Eskom	Guideline	Generation Engineering

Title: **Mill Reducer Gearbox Maintenance Guideline**

Unique Identifier:	**240-56063919**
Alternative Reference Number:	**N/A**
Area of Applicability:	**Generation, Engineering**
Documentation Type:	**Guideline**
Revision:	**2**
Total Pages:	**18**
Next Review Date:	**August 2028**
Disclosure Classification:	**CONTROLLED DISCLOSURE**

APPROVED FOR AUTHORISATION
☑ GENERATION ENGINEERING
DOCUMENT CENTRE ☎ X4962

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PCM Reference : **240-53459108 (Boiler)**

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TABLES

1. INTRODUCTION

This standard provides the guideline for maintenance of mill reducer gearboxes, and records.

2. SUPPORTING CLAUSES

None

2.1 SCOPE

The information gathered during inspections by Eskom and the manufacturer, and any specific Eskom requirement will determine the scope of work to repair, refurbish or re-manufacture the gearbox.

For the re-manufactured gearbox, the following items will be included in the scope of work and supply:

a. Replacement of all gears.
b. The replacement of all rolling element bearings.
c. The replacement of all nuts and bolts.
d. If used, the re-lining of all journal bearings and thrust plates.
e. Re-boring the bearing sleeves after skimming the joint faces. .
f. Machining, Re-lining and boring of bearing sleeves if required.
g. Replacement of all keys and re-cutting of all key ways if required.
h. For external lubrication systems, the replacement of all pumps, instruments, pressure and flow switches.
i. Gearbox casing internals to be coated with zinc-based primer and suitable epoxy coating.

For a refurbished gearbox, the following items will be included in the scope of work and supply:

a. Replacement of all damaged gears. Old gears mating with new gears will have to be re-ground to restore the gear profile.
b. If a gear/shaft assembly has been dismantled, the regrinding of the gear to ensure concentricity.
c. The replacement of all rolling element bearings for gearboxes in which bearings have exceeded 50% of their L_{10} design life. These items should ideally be replaced during a refurbishment as their cost is far less than the risk of a premature gear failure as a result of a bearing failure.
d. The replacement of all damaged nuts and bolts.
e. If white metal bearings are used, the re-lining of all journal bearings and thrust plates.
f. Re-boring the bearing sleeves after skimming the joint faces.
g. Machining, re-lining and boring of bearing sleeves if required.
h. Replacement of keys and re-cutting of key ways if required.
i. For external lubrication systems, the replacement of all pumps, instruments, pressure and flow switches.
j. Gearbox casing internals to be coated with a zinc-based primer and suitable epoxy coating.

Repaired gearboxes:

For a gearbox requiring repairs, the items requiring repair or replacement will depend on the nature of the failure and the extent of the resultant damage.

2.1.1 Purpose

This guideline addresses the re-manufacturing, refurbishment or repair requirements for gearboxes with either horizontal shafts and horizontal split casings or vertical shafts and horizontal split casings. Both gearbox types make use of spur or helical internal gearing, with the vertical shaft boxes making use of spiral bevel input gear sets. All gearboxes are fitted with external lubrication units. Casings are typically of cast steel but may be of the fabricated type.

Typical installations for horizontal shaft spur and helical boxes are tube mill reduction gearboxes installed at Arnot, Kendal, Lethabo, Majuba, Tutuka, Matimba and Komati Power Stations.

Typical installations for gearboxes vertical shaft boxes employing spiral bevel input sets are vertical spindle mills installed at Arnot, Duvha, Hendrina, Kriel, Matla, Komati, Camden and Grootvlei Power Stations.

This guideline is intended to provide a reference from which to select gearboxes requiring maintenance and to specify the work to be carried out when repairing, refurbishing or returning gearboxes to an “as new” condition. Information regarding maintenance and monitoring regimes and requirements are also given to assist in identifying gearboxes requiring work and maximising gearbox availability. Guidance is also given on quality assurance requirements for gearboxes and their components.

