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EXECUTIVE SUMMARY

The Auto-variable hydraulic blade pitch Axial flow fans – generally referred to as Axial flow Fans – is a complex machine, and inherent to its function of supplying air into the Boiler combustion chamber and gas extraction via the Air Heaters and gas cleaning plants, is subject to extreme operating conditions that can lead to severe service and design life reductions if not maintained and operated within the design base.

The organisations' Management and Maintenance personnel must have a clear understanding that the execution of Axial flow Fan maintenance cannot be presented as a “normal maintenance crew” task. The effective maintenance of the machine presents a multitude of intricate and inter-related details, and if not correctly managed with the appropriate knowledge and skill levels, it will result in severe plant damage and production losses.

Continued operation of the plant, with known deficiencies, such as oil leaks, worn blades, high vibrations and deficient adjacent plant conditions will result in the accumulation and exaggeration of damage to components with severe consequences of plant load losses or equipment damage/failure – and is best addressed on urgent basis, in order to sustain relative reliability between operational shut-downs.

The effective Management of the Routine & Preventative Maintenance program requires an in-depth knowledge of the machine and processes recommended within this Specification.

Periodic evaluation of compliance to planning, processes and engineering analysis requirements is essential to achieve sustainable good performance.

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1. INTRODUCTION

The correct execution of maintenance on Axial flow Fans is aimed at obtaining the best performance and life expectancy of components that are subject to frictional wear, ash erosive wear and operational fatigue. Accurate detailed execution of repair scope strives to ensure that unplanned failures are eliminated in order to ensure effective operation and fan performance between planned outage intervals.

2. SUPPORTING CLAUSES

2.1 SCOPE

2.1.1 Purpose

This Maintenance Specification stipulates the minimum requirements for inspection, executing repairs, preventative maintenance and monitoring performance on the Axial flow Fans, in order to ensure that the best operational service is obtained between repair intervals.

2.1.2 Applicability

This Specification applies to **Site Maintenance** of both FD and ID Axial flow Fans installed on Eskom fossil fired Boilers. The applicable Stations fitted with Axial flow FD and ID fans are:

- Majuba
- Medupi
- Kusile

The Specification is to be used by both Eskom System Engineers and Maintenance Contractors for defining and planning of the appropriate maintenance Scope of Work, and for stating minimum requirements for compliance execution to Contractors engaged in Maintenance Contracts.

The requirements for Fan Rotor Overhaul Maintenance are covered in a separate Specification.

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] 240-89218242: Centrifugal Fan Inspection Standard.
- [2] 240-106628253: Standard for Welding Requirements on Eskom Plant.
- [3] 240-131963944: Draught Plant Preservation Standard.
- [4] 240-87694663: Fan Storage Standard.
- [5] 240-121468227: Draught Group Balancing and Vibration protection levels Standard.
- [6] Applicable NDT and wall thickness monitoring standards.
- [7] Station Draught Plant Return to Service procedure.
- [8] Station Strategic Spare Rotor preservation procedure.

2.2.2 Informative

- [9] 240-111508338: Process Control Manual (PCM) for Outage Management.
- [10] 240-89218264: ID Fan's out of capacity guideline.

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- [11] 240-61379840: Management & reporting of Strategic Spares.
[12] 240-89217730: Standard for Draught Plant Protection functions.
[13] Specification for the Overhaul of Auto-variable blade pitch Axial flow fans

2.3 DEFINITIONS

Definition	Description
Auto-variable	The angle of Blade fan blade pitches are can be varied on-load in order to control the flow and pressure requirements & fluctuations in the Boiler furnace.
Bearing fairing	Inner tube supporting the bearings/housings, circular shaped in design and in-line with the inlet-cone & impeller centre sections to guide flow.
Blade and blade shaft	The Blade is the mechanism used to provide the pressure and flow functionality as acquired through the rotation of the Fan Impellers. The blade shaft in turn supports and suspends each Blade from the rotating Impeller and is able to rotate around its own axis in order to facilitate the pitching of the Blade.
Blade leading- and trailing edge	The leading edge refers to the blade-edge facing the incoming direction of air/gas flow. The trailing edge refers to the opposite side, being the blade edge in the down-stream flow direction.
Blade pressure-side of pressure surface	The pressure-side of the blade refers to the concave (hollow) side of the blade, which is also the 'eroding' side of the blade profile.
Blade shaft bearing cartridge	A set consisting of thrust and locating bearings with sealing mechanism and lubricant that supports each individual blade shaft, while facilitating rotation as well as supporting the centrifugal forces created through the rotation of the Impeller & Blades.
Blade stroking	Stroking is defined in the sense of aligning the internal Hydraulic/Mechanical settings against the external Electrical/C&I control settings.
Blade tip clearance	This is the specified and allowable clearance – dictated by a maximum and minimum value – between the blade edge (tip) and the outer casing.
Casing Fixed vanes	Aerodynamically shaped & positioned vanes between the outer casing and inner fairing – forms the support of the inner fairing, and guides/ corrects the turbulent flow behind each blade set/stage.
Discharge evase (Diffusor)	Casing section behind the fan blades/stages. A passage of gradually increasing area through which the air discharged by a fan must pass. The velocity of the air is gradually reduced and much of the kinetic energy is transformed into equivalent pressure energy.
Discharge fairing	Tunnel section to guide flow on the fan outlet area – used also to provide access to the hydraulic blade pitch equipment/compartments.
Electric positioner	The fan-external mechanism used to position and control the fan-internal hydraulic mechanism.
Fan inlet casing	The Inlet box is generally provided by the Fan designer (OEM) / supplier and is considered as part of the Fan – it is designed to reduce inlet pressure drop and contains important process measuring points where instrumentation is installed.

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Definition	Description
Fan Stall	The phenomena of disturbing the natural flow-angle through the Fan blades, which produces an unnatural high frequency vibration – similar to the phenomena described in pumps as “cavitation”. Stall is brought about by incorrect operational conditions on the Fan blades as well as the incorrectly controlled plant process (operational controls).
Hydraulic Blade pitch Actuator	The fan-internal hydraulic mechanism used to change the blade pitch angle – with all blades synchronised to pitch simultaneously.
HVOF	Technological process of applying metal coatings onto substrate materials for damage repair or wear protection.
Hydraulic Servo valve	The hydraulic positioner valve facilitating blade opening or closing and the rate of travel. The Servo Valve is either integral to the Hydraulic actuator or a separately identifiable component, and is actuated/ controlled by the electric positioner/actuator.
Inlet cone	Applicable to ID Fan designs. A dome-shaped guide, placed in line with the central section of the impeller to streamline flow into the flow-area.
Moment Balancing	Refers to the method of establishing the balanced placement of components rotating around a centre-line in order to eliminate any form of un-balance.
MoS2	Molybdenum Disulphide is a graphite-containing ‘dry’ or ‘wet’ lubricant also available in spray-on format, used as an anti-friction agent.
Rotating Union	The mechanism to pass hydraulic control oil from the stationery oil-supply system through to the rotating Fan.
Rotor track casing	The central or core section of the Fan casing providing the support for the fixed/turning vanes, Rotor fan rotor support structure as well as the surrounding machined track to present the Blades with a defined rotating clearance.

2.3.1 Disclosure Classification

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

2.4 ABBREVIATIONS

Abbreviation	Description
AEM	Alternative Equipment Manufacturer
BOM	Bill of Material
C&I	Control & Instrumentation
CW	Cooling Water
dP	Differential Pressure
DP/DPI	Dye Penetrant (NDT Inspection method)
DTI	Dial Test Indicator (Clock-gauge)
FD Fan	Forced Draught Fan
FFP	Fabric Filter Plant

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Abbreviation	Description
HP	High Pressure
HVOF	High Velocity Oxygen Fired
ID	Inside Diameter
ID Fan	Induced Draught Fan
KS	Kusile Power Station – in the content of this document this abbreviation is extensively used, sometimes in conjunction with the Medupi (MD) and Majuba (MJ) abbreviations
MD	Medupi Power Station – in the content of this document this abbreviation is extensively used, sometimes in conjunction with the Kusile (KS) and Majuba (MJ) abbreviations
MJ	Majuba Power Station– in the content of this document this abbreviation is extensively used, sometimes in conjunction with the Medupi (MD) and Kusile (KS) abbreviations
MoS2	Molybdenum Disulphide
MP/MPI	Magnetic Particle (Inspection)
NCR	Non-Conformance Report
NDE	Non-Destructive Examination
NDT	Non-Destructive Testing
OD	Outside Diameter
OEM	Original Equipment Manufacturer
P&SCM	Procurement & Supply Chain Management
PCD	Pitch Circle Diameter
PCV	Pressure Control Valve
PF-piping	Pulverised Fuel piping
PRV	Pressure Relief Valve
PS	Power Station
QCP	Quality Control Plan
RCA	Root Cause Analysis
RTS	Return To Service
SAH	Steam Air Heater
SCOT	Steering Committee of Technology
SOW	Scope of Work
TIR	Total Indicated Run-out
UV	Ultra Violet

2.5 ROLES AND RESPONSIBILITIES

- a) Station System Engineers must be well versed on the content of the Specification and ensure that it is correctly implemented as part of the requirements for the Maintenance program, Outage SOW, and Quality Control processes and procedures.

