Lifetime Reliability • Solutions

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Contents of the 'Failure Mode Effects Analysis the Plant Wellness Way' Distance Education Course FMEA Training Online

Use the FMEA process in your plant and equipment design, and for root cause analysis of your plant and equipment failures

Course Content
Failure - what is a failure?
Mode - what is a failure mode?
Effects - what is a failure mode effect?
Analysis - what is an FMEA?

Three assignments
Failure Cause Identification
Component Level FMEA
Functional Level FMEA

History of FMEA Development
FMEA was developed by NASA as a formal design methodology in the 1960s.
FMEA - When?
Intended for Use During Design

- The analysis is successfully performed preferably early in the development cycle so that removal or mitigation of the failure mode is most cost effective. FMEA timing is essential; if done early enough in the development cycle, then incorporating the design changes to overcome deficiencies identified by the FMECA may be cost effective.

During Operations

- The analysis can further be used during operations as the first fundamental step to Reliability Centred Maintenance, to allow improvements of the system's reliability/safety and or maintainability.
- FMEA is an effective RCFA tool to identify potential causes of a failure event.

Building Reliable Plant and Equipment

Why do an FMEA?
To perform a comprehensive identification and evaluation of all the unwanted effects within the defined boundaries of the system being analysed, and the sequences of events brought about by each identified item failure mode, from whatever cause, at various levels of the system's functional hierarchy;
The determination of the criticality or priority for addressing/mitigation of each failure mode with respect to the system's correct function or performance and the impact on the process concerned;
A classification of identified failure modes according to relevant characteristics, including their ease of detection, capability to be diagnosed, testability, compensating and operating provisions (repair, maintenance, logistics, etc.);
Identification of system functional failures and estimation of measures of the severity and probability of failure;
Development of design improvement plan for mitigation of failure modes;

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Support the development of an effective maintenance plan to mitigate or reduce likelihood of failure
Etc. (see US, UK, ISO and NASA references)

Reliability Engineering Terms
Failure: Termination of the ability of an item to perform a required function
Failure Mode (Dominant): Manner in which an item fails (theoretical focus, RCA or experienced). The effect that you see when an item fails. Failure modes can be electrical (open or short circuit, stuck at high), physical (loss of speed, excessive noise), or functional (loss of power gain, communication loss, high error level).
Failure Effect: Consequence of a failure mode on the operation, function or status of the item
Failure Mechanism; The processes by which failure modes are induced. It includes physical, mechanical, electrical, chemical, or other processes and their combinations. Knowledge of failure mechanism provides insight into the conditions that precipitate failures.
Function: A verb-noun combination describing the purpose of a design
Requirement: A function performing with a certain characteristic
Failure Site: The physical location where the failure mechanism is observed to occur, and is often the location of the highest stresses and lowest strengths.

Failure Mode Effects Analysis (FMEA)

A Maintenance Strategy Selection Process

Failure Means Functional Failure
Failure occurs when an item is no longer capable of performing its intended function
Function of an item is it's role or purpose in a process or business
Need to understand the operational process to fully understand an items function and when it fails to perform the function
Need to understand Function in terms of Performance Requirements and equipment or process Capabilities
Need to understand how function is impacted.
What failure types are likely
What causes these failures
How to eliminate the failures
How to minimise the consequence of potential failures

The Physics of Parts Failure

Stress from Distortion Fails Machinery

Degradation Rate Vs Temperature
Svante Arrhenius
The Nobel Prize in Chemistry 1903

Know the Stress Limits of Your Parts

The Equipment Designer Wanted a Long, Trouble-Free Service Life

Causes of Atomic and Microstructure Stress

Failure is ALWAYS a Design Requirement/Criteria

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All Products Fail!
Determining how they fail, when they will fail, and why they fail allows a designer to address failure as an acceptable design constraint.
Failure is an acceptable design outcome if the Customer is satisfied – this becomes the Design Quality.
Our goal during operation is preventing failure before the design criteria.

