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1. INTRODUCTION

Condition on balance of plant in Eskom power stations is monitored manually and periodically with hand held (portable) instruments. The reason for using portable instruments is that the equipment being monitored does not have online sensors on all the components that need to be monitored.

This manual describes the context and process for hand held condition monitoring at Eskom power stations, and defines the service, service management and quality framework required to carry out effective hand held condition monitoring. Service sourcing matters are also covered together with technical requirements for the assoicated technology. It must be used to conduct and manage condition monitoring on balance of plant, i.e. all equipment in auxiliary plant, and plant auxiliary equipment.

2. SUPPORTING CLAUSES

2.1 SCOPE

2.1.1 Purpose

This document is used to guide the execution of Hand Held condition monitoring at Eskom coal and nuclear power stations. Hand held condition monitoring covers anomalies related to bearings, shafts, impellers, foundations and footings, electrical panels and junction boxes, transformer cooling system components, and conveyor belt idlers.

2.1.2 Applicability

This document shall apply to Generation coal fired and nuclear power stations, in particular the following departments:

a) Systems Engineering
b) Performance and Testing
c) Maintenance
d) Work Management

The equipment targeted by this manual is equipment monitored using portable instruments.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs. The following document(s) contain(s) provisions that, through reference in the text, constitute requirements of this document. At the time of publication, the edition(s) indicated were (was) valid. These documents are subject to revision and users are responsible to ensure that the most recent edition(s) of the document(s) listed below are used / referenced.

2.2.1 Normative

[1] The related PCM is “Optimise Operational Asset Performance” - 240-45921037

[2] Eskom Standard 36 -1095: "Vibration-Based Condition Monitoring of Rotating Auxiliary Plant"

[3] Eskom 36 - 511 Infrared Thermography Standard

[4] Eskom 36 - 53 In-Service Monitoring of lubricating oils and hydraulic fluids

2.2.2 Informative

[5] Eskom Standard GGL 36 - 53 "In-Service Monitoring of lubricating oils and hydraulic fluids"

[6] ROUTINE WORK MANAGEMENT MANUAL - GGM1490.

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2.3 DEFINITIONS

Definition	Description
Balance of Plant equipment	Equipment in auxiliary plant, and plant auxiliary equipment in a power station
Vibration	The physical phenomenon present in a rotating or reciprocating machine
Thermography	Use of infrared thermal imaging with an IR camera

2.3.1 Disclosure Classification

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

2.4 ABBREVIATIONS

Abbreviation	Description
CM	Condition Monitoring
CMMS	Computerised maintenance management system
Pdm, check 13 4.1.12	

2.5 ROLES AND RESPONSIBILITIES

Engineering and Maintenance sections need to ensure that this document is followed.

2.6 PROCESS FOR MONITORING

This document needs to be updated when there are changes in procedures relating to hand held condition monitoring.

2.7 RELATED/SUPPORTING DOCUMENTS

a) Definition of Requirements for Tools and Software for Hand Held Condition Monitoring
b) Condition Monitoring process as described in ISO 17359
c) Diagnosis and prognosis standards ISO 13381 Part 1 and ISO 13379.
d) Standard ISO 18434: 2008 Part 1.
e) Eskom manual ROUTINE WORK MANAGEMENT MANUAL - GGM1490.

3. CONDITION MONITORING

3.1 OVERVIEW

Keeping equipment in a condition close to their designed or required operating state requires periodic determination of their conditions and taking necessary remedial actions. The process of determining the conditions is commonly referred to as condition monitoring. Condition monitoring is a form of predictive maintenance (PdM**)**. Hence the purpose of condition monitoring is to keep machines in good health so that the machines do not breakdown unexpectedly. Condition monitoring is a key input to maintenance planning.

Condition Monitoring of each equipment takes place as specified in the equipment's maintenance plan. The maintenance plan specifies what failure modes are to be monitored, and frequency of monitoring. Hence equipment's maintenance basis drives the equipment's condition monitoring schedule. Condition assessments may uncover faults or non-conformities. Faults or non-conformities need to be corrected. The specified remedial work is managed by the maintenance management system (CMMS) SAP.

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Testing and quality assurance of corrective work is a part of the work execution phase.

The techniques measure equipment operating characteristics such as vibration, temperature, lubrication, etc. These characteristics can be interpreted to indicate the presence of problems within the machine. Condition monitoring techniques that are currently accepted and used at Eskom include:

a) Vibration Measurement and Analysis
b) Thermal Imaging (Infrared Thermography)
c) Oil Analysis
d) Ultrasonics
e) Motor current and voltage Analysis
f) Wear debris monitoring
g) Corrosion/erosion
h) Temperature
i) Visual/ wear/physical

Other techniques such as machine performance monitoring and statistical process monitoring are not included in Hand Held Condition Monitoring. Condition Monitoring is expected to provide information that can be used to make decisions about plant operations, health, and maintenance.

3.2 CONTEXT FOR CONDITION MONITORING

Condition Monitoring plays a role in Condition based maintenance, reliability, health, performance, and life of plant. Condition monitoring is applied to determine condition of plant and hence specify and carry out required maintenance. Condition monitoring is expected to:

a) Improve equipment reliability through effective prediction and prevention of equipment failures.
b) Identify and avoid conditions that reduce equipment life (e.g. misalignment, lubricant contamination, etc.), thereby improving or optimising equipment performance, reliability and life.

Condition monitoring provides information that will be used to:

c) Determine if time based maintenance or outage can be delayed or should be brought forward
d) Determine the duration of an outage more precisely.
e) Determine the areas focus areas and work requirements for an outage.
f) Determining the spares and material likely to be required during the outage.

An effective condition monitoring program does not translate into zero downtime or machinery failures, but it will reduce unforeseen problems and contribute to improved reliability.

Condition monitoring relates to other functions such as maintenance, work management, engineering, operating, and planning, that are also involved in maintaining plant health. Figure 1 shows the closely related processes in an ideal context.