2.1.2 Applicability

This is applicable to all the mill reduction gearboxes at all coal fired Power Stations Gx”.

2.2 NORMATIVE/INFORMATIVE REFERENCES

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

2.2.1 Normative

[1] 240-56064555: Extreme Pressure Gear Oils Standard

[2] 240-83539994: Standard for Non-Destructive Testing (NDT) on Eskom Plant

[3] ISO 9001: Quality Management Systems – Requirements

[4] 240-53114026: Project Engineering Change Management Procedure

2.2.2 Informative

The following standards form part of this guideline. The user should consult with the gearbox manufacturer to determine the applicability of any specific standard to a particular gearbox and its components.

[5] ANSI/AGMA 2000 –A88, Gear Classification and Inspection Handbook – Tolerances and Measuring Methods for Unassembled Spur and Helical gears (Including metric equivalents).

[6] ANSI/AGMA 2004-C08, Gear Materials and Heat Treatment Manual.

[7] ANSI/AGMA 2005-B88, Design Manual for Bevel Gears.

[8] ANSI/AGMA 2008-B90, Assembling Bevel Gears.

[9] ANSI/AGMA 6000-A88, Specification for Measurement of linear Vibration on Gear units.

[10] ANSI/AGMA 6101-E08, Design and Selection of Components for Enclosed gear Drives.

[11] ANSI/AGMA 6010-E88, Standard for Spur, Helical, Herringbone, and Bevel Enclosed Drives.

[12] ANSI/AGMA 6025-D98, Sound for Enclosed helical, Herringbone, and Spiral Bevel Drives.

[13] ANSI/AGMA 9005-E02, Industrial gear lubrication.

[14] ANSI/AGMA 6013-A06, Standard for Industrial Enclosed Gear drives.

[15] ANSI/AGMA 6113-A06, Standard for Industrial Enclosed Gear Drives (Metric Edition)

[16] AGMA 912-A04, Mechanisms of Gear Tooth Failure.

[17] AGMA 923-BO5, Metallurgical Specifications for Steel Gearing.

[18] AGMA 925-A03, Effect of Lubrication on Gear Surface Distress.

[19] AGMA ISO 14179-1 GEAR REDUCERS - THERMAL CAPACITY BASED ON ISO/TR 14179-1

[20] AGMA 2001-D04, Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth.

[21] AGMA 2004-C08, Gear Materials, Heat Treatment and Processing Manual.

[22] AGMA 2101-D04, Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth (Metric Edition).

[23] AGMA 6001-E08, Design and Selection of Components for Enclosed Gear Drives.

[24] ISO 17485:2006, Bevel Gears – ISO System of Accuracy.

[25] BS 436: Part \3: 1986, Spur and helical gears, Method for calculation of contact and root bending stress limitations for metallic involute gears.

[26] BS 436: Part 4: 1996 (ISO 1328-1:1995), Cylindrical gears-ISO system of accuracy, Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth.

[27] BS 436: Part 5: 1997, (ISO 1328-2:1997), Cylindrical gears – ISO system of accuracy, Definitions and allowable values of deviations relevant to radial composite deviations and runout information.

[28] DIN 3961, Tolerances for Cylindrical Gear teeth.

[29] SABS ISO 9001:2008, Quality systems * Model for quality assurance in design, development, production, installation and servicing.

2.3 DEFINITIONS

Definition	Description
"As new", re-manufactured, rebuilt or fully overhauled gearboxes	Gearboxes subjected to a complete overhaul and fitted with a complete set of new internal components meeting all the original design criteria and subject to the same quality assurance requirements as a new gearbox.
Refurbished gearboxes	Gearboxes where work is carried out on the gearbox to restore the gearbox as close as possible to original performance requirements. Such work includes replacement of selected working components and/or work on/or repair to selected items.
Repaired gearboxes	Gearboxes in which specific items which have failed or considered to have failed or reached the end of their design life have been replaced.
Components or items	Refers to casings, gears, shafts, keys, bearings, lubrication systems, dowel pins, nuts, bolts, covers, dip sticks, breathers, seals and any other item required to complete the gearbox assembly.
Supplier or manufacturer	The company responsible for carrying out the repair, refurbishment or overhaul of a gearbox.
Original Equipment Manufacturer (OEM)	The company responsible for the design and manufacture of the original gearbox, including all its components.
L_{10} Life	The number of revolutions or hours that 90% of a group of apparently identical bearings will complete or exceed before fatigue is expected to occur.