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- b) Each Power Station is responsible to implement the minimum requirements described in this Specification and to develop a spares stockholding plan to support the execution of Maintenance work.
- c) Where a Contractor is used for executing the maintenance work, the Contractor shall possess the required detailed execution procedures, training material and trained personnel to facilitate accurate execution of the stipulated maintenance repair work in accordance with this specification. The approval of any external procedures and training material is subject to review and approval by the Employer's Engineer.
- d) The Eskom Corporate specialist function must execute compliance audits to evaluate the correct implementation and adherence to the requirements of this specification.

2.6 PROCESS FOR MONITORING

Compliance monitoring to this specification will be via peer reviews and Quality Audits.

2.7 RECORDS

The following documentation shall be produced as a result of this Specification;

- a) The Eskom Engineer shall develop and utilise Scope of Work documentation to guide effective and complete scoping for the specific station.
- b) The Eskom Engineer shall develop the referenced documents recommended in this Specification, pertaining to performance monitoring and Rotor/blade servicing intervals & store the associated condition assessment records generated from these activities.
- c) Each relevant Power Station shall develop the spares stockholding capability to support the accurate execution of required scope for a specific outage.
- d) The Maintenance Contractor shall possess instruction documents to guide accurate execution of the detailed tasks in accordance to this guideline.
- e) The Maintenance Contractor shall possess/develop Inspection Reporting documentation to facilitate effective and accurate condition reporting analysis and Quality Control of the execution.
- f) The Maintenance Contractor shall develop Quality Control documentation to secure effective verification and record-keeping of the quality of execution.
- g) The Maintenance Contractor shall manage and submit a detailed list with spares requirements based on the requested Scope of Work related to a particular outage.

3. MAINTENANCE REQUIREMENTS

3.1 AXIAL FLOW FANS SYSTEMS BREAKDOWN AND DEFINITION

3.1.1 Fan Casing (Static parts)

The Casing/stator structure consisting of the Inlet box, Main casing and Discharge-evase (diffusor) casing sections, and featuring at a more detailed level the Rotor-track & Inner fairing, fixed vanes, shaft seals, thermal compensators, access doors & covers, supporting foundations, and thermal insulation.

3.1.2 Rotating Assembly

The Rotating Assembly, generally referred to as the Impeller, is mounted on the main shaft and includes the Hydraulic Actuator and Fan-side coupling. FD Fans have a single impeller supported in an "overhang" arrangement with the supporting bearings/housings on the drive-side of the fan. ID Fans consist of a two-stage design with the Rotor, supported by an integral housing with bearings between the

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stages. With the different designs between OEM's and applications in the current Eskom fleet of ID Fans, the bearing housing is an integral part of the Rotor, while for the FD fans the bearing housings are separated. Incorporated in the Rotating Assembly is the blade-pitch regulating system to facilitate synchronised pitching of every Blade, and for ID Fans synchronised pitching of every Blade and stage.

3.1.3 Blades and attachments

Blades are fitted to the rotor as an impeller set, in pre-determined positions & sequence. The correct attachment of blades is an item of critical importance and is mostly achieved by means of high-strength torqued bolts. The Blades for the MD & KS FD Fans are attached alternatively by means of a centre screw-connection combined with a locating key. The Blade-bases with attachment bolts are recessed into the impeller for smooth & protected air/gas flow, and the bases contains seals to prevent gas/ash ingress into the impeller internals.

3.1.4 Bearing Housings and Bearing sleeves

The shaft and impeller rotation is supported & facilitated by sleeve-bearings fitted in housings – one bearing accommodating the trusting/locating function and the other bearing is used in a floating mode. Bearings are force-lubricated from an external lubrication system. As noted under the Rotating Assembly description above, generally the FD Fan DE & NDE bearings are fitted within individual housings, whereas for the ID Fans the two housings are joined/combined and form a connecting tube between the two stages.

3.1.5 Hydraulic actuating system

The Hydraulic Blade-pitching actuator transfers the high pitching-force to internal mechanical linkages and consist of mainly three components, namely the Hydraulic Ram, Servo-positioner valve and Rotating Union. The hydraulic actuator and servo positioner is integral to the Rotor and not generally accessible. The Rotating Union transfers control oil from static to the rotating motion and is attached onto the Impeller, accessible and connected with the external control linkages.

3.1.6 Lubrication and Hydraulic oil supply systems

The Lubrication oil supply system provides lubrication to the Fan & sometimes incorporates lubrication to the Main Drive Motor bearings as well. The Hydraulic oil supply system provides hydraulic pressure to operate the Blade pitching system and generally at a much higher pressure than what is required for the bearing lubrication system. With varying designs, the lubrication & hydraulic oil supply systems can be incorporated into the same tank and valve system, or is installed as completely separate systems. The typical system consists of the basic elements like the tank, pumps & drive motor, cooler, control-valves, connecting pipework and the protection instruments.

3.1.7 Main Drive Motor and connecting shaft

The Main Drive Motor and bearings are standard as for any other fan design arrangement. The connecting shaft between Motor and Fan extends through the Fan Inlet Box and is connected on both sides with Turbo-flex couplings, thereby presenting some variation on the typical fan alignment requirements.

3.1.8 Sealing Air (SA) Fans

The Sealing Air Fans are mostly required on ID Fan-installations due to the elevated operating temperature surrounding the fan and bearings, and the risk of possible ash ingress.

3.1.9 Electric positioner and control linkages

The control of the Blade-pitch positioner consist of an electric actuator, external linkage and position indicator, and the internal connecting linkages.

3.1.10 Fan protection systems

Extensive care is taken with instrumentation to provide accurate fan operating parameters – pressure, flow, and temperature – in order to plot the fan operating parameters for integrated “Stall” condition protection. The Bearing vibration protection layout varies between installations with either internal bearing-mounted or external casing-mounted vibration measurement instrumentation.

3.1.11 Fan Instrumentation

The above-noted Protection-instrumentation together with other standard Process-instrumentation requiring to be maintained and controlled with the effective use of checklists.

DETAILED COMPONENTS AND SERVICE REQUIREMENTS

It should be clear from the list of equipment below that the Power Station should ensure that thorough inspection and monitoring plans are implemented in order to manage the health & performance of the Axial Flow fans.

3.2 FAN CASING (STATIC PARTS)

3.2.1 Fan Inlet equipment & plant

- a) Air intake (ducting)
 - 1) FD Fan intakes are normally located high up in the boiler house to capture air at an elevated temperature. It is important to manage the cleanliness of the suction area:
 - i. The intake bell-mouth should ideally be in the vertical orientation to prevent the settlement of large debris.
 - ii. Horizontal intake orientations require frequent cleaning (MJ).
 - iii. Boiler house ash leakages result in ash particles rising with the hot air to the top, towards the FD Fan suction intake – such leakages from PF-piping, damper glands, duct thermal compensators, and eroded positive pressure ducting, etc. must be avoided.
 - 2) FD intake temperature control dampers, which are used to select a flow-path from various sources, must be monitored, and control logic failures that are designed to maximise inlet temperatures must have a “fail-safe” mode to prevent accidental closure of the FD Fan inlet flow-path.
 - 3) FD inlet sound insulation are provided by silencers that require inspection and it is critical to ensure that no objects/tools/equipment utilised for access & inspection is left inside the flow area.
- b) Steam Air Pre-heaters (SAH) located before the FD fans could have a vast effect on the efficient operation of Axial FD Fans, thus making it absolutely essential to preserve the condition of this plant:
 - 1) Steam emitted from leaks on the SAH will result in severe water-droplet erosion on blades, which rapidly deplete the capability of the blades to produce the required pressure as well as a rapid reduction of blade-life.
 - i. Remaining useful Blade life can be reduced by a factor of 10 times if this aspect is not well-managed.
 - 2) Blocked SAH's have to be monitored and cleaned, and it cannot be emphasised enough to caution against the negative effect SAH blockages have on Axial-fan suction-side pressure increases. The typical effects are:
 - i. A reduction in the pressure-delivering capability.

