Procedure

Sydney WATER

Failure Mode Effects and Criticality Analysis (FMECA)

1. Overview

1.1. Objective

Sydney Water's maintenance objective is to ensure that assets achieve their design service requirements within acceptable risk at lowest life cycle costs. The purpose of this procedure is to document the procedure for undertaking Failure Mode Effects and Criticality Analysis for Sydney Water's facility assets. The objective is to identify the items where modification to the design or the operating, inspection, or maintenance strategies may be required to reduce the severity of the effect of specific failure modes. It can be performed to meet a variety of different objectives, for example, to identify weak areas in the design, the safety-critical components, or critical maintenance and test procedures.

1.2. Scope

Failure mode effect and criticality Analysis shall be undertaken at:

- Concept stage
- Detail design stage
- Commissioning stage and
- Operational and Maintenance stage when significant changes have taken place in the operating context or asset component configuration or every ten years whichever is the lesser.

1.3. Summary

This procedure is based on:

- US MIL-STD-1629A, Procedures for Performing a Failure Mode, Effects and Criticality Analysis, It provides a qualitative approach.
- British Standard BS 5760, that provides a quantitative approach

Failure modes, effects and criticality analysis (FMECA) is generally undertaken to determine critical maintenance or renewal required for any asset. It can also be used to determine the critical failure mode and the consequences of a failure for SWC assets. (FMECA) is an extension of FMEA which aims to rank each potential failure mode according to the combined influence of its severity classification and probability of failure based on the best available data. By determining the critical failure mode of an asset it is possible to target and refine maintenance plans, capital expenditure plans, and investigative activities, to address the potential failure.

Risk Priority Number (RPN) is obtained by quantifying the severity, probability and detectability score. This is used to prioritize asset remedial activities.

2. Procedure to conduct FMECA

2.1. Basic information required for the FMEA process.

What does the System do? **Mission**.

What is its function? **Function**

How could it fail to perform its function? Failure **Mode**.

What happens if it fails? **Effect** of Failure.

What is the Likelihood of failure? **Occurrence (O)**

What is the consequence of failure? **Severity (S)**

What is the predictability of failure? **Detectability (D)**

What is the Risk Priority Number (RPN)? **RPN = O x S x D**

2.2. General requirements for FMECA

- FMECA Team shall consist of Designers, Planners, Operators, and Maintainers.
- Identify the critical Asset / Maintainable Unit (Top 20 % failures using Pareto principle)
- Apply FMECA to develop the most cost effective maintenance for the Asset / Maintainable Unit. The Asset / Maintainable Unit is regarded as the **maintainable unit** this is the lowest level of disaggregation over which we have control over its maintenance.

2.3. Steps involved in EMECA

1. Define system boundaries for analysis. Identify the Asset / Maintainable Unit or system being analysed.
2. Understand system/Asset / Maintainable Unit/item requirements and function. Collect information on the Asset / Maintainable Unit/item, its process **disaggregation, failure history**, Manuals, P & I Diagrams etc. Conduct Pareto analysis of the failure frequencies and select the top 20% failure of the most frequent fail classes.
3. Define failure/success criteria for the system/ Asset / Maintainable Unit/item.
4. Determine each Asset / Maintainable Unit /item potential failure modes,
5. Determine the causes of the failures for each mode
6. Determine the effects and consequence of the failure for each mode.
7. Establish Asset / Maintainable Unit/item failure mode severity Severity (S) score of the failure consequence.
8. Determine item failure mode (frequency) occurrence (O) score.
9. Determine item failure mode detectability (D) score
10. Assess the risk priority for each failure mode.
11. Risk Priority Number (RPN) Score – S x F x D
12. Review actions, currently being taken, for dealing with the failure modes.
13. Develop remedial measures to eliminate or mitigate the potential fault or failure. This may require:
    i. Maintenance method changes including preventive maintenance, tooling, spares provision, Asset / Maintainable Unit replacement, condition monitoring.
    ii. Changes in operating procedure;
    iii. Production process changes
    iv. Support procedure changes; and
    v. Design changes;
14. Re-assess a revised risk priority for the failure modes.

The template to undertake this FMECA exercise is given in Table-1 below.

2.4. Ranking of Severity, Probability and Detectability

Severity. Severity is an assessment of the seriousness of the effect of the potential failure mode to the next component, subsystem, system or customer if it occurs. Severity applies to the effect only. A reduction in Severity Ranking index can be effected only through a design change. Severity should be estimated on a "1" to "5" scale. See Severity Rating Table below

Severity Ranking

Severity	Asset / Maintainable Unit	System / mission	People	Enterprise
5 **CATASTROPHIC**	Definite or presumed destruction or degradation of other functional Asset / Maintainable Unit	Complete loss of capability	Loss of life	Major plant and production loss Enterprise survival doubtful
4 **CRITICAL**	Complete failure of or damage to functional Asset / Maintainable Unit under consideration	40 % to 80 % loss of capability	Severe injury and long term damage	Moderate plant and production loss
3 **MODERATE**	Important degradation of functional Asset / Maintainable Unit under consideration or substantial increase in operator workload	10 % to 40 % loss of capability	Moderate injury with full recovery	Significant production loss
2 **MARGINAL**	Minor degradation of functional Asset / Maintainable Unit under consideration	Less than 10 % loss of capability	Minor injury	Minor production loss
1 **MINOR**	Negligible effect on performance of functional Asset / Maintainable Unit under consideration	No or negligible effect on success	No injury	No or negligible production loss
Examples of failure effect severity scales (Ref BS 5760)				

Occurrence (Event frequency). Occurrence is how frequently a specific failure cause/mechanism is projected to occur. The *likelihood of occurrence ranking number has a meaning rather than a value*.