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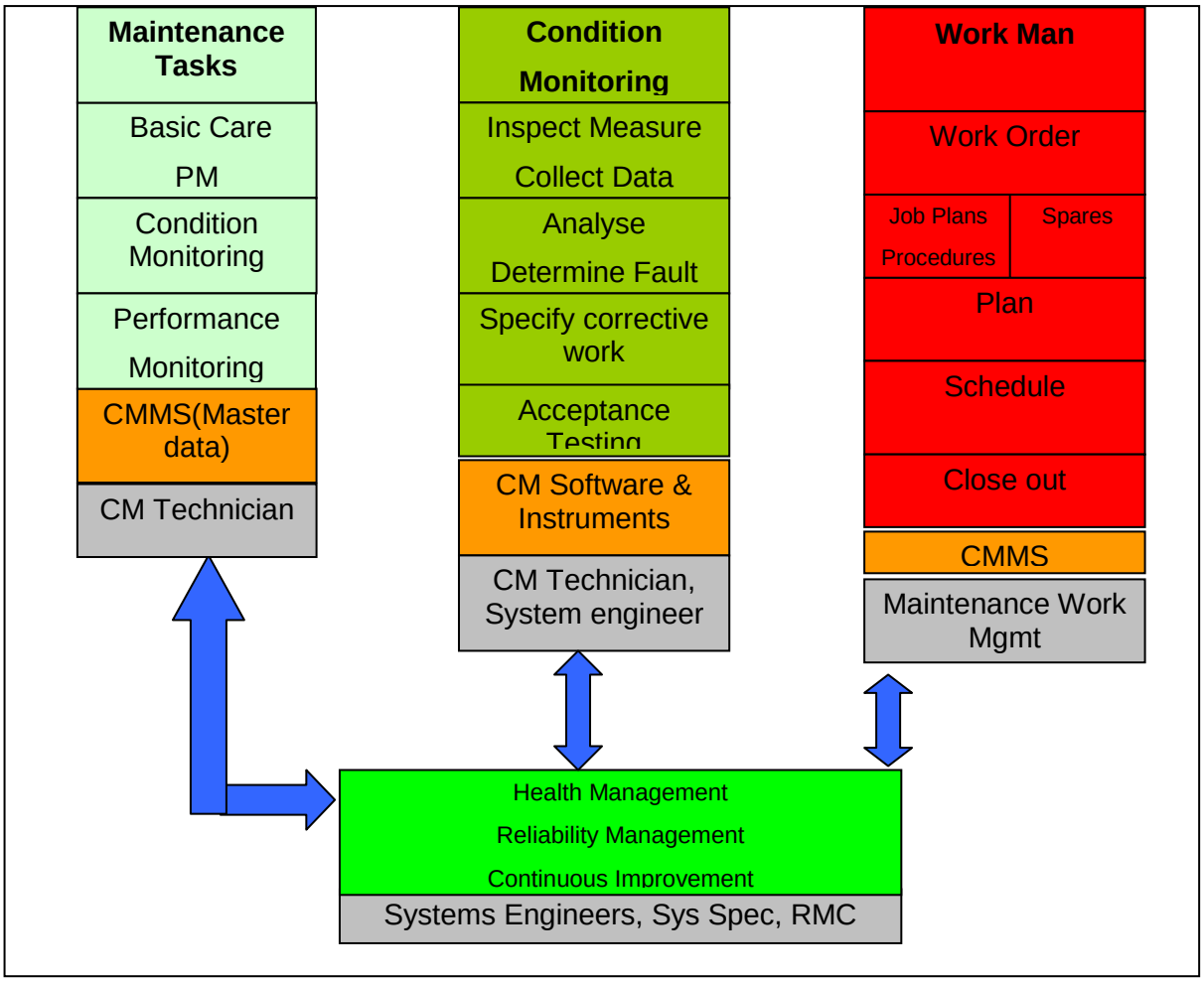

Figure 3-1: Context for condition monitoring

Each equipment's condition monitoring tasks as specified in the maintenance plan are scheduled in the CMMS (SAP). The condition monitoring technician will access and execute these tasks according to the specified schedule. Prognosis of any non-conformity, fault, or impending failure determines any corrective action. If corrective actions require repairs to the equipment, work orders will have to be created in the Work Management system (SAP). Corrective work emanating from condition monitoring will enter the work management process and therefore will need to be specified in accordance with the work management specifications. The equipment should be re-assessed against its baseline signature or a new baseline signature established before the equipment is returned to service. Equipment health is largely indicated by age, condition and conformance to design and operating specifications. Condition data and reports must be available to equipment health process. Condition monitoring aims for early detection of problems and hence positively impacts reliability. All processes and functions should be monitored and assessed periodically to determine need and potential for improvements. The condition monitoring process generates such required data which must be made accessible for analysis.

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3.3 FUNCTIONS OF CONDITION MONITORING

The condition monitoring function is responsible for the following:

a) Determine the condition of all targeted equipment
b) Report the condition monitoring results to the plant owner and all other stake holders
c) Advise on maintenance actions based on the condition results
d) Inform stakeholders of any major developments affecting production, safety, or environment
e) Co-ordinate the total station Condition Monitoring function
f) Keep in touch with Condition Monitoring developments both within and outside of Eskom

3.4 CONDITION MONITORING PROCESS

The general steps in condition monitoring are stated here as introduction and discussed in detail in sections that follow. The steps are:

a) Plan
b) Measure
c) Analyse
d) Diagonisis and prognosis
e) Report
f) Recommend
g) Acceptance testing
h) Record all data and transactions in a database.

Measurements are taken or data collected. The data is also analysed and compared with limits to identify the presence of any faults. The operating purpose, limits and design are considered to determine and specify the required corrective work. After the work is done quality assurance testing is conducted to determine successful clearing of the fault conditions that required correction and to confirm or re-establish a baseline.

3.5 PLANT COVERED

The equipment targeted by this manual is the rotating equipment at a power station that is not on the centre line. This equipment is monitored using portable instruments.

3.6 APPROACH TO SERVICE PROVISION

At Generation, condition monitoring is outsourced. This started when Rotek was formed and all condition monitoring resources were transferred to Rotek. Over time power stations employed other service providers. National Engineering contracts are used to enforce the terms and conditions of service provision.

3.7 STAKEHOLDER PERSPECTIVES

Each group of stakeholders are discussed in terms of roles, the subject matter that relates them to condition monitoring, how they interface with Condition Monitoring, what information and data they require. Both process execution and management requirements are covered. An ideal situation is present together with the as is.