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- ii. Increased risk of Fan “Stall” conditions, leading to catastrophic failure of the fan rotor or blades.
- c) Oxygen (O₂) controllers drive the loading of FD Fans, and ultimately also affect the ID fans, and require intensive care and monitoring.
 - 1) Calibration drift of O₂ analysers result in:
 - i. Increased flow-delivery demand on FD fans.
 - ii. Increased air-side pressure-drop through Air Heaters.
 - iii. Increased suction-demand on ID Fans.
 - iv. Increased gas-side pressure-drop through Air Heaters and FFP.
- d) Thermal Compensator ageing and rupture result in flow-ingress with a detrimental effect on FD and ID Fan flow-demand.
- e) Inlet ducting Turning vanes hold the risk of cracking and may require repairs. Depending on the lay-out/location of turning vanes, it requires additional care to secure the condition & cleanliness as debris from these areas will result in severe damage to Fans and Blades. To this extent, these components should have:
 - 1) A detailed Inspection program implemented to detect cracking.
 - 2) Clean conditions verified after execution of repairs.
- f) Access doors requires detailed servicing and closure management after shut-downs.
- g) The Regenerative Air Heaters (RAH) design consists of a fine matrix of heat-exchange elements and is a large source of system flow resistance, thus affecting the operation of both Axial FD Fans as well as Axial ID Fans if not well maintained. It is important to check of typical problem indicators to this extent:
 - i. A system pressure-increase that will result in the depletion of Fan pressure margins.
 - ii. Air Heater leakage due to incorrect seal-setting or seal operation that will result in increased loading on both FD and ID Fans. Leakage is further exaggerated when blockage occur.
- h) Fabric Filter Plant (FFP) condition monitoring and process management holds the biggest risk for performance deterioration and damage to ID fans. Typical problem areas are:
 - 1) FFP Bag “blinding” that leads to a depletion of the ID Fan’s pressure margin.
 - 2) FFP Bag leakages that result in severe blade erosion and resultant decay in performance capability.
 - i. The monitoring of the flue-gas contamination must be closely monitored and not allowed to drift outside of design-norms and operating parameters.
 - ii. Caution is noted to Power Stations fitted with a Flue Gas Desulphurisation Plant (currently KS) that requires intensive monitoring & control of emissions BEFORE the FGD, thus not attending to the normal Flue Gas Stack monitoring equipment.
 - 3) Implosion Dampers that are located on the ID Fan intakes raises the need for detailed inspection and monitoring. This is due to the following risks:
 - i. Faulty operation of these dampers can result in uncontrollable situations on Furnace pressure and ID fan overload, and thus requires meticulous attention to it during maintenance routines.
 - ii. Equipment failure could result in debris sucked through ID Fan blades with disastrous consequences (especially, but not limited to MJ).
 - iii. Designs allowing rain-water ingress contributes to blade erosion, and inspection routines should specifically inspect the fan and dampers for this condition.
 - 4) For designs that has Cell vent fans with admission dampers care should be taken during maintenance routines not to leave the dampers open. If the dampers are left open, it will result in the vent-fans being subjected to the ID fan suction pressure, which increase the speed of the fans to destruction, resulting in failure debris that will cause severe damage to ID Fan blades and fan internal housing/components.
 - 5) Ash removal system failures which results in full hoppers at bottom of FFP, which ultimately disturb the flow area, with a resulting increase in pressure-drop and imbalance on ID Fan loading-demand.

3.2.2 Inlet box

- a) The Shaft tube (FD Fans) is the fairing/guard surrounding the bearings and shaft:
 - 1) Majuba FD fans have an accessible tube, with a shaft guard requiring firm support. On-load access for inspection must be cautiously undertaken.
 - 2) Medupi FD fans have an enclosed tube prohibiting on-load access.
- b) Shaft tube (ID Fans)
 - 1) Sealing of the shaft tube/guard is important to prevent ingress of ash.
 - 2) The shaft inlet area to the shaft tube/guard contains a sealing gap to be maintained in order to control the cooling-flow through the tube – this temperature affects the thermal expansion of the shaft.
- c) Fairing “coupling cone” (ID Fans)
 - 1) Lifting of the cone during maintenance interventions require cautious control:
 - i. Execution of NDT on lifting lugs & weld is required.
 - ii. Cautious control to be taken during removal process in order to prevent damage to the labyrinth seal (MJ)
 - iii. Maintenance of guides mounted on the cone split-flange is required.
 - 2) Sealing of the inlet coupling-cone has multiple risk areas where detailed control of maintenance routines are required:
 - i. The Inlet Cone inlet edge surrounding the shaft tube.
 - ii. The Inlet Cone split flange – especially with the scheduled lifting of the cone when Rotor swaps and balancing or alignment activities are required.
 - iii. The Majuba ID fans Inlet Cone downstream opening, surrounding the Rotor coupling adaptor which contains a labyrinth seal with adjustable & controlled gaps that must be set according to the prescribed design base requirement.
 - Labyrinth seal replacement requires human access inside a closed cone for set-up control.
 - Replacement seals must be available and it should be noted that these components are refurbishable.
- d) Compensators on Fan-inlets are subject to large suction pressures, and require serviceability assurance especially on ID Fans, and should therefore be part of the regular inspection routine on the ID Fans.
- e) Access door sealing and closure-control is essential.
- f) Large inlet flow-directional vanes present a low risk of failure or wear and is subject to 3-yearly NDT for crack detection.
- g) Instrument tapping points:
 - 1) Essential instruments with casing tapping points are contained in this area requiring frequent cleaning & testing with intervention by both Mechanical and Instrumentation maintenance personnel.
 - i. Specific Note should be taken about the cautions regarding the management of thermal insulation around ID Fans instrument tapping points to prevent damage to sensitive instrumentation.
 - 2) Maintenance details requiring on-load interventions are covered in the applicable section for “Fan Instrumentation” below.
- h) Safety measures must be implemented into maintenance work instructions to secure access arrangements:
 - 1) Main casing door ease of access.
 - 2) Blade inspection access with consideration to the risk of falling.
- i) Inlet box drainage point cleaning should be undertaken as part of the maintenance program to prevent accumulation of water.

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3.2.3 Rotor track casing with fixed vanes

- a) The Outer casing forms the main body of the Fan accommodating the rotor position, and is the main section removed (top half) when performing fan Rotor swaps. The Casing section contains several important features for monitoring when performing maintenance work:
- 1) The machined Rotor track is formed on the inside diameter of this casing and is comprehensively dealt with in the next section.
 - 2) The top Casing removal requires close quality control during placement to secure a level surface within 5 mm and utilising correct stacking materials.
 - 3) The Casing outer flanges are machined and form a control surface for the inner diameter size and concentricity.
 - i. Cleaning, sealing and preservation actions are required and are of particular importance for ID Fan casings that are exposed to flue gas and water ingress.
 - ii. On ID Fans, the casing flange bolts and holes are subject to the same sealing and preservation-care as would be taken for flanges.
 - iii. Casing alignment guide-pins of various designs require a skilled installation approach:
 - Procedurised action for retracting the guide-pins where applicable (KS/MD ID).
 - Inspection and maintenance routines should contain a QC Hold/Witness checkpoint before closing casings to ensure correct preparation and internal conditions was achieved.
 - 4) Blade removal doors on Outer casing (FD Fans & MJ ID)
 - i. Particular attention should be paid to the monitoring of Blade tip clearance with removal of the doors which can intrude into the Rotor track if not installed correctly.
 - ii. Door sealing and fitting is important as the doors are positioned on the Rotor track, requiring specific controlled quality checking intervention:
 - Door must be flush with Rotor track within 1 mm.
 - Sealing and bolt-maintenance and condition inspection should be performed with every Rotor-swap intervention.
- b) The Rotor track is defined as the machined inside diameter (ID) of the main casing, providing a defined clearance between casing and blade tips, and the detection of any deformation or damage requires monitoring & reporting on 3-yearly maintenance intervals.
- 1) The execution of casing ovality and concentricity checks requires the use of several aids:
 - i. Manpower turning with safety pre-cautions in place.
 - ii. Special measuring gauge on 0.25 mm “go/no-go” decision steps.
 - iii. Reporting must be done on a pro-forma requiring Engineering interpretation and recommendations from the measurement findings.
 - 2) Rotor track ovality or eccentricity measured outside of the Manufacturer’s norm requires deliberate action, in order to prevent operational abnormalities:
 - i. Casing abnormalities resulting in a forced increase of blade-tip clearances in excess of 50% of the OEM-stipulated maximum, must be reported for immediate investigation and correction.
 - ii. Blade-tip clearance abnormalities (between individual Blades) resulting in a forced variation of more than 1.5 mm between minimum and maximum must be reported for immediate investigation and corrective action.
 - 3) Correction mechanism
 - i. For FD Fans, the bearing positions are the prime mechanism for correction of off-sets (eccentricity), while internal trimming of the rotor track may be required for correction of ovality.
 - Vertical and horizontal clearances are achieved through correct alignment.
 - If casing deformation affects stipulated clearances, the Rotor track has to be trimmed with the use hand-grinding and a curved profile to guide trimming.

