Eskom	Standard	Technology

Title: **MAINTENANCE STANDARD FOR <ADD ASSET IDENTIFIER HERE>**

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PCM Reference: **<xxxxxx>**

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Content

Tables

1. Introduction

This template shall be used to document Maintenance requirements of assets in a standardised manner. The purpose is to ensure that the asset's original design intent is maintained.

Note that this document may be expanded as required to suit the development of the specific asset maintenance requirements.

The text shown in blue, which is formatted with the Instruction style, indicates instructions or optional text. This text should be deleted in the final document. Where optional text, formatted in blue, is to be used in the document, apply the Default Paragraph Font style to text.

The requirement to document maintenance strategies, which define maintenance that is applicable to the power delivery assets, is not new. However, the initiatives to standardize the engineering design processes have dictated that a Maintenance Strategy shall be compiled as part of the process to design and specify asset classes/systems.

The Maintenance Engineering Strategy is developed as a result of the engineering performed during the design process, (or retrospectively, taking cognizance of the original design intent), to define the maintenance requirements of the asset classes.

This standard also indicates how maintenance triggers may be affected based on the specific asset's functional importance, operating environment, usage/duty cycle and health. In addition, an ageing analysis indicates intended design life, asset ageing mechanisms, specific asset health indices and calculations to determine useful end of life. This also serves as primary input to the technical and economic end-of-life assessments.

2. Supporting clauses

2.1 Scope

This Maintenance Standard is applicable to (indicate specific items of asset (e.g. transformers, breakers, protection scheme), or different groups/types thereof (e.g. Phase III EHV feeder protection schemes) with the same failure modes and hence maintenance requirements). All minimum maintenance activities are described along with the triggers for said maintenance activities and the associated logistics requirements.

This standard covers the following:

- maintenance engineering strategy,
- maintenance execution strategy,
- manage asset excursions,
- asset health , and
- asset performance.

A separate related document titled "Maintenance Implementation Standard" (MIS) maybe developed to assist with the implementation of this standard. The maintenance process and CMMS confirmations are also considered in the MIS.

2.1.1 Purpose

The purpose of this document is to stipulate the engineering requirements for maintenance of (Asset name) installed in Distribution and Transmission networks, as utilized in specific functional locations, and to indicate how the health of said asset is to be monitored such that the appropriate capital and operational investments can be made, at the appropriate times, to sustain the operational capability of the asset.

2.1.2 Applicability

This document is applicable to Eskom Transmission and Distribution Groups.

2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

Normative references are documents that are indispensable for the application of this document, i.e. documents to be used together with this document.

List the references under 'Normative' or 'Informative' as applicable, without indicating the date.

2.2.1 Normative

[1] ISO 9001:2015 Quality management systems - Requirements

[2] Guide to Integrated Risk Management, ©Eskom Ltd, 2009

[3] Act No. 85 Occupational Health and Safety Act, 1993

[4] 474-190 Design Base Standard

[5] Add additional normative document references here

2.2.2 Informative

Informative references are documents that are further sources of information referenced in your document, e.g. laws, standards, codes and procedures.

Take note of possible sources of statutory maintenance requirements as well as regulatory stipulations.

[6] 240-49230046 Failure Mode and Effects Analysis Guideline

[7] 240-49230148 Maintenance and Logistics Support Design Guideline

[8] 24-49230067 Life Data Analysis Guideline

[9] Add additional informative document references here.

2.3 Definitions

2.3.1 General

In the following table, list all definitions applicable to this document, in alphabetical order. Explain all terms used, including documents, titles and departmental references that may cause confusion if not explained. Preferably use definitions listed in international standards.

Definition	Description
Corrective Maintenance	The maintenance carried out after a failure has occurred and intended to restore an item to a state in which it can perform its required function.