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3.7.1 Performance and Test

The performance and test department is usually responsible to provide a condition monitoring service which may be outsourced. The service provider (Eskom staff or Contractors) will plan, execute and report to system engineers on equipment condition. In cases where the service is outsourced, a services coordinator will form an interface between Eskom and the service provider.

3.7.2 System Engineers

System Engineers are also responsible for plant and equipment health, behaviour, costs, work history, components replaced, etc. They are keys receivers of the conditions, faults, and recommendations for remedial actions from condition monitoring.

The results of condition monitoring (present and history) together with other asset data are used to guide decisions on work to be undertaken on equipment, e.g. repairs, adjustments, modifications, overhaul, refurbishment, replacement, etc. Therefore systems engineers and other stake holders should have the means to:

a) Access all this information from their computers.
b) Run queries, analysis, and scenario simulation.
c) Stipulate and authorise remedial work.

Presently condition reports and recommendations are presented to engineers and further information is only available on request. System engineers should avail maintenance plans for each piece of equipment. The plan must specify the following parameters for each piece of equipment whose condition needs to be monitored:

a) the failure modes
b) monitoring technique for each failure mode
c) frequency at which monitoring must take place for each failure mode.

Data that is required for plant life and reliability management from condition monitoring and visual inspections must be captured during the condition monitoring process.

3.7.3 Work Management

The objective of work management is “to ensure that all work is properly identified, planned, scheduled, assigned, executed and completed in pursuit of the work management objectives”, as described in “ROUTINE WORK MANAGEMENT MANUAL”, GGM1490.

Condition monitoring identifies work needed to remedy problems on equipment. Hence the condition monitoring process provides input to the work management process and the input needs to be specified as required by the work management process. The priority of the work requests must be stipulated so that the work can be handled appropriately in the work management process.

At present remedial work is identified by the service provider. If the work is urgent (has a high priority), the service provider raises the notification on the Work Management System but should be authorised by the system engineer.

3.7.4 Maintenance Staff

Maintenance staff conducts all required work on the equipment that is monitored. The work could be scheduled maintenance, corrective work, or breakdown repair. Corrective maintenance work is also

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specified from the results of condition monitoring and is thus a receiver of the output of condition monitoring.

3.7.5 Corporate consultant condition monitoring

The Corporate Consultant requires condition monitoring to be approached with consistency at all stations. This manual attempts to develop a framework for service consistency and data availability.

3.7.6 Group Technology

A goal is to develop, support and assure continuous improvement of processes and technology. Proper application of hand held condition monitoring is a technology best practice that adds value in fields of plant reliability, availability, efficiency and maintainability.

3.7.7 Information Management (IM) perspective

Condition monitoring uses computer tools. Condition monitoring tools should meet architectural requirements as specified in the various IM requirements.

3.7.8 Condition monitoring service provider

The service provider undertakes the following tasks for the equipment set out in a contract:

a) determines and reports conditions and faults, and
b) recommends corrective actions

The service provider is currently considered the expert on the equipment that they monitor and therefore:

a) advises the System Engineer
b) initiates urgent corrective actions
c) follow up remedial work
d) quality assures the remedial work.

The service provider requires several documents from Eskom to execute their tasks in accordance with Eskom's quality requirements. Some of these requirements are:

a) A service level agreement
b) Database/list of equipment stating equipment criticality, failure modes to be monitored, techniques required, and frequency of monitoring
c) Standards for taking measurements
d) Standards for reporting results
e) Standards for data availability and interfacing
f) Quality monitoring, control, and assessment plan
g) Standard key performance indicators and current targets.

3.8 BUSINESS PERSPECTIVE

Contracts are unique to each station and should be comprehensive in terms of defining the service, levels of service and ensuring service quality. It is necessary to monitor that condition monitoring is taking place according to stipulated schedules and quality requirements.

3.8.1 Ownership

The importance of linking the service to the most appropriate department relates to the service being provided at the required quality, being allocated appropriate budget and priority, and being able to engage service provider and service recipients. Since Engineering (system Engineers) specifies required

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maintenance and receives the condition monitoring results, it appears most appropriate to link the service to Engineering.

3.8.2 Goals, KPI's and targets

Condition monitoring must support reliability, maintenance and performance goals. Appropriate KPI's and targets need to be set, measured, monitored and action taken to achieve the goals. This is discussed further in the Section Quality framework.

4. STANDARD CONDITION MONITORING PROCESS

The required condition process shown Figure 4.1 is derived ISO 17359. The process involves planning, condition measurements, condition assessment (analyse), fault diagnosis, recommendations for fault correction, and acceptance testing (quality assurance) after remedial work is performed.

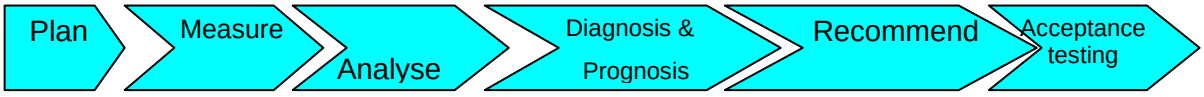

Figure 4-1: Condition Monitoring Process

4.1 PLAN

This requires compiling a master database of equipment that need monitoring, and setting up routes that provide a practical work sequence. The schedule for monitoring is sourced from the CMMS (SAP). The database must be updated when changes occur.

4.1.1 Equipment master database

The equipment master database must hold the following categories of data:

a) Identity and specifications
b) Function and Operating conditions
c) Measurement parameters
d) Measurement points
e) Alarm thresholds
f) Measurements history.

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The minimum data fields for each category are described in tables that follow.

4.1.1.1 Identity and specifications

Table 4-1: Equipment identity data fields (minimum)

Item	Description	Example
Equipment ID	(SAP No.)	3894834AZ
Description	Simple but descriptive as possible name	Motor1
Serial No.	Serial no. as assigned by manufacturer	735356222EX
Manufacturer	Name of Manufacturer	GEC
Model	Model no. as assigned by manufacturer	XR6
Voltage	Specified Operating voltage rating	380
Power	Specified operating power rating	3KW
Current	Specified operating current rating	15A
Rotating speed	Specified operating speed rating or speed range	4500 RPM
+ key technical specifications as related to type of equipment motor, gearbox, fan, etc.	Parameters that describe each type of equipment.	For motor: coupling type, etc. For Fan: blow rate, etc. For gearbox: no. of gears, etc.