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- ii. For ID fans, no adjusting mechanism on the first-stage track is available and will thus require the planned removal of the casing for extensive machining repairs.
 - iii. For ID Fans, the second-stage track provides a spigot-location on the mounting flanges and corrective adjustments must be carefully undertaken, monitored and controlled.
- c) Outlet flow-straightening vanes (fixed vanes) – are located after each stage of blades and require close monitoring for vibration fatigue and erosive wear.

1) Fixed vane NDT inspections

- i. The inspection and monitoring of erosion and welded joints on Fans is a mandatory activity guided by the relevant Inspection Standard for Fans.
- ii. Crack-detection must be part of the fan test and inspection plan, and repairs should be planned for, and undertaken if required.
 - Visual inspection for deficiencies is executed on 18 monthly intervals.
 - NDT of welds must be executed on 3-yearly intervals.
 - The station history of cracking found on Fan vanes must determine the monitoring and NDT frequency.
 - A comprehensive report must be compiled of weld-attachments and requires correct and repeatable blade referencing.
 - Repetitive cracking of vanes must be flagged, investigated and analysed in order to deal with possibilities of fatigue of the affected areas
- iii. Erosion is generally limited to fixed vanes located inside the flow area.
 - Erosion of FD Fan casings should not be present, but current experience with ash-leaks to atmosphere justifies detailed monitoring of wear on a 3-yearly basis.
 - Erosion of ID Fan casings should be very slow, requiring interventions on minimum 6-yearly intervals but current experience justifies detailed monitoring on a 3-yearly basis.
- iv. The reporting of abnormal wear on Axial flow Fan casings require a critical review and intervention into the operational conditions and rectification to incorrect practice.
- v. NDT in the form of crack & wear evaluation is executed, after which repairs must be interfaced with the Rotor swop activities.
- vi. The monitoring of fixed-vane cracking and wear patterns must be performed against a mapping plan – refer to the details noted under the applicable section for “Casing Inspection and Repairs” below.

2) Fixed vane repairs

- i. The need for planning of Casing repairs is determined from the historical experience and from the initial visual inspection at the start of the outage – confirmation of the exact scope and repair methods is finalised with the availability of a comprehensive NDT report.
- ii. The execution of Casing repairs must be interfaced with the Rotor swop program.

The execution of repairs is recommended after thorough Engineering inspection & analysis of the reported deficiencies and is supported with the issuing of a detailed repair scope and execution instruction – refer to the details noted under the applicable section for “Casing Inspection and Repairs” below.

3) The **ID Fans** vane configuration for the top casing contains features that requires caution during the performance of maintenance routines, requiring additional quality control and maintenance oversight:

- i. With Casing removal, some overhang vanes on the casing-splits require caution and monitoring when placing the casing next to the Fan.
- ii. The Majuba casings contain an added overhang vane stabiliser mechanism that has to be correctly positioned to prevent flow-induced vane-vibration.
- iii. The Kusile casings (which is different in design from Medupi) contain fixed vane stabiliser brackets to secure vane on the RH-side casing-split position to the inner tube.

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- 4) The **ID Fans** Casings contain aerofoil hollow vanes between the fixed vanes, acting as channels to provide for the supply of lubrication piping, internal instrumentation and compartment cooling flow with the following as considerations:
- Aerofoil vane erosion should be monitored and controlled in the same manner as prescribed for fixed vanes.
 - Aerofoil vanes are double skinned with internal insulating materials, which require additional management if vanes are ruptured.
 - Refer to the details noted under the applicable section for “Casing Inspection and Repairs” below
- d) Inner fairing (ID Fans Bearing compartment)
- The ID Fans bearing compartment is pressurised and insulated, thus maintenance of leakage/ingress and cleanliness requires meticulous attention.
 - Flanges on the Inner fairing form an unbolted sealing surface, and requires all-round correct sealing to prevent pressure-interference from the gas-flow area.
 - Abnormal gaps in excess of 2 mm on the Inner fairing flanges must be identified and reported for further Engineering assessment and action.
 - Caution: Excessive welding on fixed vanes could result in distortion of the flanges/gaps, resulting in extensive factory repairs.
 - Correct Welding heat-dissipating techniques must be applied.
- 4) Bearing compartment and doors (ID Fans)
- Bearing compartment internals for all ID Fans are not easily accessible, and meticulous quality control inspections of internal conditions must be undertaken before closing casings after performing maintenance work.
 - Internal details must be inspected and controlled via an approved check-list to curb unplanned failures that will require re-opening of the compartment. This checklist must include activities for the testing and verification of instrumentation.
 - Bearing compartment access doors have been provided for Kusile & Medupi ID fans, requiring additional consideration:
 - Opening of these inspection doors is only justified for investigating a suspected internal deficiency and for a 3-yearly inspection if the Fan Rotor is not swapped.
 - Re-sealing and closure of doors must be strictly quality controlled.
- e) Fan Monitoring & Protection equipment.
- Essential instruments with casing tapping points are contained in this area, and due to the environment they operate in, will require frequent cleaning, repair & testing. The typical instrumentation configuration comprise of Flow/Pressure instrumentation tapping points, vibration monitoring probes, and the Fan “Stall condition” sensing probe.
 - It is important to note that the instrument tapping points for **FD Fans** utilise the concept of a “piezo-ring”, which will require additional attention and careful maintenance work control especially during casing lifting and cleaning activities.
 - It is important to note that the instrument tapping points for **ID Fans** are exposed to flue-gas condensation, requiring additional quality control on thermal-insulation practices.
 - The maintenance of instrument/casing interfaces will require the maintenance attention of both Mechanical and Instrumentation disciplines.
 - Maintenance details requiring on- & off-load interventions are covered in the applicable section for “Fan Instrumentation” below.
- f) Casing/Impeller (shaft) seals
- FD Fans (MD/KS)
 - The ‘Klingerite’-type seals on the DE-side, located inside the Bearing-compartment must be monitored for serviceability on 3-yearly intervals.

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- ii. The NDE-side seals are located inside the Hydraulic compartment and is fitted with dedicated copper leaf-type seals with minimised settings relative to the Rotor. Settings shall be done according to the OEM prescribed parameter limits.
- 2) FD Fans (MJ)
- i. Both DE & NDE seals, located inside the Bearing & Hydraulic compartments respectively, are multiple layers of pre-cut 'Klingerite'-type seals and are serviced with 3-yearly interventions and casing removal maintenance scopes of work.
 - ii. The centralising of the seals to seat on the dedicated Rotor landings is dependent on the location of 'Quadron-plates'. Quadron plates are of split design, and its peripheral attachment to the casing requires detailed quality check intervention to assess location problems before casings/seals are dismantled.
 - iii. Quadron-plate periphery attachment points are adjusted with shim layers and/or taper jacking, in order to manipulate the shaft-seal onto its landing.
- 3) ID Fans (MD/KS)
- i. Control of these Bearing housing-to-Rotor seal-gaps is important to prevent flow-side pressure-forces from interfering with bearing pressures and which can result in losing lubrication oil into the flow-area.
 - ii. Casing DE & NDE shaft-seals are mounted onto the bearing-room sidewalls with a setting-gap control interfacing with the Fan Rotor.
 - iii. Any activity requiring a Fan casing-lift justifies a mandatory verification & recording of seal-setting gaps and tightness.
 - Bottom casing seal-gaps are accessible for verification with the top casing off and for best-practice also with the fan Rotor out – limited measuring and tightening access is available with the Rotor in position.
 - Note that clamping bolts require "Lock-tite" to be applied during the tightening process.
 - Top casing seal-gaps are accessible for verification with the casing removed.
 - iv. The Hydraulic-room Casing-section contains the third radial "shaft-seal", seated on the peripheral housing and with a setting-gap control interfacing with the Fan Rotor.
 - Any scheduled intervention of casing-opening requires recorded gap-monitoring and adjustment.
 - v. All three shaft-seal locations require dedicated profiled copper strips with clamped backing rings and clamping bolts. These components must be kept in stock as Rotor-swop spares.
- 4) ID Fans (MJ)
- i. Control of these Bearing housing-to-rotor seal-gaps is important to prevent adverse pressure-forces from interfering with bearing pressures and which can result in losing lubrication oil into the flow-area.
 - ii. Rotor-track Casing DE & NDE Rotor-seals are mounted onto the bearing-room sidewalls and are position-dowelled after setting.
 - iii. Any activity requiring the casing-lift justifies a mandatory verification of accessible seal-gaps.
 - Bottom casing seal-gaps are accessible for verification with top casing off and with the Fan Rotor installed.
 - Top casing seal-gaps are accessible only during the "casing-lift" and "casing-lowering" activity. The use of a 2mm lead-wire gauge is required for gap-verification.
 - Note that clamping bolts and locating dowels are required for securing the position of seals.
 - Seal replacement or adjustment is only possible with the Fan Rotor removed – a "dummy" Rotor is utilised for setting and must be prepared as part of the scope of work if setting is required.