Definition	Description
Functional Importance – Critical	Applicable to an asset that must operate, as designed, in order: to meet to meet legal requirements; or to meet regulatory requirements; or to ensure safety of people; or to prevent irreversible environmental harm; or to prevent economic loss (net profit) of > R99 million; or to ensure continuity of supply, where not doing so would imply failure to meet one of the above points in the Eskom or public domain.
Functional Importance – Economic	Applicable to an asset which must operate, as designed, in order to ensure continued income through the provision of services and accurate billing; or to prevent damage to, or accelerated ageing of asset resulting in economic loss, such that any economic losses (net profit) are limited to between R100 000 and R1 million.
Functional Importance – Run to Failure	Applicable to an asset where the consequences of failure are acceptable, without preventative maintenance being performed, for a period of time until normal inspection and test activities will determine the failure and correction actions can be carried out. Economic losses are limited to < R100 000.
Functional Importance – Significant	Applicable to an asset which must operate, as designed, in order to prevent impact on personnel and public; or to prevent measureable impact on environment; or to prevent damage to, or accelerated ageing of asset resulting in economic loss; to ensure continued income through the provision of services and accurate billing; or to protect the Eskom brand and reputation, such that any economic losses (net profit) are limited to between R1 million – R99 million.
Maintenance Engineering Strategy	Maintenance Engineering Strategy refers to the engineering performed during the design process (logistic support analysis) to define the maintenance requirements of the System, Structure or Component (SSC) (which typically include the following: minimum critical spares requirements; maintenance tasks definition; in-service inspection and test requirements; maintenance periodicities and triggers; training requirements; facilities; expected SSC life, etc.) that serves as primary input to the maintenance execution strategy.
Asset	Any infrastructure that has been established to enable the generation, transmission, distribution and sale of electricity.
Preventative Maintenance	The maintenance carried out at predetermined intervals or corresponding to prescribed criteria (such as measured condition or number of operations), and intended to reduce the probability of failure or the performance degradation of an item.

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

In the following table, list and describe all abbreviations used in the document, in alphabetical order.

Abbreviation	Description
CM	Corrective Maintenance
CMMS	Computerized Maintenance Management System
CoE	Centre of Excellence
FAT	Factory Acceptance Test
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
I	Inspection
IT	Inspections and Tests
PM	Preventative Maintenance
SAT	Site Acceptance Test
SSC	System, Structure or Component

2.5 Roles and responsibilities

The Manager - Design Base Asset Maintenance is responsible for the consistency and process of compiling this maintenance standard. The Transmission Grids and Distribution OUs are responsible for the selection of asset specific maintenance execution strategies per individual asset.

The Transmission Grids and Distribution OUs are also accountable for developing Maintenance Plans in line with this maintenance standard and the subsequent scheduling, work execution and capturing of the relevant information as specified by this standard and job plans and / or task list in the CMMS's.

Compliance with the requirements of this standard is MANDATORY, and where the affected OUs and Grids cannot comply with any of the specified requirements, such deviations shall be managed as per the Manage Asset Excursion process.

Any other maintenance documents developed must comply to the requirements of this maintenance standard.

In the absence of an Asset Performance Management (APM) tool, the Manager – Design Base Asset Maintenance is accountable to provide templates which allows for manual implementation of the requirements of this standards.

2.6 Process for monitoring

The Manager - Design Base Asset Maintenance will monitor the effectiveness and consistency of adoption of this standard through established report formats which will be sent to the Transmission Grids and Distribution OUs to provide the required information.

2.7 Related/supporting documents

List related documents.

Also list the forms and records that you have referred to and which shall be maintained, if there are any. If there are no related/supporting documents, insert 'Not applicable' to retain paragraph numbering.

3. Requirements

3.1 Asset identification

Identify the asset class / sub class for which this standard is applicable.

List and briefly describe the key components of the asset considered for this standard and indicate any exclusion / or boundaries.

