FMEA for Maintenance Engineers

A Practical Guide to Failure Mode and Effects Analysis

AssetStage

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What Is FMEA?

Failure Mode and Effects Analysis (FMEA) is a systematic method for identifying:

- **What can fail** (failure modes)
- **Why it might fail** (causes)
- **What happens when it fails** (effects)
- **How bad it is** (risk ranking)
- **What to do about it** (actions)

FMEA helps you focus maintenance resources on what matters most.

Types of FMEA

Type	Focus	When Used
Design FMEA (DFMEA)	Product design	During engineering
Process FMEA (PFMEA)	Manufacturing process	Process design
Equipment FMEA	Physical assets	Asset management
System FMEA	Interconnected systems	System reliability

This guide focuses on **Equipment FMEA** for maintenance applications.

When to Use FMEA

Good Applications

- **New equipment installation** - Understand failure modes before commissioning
- **Chronic bad actors** - Equipment with recurring failures
- **Critical equipment** - High consequence of failure
- **PM optimization** - Developing RCM-based maintenance strategies
- **Incident investigation** - Understanding failure progression
- **Design modifications** - Evaluating proposed changes

Poor Applications

- **Every piece of equipment** - Too time-consuming, focus on critical items
- **Very simple equipment** - Overhead exceeds value
- **Equipment being replaced** - Invest effort in replacement instead
- **Without follow-through** - FMEA without action is wasted effort

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The FMEA Process

Step 1: Define Scope

Before starting, clearly define:

Question	Answer
What equipment?	(e.g., Seawater Lift Pump P-4501A)
What boundaries?	(e.g., From suction flange to discharge flange, excluding motor)
What operating context?	(e.g., Continuous duty, offshore platform, corrosive environment)
What level of detail?	(e.g., Component level for critical, subassembly for others)
Who is the team?	(e.g., Maintenance eng, operator, reliability eng, OEM rep)

Step 2: Identify Functions

List everything the equipment is supposed to do.

Primary functions: The main reason the equipment exists **Secondary functions:** Other requirements it must meet

Example: Centrifugal Pump

#	Function	Performance Standard
1	Transfer fluid from A to B	Flow rate: 450 m^3/hr minimum
2	Develop required pressure	Head: 85 meters minimum
3	Contain fluid	Zero external leakage
4	Not overheat	Bearing temp < 80°C
5	Not vibrate excessively	< 4.5 mm/s velocity
6	Start on demand	Start within 10 seconds
7	Meet environmental requirements	Noise < 85 dB at 1m

Step 3: Identify Failure Modes

For each function, identify HOW it could fail to meet the performance standard.

Function: Transfer fluid (450 m^3/hr minimum)

Failure Mode	Description
No flow	Pump produces zero output
Low flow	Output below 450 m^3/hr
Intermittent flow	Flow stops and starts
Reverse flow	Flow goes backward (when stopped)

Function: Contain fluid (zero external leakage)

Failure Mode	Description
Seal leak (minor)	Dripping, < 1 L/hr
Seal leak (major)	Continuous stream, > 1 L/hr
Casing leak	Leak from casing/cover
Flange leak	Leak from connections

Step 4: Identify Failure Effects

For each failure mode, describe what happens at three levels:

Level	Question
Local	What happens at the equipment?
System	What happens to the system/process?
Plant	What happens to production/safety?

Example: Seal leak (major)

Level	Effect
Local	Fluid spraying from seal area, contamination of surroundings
System	Loss of fluid inventory, potential pump damage if run dry
Plant	Water injection system offline, production deferral, potential environmental incident

Step 5: Identify Causes

For each failure mode, identify root causes. This is where your maintenance experience matters.

Failure Mode: Seal leak (major)

Cause	Category
Seal faces worn beyond tolerance	Wear
Seal faces damaged by debris	Contamination
O-rings degraded	Age/chemical attack
Shaft sleeve worn	Wear
Misalignment	Installation error
Running dry	Operational error
Incorrect seal for application	Design error
Exceeded pressure rating	Operational error

Step 6: Identify Current Controls

Document what's currently in place to prevent, detect, or mitigate each failure.

Detection Controls: How do we know it's failing? **Prevention Controls:** What do we do to prevent it?

Control Type	Example
Scheduled PM	Replace seal every 2 years
Condition monitoring	Vibration monitoring weekly
Operator rounds	Visual inspection daily
Instrumentation	Temperature alarm
Redundancy	Standby pump available

Step 7: Assess Risk (RPN Scoring)

Rate each failure mode on three scales, then multiply for Risk Priority Number (RPN).

Severity (S): How bad is the effect?

Rating	Severity	Description
10	Hazardous - No warning	Death or serious injury possible, no warning
9	Hazardous - With warning	Death or serious injury possible, with warning
8	Very high	Major environmental incident or $1M+ loss
7	High	Significant production loss or $500K+ loss
6	Moderate	Production impact or $100K+ loss
5	Low	Minor production impact or $50K+ loss
4	Very low	Minor impact, $10K+ loss
3	Minor	Slight inconvenience, < $10K loss
2	Very minor	Noticed by trained personnel only
1	None	No discernible effect

Occurrence (O): How often does this failure mode occur?