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- iv. Due to problematic gap-assessments, a controlled condition monitoring method is strongly suggested to establish information if measurement and/or replacements are necessary – refer to the stipulated details in the section for “shaft seals” below).
 - v. The Hydraulic compartment Casing to Rotor-seals are mounted inside the Hydraulic room and require setting-controls on a 3-yearly basis with moderate adjustments possible. These seals are also dowelled in position after setting.
 - vi. Replacement seals must be available as part of the spares holding, and it should be noted that damaged components are refurbishable.
- 5) For ID Fans, both DE & NDE Bearing-compartment seal-cavities as well as the hydraulic-compartment seals have been provided with pressure-measuring tappings, routed to the external mounting-rack on the casing.
- i. During casing removals, the health and positioning of the piping must be maintained.
 - ii. Requirements for testing of pressure drop as a mechanism to verify the health of casing-seals are detailed in the applicable section on “Seal Air fan” and “Fan commissioning” below.
- g) Safety measures applicable to the Rotor track casing:
- i. Rigging of the top removable casing section requires a detailed risk-assessment and procedure to safeguard the removal activity.
 - Removal of the FD Fan Rotating assembly requires rigging manipulation in both axial and vertical directions, requiring the use of special rigging tools and experienced personnel.
 - Removal of the ID Fan top Rotor track & Hydraulic room Casing sections is best facilitated as an assembled unit with the overhead hoist which is centrally positioned for the Rotor, with the associated special quality control and safety measures.
 - Removal of the ID Fan top casing requires axial as well as vertical manipulation justifying additional quality and safety controls to be put in place in order to prevent damage to fan equipment and injury to maintenance staff.
 - ii. Internal access to inspect fixed vanes and blades – especially on the top half of Rotor & Casing – presents a safety risk for falling, which should be part of the pre-job briefing and preferably offer a means of assisting access.
 - iii. Removable internal ladders present a better solution than obstructing scaffolding, but it is essential for Power Stations to devise a fool-proof mechanism to prevent an omission to remove the ladders before closing the doors. Ideally, an inspection to confirm removal should be included as a hold-point in the maintenance quality control program for the fan.

3.2.4 Diffusor casing

- a) The casing section contains components that require minor maintenance intervention, except for instruments and access doors.
 - 1) Flanged connection to the Rotor-track Casing which may require sealing when removed and adjustment to correct alignment when required.
 - 2) Internal fairing with access doors to the Hydraulic compartment.
 - 3) External diverging discharge for flow/pressure recovery and laminar flow to aid with flow-measurement.
- b) The internal fairing alignment with the Rotor and flow area is important to minimise ingress of ash into the fairing, and must be controlled/corrected to axial gaps of maximum 15 mm, and radial deflection of maximum 5 mm.
- c) Internal fairing supporting stays are subject to NDT on welds as noted for the other casing sections on a 3-yearly basis.
- d) Hydraulic compartment (FD Fans)
 - 1) The rear-mounted access door sealing control is important to prevent positive pressure ash ingress into the compartment.

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- 2) The fairing contains a sealing interface with the impeller (casing to Rotor seal) inside the Hydraulic compartment and requires inspection for serviceability on 18-monthly basis.
- 3) FD fans contain no compartment instrumentation.
- 4) The compartment contains the blade pitch adjusting connections and are dealt with under the appropriate section for “Electric positioner and Control linkages” below.
- e) Hydraulic compartment (ID Fans)
 - 1) The Hydraulic compartment is functionally part of the Rotor track casing and access is facilitated through the internal fairing and doors.
 - 2) The Hydraulic compartment access doors are individually separated from the Inner fairing and are sealed in order to prevent ash-ingress due to the pressurised fan-outlet.
 - 3) The Compartment Labyrinth seal gaps are controlled and requirements are noted under the former section dealing with all Casing seals.
 - 4) The compartment is pressurised via the use of sealing/cooling fans, and contains several features required for monitoring and correction during access interventions:
 - i. Temperature measurement.
 - ii. Pressure measurement tapping.
 - iii. Pressurised air channels – this requires a cleanliness report to be compiled when any maintenance work is performed in the Hydraulic compartment, with recommended remedial action where required.
 - 5) Other components of the compartment include the blade-pitch adjusting connections and these are dealt with in the appropriate section for “Electric positioner and Control linkages” below.
 - i. The Kusile & Medupi ID fans require controlled inspection of fitting-condition and tightness.
 - ii. All ID Fans require controlled setting and stroking of the blade-pitching limits before closing doors.
- f) External Casing access doors require the provision of an access platform when performing standard maintenance and require sealing with quality controlled checks before closure after conclusion of work.
- g) Instrument tapping points:
 - 1) Essential instruments with casing tapping points are contained in this area requiring frequent cleaning & testing.
 - 2) The maintenance of some instrument interfaces requires the intervention of both Mechanical and Instrumentation personnel.
 - 3) Maintenance details requiring on- & off-load interventions are covered in the applicable section for “Fan Instrumentation” below.
- h) Safety measures applicable to the Diffusor casing:
 - 1) Access ladder to external door have to be provided, if not permanently installed.
 - 2) Access ladder to the internal fairing door may be required, with controlled closure checks to ensure that ladder was removed after maintenance and before boxing up.
 - 3) CAUTION: for ID Fans, the inner fairing acts as a “dead-space” where flue gasses are trapped – this area is to be purged before access is permitted.
 - 4) For Medupi ID Fans – Caution should be taken when opening the door hatch as it is prone to severe internal ash settlement presenting the risk of “ash-flooding” when the hatch is opened.

3.2.5 Casing NDT Inspection and Repairs

- a) Fixed vane crack NDT inspection & reporting
 - 1) The inspection and reporting of cracks on fixed-vanes require the development of a unique format for each Fan casing with a referencing of vanes in order to support the need for repeatable history tracking.

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- 2) The starting point for the numbering of the flow-directional fixed vanes is in the 9 o'clock position – viewed when facing in the direction of flow, with the first vane above the casing split on the top casing.
 - i. Vanes on the 2nd stage impellers are viewed and marked in the same orientation.
 - ii. A similar approach is followed with the identification numbering of other fixed and profiled vanes.
 - 3) The reporting format further differentiates between welds of fixed vane attachment welds on the inner fairing versus outer casing, and leading-edge versus trailing-edge.
 - 4) Report of cracks must be supported with photographic evidence, and a description of the approximate length and location, e.g. inside the weld or in the fixed vane.
- b) Erosion monitoring of casings and vanes.
- 1) Erosion plotting must be standardised with the use of a set of procedures and lay-out template in order to present repeatable inspection & reporting results.
 - 2) The inspection findings are documented for record purposes so that future inspection findings can be comparatively mapped against previous outage findings.
 - 3) Axial fan casings, subject to erosive operating conditions, require plotting of the wear-survey in order to capture the pattern and repair trends with the following intensity, decided pending the visual findings.
 - i. In areas with a low rate of erosion, a sampling matrix of 1000x1000 mm is required.
 - ii. For an intermediate rate of erosion, increase the sampling matrix to 500x500 mm.
 - iii. A high Rate of erosion with severely affected areas, require a smaller grid of sampling of 50x50 mm.
- c) Fixed vane crack repairs
- 1) A detailed repair procedure is required, with specific focus on how to control heat distribution and thermal expansion of vanes/welds during repairs.
 - 2) Weld execution requires tight quality control in order to secure accurate execution of the approved repair procedure, and as a minimum should include the following aspects:
 - i. Casing positioned correctly without induced distortion.
 - ii. Complete excavation and repair of cracks with NDT verification.
 - iii. Controlled pre- & post-heating of thicker casing sections to avoid the creation of a severe heat affected zone due to rapid cooling.
 - iv. Non-stop welding around leading & trailing edges.
 - v. Mild dressing of weld and undercuts to achieve a smooth bulge-free weld surface – with caution against over-dressing and thinning of the vane.
- d) Casing erosion repairs
- 1) Replaceable liners is required for repairs and the manufacturing & installation of liners must be based on approved designs and drawings.
 - 2) The design shall consider the effective streamlining of the liner profile in combination with the desired wear-life.
 - 3) Flat-plate vanes of more than 6 mm thickness must be fitted with a hard-wearing leading-edge liner.
 - 4) Engineered profiled wear-liners are required for the repair of fixed-vanes and hollow-vanes with thickness in excess of 16 mm, with the following requirements:
 - i. The original structure is re-instated in accordance with original design/installation.
 - ii. Engineered profiling is proposed with consideration of the disturbance of the flow-dynamic patterns within the casing caused through the fitment of excessive liners.
 - iii. Aerofoil profiled supports, with severe wear on the leading-edge would also require lining along the sides to protect the original structure from damage.
 - iv. Profiled liners should be manufactured from a maximum 4 mm erosion resistant plate and weld-attached in a way to prevent complete erosion of the attachment interface.