2.3.1 Classification

Controlled Disclosure: Controlled Disclosure to External Parties (either enforced by law, or discretionary)

2.4 ABBREVIATIONS

Abbreviation	Description
AGMA	American Gear Manufacturers Association
ANSI	American National Standards Institute
Gx	Generation Division
MPI	Magnetic Particle Inspection
NDT	Non Destructive Testing
OEM	Original Equipment Manufacturer
PCD	Pitch Circle Diameter
SANS	South African National Standard

2.5 ROLES AND RESPONSIBILITIES

The Power Station Engineering Manager is responsible for the implementation of this guideline at the Power Station and control of Engineering Change Procedure in accordance to [5].

Boiler Process & Firing Systems Care Group Process Engineering is responsible for the periodic review of this document.

Generation Safety and Assurance are responsible for coordinating vendor assessments and supplier approvals for the refurbishment and repair of mill gearboxes.

2.6 PROCESS FOR MONITORING

None

2.7 RELATED/SUPPORTING DOCUMENTS

None

3. MILL REDUCER GEARBOX MAINTENANCE GUIDELINE

3.1 GENERAL REQUIREMENTS

3.1.1.1 Suppliers

Only Eskom approved suppliers should carry out repairs or refurbishment of Eskom tube mill and vertical spindle mill gearboxes. Suppliers should have a quality management system in terms of ISO 9001.

3.1.1.2 Design Specifications

When repairing or refurbishing a gearbox, suppliers shall attempt to reinstate the gearbox to the original design requirements where possible. Any deviations from the original design shall be pointed out before work commences. The supplier shall state the design standard used in the repair or refurbishment of the gearbox. In the absence of a specific design standard, BS 436 may be used to determine the accuracy limits required for the gearbox repair. Gears that cannot be repaired to fall within the limits of the agreed design standard should be replaced.

3.1.1.3 Replacement and repaired gear sets

If a single gear in a mating set needs to be replaced, the mating gear should be reground to the same standard as the new gear. Alternatively the complete set should be replaced. Replacement gears should be manufactured from the same or equivalent material to the same or higher degree of accuracy as the original set and be subjected to the same heat treatment processes.

3.1.1.4 New gear sets

In gearboxes where complete gear sets are replaced, the supplier shall supply gears to the original ratio and design rating, unless Eskom agrees to a ratio change or a rating change.

3.1.1.5 Bearings

Where bearings have been specifically designed for a particular gearbox, the same bearings from the same manufacturer should be used in the repaired or refurbished gearbox. Should alternative bearings of a different design or rating be considered, for cost or availability purposes, the new gearbox design rating and bearing L_{10} life shall be checked against the original requirements for the application.

3.1.1.6 Lubricants

Lubricants used to refill gearboxes shall meet the grade requirements of the original equipment manufacturer and 240-56064555 for extreme pressure gear oils.

3.1.1.7 Non-destructive testing

Personnel performing non-destructive examinations shall be qualified to do so in terms of Eskom requirements, 240-83539994.