Removing or controlling one or more of the causes/mechanisms of the failure mode through a design change is the only way a reduction in the occurrence ranking can be effected.

Estimate the likelihood of occurrence of potential failure cause/mechanism on a "1" to "5" scale. Only occurrences resulting in the failure mode should be considered for this ranking; failure-detecting measures are not considered here. See Occurrence Rating Table below

Range Estimates of failure probability can be used to rank probabilities of occurrence or, alternatively, item failure rates may be employed. Frequency ranges for process Asset / Maintainable Unit typically:

Rank	Occurrence Criteria	Occurrence Rates (Cycles, Hrs etc.) - Ref Dodson Reliability HB	Failures per year in Process industry – Ref Moss Reliability Assessment
1 - Unlikely	Unlikely Unreasonable to expect this failure mode to occur	1/100,000	-
2 -Very Low	Isolated – Based on similar designs having a low number of failures	1/10,000	<0.0l
3- Low	Sporadic – Base on similar designs that have experienced occasional failures	1/1,000	0.01 to 0.1
4- Medium	Conceivable – Based on similar designs that have caused problems	1/100	0.1 to 1.0
5-High	Recurrent – Certain that failures will ensure	1/10	> 1
Examples of failure occurrence scales			

If available from a similar process, statistical data should be used to determine the occurrence ranking.

Detection is the ability to detect the cause/mechanism/weakness of actual or potential failure. In Design FMEA, this must occur before the component, subsystem, or system is released for production. In Process/Service FMEA it must occur in time to prevent distribution in case of a product or catastrophe in case of an Asset / Maintainable Unit. In order to achieve a lower ranking, generally the planned control (eg, preventative activities) has to be improved. See Detection Ranking Table below.

When assessing the probability that the current controls will prevent or detect the cause of the failure mode; do not assume that the detection rating will be low because the occurrence rating is low.

Detection Ranking (Ref Dodson Reliability Handbook)

Rank	Detection Criteria	Probability %
1	Very High Probability of detecting the failure before it occurs. Almost always preceded by a warning	80 – 100
2	High Probability of detecting the failure before it occurs. Preceded by a warning most of the time	60 – 80
3	Moderate Probability of detecting the failure before it occurs. About 50%chance of getting a warning	40 – 60
4	Low Probability of detecting the failure before it occurs. Always comes with little of no warning	20 – 40
5	Remote Probability of detecting the failure before it occurs. Always without a warning	0 - 20
Examples of failure detection scales		

Risk Priority Number (RPN). The **R**isk **P**riority **N**umber is the product of the Severity, Occurrence, and Detection rankings.

Risk Priority Number = Severity x Occurrence x Detection

The RPN, as the product S x O x D, is a measure of design/process risk. This value should be used to rank order the concerns in the Design/Process (e.g., in Pareto fashion). The RPN will be between 1 and 125. For higher RPNs the team must undertake efforts to reduce this calculated risk through corrective action(s). In general practice, regardless of the resultant RPN, special attention should be given when severity is high.

If the RPN Number is more than 33 you need to investigate the possibility to renew or replace the asset based on

- Condition (Poor grade 4),
- Total Maintenance cost in last 5 yrs > than 60 % of replacement value
- Remaining Life less than 5 yrs
- Spares availability (long lead time, obsolescence)

2.5. Clarification of Failure modes, problems or symptoms

Example for a Submersible Pump Failure:

Symptom Detected (Failure Mode) or Problem at Maintainable unit level	Cause at Hardware or Part level of maintainable unit's
Increase in pump down time	Choke
Pump failed to start	Jam
Pump unable to start when called for by level signal	Broken shaft
Pump unable to start when called for by level signal	Bearing failure
Water found in oil chamber	Seal failure
Increase in pump down time	Incorrect seating
Increase in pump down time	Wear Ring Failure
Water found in oil chamber	O-ring fault
Leakage / low pumping rate	Damaged/cracked casing
Noise	Loose impeller
Low pumping rate	Impeller damaged

General Common Problems or Symptoms

- Dirt or foreign matter in mechanism, pipe
- Breakage or jamming due to overloading or misapplied load
- Breakage due to wear and tear
- Lubricant lacking, deteriorated or dirty
- Securing or mounting nut/bolt/fastener loose or missing
- Foundations not firm or secure
- Corrosion, rust
- Balance (vibration)
- Filter blocked or dirty
- Alignment incorrect
- Power supply failure
- Fire damage
- Design or manufacture fault
- Overheating due to lack of coolant, or cooling surface blocked
- Fracture of pipe or vessel due to welding fault, thermal stress or fatigue
- Loss of hydraulic fluid
- Incorrect assembly
- Part missing, loose or falls off
- Seal leaking
- Leak in pipe, valve, tap, etc.
- Hose damaged
- Vermin – e.g. rat chews through insulation, bird makes nest in air inlet,
- Flood / water damage
- Drain blocked
- Electrical insulation failure
- Electrical connection failure
- Consumable not replenished, e.g., lubricant
- Catalyst regeneration required
- Balance incorrect (
- Vandalism
- Water supply failure
- Protective device failed

Table –1: Template to undertake FMECA.