- 5) The repair of solid-vanes up to the thickness of 16 mm, have the following requirements:
 - i. In the case of mild erosion, the weld build-up of eroded vanes is acceptable.
 - ii. In case of more severe erosion, the use of erosion-resistant materials attached to the leading edges of the vanes and with the leading edges profiled as required from the initial design is preferred.
- 6) Aerofoil vanes with a nose-radius of less than 8 mm must be fitted with a solid leading-edge/nose liner and if the radius is more than 8 mm, the use of a pre-formed weld-attached liner with hard-wearing material is more appropriate.
- 7) It must be observed that the repair of Fixed/hollow vanes on ID Fans require the application of thermal insulation in accordance with the original OEM stipulation.

3.2.6 Insulation & Cladding

- a) Due to the need for frequent Rotor swaps, insulation surrounding the casing-split and compensator areas are designed and applied to facilitate the maintenance activity.
- b) Unlike other (centrifugal) fans, the repeated Rotor swap activity requires additional inspection interventions to ensure that re-instatement of insulation is according to drawing design specifications and function, attending to the following particular aspects:
 - 1) It should be performed in a way that prevents ingress of water onto the insulation & skin-casing.
 - 2) Correct details of insulation surrounding the instrument tapping points in order to prevent cooling and condensation of flue-gas inside impulse-piping.
 - 3) Correct insulation surrounding external vibration monitoring instrumentation and “measuring cavities” created for the purpose of additional external monitoring interventions.
 - 4) Correct insulation lay-out and installation surrounding the quick-removal or split-panels for compensator and instrument inspections.
- c) The life-expectation of insulation material is in excess of 20 years but incidents of water ingress result in drastic useful design life-reduction. It is recommended that the bottom-casing insulation is inspected for functionality after the prescribed period.

3.2.7 Overhead Hoist and access platforms

- a) The serviceability of the Fan & Motor Overhead Hoist is essential, given the frequent Maintenance interventions, and requires a dedicated Servicing and testing plan that is undertaken prior to any 3-yearly planned outages on the Fans.
- b) Access Platforms and Steel structures are inspected before and after the execution of Rotor swap maintenance, attending to the following critical aspects:
 - 1) Platform cleanliness – removal of any debris.
 - 2) Platform damage or re-instatement – i.e. if handrails had to be removed to facilitate the swap activities.
 - 3) Repeat inspections of critical steel structure interfaces on steel platforms and supporting steel structure may be required, with attention on:
 - i. Hoist crawl-beam structure expansion joints.
 - ii. Crawl-beam cleanliness – especially where beams are exposed to coal/ash droppings and build-up.
 - iii. Discharge ducting thermal expansion slide-pads.
- c) Concrete platforms require some basic care to prevent premature deterioration of its condition:
 - 1) Prevention of oil deposits onto the concrete, justifying maintenance preventative actions.
 - 2) Inspection and reporting of the concrete structure for signs of cracking or spalling. Defects found should be investigated further and NDT performed to ascertain the condition of the concrete structure if/when surface or structural defects are noted.
 - 3) Inspection and verifying of Casing and Bearing mounting pedestal anchor bolt tightening torques.

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- i. Uncontrolled flogging of bolts is not allowed. Bolt torque should be done with the use of a controlled torque-applying tool and torque setting recorded on the maintenance work quality control check-sheet.
 - ii. Locations – such as bearing pedestals – where it may not be possible to obtain appropriate tools or space for the execution of torque-application, the Contractor must submit a Quality concession for investigation and acceptance.
 - iii. Any signs of bolt-rotation under torque must be reported to Engineering.
 - iv. Protection of bolts/threads against corrosion.
- 4) Inspection and reporting of foundation bolt base & packer-grouting for signs of disturbance or damage.

3.3 ROTATING ASSEMBLY

3.3.1 Fan System health

a) On-line Fan performance assessment

- 1) Important aspects for performance monitoring – which is different from the Centrifugal fan norms – apply to Axial flow fans. Several functionalities are provided to conduct performance assessments on Axial flow Fans, as well as assessment of effects from adjacent Plant.
- 2) It is important to have a structured approach to information gathering in order to establish the health of the fan and associated fan systems involving the following aspects:
 - i. Rotor performance deficiencies are identified through Flow/Pressure measurement while it must be noted that indication errors, which are caused through instrument failures, tapping point or impulse pipe blockages, can also result in misleading readings.
 - ii. Measurement and trending of the flow balance between the LH and RH fans is important for fault-finding on Fans as well as to support Air Heater and Fabric Filter Plant (FFP) performance. A strict control on the correct execution of hydraulic & electric blade stroking is required.
 - iii. Flow balance & Flow-quantity versus blade pitch position is an important verification used to detect hydraulic or electric actuator failures.
 - iv. Suction/inlet (absolute) pressure and temperature measurements are utilised to perform flow-density calculations, thus requiring off-load verification as well as on-load monitoring.
 - v. Fan generated differential Pressure (dP) is an important indicator of system pressure drop and developing deficiencies. The capability and threshold of the fan to generate pressure is heavily affected by blade wear and incorrect blade tip-clearance conditions.
 - vi. It should however be considered that the Fan flow measurement can also be affected by casing and measuring point irregularities which can indicate constant deviations from the norm.
 - vii. Increasing fan dP or increased motor current usage are reliable tell-tale indicators of a fault condition developing in the equipment and should be investigated further by engineering.
 - viii. The Fan flow & pressure measurements formulate the input to the fan “Stall”-warning as well as the fan performance curve, thus dictating its vital importance for accuracy, and the need for meticulous maintenance execution when required.
 - ix. The Axial Fan “STALL” phenomena is a critical parameter that is monitored, and when this condition is initiated, it is generally caused by poor process system operational condition management. The primary intent of this alarm is to protect the Rotor against catastrophic failure.
- 3) The performance of fans is heavily dependent on the health of adjacent plant, of which the following aspects require intensive monitoring: (Also refer to stipulated details noted on the section for “fan inlet equipment” above)
 - i. Secondary Air duct pressure control.
 - ii. Excess oxygen (O₂) control.