3.1.2 Guides to identifying gearboxes requiring refurbishment

3.1.2.1 Types of maintenance

Gearboxes may be considered ready for overhaul or refurbishment either on a planned interval (time based maintenance) or based on condition (condition based maintenance). Both these techniques intend to prevent sudden or catastrophic failures usually caused by metal fatigue or component overloading. Fatigue related failures, or failures due to latent defects within components, or due to incorrect component selection or replacement, may occur within the design life without being identified by any performance or condition monitoring techniques.

a. **Refurbished Time based maintenance:** Planned intervals, commonly referred to as preventative or time based maintenance, is based on mathematical probabilities of a set number of failures occurring within a predetermined design life. The design life is based on predetermined loading conditions, operating procedures, and the customers required reliability or safety factors. Usually one or more of the bearings determines the minimum design life of a gearbox. The predetermined intervention period is usually conservative and results in increased maintenance costs when compared with condition based maintenance.

b. **Condition based maintenance:** Various monitoring techniques are used to indicate the condition of the gearbox, its specific components, or the lubricant used, to the operator. In gearboxes, such techniques may include lubricating oil analysis, vibration monitoring, thermography and visual inspections. Horizontal shaft gearboxes may be opened from time to time to check end float, gear contact patterns, backlash and general gear and bearing condition prior to carrying out a full overhaul or refurbishment. For vertical shafts limited inspections of the gear flanks and general internal condition may be carried out through inspection ports. In these gearboxes it is not advisable to remove the top cover as gear alignment will be affected.

    - **Vibration monitoring:** Various international standards suggest vibration limits for gearboxes. In general however, these standards only provide initial limits for typical applications. Experience and ongoing vibration monitoring trending will determine actual safe operating limits for gearboxes in-service.

The following table provide initial limits for monitoring overall vibration levels in gearboxes. It is advisable that equipment capable of performing spectral analysis and time waveform analysis is used to detect specific faults in the gearbox. Although vibration analysis is beyond the scope of this document, it is worth

noting that only detailed spectral and time wave form analysis can detect conditions such as coupling misalignment, broken or cracked gear teeth, mechanical looseness, pitch errors and loose joints. Ensure that monitoring equipment used is correctly set for the frequency ranges of the equipment being monitored and that monitoring personnel are qualified to perform the task.

Table 1: Suggested Vibration Level Limits [9]

Condition and inspection frequency	Overall Vibration Limit in mm/s
Good condition, take readings monthly and trend results.	< 2 mm/sec.
Acceptable condition requiring more frequent monitoring. Monitor 2 weekly or weekly if vibration levels are increasing.	2 – 5 mm/sec.
Shut down gearbox and open for inspection.	> 5 mm/sec

- **Lubricating oil analysis:** Appendix A, extracted from Eskom guideline 36-53, "In service monitoring of lubricating Oils and Hydraulic Fluids", provides suggested limits for the in-service monitoring of gearbox lubricants. Lubricating oil analysis can indicate the general condition of the gearbox as well as the lubricating oil and in conjunction with vibration analysis and visual inspections the user can determine through experience whether the gearbox requires refurbishment or a complete overhaul.
- **Visual observation:** Listening to, looking around and touching the gearbox can give an indication of mechanical damage and early detection of gearbox leaks.

c. **Proactive maintenance:** Attempts are made to change the operating regimes, design or environment to improve gearbox life and reduce the need for more costly overhauls, repairs or refurbishment's.

In order to achieve maximum gearbox life, the user should attempt to use components that meet the original design criteria specified by the original gearbox manufacturer. In addition the user may consider using improved quality lubricants, finer filters and breathers and instituting a program of routine external oil filtration. It has been shown that reductions in oil contamination levels can significantly extend gear and bearing life.

The early detection and repair of minor faults on an ongoing basis can significantly extend the life and improve the reliability of the gearbox. These can be detected by regular monitoring of the gearbox. Repairing minor faults can prevent major faults listed in the table below.

Table 2: Typical Faults

Minor faults	Major faults
Oil leaks	Bearing failures
Pulverized fuel or dirt ingress	Gear tooth damage
Water contamination	Rusting/corrosion.
Oil starvation (blocked filters)	Abnormal bearing wear.
Overheating (wrong oil, low oil level, overloading, faulty or incorrect flows, coolers, etc.).	Mechanical looseness. (e.g. shaft, key and gear bore)
Coupling and drive train alignment.	Shaft damage.