3.2 Design intent

Maintenance requirements contribute to achieving the design intent, i.e. what the maintenance should sustain. In order to accurately specify the maintenance requirements, it is necessary to understand the design intent in terms of the intended:

- Purpose of the asset – functions that the asset should perform.
- Performance of the asset and associated indicators – the intended reliability, maintainability, dependability, security, etc.
- Operating (physical and electrical) environment the asset can tolerate – the intended operating environment.
- Operating limits – limits within which the asset shall be operated (load etc.).
- Intended design life of the asset.

Document the design intent at a high level, which maintenance will sustain, and against which the maintenance can be specified further in this document. Where this is covered in other documents, you may make reference to such documents.

3.3 Maintenance Engineering Strategy

The Maintenance Engineering Strategy refers to the engineering performed during the design process (logistic support analysis) or retrospectively, taking cognizance of the original design intent, to identify the asset care requirements of the asset classes/systems, which includes:

i. Maintenance activity determination (3.3.1)

ii. Asset and maintenance data required (3.3.2)

iii. Identify the required Task manuals (3.3.3)

iv. Maintenance spares (3.3.4)

v. Facilities and training requirements (3.3.5)

3.3.1 Maintenance Activity Determination

The maintenance activities and associated triggers are derived from an FMECA study as per Appendix A. For retrospective analysis of current designs use FMECA Worksheet A1, for new asset designs use FMECA Worksheet A2.

The maintenance activities from the FMECA study are collated and analysed further as per the Maintenance activity table in Appendix B. For retrospective analysis of current designs use Maintenance activity Table B1, for new asset designs use Maintenance activity Table B 2. Take note that the asset classification tables in section 3.4.1. are necessary to complete the Maintenance activity Table B 2.

3.3.2 Asset and maintenance data required

3.3.2.1 Asset data to be captured

The following minimum asset data must be captured in the Computerized Maintenance Management System (CMMS) to suitably describe the asset.

Note: Asset data lists to be identified in consultation with CMMS custodians for the CMMS.

A typical example for Transformers/Reactors, Bushings and Tap Changers is:

- Manufacturer
- Serial Number
- Manufacturer Type No.
- Manufacturing Year
- Year Commissioned
- Single or three phase
- Open or Sealed unit
- Primary Voltage
- Secondary Voltage (where present)
- Tertiary Voltage (where present)
- Apparent Power

3.3.2.2 Maintenance data to be captured

The capture of maintenance data is of critical importance to enable the determination of the next / follow up maintenance cycle, the determination of asset health.

No work orders without the required feedback should be closed.

The maintenance data must be captured in accordance with condition monitoring (Inspections and Tests (IT)), Preventative Maintenance (PM), Corrective Maintenance (CM), Statutory Maintenance and Investigation (I) results as listed in specific job plans / task lists.

The following minimum asset data shall be captured in the CMMS. Some of this information could be sourced from (including Factory Acceptance Test (FAT) and Site Acceptance Test (SAT) where relevant to a specific asset).

Note: The required AHI inspection and test information should also be added in the table below.

Maintenance data requirements must be in table format for all asset types.

Table 1 below shows a typical example for Transformers and Reactors.

Table 1: Maintenance data fields

Maintenance activity	Data type	Source	Source activity
1. Transformer Electrical Tests			
1.1 Insulation DC Resistance	MΩ: No.	Maintenance Test Report	FAT: SAT, PM, CM, I
1.2 Winding Tan Delta	%: No.	Test Report	FAT: SAT, CM, I
1.3 Winding Capacitance	μF: No.	Maintenance Test Report	FAT: SAT, CM, I
1.4 Winding Insulation Resistance			
1.4.1 HV to Earth	MΩ: No.	Maintenance Test Report	FAT: SAT, PM, CM, I
1.4.2 LV to Earth	MΩ: No.		
1.4.3 HV to LV	MΩ: No.		
1.5 Core Insulation Resistance	MΩ: No.	Maintenance Test Report	FAT: SAT, PM, CM, I

3.3.3 Required task manuals

List all required task manuals as identified in the task table (Table 1) and compile the task manuals as separate documents.