4.1.1.2 Function and operating conditions

Minimum data to describe equipment functions and operating conditions are shown in Table 4.2.

Table 4-2: Equipment function and operating data fields

Item: Motor1	
Function: Description function in plant	Drive for slurry pump1
Criticality: Designated criticality	Critical
Physical location: The physical location in the plant to assist in finding and identifying the equipment	Behind pump house at waste water works.
Plant codification number (KKS or AKZ)	389283293828
Operating Conditions: Temperature, pressure, speed, etc.	Normal speed 36000 rpm

4.1.1.3 Measurement parameters, locations and characteristics

For each failure mode: set the parameters to be measured, condition monitoring technique to be used, and periodicity of measurements. Table 4.3 illustrates an example. The parameters are extracted from the applicable Eskom standards:

- Eskom 36 - 1095 for vibration
- Eskom 36 - 53 for oil and lubricating fluids
- Eskom standards may point to external standards.

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Table 4-3: Example of Measurement techniques, locations, parameters, orientation and alarms

Technique	Location	Orientation	Parameter
Vibration	DE	Horizontal	Overall
		Horizontal	Spectral
		Horizontal	narrow band
		Vertical	Overall
		Vertical	Spectral
		Vertical	narrow band
		Axial	Overall
		Axial	Spectral
		Axial	narrow band
	non DE	Horizontal	Overall
		Horizontal	Spectral
		Horizontal	narrow band
		Vertical	Overall
		Vertical	Spectral
		Vertical	narrow band
		Axial	Overall
		Axial	Spectral
		Axial	Narrow band
Thermography – IR	Electrical connections	Horizontal	Temperatures
	Rotor & stator	Horizontal	Temperature

4.1.1.4 Measurement parameters for oil samples

For each failure mode set the parameters to be measured, condition monitoring technique to be used, and periodicity of measurements. Table 4.4 lists the parameters. The parameters are extracted from the applicable Eskom standards:

- Eskom 36 – 53
- Eskom standards may point to external standards.

Table 4-4: Measurement parameters for oil samples

Parameter
1. Appearance and smell (odour);
2. Particle Quantification (PQ);
3. Cleanliness
4. Total acid number (TAN) -ASTM D974
5. Total base number -(ASTM D974, ASTM 2896, ASTM D 664).
6. Viscosity -(ASTM D445).
7. Crackle test for free water.

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8. Water content -(ASTM D1533-Karl Fischer Reaction Method).
9. Water Content -(ASTMD1744-Karl Fischer Reagent).
10. Demulsibility and water separability (IP 19, ASTM D1401, ASTM D 2711).
11. Wear debris analysis (WDA) or Ferrography.
12. Additive content and wear metals -(ASTM D5185-ICP) or FTIR or RDE (ASTM D6595);
13. Rust inhibitor -(ASTM D665).
14. Flash point -(ASTM D92-Cleveland open cup, ASTM D93-Pensky-Martens closed cup).
15. Volume resistivity -(ASTM D1169 -Fire resistant fluids (FRFs only)).
16. Density -(ASTM D1298 (FRFs)).
17. Air release value -(ASTM D3427).
18. Foaming characteristics -(ASTM D892).
19. Insolubles, pentane and toluene -(ASTM D893 procedures A and B, ASTM D4055).
20. Oxidation stability -(ASTM D2272 (RBOT)).
21. Blotter Spot test for soot and remaining oil dispersency.

4.1.2 Set up routes

Initially the work needs to be arranged into suitable routes taking into account location of equipment, measurement that need to be taken, etc. , for convenience and to fit in with operating schedules. These routs can be modified as and when necessary.

4.1.3 Establish base line signatures

In cases where base line signatures do not exist, they need to be initially established and recorded in the database.

4.1.4 Re-establish/confirm baselines

In cases where operating conditions changed, new, repaired, or reconditioned equipment is brought into service, baseline signatures need to be confirmed or re-established.

4.2 MEASURE

When condition measurements are taken, the equipment must be operating under normal conditions. e.g. load and speed. Measuring instruments may be connected to equipment via required sensors. In the case of thermography, infra-red images are taken with a camera and there is no connection or attachment required. In the case of lubrication measurements, fluid samples are extracted from the equipment. Measurement parameters for each technique are indicated in Table 4.3 and Table 4.4. Type of measurements are summarised in Table 4.5.

Table 4-5: Summary of types of data to be collected

Technique	Type of data to be collected	
Vibration	Trends and spectrums overall, spectral bands and narrow bands	Per measurement point
Thermography	Images	specified orientation
oil analysis	oil samples	Number of samples specified

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4.2.1 Store data and accumulate history

Measurement data for each assessment are stored in the database, linked to the relevant equipment and appended to the equipment's previous record. Measurements results must be stored for both equipment with no non-conformances and equipment with non-conformances. The measurements history must accumulate over the life of the equipment.

4.3 ANALYSE - DETERMINE CONDITION OF EQUIPMENT

Condition monitoring data must be assessed to determine a diagnosis and severity. If no fault is detected the results must still be reported. If any uncertainty is detected further special diagnostic may be required to determine root cause. A prognosis must be made of how any non-conformance is likely to impact machine condition, operations, safety and the environment as may be relevant. Analysis methods per technique consistent with Eskom standards (36-53 and 36-1095), are recommended in Table 4.6. Use of equivalent or more accurate analysis techniques can be negotiated.