3.1.2.2 Gearbox history and design

Gearboxes are designed and selected for a specific set of operating conditions and pre-determined loading conditions. Gearboxes are designed according to various design codes based on a number of factors such as power, speed, material strength, fatigue considerations and safety factors. Historically gearboxes were designed with planned maintenance as the maintenance regime of choice.

When maintenance is carried out on a gearbox, attempts must be made to maintain or reinstate original design performance criteria. Although every attempt should be made to return the gearbox to "as new" condition against the original design code, this may not be economically feasible for repaired or refurbished gearboxes. On the other hand, re-manufactured boxes should be built against the original design code as far as is practically possible. The re-manufacturer if not the OEM, may not have access to the same foundry, heat treatment and machining facilities as originally used. Notwithstanding these considerations, the re-manufactured gearbox should still meet the minimum performance criteria originally specified for the application.

3.1.2.3 Procedures to be carried out by Eskom when removing a gearbox for repair, re-manufacture or refurbishment

a. Identify the gearbox to be maintained. This may be based on indications supplied by condition monitoring techniques or based on gearbox running hours to date. If sufficient history and design information is available for the gearbox type, a more accurate prediction of gearboxes expected life may be performed using techniques such as a Weibull analysis;

b. Obtain all the relevant information regarding the operating and maintenance history of the gearbox;

c. Location of the gearbox;

d. Hours of service to date;

e. Previous repairs, work done, reason for the work and running hours when the work was carried out;

f. Running hours on the gearbox since previous repairs, refurbishment or rebuild;

g. Clean and record the nameplate details and where visible the shaft end stampings (these may correspond to job numbers, cast or forging numbers, drawing numbers or unique identification numbers);

h. Make a note of the type, size and rating of the couplings used on the input and output shafts;

i. Note the direction of rotation of both the input and output shafts;

j. Obtain the original purchasing requirements detailing the design and performance criteria of the gearbox. This should include:

- Design mechanical and thermal ratings (splash lubricated boxes) and service factors. Note the Standard used to determine these ratings. If necessary consult the original equipment manufacturer;
- Gear dimensions (outside diameter (OD), pitch circle diameter (PCD), pressure angle, helix angle, face-width and centre distances);
- Gear materials;
- Gear speeds;
- Gear types (spur, helical, double helical or herringbone);
- Number of teeth on each gear;
- Modules of meshing pairs (Number of teeth dived by PCD);
- Methods of final machining (profile ground, hobbed, shaved);

- Accuracy (AGMA, DIN or ISO quality numbers);
- Methods of heat treatment (through hardened, nitrided, carburised, induction or flame hardened);
- Bearing numbers, clearance (C2, C3 etc), brand (FAG, SKF, KOYO, NSK, NTN etc), and location (eg DE input);
- Lubrication system details if required (type, system capacity, flow rates, pressures);
- Lubricant brand, grade and lubricant specification if available (e.g.. BP Energol GRXP 220, AGMA 5 or 5Epor DIN 51517 part 3);
- Relevant technical drawings or drawing numbers;
- Input and output specified couplings, type and size. Note any differences from couplings actually used and the reasons for the changes.

k. Inspect the gearbox and its lubrication system prior to opening for signs of leaks and damage that may require repair or replacement. For gearboxes requiring remanufacture or refurbishment, note the types and makes of pumps, valves, pressure gauges, switches etc. These items may have become obsolete and may require upgrading during remanufacture or refurbishment.

l. Drain the lubricant charge and dispose of according to recognised procedures. If a failure investigation is required, take lubricant samples prior to draining. Record any other relevant observations.

m. Remove the gearbox from service and transport to the power station workshop.

n. For gearboxes with horizontal shafts and horizontal split casings; remove the top half of the casing to inspect the internal components. For gearboxes with vertical shafts, note that only general component condition can be checked and recorded.

o. Visually inspect the gears for signs of wear, profile changes and flank damage. Record any significant observations. If possible, inspect gear running contact patterns, backlash and shaft end floats.

p. Check the bearings for obvious signs of wear and damage. Record all observations.

q. Confirm the basic bearing and gear details with the original design information. Record any changes.

r. Replace the top cover and prepare the gearbox for shipment to the gearbox manufacturer.

s. Prepare the initial schedule and scope of work required to repair, refurbish or remanufacture the gearbox.