3.3.4 Maintenance spares

List all maintenance spares that are required to be in stock for the execution of the required maintenance tasks.

OU's / Grids must determine the stock levels required.

3.3.5 Facilities and training material

Indicate any special facilities, such as workshops that may be required to carry out the maintenance.

List any special equipment / tools that may be required to carry out maintenance.

Indicate the training curriculum for the identified maintenance tasks.

3.4 Maintenance Execution Strategy

The Maintenance Execution Strategy refers to the asset specific maintenance tasks and triggers which the Grids and OUs use for the creation of Maintenance Plans. The maintenance tasks are created from the maintenance activity table (Appendix B) based on the following:

- Common outage requirements for the maintenance to be undertaken
- Common craft requirements for the maintenance to be undertaken
- Common trigger as to when the maintenance must be undertaken

These tasks become job plan titles in Maximo and task list titles in SAP PM. The activities form the job operational steps in job plans / task lists

An asset risk framework (Asset classification) is adopted, which is based on defined Asset Conditions (health), Environment, Usage / Duty Cycle and Functional importance (Criticality based on consequence of failure and Operational factors) within the parameters of the Maintenance Engineering Strategy.

To select the optimal maintenance triggers for the creation of PMs, the following components of the maintenance execution strategy are to be carried out:

i. Asset classification (3.4.1)

ii. Maintenance task selection (3.4.2)

iii. Functional equipment grouping (3.4.3)

3.4.1 Asset classification

In order to ensure that the Operating Units and / or Grids classify individual assets in a consistently similar manner, tables are provided below.

Questions to be answered below are designed to lead to the most appropriate maintenance strategy for a transformer and associated bay equipment. The first 'Yes' answer will determine the classification of a transformer and the remaining questions for that section are to be ignored.

An asset classification tool (e.g. excel based tool) shall be developed and made available to the OUs prior implementation of this standard. Such a tool shall identify sources of information for the below asset classification questions.

The criteria for asset classification questions shall not be subjective.

Table 2: Asset classification

A. Functional Importance	**Critical**	**Significant**	**Economical**
Is the substation/corridor un-firm?	Yes		
Is the supply to a Key Customer?	Yes		
Is the transformer connected to Koeberg network?	Yes		
Is the transformer in a built-up area or near a water source?	Yes		
Is the transformer operating between 30% and 50% load?	Yes		
Is the transformer above 20 MVA?		Yes	
Is the answer to all the questions above 'No'?			Yes

B. Duty Cycle	**High**	**Low**
Is the transformer loaded above 75%?	Yes	
Is the maximum winding temperature above 85 °C?	Yes	
Is the transformer tapping more than 100 times a month?	Yes	
Are more than five line faults recorded at the substation per annum?	Yes	
Is the answer to all the questions above 'No'?		Yes

C. Operating Environment	**Harsh**	**Mild**
Is the substation within 100 km from the coast?	Yes	
Is the substation within a mining, industrial or metro area?	Yes	
Is the transformer at a Coal-fired Power Station	Yes	
Is the answer to all the questions above 'No'?		Yes

3.4.2 Maintenance task selection

The Maintenance tasks in Table 3 below are created based on the maintenance task determination (3.3.1).

The maintenance task table is used by the maintenance planner to identify maintenance tasks & triggers for the PMs to be created in the CMMS for the assets which this standard applies to.

