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Standard Guide for Applying Failure Mode and Effect Analysis (FMEA) to In-Service Lubricant Testing[1]

This standard is issued under the fixed designation D7874; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes a methodology to select tests to be used for in-service lubricant analysis. The selection of fluid tests for monitoring failure mode progression in industrial applications applies the principles of failure mode and effect analysis (FMEA).

1.2 Although typical FMEA addresses all possible product failure modes, the focus of this guide is not intended to address failures that have a very high probability of unsafe operation as these should immediately be addressed by other means.

1.3 This guide is limited to components selected for condition-monitoring programs by providing a methodology to choose fluid tests associated with specific failure modes for the purpose of identifying their earliest developing stage and monitoring fault progression. The scope of this guide is also focused on those failure modes and their consequences that can effectively be detected and monitored by fluid analysis techniques.

1.4 This guide pertains to a process to be used to ensure an appropriate amount of condition monitoring is performed with the objective of improving equipment reliability, reducing maintenance costs, and enhancing fluid analysis monitoring of industrial machinery. This guide can also be used to select the monitoring frequencies needed to make the failure determinations and provide an assessment of the strengths and weaknesses of a current condition-monitoring program.

1.5 This guide does not eliminate the programmatic requirements for appropriate assembly, operational, and maintenance practices.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D7684 Guide for Microscopic Characterization of Particles from In-Service Lubricants

D7720 Guide for Statistically Evaluating Measurand Alarm Limits when Using Oil Analysis to Monitor Equipment and Oil for Fitness and Contamination

2.2 *IEC Standard:*

IEC 60812 Analysis Techniques for System Reliability—Procedure for Failure Mode and Effects Analysis (FMEA), 2006

3. Terminology

3.1 *Definitions:*

3.1.1 *cause(s) of failure, n*—underlying source(s) for each potential failure mode that can be identified and described by analytical testing.

3.1.2 *component incipient failure, n*—moment a component begins to deteriorate or undergo changes that will eventually lead to the loss of its design function.

3.1.2.1 *Discussion*—This moment may not be easily detectable because of sensitivity limitations of monitoring instrumentation or a lack of measurable change in performance characteristics or both.

3.1.3 *criticality number, C, n*—product of the severity (*S*) and occurrence (*O*) numbers for a given failure mode's causes and effects.

3.1.4 *design function, n*—function or task that the system or component should perform.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.1.5 *detection ability number, D, n*—ranking number that describes the ability of a specific fluid test to successfully detect a failure mode's causes or effects. A scale is used to grade detection ability numbers; see an example in 6.4.7.

3.1.6 *effect(s) of failure, n*—potential outcome(s) of each failure mode on the system or component.

3.1.7 *failure-developing period, FDP, n*—period from component's incipient failure to functional failure.

3.1.8 *failure mode, n*—physical description of the manner in which a failure occurs.

3.1.9 *failure mode and effect analysis, FMEA, n*—analytical approach to determine and address methodically all possible system or component failure modes and their associated causes and effects on system performance.

3.1.9.1 *Discussion*—This approach can be used to evaluate designs and track risk-reducing improvements to equipment reliability.

3.1.10 *failure modes, effects, and criticality analysis, FMECA, n*—extension to FMEA that involves ranking the risk associated with failure modes to allow prioritization and selection of an appropriate maintenance strategy.

3.1.10.1 *Discussion*—A metric-describing criticality is determined by the product of a severity number (*S*) and its occurrence number (*O*) for each given failure mode's causes and effects.

3.1.11 *functional failure, n*—inability of the component or system to perform its required design function.

3.1.12 *occurrence number, O, n*—ranking number that describes the probability of occurrence of a failure mode's causes and effects over a predetermined period of time based on past operating experience in similar applications; see an example in 6.3.2.

3.1.13 *P-F curve, n*—illustration of component failure progression (component condition versus time) from incipient failure to functional failure (*F*).

3.1.14 *P-F interval, n*—period from the point in time in which a change in performance characteristics or condition can first be detected (*P*) to the point in time in which functional failure (*F*) will occur as illustrated on a *P-F* curve.

3.1.15 *severity number, S, n*—ranking number that describes the seriousness of the consequences of each failure mode's causes and effects on potential injury, component or equipment damage, and system availability.

3.1.15.1 *Discussion*—A scale is used to grade severity numbers. See an example in 6.3.1.

4. Summary of Guide

4.1 This guide is designed to aid the user to optimize their condition-monitoring program.

4.2 Failure mode and effect analysis (FMEA) is applied by the user of this guide to those machines selected in their condition-monitoring program based on their significance to production and safety. The user of this guide determines the possible failure modes for each machine and applies FMEA separately for each failure mode. A severity number (*S*) is assigned for each failure mode's causes and effects.

4.3 The user of this guide then determines how frequently the failure mode's causes or effects are likely to occur based on past operating experience under similar applications for a predetermined time period. An occurrence number (*O*) is assigned for each failure mode's causes and effects.

4.4 The severity and occurrence numbers are constant for each failure mode's specific cause or effect. Calculating the product of the severity and occurrence numbers (criticality number) for all failure modes' causes and effects allows the user to establish a ranked hierarchy of the risk associated with equipment failure. A table matrix of severity versus occurrence ranks can then be used to allow the user to determine whether a given failure mode's cause or effect is tolerable and requires periodic inspection, fluid testing, or design modification (for example, Table 1). This is used to justify the need for testing of specific failure modes' causes or effects within a predictive maintenance program.

4.5 For those failure modes' causes and effects that require fluid testing, several test methods should be considered. A detection ability number (*D*) is determined by the user for each test method based on the test's ability to detect the failure mode's causes and effects. By comparing the ranking of criticality numbers with their corresponding detection ability

TABLE 1 Criticality Matrix

	Severity Number				
Occurrence Number	S-1 Insignificant	S-2 Marginal	S-3 Moderate	S-4 Critical	S-5 Catastrophic
O-1 Improbable	Tolerable	Tolerable	Periodic Inspection	Periodic Inspection	Testing
O-2 Remote	Tolerable	Periodic Inspection	Periodic Inspection	Testing	Testing
O-3 Occasional	Periodic Inspection	Periodic Inspection	Testing	Testing	Testing
O-4 Probable	Periodic Inspection	Testing	Testing	Testing	Design Modification
O-5 Frequent	Testing	Testing	Testing	Design Modification	Design Modification