evaluated during a maintenance task along with the reportable condition associated with that failure. Along with other reports available within PMBD, As Found Checklists can be downloaded as a .pdf for easier use and sharing within a maintenance department.

These reports are available within each component template after a specific task is selected. A .pdf report titled, "As Found Checklist Report" appears for the user to download.

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As Found Checklist

Component Template: Pump - Horizontal - Multistage - Barrel Type

Task Name: Oil Analysis

Unsatisfactory Condition	Failure Location	Reportable Condition
☐	Automatic Oilers	Improper oil flow
☐	Bearing Oil Slinger Ring	Excessive wear
☐	Bearing Seals - Labrynth	Excessive wear
☐	Bearings - Antifriction (radial and thrust)	Excessive wear
☐	Bearings - Kingsbury type	Excessive wear
☐	Bearings - Sleeve	Excessive wear
☐	Breather Caps & Sight Glass Vents	Clogged
☐	Lube Oil	Degraded
☐	Lube Oil Cooling Heat Exchanger or Internal Bearing Cooler	External leakage
☐	Lube Oil Cooling Heat Exchanger or Internal Bearing Cooler	Fouled or plugged
☐	Lube Oil Cooling Heat Exchanger or Internal Bearing Cooler	Internal leakage
☐	Lube Oil System	Clogged Filter or Strainer
☐	Lube Oil System	Excessive wear of the Aux Oil Pump
☐	Lube Oil System	Excessive wear of the Gear Drive Oil Pump
☐	Lube Oil System	Leakage

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