The Interpretation of the maintenance task table is as follows:

- **Trigger Modifiers:** The trigger modifiers are defined as per the Asset Classification tables in section 3.4.1 and they determine how often maintenance tasks should be done (frequencies).
- **Permutations:** The permutations are a combination of the different trigger modifiers response options. An asset can be in either a harsh or mild environment, but never both.
- **No's 1,2,3…..n:** Each of these numbers represent a unique maintenance execution strategy for the asset that has been classified. Each maintenance task is subsequently referenced to the column where this number lies.
- **Maintenance Tasks:** Maintenance tasks represent a grouping of maintenance activities.
- **FMECA: reference:** The FMECA reference provides the link between the maintenance tasks and the FMECA study in appendix A.
- **Trigger:** The trigger indicates whether the maintenance should be carried out based on condition status; time based or even run to failure where a corrective maintenance is initiated.
- **Key:** It's a legend for the maintenance frequencies identified. E.g. 6M means that the maintenance task needs to be carried out every six months.
- **Outage:** A 'Y' indicates that an outage is required to carry out the maintenance task.
- **Skills level:** Where specified, this indicates whether specialised skills are required to carry out a specific task or not.

Table 3: Maintenance Tasks

Equipment Sub Class Family:		zzz																																					
Trigger Modifiers		Permutations	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33			Key	
	Functional Importance	Critical																									X	X	X	X	X	X	X	X				1M	One monthly
		Significant																	X	X	X	X	X	X	X	X												6M	Once every six months
		Economic									X	X	X	X	X	X	X	X																				1Y	Once every year
		Run to fail	X	X	X	X	X	X	X	X																												2Y	Once every two years
	Usage / Duty Cycle	High			X	X			X	X			X	X			X	X			X	X			X	X			X	X			X	X				3Y	Once every three years
		Low	X	X			X	X			X	X			X	X			X	X			X	X			X	X			X	X						4Y	Once every four years
	Environment	Harsh		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X					
		Mild	X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X						
	Health	Very Good / Good	X	X	X	X					X	X	X	X					X	X	X	X					X	X	X	X									
		Fair / Poor / Very Poor					X	X	X	X					X	X	X	X					X	X	X	X					X	X	X	X					
	Spare	In Store																																	X				
Activity No	Maintenance Tasks	Activity Ref No	Trigger (Time and/or Status)																																	Outage Y/N	Manual Y/N	Quality Criteria	
Condition Monitoring																																							
1...n	Inspection or Test Task 1...n																																						
Preventive Maintenance based on Time																																							
n...o	Maintenance Task n...o																																						
Preventive Maintenance based on Condition																																							
o...p	Maintenance Task n...o																																						
Corrective Maintenance:																																							
p...q	Maintenance Task n...o																																						
Statutory Maintenance																																							
q...r	Maintenance Task n...o																																						

Note: Excel format to be maintained.

3.4.3 Functional equipment grouping

To minimise outages, maintenance tasks for multiple assets in same bay / circuit / substation should be grouped and executed during the same outage.

This functional grouping must be completed prior to the compilation of the maintenance plan.

3.5 Manage Asset Excursions

Asset excursions should be managed as per the Process Control Manual (PCM) for Manage Asset Excursion (MN 240-45920941).

3.6 Asset health

3.6.1 Design life expectancy and failure issues

Indicate the design life of the asset and factors that can contribute to the deterioration of the life of that asset. Where possible, indicate specific ageing material and components with scenarios/conditions, which can be measured or determined, and the associated impact on the remnant life.

3.6.2 Condition assessment techniques

Specific Asset Health Indicators are to be developed, based on actual asset condition measures, age, operational history and environment. Note that these AH inspection and test activities are included as part of normal maintenance activities.

This information must be represented in tabular format as follows:

Table 4: Offline Partial discharge scoring description

Condition rating	Description
A	PD <= background noise (pC)
B	PD = One or two scattered PD signals
C	PD = Multiple scattered PD signal
D	PD= Localised PD activity at a specific location
E	PD = Localised PD activity at several locations

Where:

- ‘A’ means the component is in ‘as new’ condition (score=4);
- ‘B’ means the component has some minor problems or evidence of ageing (score=3);
- ‘C’ means the component has many minor problems or a major problem that requires attention (score=2);
- ‘D’ means the component has many problems and the potential for major failure (score=1); and
- ‘E’ means the component has completely failed or is damaged or degraded beyond repair (score=0).