Table 4-6: Recommended analysis methods based on Eskom standards

Technique	Recommended Analysis methods
Vibration	As per Eskom standard 36-1095 1 Time Waveform analysis 2 High & low frequency envelope analysis
Oil analysis	As per standard Eskom 36-53 1. Appearance and smell (odour); 2. Particle Quantification (PQ); 3. Cleanliness -(ISO 4406: 1999). 4. Total acid number (TAN) -ASTM D974. 5. Total base number -(ASTM D974, ASTM 2896, ASTM D 664). 6. Viscosity -(ASTM D445). 7. Crackle test for free water. 8. Water content -(ASTM D1533-Karl Fischer Reaction Method). 9. Water Content -(ASTMD1744-Karl Fischer Reagent). 10. Demulsibility and water separability (IP 19, ASTM D1401, ASTM D 2711). 11. Wear debris analysis (WDA) or Ferrography. 12. Additive content and wear metals -(ASTM D5185-ICP) or FTIR or RDE (ASTM D6595); 13. Rust inhibitor -(ASTM D665). 14. Flash point -(ASTM D92-Cleveland open cup, ASTM D93-Pensky-Martens closed cup). 15. Volume resistivity -(ASTM D1169 -Fire resistant fluids (FRFs only)). 16. Density -(ASTM D1298 (FRFs)). 17. Air release value -(ASTM D3427). 18. Foaming characteristics -(ASTM D892). 19. Insolubles, pentane and toluene -(ASTM D893 procedures A and B, ASTM D4055). 20. Oxidation stability -(ASTM D2272 (RBOT)). 21. Blotter Spot test for soot and remaining oil dispersency.
Thermography	Eskom 36 - 511 Infrared Thermography Standard

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4.4 DIAGNOSIS AND PROGNOSIS (ISO 13381 PART 1, ISO 13379)

Any alarm or failed condition must be analysed to diagnose any fault. After determination of the fault the route to failure must be determined. If more than one set of measurements were taken either with the same or different condition monitoring techniques, the faults must be combined and addressed holistically to give a consolidated view of the condition, diagnosis and prognosis.

4.5 RECOMMEND CORRECTIVE ACTION

A recommendation has to be made for every fault detected. The recommendation will indicate the actions required to correct or further monitor the fault as well as their urgency for action, e.g. immediate, within 1 month, etc.

4.6 REPORT

Each piece of equipment monitored must have a report after each monitoring event. Further details on reporting is given is Section 5.5.1.

4.7 COMMUNICATE RESULTS

The results of each condition monitoring event must be communicated to all stake holders. The relevant stake holder groups and their interests are given in Table 4.7

Table 4-7: Condition monitoring groups and their interests

Stake holder group	Interest
Performance and Test department	Ensure service provision (source and manage the service). In some cases the maintenance department performs this role.
System Engineers	Are responsible for plant health
Maintenance department	Are responsible for carrying out required repairs. In some cases the maintenance department also ensures service provision of condition monitoring.
Work management department	Are responsible to plan and schedule work arising from condition monitoring.
Services Coordinator	Handles all contract and operational administrative matters

4.8 ACCEPTANCE TESTING

After corrective work is done on equipment the equipment must undergo acceptance tests. These tests ensure that that equipment operates to design, manufacturer or operating specifications. The results may be used as a new baseline depending on the corrective work done.

5. SERVICE DEFINITION AND MANAGEMENT

Condition monitoring services are sourced from Condition monitoring service providers. This section:

a) Describes the services and the levels of service required, and provides
b) Understanding of the service being outsourced
c) How the service fits into operations, and
d) How the service fits into business.

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5.1 CONDITION MONITORING – SERVICE DEFINITION

Condition monitoring is to determine and report the condition of equipment as per equipment condition monitoring schedule, and provide the Condition monitoring data for the purposes of equipment health, performance monitoring, and maintenance planning.

5.2 EQUIPMENT SCOPE

In this case, the rotating equipment that forms the balance of plant at the as specified in the RBO Manual is covered. Plant on the centre line is excluded.

5.3 SERVICE RECIPIENTS

Condition monitoring is an engineering service. Managing health of equipment is best done by an engineer. The engineer would need to determine the condition of equipment and take necessary actions to keep the plant in a state of health commiserate with production requirements. Hence the requestor and receiver of Condition Monitoring service is the engineer responsible for plant health. Planning and scheduling all the work required on plant is a task for maintenance planning.

In the case of service provision by outsourced service providers, a Services coordinator or Contract supervisor should be the link for all contractual and administrative matters.

5.4 SCOPE OF SERVICES

The scope is described in terms of the failure modes that must be assessed, the procedures to be executed to deliver the data and reports, and provision of tools.

5.4.1 Failure modes and mechanisms

Condition Monitoring is required to address the following typical failure modes and mechanisms using any combination of Condition Monitoring techniques:

5.4.1.1 Failure Modes

a) Imbalance
b) Misalignment
c) Power inefficiency

5.4.1.2 Failure mechanisms/causes

a) Bearings
b) Footings
c) Belt tension
d) Lubrication
e) Electrical Insulation
f) Electrical connections

5.5 DELIVERABLES

The condition monitoring service delivers reports and data.

5.5.1 Reports

There are two categories of reports.

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5.5.1.1 Work administration reports

These reports indicate adherence to the scope of work summarising equipment categories and overall conditions of each piece of equipment. It will indicate:

a) which equipment was due for monitoring,
b) which equipment was checked, and
c) the condition status of each piece of equipment, i.e. conforming or non-confirming.

5.5.1.2 Equipment Condition reports

Each system engineer of each plant area is to receive reports on the condition, diagnosis, prognosis, and recommendations for every piece of equipment monitored in the relevant plant area. The reports need to be also summarised with relevant supporting data available on request.

5.5.2 Data

All condition data for the reporting period must be in Excel or CSV format and handed over to the Services co-ordinator. It must also be possible to download the entire condition monitoring data base when required.

5.6 SERVICE QUALITY

The processes that produce acceptable condition monitoring service need to be controlled such that they are executed as intended. The Condition Monitoring service needs to be provided by people with the right skills using appropriate technology, and according to accepted standards as specified in the Quality Framework of Section 6.

5.7 DOCUMENTATION

The service provider must have a quality system, supporting documentation and records that ensures the effective planning, operation and control of its processes and this should align with Eskom's quality framework.

5.8 TECHNOLOGY

The following conditions apply:

a) The service provider provides their own software, hardware and measuring devices as per requirements in Appendix A.
b) All electronic data must be recoverable at least to the last executed schedule.

5.9 CONTRACTUAL AGREEMENTS

The contract will be based on the NEC contracts as implemented by Eskom Procurement with an accompanying Service Level agreement titled SLA for hand held condition monitoring.