FAILURE MODE ANALYSIS (FMEA),															Rating scale for Severity, Occurrence, Detection from 1 to 5																																
Facility No.	Facility (Level 1)	System No.	System (Level 2)	Item No.	Item (Level 3) Maintainable Unit	Item Quantity	Item Functional Failure Mode No.	Item Functional Failure Mode	Symptom Detected (Failure Mode) or Problem at Maintainable unit level	Local Effect	Effect on facility Mission	Item Hardware (Part) Failure mode No.	Cause at Hardware or Part level of maintainable unit's	Root Cause is mechanism of Maintainable unit's Part failure	Severity	Failure Data	Item Failure Mode Rate lamda p	Occurrence from data	Occurance estimated (when Failure = 0)	MTBF (x1000 hours)	P-F Interval	Crticality (SxO)	CRTITICALITY TOP 10 RANKING / FREQUENCY	Detectability	Predictable by Condition Monitoring	Detectable by Operator	Criticality Type	WI Number	WI Item Number	WI Frequency (months)	RPN	RPN RANKING TOP 10 RANKING / FREQUENCY	Failure Mode Proportion for Item (alpha)	Mission Failure Probability (beta)	Time at Risk Proportion (t)	Item Hardware Failure Mode Frequency, F/Mhrs Lamda O	Item Functional Failure Mode Frequency	Item Failure Frequency	System Failure Frequency	Facility Failure Frequency	System contribution to Facility failure (%)	Item Contribution to Facility failure (%)	Item Functional Failure Mode Contribution to Facility Failure (%)	Item Hardware Failure Mode Contribution to Facility Failure (%)	Item Hardware Failure to Facility failure Rank (top 20)	Current Provision Against Failure	Recommendation

3. Context

3.1. Definitions

Term	Definition
Current Controls.	Current design or process controls are descriptions of the controls that either prevent to the extent possible the failure mode from occurring or detect the failure mode should it occur.
Detection	This is the ability to detect the cause/mechanism/weakness of actual or potential failure.
Occurrence (Event frequency).	Occurrence is how frequently a specific failure cause/mechanism is projected to occur. The *likelihood of occurrence ranking number has a meaning rather than a value*.
Potential Cause(s)/Mechanism of Failure	Potential Cause of Failure is defined as how the failure could occur, described in terms of something that can be corrected or can be controlled, or an indication of a design weakness, the consequence of which is the failure mode.
Potential Effect(s) of Failure	Potential Effects of Failure are defined as the effects of the failure mode on the function, as perceived by the customer. The customer in this context could be the next operation, subsequent operations or locations. Each must be considered when assessing the potential effect of a failure.
Potential Failure Mode.	A Potential Failure Mode is defined as a manner in which a component, subsystem, system or process could potentially fail to meet the design intent and/or the process requirements.
Recommended Action(s)	Corrective action should be first directed at the highest ranked concerns and critical items.
Revised Risk Analysis	After the corrective actions have been identified, estimate and record the resulting severity, occurrence and detection ratings. Calculate and record the resulting RPN.
Risk Priority Number (RPN).	Provides a quantitative measure of risk. The **R**isk **P**riority **N**umber is the product of the Severity, Occurrence, and Detection rankings.
Severity	Severity is an assessment of the seriousness of the effect of the potential failure mode to the next component, subsystem, system or customer if it occurs.

3.2. Responsibilities

The FMECA procedure **shall be conducted at:**

- Concept stage by the designers and planners
- Detail design stage by designers.
- Commissioning stage by the contractor.
- Operation stage by the operators, planners and maintainers to review the maintenance requirements

Position	Responsibility
Manager - Strategic Asset Management (SAM)	Procedure owner
Maintenance Strategy Leader – SAM	Procedure development and review
Planners, Designers, Contractors & Operators	Procedure implementation
Management System Administrator	Policy publishing (in BMIS); initiating scheduled policy review cycles and incorporating of amendments

3.3. References

Document type	Title
Legislation	• Occupational Health & Safety Act
Other documents	• US MIL-STD-1629A, Procedures for Performing a Failure Mode, Effects and Criticality Analysis, It provides a qualitative approach. • British Standard BS 5760, that provides a quantitative approach

4. Document control

Procedure title: Failure Mode Effects and Criticality Analysis (FMECA) procedure		
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Procedure Owner	Manager, Strategic Asset Management (SAM)	
Prepared by:	SAM - Maintenance Strategy Leader	
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5. Revision control chart

Please refer to Sydney Water's Business Management Information System (BMIS) for version control details.