How might My Machine/System fail?

Functional Analysis

- What is the function of the Pump?
  - Primary Function
  - Secondary Function

Failure Modes – "What You Detect when it Fails."

Hidden Failures
There are failures of equipment items that either don't get used regularly or only get used when something goes wrong
Standby equipment e.g. a standby pump
Protection equipment e.g. Fire extinguisher, 2nd safety limit on a machine movement
You typically only know these items have already failed when you really need to use them
Carry out Failure Finding tasks. These are simple function checks e.g. changeover to standby pump; test the safety valve under controlled conditions

Identify the Functional Failures

System / Components Function

If things go wrong… what will be the resulting Impacts?
How will problems with a particular piece of Equipment, Process or System effect the business / organisation? How much money is lost with each failure?
What is the current situation?
What should it be?
How important is it compared to other Equipment, Processes or Systems?
What should we start on first?

If things go wrong… what will be the resulting Effects?
ON PRODUCTION:
How will problems with a particular piece of Equipment, Process or System effect the operation?
How important is it compared to other Equipment, Processes or Systems?
ON BUSINESS:
How much money is lost business-wide with each failure?
How will it impact the business / organisation?
ON CUSTOMERS:
What is the current situation?
What should it be?
What should we start on first?
Identify each Functional Failure's Effects

Is the Failure Mode a Valid Concern?

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Top-Down Block Diagram Analysis
Start at the top level & draw the process as a block diagram
Take each item and draw it's process block diagram
Only go to a lower level if there is too much complexity to analyse effectively
For selected analysis level rate the criticality of the item

Functional and Hardware Approaches
Functional Analysis of a System

Parts Level FMEA (Hardware Analysis)

Simple Failure Mode Effects Analysis Table (FMEA the Plant Wellness Way Table)

From FMEA to Selecting Maintenance Tasks

Measure Likely Improvement from the Task

Doing an FMEA in the Context of Maintenance Practices
The must be a balance between…
Planned Functional Tests (Hidden Failures)
Condition Based Maintenance (Induced Failures)
Planned Preventive Maintenance (Usage/Time Failures)
Breakdown Maintenance
and this will vary from industry to industry and between applications within industries.

The FMEA Team
A thorough FMEA is a result of a team composed of individuals qualified to recognize and assess the magnitude and consequences of various types of potential inadequacies in the product design that might lead to failures.
Advantage of the team work is that it stimulates thought process, and ensures necessary expertise.

Deficiencies of FMEA
Slow
Tedious on low levels for complex systems
Difficult if system has numerous operating modes
Difficult to effectively present relationships between failure modes and causes
Inability to measure overall system reliability
Cannot measure design improvements
Requires facilitation of the process

Functional Level Item Review
ASK
What are the Inputs & Output/ Connections into this item? eg. Services, utilities (signal, power supply, air, hydraulics etc)
How could these Inputs & Output fail or cause the item to fail? Treat as a 'black box' (don't know what is inside the item)
What can happen to the item as a whole eg fire, external impact
List without discussion
Write down Failures Modes. Be specific - separate if too broad
Discuss only to understand what is meant by the failure mode. What do you mean by that?

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Ask 'What Else' until no more answers?

List the Functional Failures
ASK
What is the function of the item?
What could go wrong or how could the Function fail?
List
Write down Functional Failures
Must be directly related to the item Function

List the Failure Modes for Each Failure
ASK
What could go wrong. How could Function failure occur?
List without discussion
Write as a Failure Mode (verb-noun combination)
Be specific - separate if too broad
Discuss only to understand what is meant by the failure mode. What do you mean by that?
Ask 'What Else' until no more answers?
What problems have occurred before?
Use existing maintenance and operational tasks as hints
Use a prompt list eg previous slide
Review each major component of the item
Are there any hidden failures?