Note that the Factor is simply a numeric associated with the Condition Rating for the purposes of calculating the score.

3.6.3 End of life criteria

The asset health index rating provides the end of life criteria for the asset class concerned.

The Health Index is calculated as Total Score × 100/Max. Score

Table 5: Asset health criteria

	Asset/asset health index criteria	Weight (1-4)	Condition rating	Factors	Maximum score	Score
1	Parameter A	4	A,B,C,D,E	4,3,2,1,0	16	
2	Parameter B	2	A,B,C,D,E	4,3,2,1,0	8	
3	Parameter C	1	A,B,C,D,E	4,3,2,1,0	4	
4	Parameter D	2	A,B,C,D,E	4,3,2,1,0	8	
Max. Score: 36						Total Score

Table 6: Asset health index scale

Health index	Condition	Description	Requirements
85 - 100	Very Good	Some ageing or minor deterioration of a limited number of components	Normal maintenance
70 - 85	Good	Significant deterioration of some components	Normal maintenance
50 - 70	Fair	Widespread significant deterioration or serious deterioration of specific components	Update maintenance execution strategy as per section 3.4
30 - 50	Poor	Widespread serious deterioration	Start planning process to replace or rebuild considering risk and consequences of failure
0 - 30	Very Poor	Extensive serious deterioration	At end-of-life, immediately assess risk; replace or rebuild based on assessment.

3.7 Asset Performance

Indicate how the performance of the said asset should be measured.

E.g. To determine how well power lines are performing, the following measures are used:

i. Availability, and

ii. Reliability

Availability

The availability is defined as the time that an asset is in service or is serviceable (can be put into service). Asset becomes unavailable when there is a failure that prevents it from performing the required function.

Unavailability can also be due to planned maintenance. For the purpose of monitoring the availability, power lines un-planned, un-availability and planned un-availability will be measured. The source data will be from the CMMS, for planned maintenance and from the asset performance system reports (TIPS/NEPS) for un-planned maintenance (line failures). Planed un-availability of a power line can be minimised through performing live line maintenance.

Reliability

Reliability is a measurement of the number of times a asset cannot perform its required function. In the case of power lines the measure is Faults/100km/annum.

A power line can have a high availability but yet be very unreliable due to the fact that flashovers can be extinguished by opening the line circuit breaker and automatically returning the line to service within a few 100ms. Line fault data can be obtained from the control and performance reports. Line circuit breaker trip and auto reclose times is also available from SCADA systems.

Note: Other asset classes may require additional or different performance measures such as failure rates, mean time between failures (MTBF) etc.

3.7.1 Failure causes to be recorded in performance management systems

To enable the trending of failure causes and to monitor the effectiveness of the Maintenance Engineering and Execution Strategies in preventing failures, it is required that incidents be investigated and the root cause/s of the failures be determined and captured in the appropriate systems. Standard failure causes, as identified in the FMECA, are listed below (typical transformer failure causes are shown in this example) such that these specific names can be captured in the CMMS and Performance Management System.

Note: The below list of failure causes shall be discussed with the performance custodian prior finalisation.

Table 7: Failure causes

Component	Failure mode	Root cause
1. Winding	1. Collapsed windings	External short circuit/s
		Bracing failure
	2. Inter-turn winding fault/winding insulation flash over	Surge arresters
		Lightning/switching surges
		Insulating oil
		Corrosive sulphur
	3. Paper degradation	Moisture
		Heat
		Acidity
		Oxygen

4. Authorization

This document has been seen and accepted by:

(The following table must be completed to reflect all parties that were involved in the Comments Review Process for this document. Standard Policy dictates that these are all the parties/managers/managers of divisions that are affected by the content of this document.)