5.10 SERVICE MANAGEMENT

The following applies where the condition monitoring service is outsourced.

5.10.1 Service acquisition

A suitable service provider must be contracted via an open tender process. There must be an invitation to tender/submit proposals. The responses must be evaluated against set criteria to reveal the most suitable vendor.

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The vendor's quality system is important for a reliable and professional service. The following requirements apply.

a) Vendor must be Quality accredited by an accredited body, e.g. ISO, BSS
b) Instruments must hold valid calibration certificates.
c) All staff working on site must be certified to the level required to do their tasks.
d) Staff competency profile must include and match qualifications, experience and customer requirements.
e) Competencies for testing, monitoring, and evaluation using common techniques must be present in the vendors staff working on site.
f) It should be made clear in the contract that all data that identifies equipment and their conditions remains the property of Eskom at all times. This includes all data collected by the service provider.

5.10.2 Contract management

The contract should be co-coordinated from a single point. A service co-coordinator or contract supervisor should be the interface between Eskom and service provider, handling all contract service issues as well as administration issues such as quality of service invoicing, payments, etc.

5.11 PROCESS INTERFACING

The Condition Monitoring process interfaces with Work Management, Maintenance, and Engineering through the service co-coordinator. Interfacing should accomplish the following

5.11.1 Service co-coordinator

The service coordinator handles:

a) all contract administration matters
b) tracks service provider work administration
c) tracks service provider performance

5.11.2 Systems Engineers

The service provider is to supply all reports on a plant area to the relevant system engineer. The service provider must provide all conditions, diagnosis, prognosis, and recommendation to system engineers as required.

5.11.3 Maintenance

The service provider must explain all conditions, diagnosis, prognosis, and recommendation with maintenance staff as required.

5.11.4 Work Management

The service provider must raise urgent conditions immediately in consultation with System Engineer and maintenance in order to take corrective work.

5.12 GOALS, KPI'S & TARGETS

It is necessary to track the condition monitoring service, its effectiveness and economic benefits. The relevant indicators and targets are discussed here. It is intended that these indicators will encourage exchange of ideas between operators, maintenance, engineering, and the condition monitoring personnel.

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5.12.1 Service is operating properly

The following indicators must be tracked to monitor that the service is operating as planned.

a) Service provider is doing his scope of work, on- time, and according to Quality framework as described in Section 6.
b) Report against scope of work and equipment monitoring schedule
c) Periodic and adhoc assessments should be conducted on Service provider
d) Engineers and maintenance staff can raise and resolve matters with service provider.
e) Send all complaints to Service co-coordinator
f) Each report must contain names and qualifications of the analysts that took measurements and made recommendations. The instruments used must also be stated on the report.

5.12.2 Deliverables are delivered

Reports are to be delivered to all stakeholder at minimum in abnormal cases System Engineers and service coordinator.

5.12.3 Performance of service provider

The following indicators should be monitored to track service effectiveness.

a) Number of correct predictions,
b) Number of incorrect predictions
c) Number of repeat faults
d) Number of unplanned work orders arising out of issues that should be revealed by condition monitoring.

The situation should be discussed with the service provider and action should be taken to improve as necessary.

5.12.4 Condition monitoring effectiveness

a) Failed parts and root causes of the failures must be tracked.
b) The means of preventing such failures or prolonging component life must also be noted and tracked.
c) The number of unnecessary, intrusive maintenance tasks
d) The number of PM's that are revised or eliminated by Condition Monitoring techniques.
e) Mean Time Between Failures (MTBF).
f) Mean Time to failure
g) Total hours worked on emergency jobs to be measured as a percentage of total hours worked.

5.12.5 Identify areas for improvement

Work orders should be analysed to determine recurring failures or tasks. This information would direct improvement efforts to required areas.

5.13 EMPLOYER RESPONSIBILITIES

The employer has responsibilities to support the service provider and allow them to deliver the expected services. The responsibilities are summarised here.

a) Provide office space and furniture for service provider.
b) Access to the computer network for service providers computers.

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c) Provide a system engineer for each plant area, to liaise with Condition Monitoring service provider.
d) Documents as listed in Quality framework, e.g. Maintenance basis, measurements locations for each machine, alarm levels, etc.
e) Map of physical plant layout and location of each equipment.
f) Equipment clearly identified and its location in the plant.

6. QUALITY FRAMEWORK

Quality is about doing the right things right. The processes that produce acceptable condition monitoring service need to be controlled such that they are executed as intended. The quality system is indicated by suitable policies, guidelines, standards and procedures. Quality control is taking measures to ensure quality. Quality assurance is the verification that QC has taken place. The system of controlling the process is the quality management system and consists mainly of process and technology standards, and contractual agreements. This section describes a framework within which the required levels of quality may be attained.

The quality system is comprised of the documents describing the system, process execution, specifications, and standards that apply. The intention of the quality system is to ensure process effectiveness and avoid non-conformities. Since the situation is under constant pressure to keep up to date, provision for process modification and improvement is needed.

The purpose and drivers for quality are described in the quality policy and objectives.

6.1 QUALITY POLICY

a) Provider must be certified
b) All work to be quality assured before return to service

6.2 QUALITY OBJECTIVES

The quality program should achieve the following objectives:

a) Consistent measurements, analysis, and recommendations
b) Corrective recommendations matching maintenance findings
c) Prevention and elimination of non-conformances
d) Deveop to maturity what exists
e) Continuoulsy improve.

Actions to attain the quality objectives are described below. The actions are supported by relevant documentation that integral to the standard condition monitoring process. The first two quality objectives are met by measuring process efficiency and effectiveness.

6.3 TRACK PROCESS EFFECTIVENESS

Measurements need to be in place to monitor that the process achieves the following:

a) Consistent measurements
b) Accurate analysis and diagnosis
c) Recommend corrective actions that actually fix problems

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Work execution should be measured in terms of:

a) Executing the entire schedule in time
b) Reports should accurately reflect the work done.

Service effectiveness will be initially indicated by a decrease in emergency repairs and unexpected equipment failure.