Prioritise Failure Modes
ASK
What is the consequence rating of this failure?
What is the likelihood rating of this failure?
Write next to the item its Criticality Rating
Prioritise Criticality Rating of failure modes for an item from highest to least

Analyse Failure Causes
ASK for each
What causes the failure mode. List items without discussion ('Post-it Note' brainstorm)
Arrange causes into a logical causal tree
Ask 'what else' (causes)

Analyse Failure Cause Sources
ASK for each
Who has most influence on the Failure Mode causes?
Record Defect Elimination tasks for causes. Who to do?

Selecting Maintenance Tasks (Top Down)
ASK for each
Is there any effective and economic defect elimination tasks for the failure mode? Is the risk controlled?
Is there any effective and economic equipment servicing tasks that can be carried out at fixed intervals? e.g. Filter changes, greasing. Record tasks and frequency. Is the risk controlled?
Is the failure mode hidden (e.g. protection systems)? Record effective and economic failure finding tasks and frequencies. Is the risk controlled?

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Is there inspection or CM tasks that will detect the failure, which will allow failure consequences to be minimised? Record effective and economic tasks and frequency. Is the risk controlled?
Is a Scheduled Repair/replace task effective and economic?
Use optimisation models where required.

Selecting Maintenance Tasks (Bottom Up)
ASK for each
Is there any effective and economic defect elimination tasks for the part failure? Is the risk controlled?
Is there any effective and economic equipment servicing tasks that can be carried out at fixed intervals? e.g. Filter changes, greasing. Record tasks and frequency. Is the risk controlled?
Is the failure hidden e.g. protection systems? Record effective & economic failure finding tasks and frequencies. Is the risk controlled?
Is there inspection or CM tasks that will detect the failure mode, which will allow failure consequences to be minimised? Record effective and economic tasks and frequency. Is the risk controlled?
Is a Scheduled Repair/replace task effective and economic?

FMEA Implementation
Analysis is usually not the problem
Analysis is usually fun stuff
Implementation is ALWAYS a problem
Implementation is a pain…
A good implementation is usually 5 to 8 times the work of the analysis
Where possible make sure that recommended actions are easy to implement. As much of the data that is required for implementation should be included.
Take on responsibility yourself for issues under your control. Things take forever if it is always someone else's job.

FMEA Process – Preliminary Tasks
Planning
Scope
Where it fits into bigger company picture
Revision control
Expert availability
Milestones for completion
Action strategies for high critical FM's identified
Collation of documentation:
Diagrams
P&ID's
FBD's (breakdown of system into sub-systems showing functional relationships)
CMMS data (Maintenance programs, WO's, reliability data, Hierarchies)
Asset management documentation as applicable
OEM Manuals
Design information (ex: HAZOP results)

FMEA Process – More Preliminary Tasks
Criticality analysis (safety, risk policy)
Company specific
Severity classifications grouping
Environment

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Statutory/Safety/Government
Investment Protection (performance & reliability) /Contractual/Insurance
Probability/frequency of occurrence (from maintenance history)

Post FMEA Process
Summary report
Any unusual conditions
Effects of redundant element failures
Recognition of especially critical design features
Remarks to amplify important findings
References to entries for sequential failure analysis
Significant maintenance requirements
Dominant failure causes
Dominant failure effects
Design inputs

FMEA Summary
Is it required?
Define system boundary
Understand functions
Define criteria (severity classes)
Determine Failure Modes and Effects
Establish severity
Determine frequencies
Draw up criticality table
Report findings

Activity 1 – Parts Level Failure Mode Effects Analysis (FMEA)
Develop a Physics of Failure Life Cycle Table for the bearing OR for a part in your own equipment

Activity 2 – Parts Level Failure Mode Effects Analysis (FMEA)
Do a Hardware FMEA for this equipment part OR for a part from equipment in your operation —make your own 'simple' FMEA Table. You must do at least 6 separate failure modes

Activity 3 – Functional Failure Mode Effects Analysis (FMEA)
Do a Functional FMEA for this item of plant OR for an item of plant in your operation —make your own 'simple' FMEA Table. You must do at least 6 separate failure modes