Name and surname	Designation

5. Revisions

Date	Rev.	Compiler	Remarks

Date	Rev.	Compiler	Remarks
Month 20xx	X	Insert initials and surname	Specify reasons for compiling document.
Month 20xx	X	Insert initials and surname	Specify reasons for revising document. List all changes to the document, as well as authorities for these changes.

6. Development Team

The following people were involved in the development of this document:

- Insert text here

7. Acknowledgements

Insert text here.

Annex A – Maintenance analysis

A.1 FMECA worksheet (Retrospect Design)

Table A.1: FMECA worksheet

Eskom	**FMECA TEMPLATE FOR MAINTENANCE STANDARD POWER TRANSFORMERS AND REACTORS (>1MVA AND >1000V)**	Template Identifier	240-xyz
		Template Revision	1
		Document Identifier	240-69387838.
		Effective Date	1 December 2014
POWER TRANSFORMER FAILURE MODE CRITICALITY and EFFECT ANALYSIS	**September 2014**		
1. COMPONENT DESCRIPTION: CORE			

	Function of Component	**Functional Failure**	**Failure Mode**	**Failure Effect - Component**	**Failure Effect - System(transformer)**	**Root Cause**	**Probability**	**Severity ranking**	**Risk score**	**Equipment Risk Category**	**Maintenance Task**	**Outage?**	**Job Plan/File**	**Skills group**

NOTE 1: Refer to table 2 – Likelihood Criteria, in Eskom's Guide to Integrated Risk Management [2].

NOTE 2: Refer to table 1 – Consequence Criteria, in Eskom's Guide to Integrated Risk Management [2].

NOTE 3: Refer to table 3 – Risk Matrix and Table 6 Priority for Attention, in Eskom's Guide to Integrated Risk Management [2]

A.2 FMECA worksheet (New Designs)

FMEA

Ref	Function / item	Failure mode	Failure mechanism / cause	Failure effects: Local	Failure effects: Next Higher	Failure effects: End	Detection method	Compensating provisions	Outcome: Maintenance Determination / Recommendation
1.1	Pressure sensor, number XYZ	No output	Mechanical or electrical damage	No pressure input to analogue-to-digital converter of control system	Control system inhibits start-up sequence	No effect	Control system start-up test function	Visual alarm on operator console/ redundant sensor	None
1.2	Pressure sensor, number XYZ	Out of range output	Electrical damage	Out of range pressure input to analogue-to-digital converter of control system	Control system initiates shutdown sequence	Over-pressure of vessel possible	Control system continuous test function	Visual and audible alarm on operator console	
1.3	Pressure sensor, number XYZ	Inaccurate output	Electrical damage	Inaccurate pressure input to analogue-to-digital converter of control system	Incorrect control of pressure system	Over or under-pressure of vessel possible	None	None	

Criticality (Risk) Assessment

Ref	Usage, Environment and Health / Functional Importance	High / Harsh / Good: Critical	Significant	Economic	Run to failure	Low / Harsh / Good: Critical	Significant	Economic	Run to failure	High / Mild / Good: Critical	Significant	Economic	Run to failure	Low / Mild / Good: Critical	Significant	Economic	Run to failure	High / Harsh / Poor: Critical	Significant	Economic	Run to failure	Low / Harsh / Poor: Critical	Significant	Economic	Run to failure	High / Mild / Poor: Critical	Significant	Economic	Run to failure	Low / Mild / Poor: Critical	Significant	Economic	Run to failure
1.1	Probability[1]	D				C				D				B				C				B				C				A			
	Consequence[2]																																
	Risk[3]																																
1.2	Probability[1]	E				E				E				E				E				E				E				E			
	Consequence[2]																																
	Risk[3]																																
1.3	Probability[1]																																
	Consequence[2]																																
	Risk[3]																																

NOTE 4: Refer to table 2 – Likelihood Criteria, in Eskom's Guide to Integrated Risk Management [2].