6.4 PREVENTION AND ELIMINATION OF NON-CONFORMITIES

Preventing and eliminating non-conformances are discussed. Quality aspects that are instrumental in prevention of non-conformities are listed below

a) Equipment must be identified correctly and tags must be readable.
b) Tools are to be calibrated as per manufacturers' specifications.
c) Use of the correct skills levels
d) Use of correct repair procedures

Eliminating causes of non-conformities are done by having a procedure in place to raise issues, determine corrective actions and follow through on corrective actions.

6.5 STANDARDS FOR PROCESS EXECUTION

The required condition process is based on ISO 17359. The process involves planning, condition measurements, condition assessment, fault diagnosis, fault correction recommendations, and quality assuring corrective work.

Figure 6-1: Condition Monitoring Process

6.5.1 Taking condition measurements

Portable measuring devices are to be used on equipment listed in the scope of work. The following Eskom Standards apply:

a) Vibration measurements are to comply with Eskom Standard 36 -1095: "Vibration-Based Condition Monitoring of Rotating Auxiliary Plant"
b) Oil measurements are to comply with Eskom Standard GGL 36 - 53 "In-Service Monitoring of lubricating oils and hydraulic fluids"
c) Thermal imaging must comply with Standard ISO 18434: 2008 Part 1.

6.5.2 Analyse - Determine condition of equipment

Condition monitoring data must be assessed against alarms or thresholds, or analysed to determine the condition of the failure mechanisms. If no fault is detected the results must also be reported. If any uncertainty is detected further diagnostic measurements must be taken. If any fault is indicated the next step, diagnosis and prognosis, must be followed.

The condition can be: good, alarmed, or failed.

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6.5.3 Diagnosis and Prognosis

Any alarm or failed condition must be analysed to diagnose any fault. After determination of the fault the route to failure must be determined. If more than one set of measurements were taken either with the same or different condition monitoring techniques, the faults must be combined and addressed holistically to give a consolidated view of the condition, diagnosis and prognosis. The applicable standards are ISO 13381 Part 1 and ISO 13379.

6.5.4 Recommend corrective action

A recommendation has to be made for every fault detected. The recommendation will indicate the actions required to correct or further monitor the fault as well as their urgency for action, e.g. immediate, within 1 month, etc.

6.5.5 Report

Each piece of equipment monitored must have a report after each monitoring event. Further details on reporting are given in Deliverables Section 5, point 5.5.1

6.5.6 Communicate Results

Results of each condition monitoring event must be communicated to all stake holders listed in Table 4.7

6.6 TECHNOLOGY

The service provider must provide software, hardware and measuring devices as per Appendix A - Technology Specifications for Hand held condition monitoring. The requirement contains specifications for:

a) Minimum features and functionality of measuring/monitoring instruments.
b) Equipment and software that may be connected to Eskom IT infrastructure
c) Backup of computer systems and data
d) Technology governance and interface with Eskom Information Management.
e) System availability and support
f) Software licenses

6.7 SKILLS

Technician experience is crucial in arriving at accurate fault detection and failure prediction because all required data may not be collected or available e.g. process conditions when measurements were made. Hence the CM service needs to be provided:

a) by people with appropriate skills,
b) using appropriate technology, and
c) according to accepted standards as specified in this and related quality requirements.

The following are the requirement for skills.

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6.7.1 Skills for Vibration Monitoring

Skills for vibration are specified in document Eskom Standard 36 -1095: "Vibration-Based Condition Monitoring Of Rotating Auxiliary Plant". The following Rules also apply.

Rules:

a) A technician or analyst may not conduct work above his/her education and experience qualification. E.g. As specified in the Eskom Vibration standard, a Level/category 1 Vibration analyst may take vibration measurements, but not conduct diagnosis and prognosis for delivery to Eskom.
b) The vibration analysis team must be led by at least a Level 3.
c) The Level 3 must take responsibility to develop the monitoring program, route and measurement procedures for each machine, verifying the quality of the data and reports.
d) Measurements can be taken by lower levels. If this is the case, the entire process must be supervised (define supervised) by a Level 3.

6.7.2 Skills for Thermal Imagery

To be determined.

6.7.3 Skills for taking and analysing oil samples

Skills requirements for oil measurements and analysis are to comply with Eskom Standard GGL 36 - 53 "In-Service Monitoring of lubricating oils and hydraulic fluids"

6.8 CONTRACTUAL AGREEMENTS

The contractual terms of service provision, levels of required sevice, incentives and penalties are contained in a Professional Services Contract that is binding to each party. Terms for modification and dispute resolution are also covered.

6.9 DOCUMENTATION

Documents are necessary to ensure the effective planning, operation and control of the condition monitoring process. The required documents are given in Table 6.1

Table 6-1: Documents required for hand held condition monitoring

Name	Description	Purpose	Source
Plan CM			
Process, instrument, & power line diagrams	Plant schematics	determine equipment criticality	E
Reliability diagram	Functional and reliability hierarchy	determine equipment criticality	E
Equipment criticality designation	To be determined from above documents	determine work order criticality	E
Equipment and site layout	Physical positions of equipment on premises	To correctly identify and locate equipment	E
Maintenance history of equipment	Report of tests, work carried out, parts changed, modified, etc.	For health and life management	E
Reliability data	Failure history	To track reliability	E
Maintenance Plan	List of maintenance actions, frequencies, etc.	To guide the CM tasks	E
Failure mechanisms &	List of the failures addressed by	Guide for what problems CM	E