3.1.3 Procedure to be followed by the manufacturer when receiving and checking a gearbox at the manufacturers works

a. The following checks should form part of a manufacturers receiving inspection and may be carried out by Eskom prior to shipping to the manufacturers' works:

- The manufacturer on receiving the unit will clean and record the nameplate details and/or shaft end stampings. The manufacturer will check the delivery documents and the client/Eskom's initial work requirements.
- The manufacturer will remove the top of the case and record the layout of the gearing.
- The manufacturer will record:

i. the running contact pattern, for gearboxes with horizontal shafts;
ii. Backlash for each reduction stage, for gearboxes with horizontal shafts;
iii. Shaft end floats, for gearboxes with horizontal shafts;
iv. Any visual signs of damage wear or profile change;

v. The manufacturer will remove the shafts, bearings and gears from the case.

b. The following checks will be performed by the manufacturer on the gears:

- A 100% MPI of all gear teeth; all indications must be recorded.
- Visual inspections of all gear flanks for changes in profiles wear or damage.
- Gear shaft assemblies on worn or damaged gears, should be placed in a press and dis-assembled. The shaft and bore of the gear should be checked for signs of fretting and corrosion.
- For dismantled gear/shaft assemblies, MPI all key-ways and measure and record the dimensions of all keys and keyways.
- Measure the dimensions of the gear boxes and the shaft diameters to check and confirm fits and tolerances.
- If new gears are required and no drawing exists, record face-width, number of teeth, gear types and heat treatment method (through hardened, nitrided, carburized, induction or flame hardened).

c. The following checks will be performed by the manufacturer on the bearings:

Bearings should be removed, if possible, without damaging them. For refurbished and re-manufactured gearboxes, it is good practice to replace all bearings. In the case of repaired gearboxes, if a bearing has completed less than 50% it's L_{10} design running hours and the bearings are in good condition, as inspected and verified as suitable by the original bearing manufacturers' technical department, or a suitably qualified person, they may be re-installed for further service. If bearings, which have completed a significant portion of their L_{10} design life are re-used, the manufacturer may waive any guarantees on the repairs. Generally, the use of the old bearings is not recommended.

- Visually inspect the rolling elements and raceways for signs of wear and damage.
- Check the outer races for signs of movement in the bearing bores of the case and for signs of fretting and corrosion.
- Check the wear patterns of the bearing races for indications of misalignment.

d. The following checks will be performed by the manufacturer on the shafts:

- MPI the shaft with attention to keyways, fillet radii and changes in section of the shaft.
- Check all bearing seats for signs of wear.
- Measure the bearing seats to check fits and tolerances and compare with the selected or specified bearing.
- Check oil seal tracks for signs of damage or wear.

e. The following checks will be performed by the manufacturer on the casing:

- Inspect case joints for the presence of paper or other gasket materials.
- Check condition of all machined joint faces for damage.
- Check alignment of joint faces with gearbox feet and mounting faces.
- MPI all bearing bores and case feet.
- Dye penetrant test entire case after cleaning if required.
- Visually inspect all bores for signs of wear.

- For fabricated boxes, MPI all welds.
- Re-assemble case (with gasket if required) and tighten all bolts to the manufacturers specified torque.
- Measure all bearing bore diameters (vertically and across the joint).
- Measure centre distances of each bore and compare with drawing requirements.

f. The following checks will be performed by the manufacturer on the lubrication systems:

If an external lubrication system is used, details are to be supplied to the manufacturer. For re-manufactured gearboxes, the lubrication system may be sent to the manufacturer for refurbishment.