Rating	Occurrence	Probability
10	Very high	> 1 in 2 (> 50%)
9	High	1 in 3 (33%)

Rating	Occurrence	Probability
8	High	1 in 8 (12.5%)
7	Moderate	1 in 20 (5%)
6	Moderate	1 in 80 (1.25%)
5	Low	1 in 400 (0.25%)
4	Low	1 in 2,000 (0.05%)
3	Very low	1 in 15,000 (0.007%)
2	Remote	1 in 150,000 (0.0007%)
1	Nearly impossible	< 1 in 1,500,000

Detection (D): How likely is it to be detected before causing the effect?

Rating	Detection	Description
10	Absolute uncertainty	No known control, cannot detect
9	Very remote	Controls probably won't detect
8	Remote	Controls have poor chance of detection
7	Very low	Controls have very low chance
6	Low	Controls have low chance
5	Moderate	Controls may detect
4	Moderately high	Controls have moderately high chance
3	High	Controls have high chance
2	Very high	Controls will almost certainly detect
1	Almost certain	Controls will detect, proven methods

Calculate RPN:

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RPN = Severity × Occurrence × Detection
Range: 1 to 1,000
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Step 8: Prioritize and Take Action

Prioritization Guidelines:

RPN Range	Priority	Action
> 200	Critical	Immediate action required

RPN Range	Priority	Action
100-200	High	Action within 1 month
50-100	Medium	Action within 3 months
< 50	Low	Monitor, address opportunistically

But also consider:

- Any Severity = 9 or 10 requires action regardless of RPN
- High occurrence items may warrant action even with low RPN
- Easy wins (low effort, high impact) should be prioritized

Action Types:

Action Type	Purpose	Example
Design change	Eliminate or reduce failure	Install seal flush system
PM task	Prevent failure	Replace seal every 18 months
Condition monitoring	Detect degradation	Install vibration sensor
Procedure change	Prevent operational errors	Add startup checklist
Training	Improve human reliability	Seal replacement training
Redundancy	Mitigate effect	Install standby pump
Spare parts	Enable quick recovery	Stock critical spares

Step 9: Reassess After Actions

After implementing actions, re-score to verify improvement.

State	S	O	D	RPN
Before	7	6	5	210
After (new PM task)	7	3	5	105
After (+ condition monitoring)	7	3	2	42

FMEA Worksheet Template

Item	Function	Failure Mode	Effect (Local)	Effect (System)	Effect (Plant)	Cause	Current Controls	S	O	D	RPN	Recommended Action	Resp.	Due	New S	New O	New D	New RPN

Worked Example: Centrifugal Pump FMEA

Equipment Information

Field	Value
Equipment	Seawater Lift Pump P-4501A
Location	Offshore Platform Alpha
Class	ISO 14224: 1.1 Centrifugal Pump
Manufacturer	Sulzer
Model	MSD-D 80-200
Service	Seawater for water injection
Criticality	A - Production Critical
Operating Hours	8,000 hrs/year continuous

Function List

#	Function	Performance Standard
F1	Pump seawater	450 m^3/hr at 85m head
F2	Contain seawater	Zero external leakage
F3	Operate within temperature limits	Bearing temp < 80°C
F4	Operate within vibration limits	< 4.5 mm/s
F5	Start on demand	Start within 10 seconds

FMEA Analysis (Partial)

F2: Contain seawater - Zero external leakage

FM	Failure Mode	Effect (Local)	Effect (System)	Effect (Plant)	Cause	Current Controls	S	O	D	RPN	Action
2.1	Seal leak - minor (< 1 L/hr)	Visible dripping, wet area	Slight inventory loss	No immediate impact, housekeeping	Wear - normal life	PM: Replace seal @ 16,000 hrs	3	5	3	45	None - acceptable
2.2	Seal leak - major (> 1 L/hr)	Continuous spray, motor contamination risk	Significant inventory loss, pump damage if run dry	Production deferral if both pumps fail	Worn seal faces	PM: Replace seal @ 16,000 hrs	7	4	5	140	Add vibration monitoring
2.2	Seal leak - major	As above	As above	As above	Debris in seal faces	Strainer upstream	7	3	5	105	Increase strainer PM frequency
2.2	Seal leak - major	As above	As above	As above	Dry running	Low level alarm	7	2	3	42	None - acceptable
2.3	Casing leak	External leak at joint	System contamination	Production deferral	Gasket failure	Inspection @ major PM	6	2	4	48	None - acceptable
2.3	Casing leak	As above	As above	As above	Corrosion	Thickness testing @ 5 yrs	6	2	3	36	None - acceptable