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- iii. Furnace pressure control.
- iv. Duct & Compensator perforations (leakages) – causing ingress on Gas-side, and loss on Air-side.
- v. Air heater blockage and bypass.
- vi. Fabric Filter Plant dP, bag leakage and ash-removal system failure.
- 4) Reference should also be made to the “ID Fan out of Capacity” Guideline for detailed support.
- 5) The detailed monitoring of Fan vibration levels and vibration spectrum analysis provides a clear indicator of fan health – refer to the applicable section on “Fan protections” below.
- 6) Plant walk-down requirements are provided in the applicable section for “Inspection and Testing” below.

b) Online Fan Rotor health assessment

- 1) Rotor service life is established through design, but can be adversely affected by poor/incorrect refurbishment quality, installation quality and operational conditions. Rotor services is planned & executed with pre-defined intervals – and does not rely purely on fan performance indicators only.
- 2) While the recommended fixed service interval is the main driver for Rotor replacements, unacceptable health of a Rotor would be a contributing reason to influence premature replacement, while the Rotor performance may still be a healthy indicator.
- 3) Rotor deterioration or unacceptable conditions is detected through a few monitored aspects:
 - i. Vibration spectrum – apart from the on-line monitoring system, the use of detailed vibration spectrum analysis will enable engineering to identify deficiencies on Alignment, Casing deficiencies, blade deficiencies, balancing drift, and internal looseness and it is essential to have a good condition monitoring program in place.
 - ii. Loss of oil – evident in system level, or observe on bearings, or flow area
 - iii. Blade pitch failure – Hydraulic actuator failure, imbalance of blade angles versus performance due to blade wear.
 - iv. Bearing temperatures – trending and cooling water supply fluctuations.
 - v. Blade condition – performance, stall or pitch failure.
- 4) A comprehensive on-line Monitoring and Inspection program should be in place, prompting for the regular reporting and trending of plant condition and developing failure trends. A suitably skilled Contractor or online monitoring specialist should be responsible for the compilation, presentation & management of documentation to guide the essence & quality of inspections for feedback information to the relevant System Engineer – refer to the applicable section for “Inspection and Testing - On-line inspections” below.

c) Off-line Inspection and reporting

- 1) The purpose of Off-line inspection & reporting is to identify additional factors – over and above the recommended/approved Scope of Work - that require analysis and consideration for inclusion into the repair scope of work.
- 2) A comprehensive Inspection listing should be put in place, guided by a well-documented check-sheet, prompting for the report of condition is required. A suitably skilled Contractor is responsible for the compilation, presentation & management of the Inspection plan with associated check-sheets, structured to guide the essence & quality of inspections for feedback information to the Engineer. Refer to the applicable details noted in the section “Inspection and Testing – Outage condition and SOW Inspections” below.
- 3) Analysis and Engineering recommendation on the reported outcome of inspections are required, e.g. on aspects like Blade/casing erosion/failures, out-of-specification blade tip-clearances, wear trends, etc. which would require further evaluation & input prior to submitting reports to the Client.
- 4) Additional Scope aspects that affect the ability & reliability of the Fan to perform its required function and operational design load must be addressed within the correct formal reporting and outage/maintenance management governance structures.

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3.3.2 Rotor Replacements (Swop)

a) Rotor Swop Planning and Scheduling

1) Planning schedule

- i. A comprehensive swop-schedule, which considers and appropriately integrates Station Outage planning and Rotor swop history, is required.
- ii. Site Engineering is foremost responsible for the scheduling & record-keeping of specific details surrounding the Rotor condition monitoring, Blade wear and replacements, historical Rotor swops and life-affecting incidents.
- iii. The OEM/AEM is co-responsible to track Rotor swop history to facilitate sound scope of work recommendations.

2) Majuba FD

- i. The original OEM recommendation was to schedule Rotor swops for servicing on two-yearly intervals.
- ii. Based on the conditions and findings during the initial Rotor swop, the damage assessment was considered severe enough to warrant the execution of several assessments for design changes and amendments to maintenance practices in order to improve on the Rotor reliability and service life.
- iii. Eskom current assessment is that reliable operation is achieved with 6 to 8 years of Service life.
- iv. Mitigations implemented to justify and support the Service life extension was:
 - Blade shaft fatigue life – Initial Risk: re-design with mandatory crack testing.
 - Blade shaft thrust bearings – Initial Risk: Change grease to oil lubrication.
 - Hydraulic actuator – Initial Risk: Implement checks on seal quality, component concentricity & alignments.
 - Hydraulic actuator mounting configuration – Remaining Risk: Has to be managed with good maintenance practices.
 - Servo valve – Initial Risk: Addressed by removing chattering ports and improving component concentricity & alignment.
 - Rotating union – Remaining risk: Addressed with improvement on refurbishing quality and compulsory refurbishment & testing.
 - Blade base seals and impeller port wear – Initial Risk: Modifications with DU bush insertion & port alignment.
 - Fan main bearings – Remaining Risk: Addressed by applying clean installation practices and improved Quality Control. Dust ingress causing shaft damage, improved with the addition of IP55 dust seals.
 - Rotor imbalance requiring extensive balance weights – Initial Risk: Risk mitigated with change of component balancing philosophy during overhauls.
 - Overhaul quality – Initial & remaining Risk: Mitigated by implementing accurate and stringent Quality Control measures.

3) Majuba ID

- i. The original OEM recommendation is to schedule a Rotor swop on two-yearly intervals for a new Rotor and thereafter yearly.
- ii. Based on the conditions and findings during the initial Rotor swop, the damage assessment was considered as severe, which required several assessments for design changes and improvement in maintenance practices in order to improve on the Rotor reliability and service life.
- iii. Eskom current assessment is that reliable operation is achieved with 4 to 6 years of service life.
- iv. Mitigations implemented to justify the Service life extension:
 - Blade shaft fatigue life – Initial & remaining Risk: Mitigated by mandatory crack testing.

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- Blade shaft thrust bearings – Initial & remaining Risk: Mitigated by controlling the bearing ball-size specification/grading during Rotor overhauls.
- Hydraulic actuator – Remaining Risk: Mitigated by introducing actuator to pre-installation testing and TIR control.
- Servo valve wear – Initial & remaining Risk: Mitigated by controlling the correct repair specification.
- Blade base seals and impeller port wear – Initial & remaining Risk: Improve and correct swop Quality Control, and correct repair-quality during overhauls.
- Fan main bearings and seals leakage – Initial and remaining Risk: Mitigated with correct swop Quality Control measures.

4) Medupi/Kusile FD

- i. The original OEM recommendation is to schedule Rotor swops for servicing on 4-yearly intervals.
- ii. The four-yearly interval does not align and correctly phase with the current Station Outage philosophy, and justification to adapt the service intervals is currently under investigation.
- iii. Based on the conditions and findings during the initial Rotor swop (one MD sample) with a 3-year operational service-life, the damage assessment was considered as mild with the exception of a risks noted on the Hydraulic system. The mitigation of the risk is noted below.
- iv. Eskom current assessment is that reliable operation can be achieved with a 6 year service life.
- v. Mitigations implemented to justify the Service life extension:
 - Multiple areas of site-assembly (construction) damage was observed, especially where more complex activities were executed which require high levels of skill and competency – Initial Risk: The Rotor swop-methodology has been formulated to perform sensitive activities in the Workshop environment, while the Site-activities have been simplified to a swop-out of a complete Rotating Assembly (shaft & impeller) philosophy. The Fan casing configuration and special tools were adapted to support this philosophy.
 - Accurate execution of Stored Rotor preservation requirements is essential to secure protection and reliability of Blade Pitching components & seals.
 - While the general condition of components on the stripped/overhaul noted above were mostly acceptable, it was observed that severe ash ingress into the rotor internal is experienced – Remaining Risk: Failure to address station ash-emissions may lead to a consideration to incorporate an impeller pressurisation system – this is deemed a future Risk to Rotor reliability.
 - The Hydraulic actuator Servo valve spool revealed concerning levels of fretting, which could affect the reliability of the fan with the implementation of a 6-yearly swop recommendation – Initial and remaining Risk: The Servo valve spool is scheduled for inspection and cleaning on a 3-yearly basis. Further investigation to improve the service-life of this component is recommended.
 - Failure of hydraulic pressure supply flexible hoses – Remaining Risk: The recommended short 3-yearly service-life of hoses must be improved to coincide with Rotor swop intervals.

5) Medupi/Kusile ID

- i. The original OEM recommendation is to schedule Rotor swops for servicing on 3-yearly intervals.
- ii. Based on the conditions and findings during the initial Rotor swop, the damage assessment was considered as concerning (severe), which requires the execution of several assessments for consideration of design-reviews and operational & maintenance practice adjustments in order to improve on the Rotor reliability and operational service life.

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- iii. Eskom's current assessment is that for reliable operation, the Service period of 3 years must be retained, pending a larger assessment sample set and results of recommended improvements.
- iv. Mitigations implemented to justify the Service life and details of further assessments are as follows:
 - Severe condition deterioration of blade shaft thrust bearings, requiring a larger monitoring sample for final assessment – Remaining Risk: Require the monitoring of bearing-ball grading and performance.
 - Severe wear of blade shaft outer supporting bushes, which result in increased stressing of blade shafts during operation – Remaining Risk: The amount of ash passed through the fan during operation, and blade removal practices (cleanliness) are areas that should be addressed & improved.
 - The Servo-motor wear-life prompted for more frequent wear-component replacement as opposed to the desired "standard service" with only seal-replacements – Remaining Risk: Requiring a larger monitoring sample for final assessment and decision regarding a service-life extension.