- Check condition of internal lubrication pipework removed from the gearbox.
- Check oil ways and supply ports cast into casing for signs of blockages and sludge build up.

g. The following checks will be performed by the manufacturer on the other items:

- Record the details of all fastenings (nuts and bolts), dowels, washers, locking screws, seals and gaskets.
- Visually inspect all covers, oil catchers, loose bearing housings etc.

3.1.4 Quality Assurance Tests, Inspections and Documentation

The following documentation, inspections and tests are required when re-manufacturing, refurbishing or repairing a gearbox.

3.1.4.1 Gearbox history and design

If no drawing/s exists for the gearbox and its components, the supplier shall include the cost of the drawings separately in his quotation. The relevant drawing numbers must be reflected on the quality control plans.

3.1.4.2 Production Schedule and Quality Control Plans (QCP's):

The supplier shall submit to Eskom detailed quality control plans for the remanufacture, refurbishment or repair of the gearbox. QCP's should include QCP's for the manufacture or repair of individual components. The supplier should also provide a time based production schedule to Eskom prior to starting work.

3.1.4.3 Checks and documentation required on the casing:

a. Magnetic Particle Inspection report on bearing bores and mounting feet.
b. Dye Penetrant Inspection Report on Casing.

3.1.4.4 Checks on gears

a. Material certificates for all new gears.
b. Heat treatment certificates of castings and forgings.
c. Mechanical test report (tensile strength).
d. Microstructure report
e. Lead, pitch and profile measurements for new and re-ground gears.
f. Dimensional inspection versus drawing.
g. Hardness checks on finished gears and forgings.
h. MPI certificates for all gears.
i. Heat treatment certificates for all new finished gears.
j. Stamp identification on gears.
k. Check and record contact pattern, backlash and shaft end float.

3.1.4.5 Checks and documentation required for shafts:

a. Material certificates for new shafts and keys.

b. Stamp identification on shaft ends.

c. Check for looseness of gears on shafts.

3.1.4.6 Information required on bearings:

Bearing numbers, bearing clearance and brand name for all replaced bearings.

3.1.4.7 Nameplate requirements:

An additional new nameplate fitted, indicating the date of manufacture, order number, power rating, gear ratio, lubricant specification and other relevant technical details shall be fitted to the casing exterior. No original nameplates shall be removed.

3.1.4.8 No load testing:

Vibration levels shall be checked under “no-load” conditions and the results recorded for Eskom. Where possible a load test is preferred.

3.1.5 Surface and corrosion protection

The supplier shall submit details of corrosion protection measures to protect the gears and casing from deterioration during storage. If a gearbox is to be stored dry for a long period, the use of vapour phase inhibitors (VPI’s) or vapour corrosion inhibitors (VCI’s) is recommended.

The supplier must submit details of the proposed coating and method along with material data sheets to Eskom’s corrosion specialists for approval.

3.1.6 Transportation

Gearboxes should be transported in such a manner as to prevent damage to the bearings or other gearbox components and to prevent the ingress of dirt or moisture during transportation. It is preferable that suitable vibration monitoring equipment (“G sensor”) be installed for transportation and handling purposes to record any unsuitable handling conditions of the gearbox that can lead to secondary damage or warranty claims.

3.2 RECORDS

None

4. AUTHORISATION

This document has been seen and accepted by:

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5. REVISIONS

Date	Rev.	Compiler	Remarks
November 2012	0.1	LF Barker	Draft Document for review created from 36-73
February 2013	1	LF Barker	Final Document approved for Publication
February 2023	1.1	L. Botha	First Draft Document for Comments Review Process
March 2023	1.2	L. Botha	Final Draft after Comments Review Process
August 2023	2	L. Botha	Final Rev 2 Document for Authorisation and Publication

6. DEVELOPMENT TEAM

None

7. ACKNOWLEDGEMENTS

The author expresses his thanks to the members of the tube mills and vertical spindle mills liaison teams for their contributions toward this document.