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Name	Description	Purpose	Source
modes	CM	covers	
Measure			
Instrument operating procedures	As each instrument has unique features, specific operating procedures for the instrument must be provided by the manufacturer.	Measurements integrity	SP
Procedure for each step supported by specifications, standards, guidelines	Taking measurements is a complex task and each step in the process must be supported with relevant document.	Measurements integrity	SP
Safety guidelines	Measurements are taken with equipment in operation	Safety	E
Relevant External standards	Eskom standards are based on some external standards	Measurements integrity	E
Relevant Eskom Standards	Draw up a list of Relevant stds. Eskom	Measurements integrity	E
Guidelines: measurement locations	Recommendations on where sensors or probes should be placed or connected	Measurements integrity	E
Limits	Limits for alarm levels for each parameter measured on each equipment.	Frame of reference	E
Scope of work	list of equipment to be monitored stating periodicity and technology	Work management	E
Analyse			
Alarms ranges	Minimum and maximum alarm limits for each parameter measured	Frame of reference	E
Condition history	All condition data for life of each equipment	Supporting data base	SP
Diagnosis & Prognosis			
Fault & failure mechanisms	List of the faults Fault & failure characteristics	Guide diagnosis & prognosis	
Equipment schematic	Block diagram of equipment	Determine what could be wrong and how to fix	E
Equipment assembly drawings	How equipment fits together	Determine what could be wrong and how to fix	E
Recommend			
Report			
Guidelines for Data Interpretation, Reporting	Specify parameters to be reported, units of measurements. Format, content, and frequency of reports	Assists SP to meet Eskom requirements	E
Status Report:	present, trend Diagnosis, prognosis and recommendation Work history	Required deliverables	SP

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Name	Description	Purpose	Source
	Costs: YTD, ITD, current		
Technology Specifications for Hand held condition monitoring.	Instruments: Standards, features, accuracy, IT infrastructure: Rules for connecting to network, Standards, etc.	Assists SP to meet Eskom requirements	E

7. RECORDS

The procedures in this manual do not produce legally required records for retention.

8. AUTHORISATION

This document has been seen and accepted by:

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9. REVISIONS

Date	Rev.	Compiler	Remarks
February 2014	0.1	E. Stephen	Draft Document
February 2014	0.2	E. Stephen	Draft Document for Comments Review
April 2014	1	E. Stephen	Final Document for Authorisation and Publication

10. DEVELOPMENT TEAM

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

- Phuti Ngoetjana
- Simon Higgins
- Leslie Barker

11. ACKNOWLEDGEMENTS

- None

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APPENDIX A: TECHNICAL SPECIFICATIONS FOR HAND HELD CONDITION MONITORING

The technology requirements to execute and manage the condition monitoring process is described in this document and covers the following topics:

a) Minimum features and functionality of measuring/monitoring instruments.
b) Equipment and software that may be connected to Eskom IT infrastructure
c) Instruments: Standards, features, accuracy,
d) IT infrastructure: Rules for connecting to network, Standards, etc.
e) Backup and recovery of computer systems and data
f) Technology governance and interface with Eskom Information Management.
g) System availability and support
h) Software licenses

A.1 PROCESS

The process for periodic condition monitoring is described here at a high level. The detail process is described in Section "Process Description". The Service provider is expected to execute such a process.

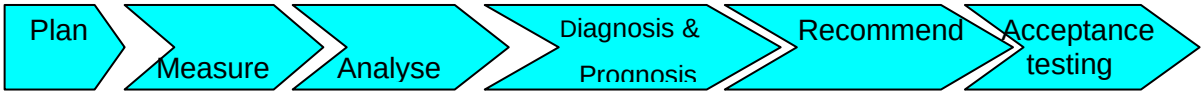

Figure A.1 - Condition Monitoring Process

A.2 TOOLS TECHNICAL SPECIFICATION

The service provider is expected to provide all tools and all computer hardware and software required to provide the condition monitoring service. The tools should comply with the following technical specifications. The power station environment is both indoors and outdoors. However it can be categorised as harsh because of the dusty conditions. The operating conditions prevailing at power stations are described below to select tools that are suitable to the environment. Also minimum features for measuring instruments are also discussed.

A.2.1 Operating Conditions

a) The air can be dusty and instruments should be protected against dust ingress. Moisture levels could be high and instruments should be sealed from moisture, Minimum IP-65 is required.
b) Hydrogen, leaks, etc. are possible and intrinsically safe instruments are applicable.
c) Ambient Temperatures could range from -10°C to 50°C.
d) Battery powered instruments should be at able to operate for at least 8 hours or achieved with a spare battery changed with no loss of data.
e) Instruments will be used both indoors and outdoors. Display screens should be readable both indoors and outdoors.

A.2.2 Calibration of instruments

All instruments must have valid calibration certificates at time of use. Calibration certificates must be made available on request.

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A.2.3 Vibration Analysers

The following are minimum requirements for vibration instruments:

a) Measurement Probes must be self-adhering, e.g. magnetic attachment, no hand held probes are allowed for safety and accuracy reasons.
b) Dynamic Range minimum of 96 dB
c) A/D Converter should be minimum 16 bits
d) Frequency Range: minimum DC-80 kHz.
e) Advanced features: Normal Averaging, Exponential, Peak Hold, Order Tracking, Synchronous Time, and Negative Averaging
f) Analysis: High Frequency, Low Frequency, Order Tracking
g) Dynamic Analysis: Overall, Spectra, Waveform, Phase
h) Output: Communication with host computer with USB, serial or Ethernet.

A.2.4 IR Cameras

IR cameras should have the following minimum characteristics:

a) image quality NETD < 80 mK
b) Auto Hot/Cold Spot Recognition
c) Temperature range -20 to +350°C
d) Data transfer to host computer system

A.3 COMPUTER SERVERS AND DESK TOPS

Computers are governed by policies and standards as set by Generation Information Management (GIM). The relevant documents are available from the IM department.

A.3.1 Connection to LAN

Application must be made via the IM department to have any computer connected to the LAN.

A.4 DATA

All condition data and reports must be made available on the Eskom Condition monitoring server where it is available. Where a server is not available data should be available in Excel or CSV format and reports must be in MS Office. Updating should take place at least monthly.

A.5 LICENCES

All software used by the service provider must have valid current licenses.

A.6 SUPPORT

The service provider's computers must be supported adequately to meet the systems availability requirements of 8 x 7 x 365.

A.7 BACK UP AND RESTORATION

All computer systems must be backed up at least once per weekly. Copies of back-ups must be available both on and off site. Restoration from backup should be within eight hours.

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A.8 CONTINUITY OF SERVICE

The service provider must ensure protection against at least the following threats:

a) service disruption,
b) corruption of data,
c) unauthorised access.

Relevant and practical business continuity plans must be in place to recover from any "disaster" at both the site office at the power station and all "head office" services that the site office depends on. These plans must link into the power stations business continuity plans as necessary. The plans must be verified each year.

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