F4: Operate within vibration limits - < 4.5 mm/s

FM	Failure Mode	Effect (Local)	Effect (System)	Effect (Plant)	Cause	Current Controls	S	O	D	RPN	Action
4.1	High vibration	Accelerated wear, noise	Reduced reliability	Potential unplanned shutdown	Unbalance (impeller erosion)	Monthly vibe check	5	5	4	100	Install continuous monitoring
4.1	High vibration	As above	As above	As above	Misalignment	Alignment check @ PM	5	4	3	60	None - adequate
4.1	High vibration	As above	As above	As above	Bearing wear	Monthly vibe check	5	4	4	80	Install continuous monitoring
4.1	High vibration	As above	As above	As above	Cavitation	Operator training	5	3	2	30	None - acceptable

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Converting FMEA to PM Tasks

FMEA findings should drive your PM strategy:

Mapping FMEA to Maintenance Tasks

FMEA Finding	Task Type	Example Task

FMEA Finding	Task Type	Example Task
Time-based failure	Scheduled replacement	Replace seal every 16,000 hours
Wear-out pattern	Condition monitoring	Monitor vibration trending
Random failure (detectable)	Inspection	Visual inspection for leaks
Random failure (hidden)	Functional test	Test backup pump monthly
Operational error	Procedure/training	Pre-start checklist
Design deficiency	Modification	Install seal flush system

Task Interval Selection

Failure Pattern	Maintenance Strategy
Wear-out (predictable)	Scheduled replacement before wear-out
Wear-out (variable)	Condition monitoring + limit
Random	Run-to-failure if low consequence
Random (safety critical)	Redundancy + proof testing
Hidden failure	Scheduled functional test

FMEA Workshop Facilitation

Before the Workshop

1. **Select equipment** - Focus on critical or problem equipment
2. **Gather documentation** - P&IDs, manuals, maintenance history
3. **Analyze failure history** - What has actually failed?
4. **Identify participants** - Operations, maintenance, engineering, OEM
5. **Schedule adequate time** - 4-8 hours for complex equipment

During the Workshop

Facilitator responsibilities:

- Keep discussion focused on one failure mode at a time
- Ensure all functions are covered
- Challenge assumptions (not all failures are “operator error”)

- Record everything - even if not consensus
- Watch for dominant personalities
- Keep energy up (breaks, snacks)

Ground rules:

- No idea is stupid
- Focus on failure modes, not blame
- Use data where available, experience where not
- Document assumptions
- Complete is better than perfect

After the Workshop

1. **Clean up documentation** - Format FMEA worksheet
2. **Calculate RPNs** - Verify math
3. **Prioritize actions** - Use RPN plus judgment
4. **Assign owners** - Every action needs a name and date
5. **Update PM program** - Implement task changes
6. **Track completion** - Follow up on actions
7. **Review periodically** - Update FMEA as conditions change

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Common FMEA Mistakes

Mistake	Problem	Solution
Confusing failure mode and cause	“Bearing failure” isn’t a mode - it’s a cause of “high vibration”	Mode = loss of function, Cause = why it happened
Too many failure modes	Unmanageable, analysis paralysis	Focus on significant modes, combine trivial ones
Too few failure modes	Miss important risks	Ensure every function has at least one mode
Same scores for everything	Defeats prioritization	Be specific about your facility/context

Mistake	Problem	Solution
No follow-through on actions	Wasted effort	Assign owners, track to completion
One-time exercise	FMEA becomes outdated	Review annually or after changes
No data used	Scores are pure opinion	Use failure history, industry data
All failures are “operator error”	Avoids addressing real issues	Challenge this - what set up the error?

FMEA-to-CMMS Integration

Recording FMEA Data in CMMS

Option 1: Document attachment

- Attach FMEA spreadsheet to equipment record
- Simple but not queryable

Option 2: Custom fields

- Add RPN field to equipment
- Track highest-risk items

Option 3: Dedicated module

- Some CMMS have FMEA/RCM modules
- Full integration with PM tasks

PM Task Traceability

Link PM tasks back to FMEA findings:

PM Task	FMEA Reference	Failure Mode Addressed
Replace mechanical seal	FMEA-P4501A-2.2	Seal leak - major
Vibration measurement	FMEA-P4501A-4.1	High vibration
Alignment check	FMEA-P4501A-4.1	High vibration

Quick Reference: FMEA Scales

Severity

10 | Death/injury possible | 6 | Production impact |
9 | Death/injury with warning | 5 | Minor production impact |
8 | Major environmental/$1M+ | 4 | $10K+ loss |
7 | Significant impact/$500K+ | 3 | Slight inconvenience |
| | 2-1 | Minimal/no effect |

Occurrence

10 | > 50% | 5 | 1 in 400 |
9 | 33% | 4 | 1 in 2,000 |
8 | 12.5% | 3 | 1 in 15,000 |
7 | 5% | 2 | 1 in 150,000 |
6 | 1.25% | 1 | < 1 in 1,500,000 |

Detection

10 | Cannot detect | 5 | May detect |
9 | Very unlikely to detect | 4 | Moderate chance |
8 | Poor chance | 3 | High chance |
7 | Very low chance | 2 | Very high chance |
6 | Low chance | 1 | Will detect |

Need help conducting FMEA workshops for your critical equipment? AssetStage provides data staging, validation, and clean import to any CMMS platform. Contact us at sales@assetstage.io

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