APPENDIX A

Table 3. Guideline for In Service Monitoring of Gearboxes

1	2	3	4	5	6	6
Test	**Test method**	**Frequency recommended**	**Warning limits**	**Condition**	**Cause**	**Action**
Cleanliness	ISO 4406 reporting	Monthly	• ISO 18/15 in clean environments. • ISO 21/18 in hostile (dirty) environments.	High contamination levels.	Faulty or poor filters or filtration equipment.	If cleanliness increases by more than one level, check filters, breathers and Maintenance procedures.
					Inadequate or faulty breathers.	Replace breathers with good quality filters.
					Dirty new and/or make-up oil.	Very dirty boxes should be drained, thoroughly cleaned by flushing and re-filled with clean oil.
					Dirty oil filling equipment.	Where possible use dedicated equipment and pre-filter oil at point of filling.
PQ	Dependent on lab used.	Monthly	Dependent on lab method. Initially 230 for dirty environments and 200 for clean environments.	Increased metallic levels in oil.	Component wear.	If PQ index is high, carry out full WDA. Or analytical ferrography.
Wear debris analysis (WDA)	Visual	Dependent on PQ index.	Identify material and wear mechanism.	Increased contamination levels and large particles present in oil.	Component wear and dirt ingress	• Identify **components** and take machine off-line if severe. • Filter oil and change oil if necessary.
Total acid number (TAN)	ASTM D974	3 monthly.	0,5 mg KOH/g Oil above new oil value.	• Increase in total acid number (TAN). • Oil Blackening.	Oil oxidation.	Check for high temperature operation, contamination and visible foaming

Table 3 (continued)

1	2	3	4	5	6	6
Test	**Test method**	**Frequency recommended**	**Warning limits**	**Condition**	**Cause**	**Action**
Viscosity	ASTM D445	Monthly	± 20 % of new oil.	Increase in viscosity	Incorrect make-up oil.	Correct by blending in sufficient oil of the same brand of a lower grade.
					Oil oxidation.	Check oil coolers. Use an oil suitable for high temperature conditions
				Decrease in viscosity	Incorrect make up oil.	Correct by blending in sufficient oil of the same brand of a higher grade.
Water content	ASTM D1533 (Karl Fischer)	Monthly	2000 ppm	High water content or free water present.	Leaking oil coolers and seals.	Check system for possible sources of water ingress and leaks. Filter oil through suitable filter to remove excess water.
					Leaks in gear casing	Identify and repair leaks.
					Case breathing due to changes in ambient conditions.	Fit more suitable filters and breathers
					Water washing of equipment.	Try to avoid washing into breathers and filling points. Check housekeeping procedures.
					Poor lubricant demulsibility.	Check suitability of lubricant for application. Check lubricant water separating characteristics.
Wear metals, additives and contaminants	ASTM D5185 (ICP)	Monthly	• Copper 50 ppm • Iron 500 ppm • Lead 50 ppm • Calcium additive 50 ppm (for borated oils) • Boron additive (50 % of new oil) • Zinc additive (50 % of new oil)	Increased wear metals.	Excessive component wear.	For increased wear metals, identify component and check operation and maintenance procedures.
					Faulty filtration	Check filters and breathers.
				Additive depletion	Oil ageing	Refer to lubricant manufacturer for comment regarding additives if new oil values not available.
					Water contamination	May cause additive depletion, especially zinc. Address reasons for high water content.

NOTE 1 Gearboxes should be selected for monitoring according to criticality and volume.
NOTE 2 Recommended sampling frequencies can be altered to suit the application.
NOTE 3 Warning limits may be adjusted with experience to suit the system and/or the lubricant.
NOTE 4 Refer to GGG 0428 for possible sources of wear metals and additive types.