NOTE 5: Refer to table 1 – Consequence Criteria, in Eskom's Guide to Integrated Risk Management [2].

NOTE 6: Refer to table 3 – Risk Matrix and Table 6 Priority for Attention, in Eskom's Guide to Integrated Risk Management [2].

Annex B – Maintenance Activity Table

B1: Maintenance Activities Table (Retrospect Design)

Activiy No (FMECA Ref No)	**Maintenance Activities**	**Risk Score (as per**	**Trigger** (e.g. time, nr of ops)	**Skills level / Lead Craft**	**Outage required Y/N**	**Task Manual required Y/N**	**Limits / Quality criteria** (Where applicable)	**Maintenance Task**	**Task No**
Condition Monitoring (onsite / remote Inspections and tests)									**1**
1.1.1	Inspect main tank for leaks	IV	Time	CNC / CNL	N	N	No oil leak	Inspection or Test Task 1…n	1.1
1.1.2	Contact Wear measurment	II	Time	CNC / CNL	N	N	Refer to Annex C for make & type depended limits		
1.1.3									
1.2.1	Earth matt resistance test	III	Time	PPM	N	Y	Less than xxx Ohms	Earth matt resistance test	1.2
1.2.3									
1.2.4									
Preventive Maintenance based on Time (Scheduled Restoration)									**2**
								Maintenance Activity n…o	**2.1**
Preventive Maintenance based on Condition (Prompted by condition monitoring results outside limits / quality criteria)									**3**
								Maintenance Activity n…o	**3.1**
Corrective Maintenance (after asset / component failure):									**4**
								Maintenance Activity n…o	4.1
Statutory Maintenance (based statutory requirements / regulations)									**5**
								Maintenance	5.1

								Activity n…o	

B2: Maintenance Activities Table (New Design)

Equipment Class:		xxx																																					
Equipment Sub Class:		yyy																																					
Equipment Sub Class Family:		zzz																																					
Trigger Modifiers		**Permutations**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33			**Key**	
	Functional Importance	Critical																									X	X	X	X	X	X	X	X				1M	One monthly
		Significant																	X	X	X	X	X	X	X	X												6M	Once every six months
		Economic									X	X	X	X	X	X	X	X																				1Y	Once every year
		Run to fail	X	X	X	X	X	X	X	X																												2Y	Once every two years
	Usage / Duty Cycle	High			X	X			X	X			X	X			X	X			X	X			X	X			X	X			X	X				3Y	Once every three years
		Low	X	X			X	X			X	X			X	X			X	X			X	X			X	X			X	X						4Y	Once every four years
	Environment	Harsh		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X					
		Mild	X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X							
	Health	Very Good / Good	X	X	X	X					X	X	X	X					X	X	X	X					X	X	X	X									
		Fair / Poor / Very Poor					X	X	X	X					X	X	X	X					X	X	X	X					X	X	X	X					
	Spare	In Store																																X				
Activity No	**Maintenance Activities**	**FMECA Ref No**	**Trigger (Time and/or Status)**																																	**Outage Y/N**	**Manual Y/N**	**Quality Criteria**	
Condition Monitoring																																							
1…n	Inspection or Test Activity 1…n																																						
Preventive Maintenance based on Time																																							
n…o	Maintenance Activity n…o																																						
Preventive Maintenance based on Condition																																							
o…p	Maintenance Activity n…o																																						
Corrective Maintenance:																																							
p…q	Maintenance Activity n…o																																						
Statutory Maintenance																																							
q…r	Maintenance Activity n…o																																						

Annex C – Maintenance Activity Limits (Task List)

For the implementation of the MES, the specific tasks naming, measuring fields description, field requirements and limits requirements need to be defined. See the attached xl file ans an example. This task list will be loaded on the CMMS to ensure standardisation throughout Eskom.

Transformers Task List Package 06 June