6) Reliability of Rotors is dependent on the detailed management of all the key Preventative Maintenance activities:

- i. Quality of overhauled Rotor with full analysis of wear & failure patterns.
- ii. Quality of swop/installation activities with analysis of wear & failure patterns.
- iii. Adherence to Operational design parameters such as emission control requirements, and general environmental cleanliness.
- iv. Observing for early signs of health-degradation and taking appropriate action.
- v. Utilising any short shutdown opportunities to assess the general internal condition under controlled access and comprehensive assessment by skilled personnel.

b) Execution of a **Rotor Blade swop**

- 1. The execution of a blade-swop activity on its own should not be the norm, as normal blade-life should surpass rotor-life. The local operational conditions have drifted towards conditions that are not conducive to standard practices generally applicable to Axial flow fans.
- 2. The requirements to guide a blade-swop activity are detailed in the applicable section for "Blades" below.

c) Execution of a **FD Fan Rotor swop**

a) Task Planning at T-3

- i. Equipment – Servicing and spares availability requirements:
 - Availability of the Overhead Hoist.
 - Insulation removal and re-instatement scope.
 - Scaffolding scope for access and overhead protection (planning for rainy conditions during the outage work).
 - Rotor (& blades) transportation from/to Stores.
 - Permit & power provision for swop-execution & testing.
 - Bypass filtration system and flushing fittings.
- ii. Spares assessment via the presentation of a comprehensive Outage BoM listing through the Contractual Scope Clarification meetings, and availability measurement controls: A Typical summary of items to specifically assess and track for availability are:
 - Spare (refurbished) Rotor, including Hydraulic actuating Devices (HAD).
 - Rotor connections: Lube flexible hoses, Hydraulic flexible hoses, instrumentation, stall probe, casing bolts.
 - Blades and attachments: Previous Blade condition assessment, blade sets, connecting pawl (KS/MD), bolts set, sealing sets.

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- Blade-regulating control connections: e.g. lay-shaft bearings & couplings, actuator.
 - Bearing replacement sleeves and housing alignment shims.
 - Lube system: e.g. filter elements, oil, control valves, relief valves, pumps, coolers, sight-glasses, flange-gaskets, oil.
 - Brake pads.
 - Casing and doors: e.g. casing/shaft seals, flange/door seals & gaskets.
 - Compensators: e.g. rotor track compensator, bolts, special washers.
 - Pre-manufactured balance weights.
- iii. Availability of a suitably qualified Task Execution supervisor – Experience references for applicable similar design fans in accordance to Contract requirements.
- iv. Team – Skill and proof of training reference for applicable fans in accordance to Contract requirements.
- b) Rotor swop Execution detailed preparation at T-1
- i. Insulation & cladding insulation requirements, specifications and control for removal & re-instatement should be in place.
 - ii. Scaffolding requirements & co-ordination for access, safety platforms and overhead (rain) protection installation.
 - iii. Access platform erection specification and co-ordination requirements with execution plan.
 - iv. Transport arrangement with 15-ton capacity, and resolution of site routes to installation point (especially in cases of large outage scopes of work).
 - v. Permit requirements & testing co-ordination. The lubrication & hydraulic system availability is required throughout the task execution process related to Rotor turning, lube oil system flushing, and commissioning readiness testing.
 - It is recommended to provide an 'external' power source and control mechanism if Station electrical boards are subject to maintenance unavailability during the outage period.
 - vi. Rigging equipment required for fan casing and rotor lifting.
 - vii. Availability of a removed Rotor support stand/cradle.
 - viii. Quality documentation submission for review & approval.
 - ix. NDT Scope, specifications, execution requirements and reporting.
- c) A comprehensive Rotor swop execution procedure should be in place and approved; and must cover the sequence of activities and prompt for critical hold and witness points with supporting details as required for approval (As a minimum the following guiding pointers are provided below).
- i. Inspection method and details for capturing findings, clearly stipulated on designated recording sheets.
 - ii. Appropriate methods implemented for fan rotor & component protection ensuring zero exposure to rain/dust contamination/damage.
 - iii. Casing ovality reporting.
 - Engineering assessment and action plan.
 - iv. Requirements for the removal and re-instatement of insulation & cladding.
 - v. Blade position/orientation requirements.
 - Rotor blades should be in open position for inspection access.
 - Rotor blades must be in closed position for tip clearance measurement and casing lift activities.
 - vi. Casing loosening, rigging & removal and placement requirements specific to each fan type.
 - Equipment health assessment and appropriate rating of rigging equipment (including required certification to confirm compliance).
 - Extraction of locating dowels (MD/KS).
 - Horizontal load control and manipulation.

- Radio communication to both casing-sides with clear rigging procedure guides.
- Placing surface and level survey.
- vii. Blade position marking.
- viii. Shaft seal assessment.
 - Recording of setting & condition
 - Engineering assessment and action plan (MJ)
 - Quadron plates fitting & alignment (MJ)
- ix. Hydraulic hose assessment.
 - Condition/damage report with recommendation and approval.
- x. Hydraulic actuator assessment and oil purge.
 - Reporting of leakage and travel rate/pressure.
- xi. Control of oil leakage, dirt ingress on hydraulic equipment.
 - Mandatory blanking of all ports during execution of maintenance work on hydraulic and oil lubrication/control systems.
- xii. Blade NDT and repairs:
 - Pre-cleaning requirements.
 - NDT areas and screening.
 - Repairs with guidance to trimming and permissions.
- xiii. Casing cleaning and NDT:
 - Pre-cleaning.
 - Reporting and reference marking verification.
 - Engineering assessment, verification and recommendation.
 - Repair controls and verification.
- xiv. Rotor rigging & removal requirements, cleaning, and transporting requirements.
 - Equipment health and rating.
 - Load control and manipulation.
 - Supporting cradle, and bolt-down.
 - Rotor cleaning and protection.
 - Release condition inspection, verification & check-sheet sign-off.
 - Transport arrangements.
- xv. Casing repair documentation and controls.
 - Refer to details in the applicable section below.
- xvi. Rotor installation preparation requirements.
- xvii. Rotor rigging and installation precautions with control of:
 - Equipment health and rating.
 - Load control and manipulation.
 - Verification of disconnected attachments.
 - Caution pinch-points and safe work practices.
- xviii. Rotor alignment in Casing
 - Refer to details in the applicable section.
- xix. Verification of NDE bearing housing alignment (MD/KS)
 - Refer to Bearing housing alignment in the applicable sections below.
- xx. Boxing-up of bearings
 - Refer to Bearing box-up requirements in applicable sections below.
- xxi. Lubrication/Hydraulic flushing requirements before applying connections to newly installed Rotor.
 - Witness and recording.
 - Verification of function re-instatement.
- xxii. Blade fitting controls with appropriate details as noted in the applicable “Blade replacement” section below.
- xxiii. Hydraulic actuator & Rotating Union:

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- Union connection control
- Union alignment (TIR) and recording.
- Connecting links set-up.
- xxiv. Blade stroking & testing methodology and verification.
 - Verify Rotor stop versus external mechanical stop and secure travel gap.
 - Functional testing.
- xxv. Sealing and preservation requirements.
 - Application of sealing on flange, bolt and pin holes.
 - Application of preservation coating.
- xxvi. Casing rigging and safe manipulation during installation.
 - Radio communication to both casing-sides from rigging guide.
- xxvii. Casing fastening and verification.
- xxviii. Blade tip clearance verification.
- xxix. Compensator health and cleaning.
- xxx. Shaft seals fitting & set-up.
 - Refer to the applicable section below.
- xxxi. Hydraulic compartment door sealing requirements.
- xxxii. Final verifications & cleanliness inspection with door closure control.

d) Execution of an **ID Fan Rotor** swop.

1) Task Planning at T-3

- i. Equipment – Servicing, availability requirements:
 - Availability of Overhead Hoist.
 - Insulation removal and re-instatement scope.
 - Scaffolding scope for access and overhead protection (rain).
 - Rotor (& blades) transportation from/to Stores.
 - Permit & power provision for swop-execution & testing.
 - Bypass filtration system and flushing fittings.
- ii. Spares assessment via the presentation of comprehensive Outage BoM listing through the Contractual Scope Clarification meetings, and availability monitoring controls. A typical summary of key items are listed below:
 - Spare (new or refurbished) Rotor.
 - Rotor connections: Lube flexible hoses, Hydraulic flexible hoses, instrumentation, stall probe, casing bolts.
 - Blades and attachments: Previous Blade condition assessment, Blade sets, bolts set, Sealing sets.
 - Blade control connections: Lay-shaft bearings & couplings, actuator.
 - Lube system: e.g. filter elements, oil, control valves, relief valves, pumps, coolers, sight-glasses, flange-gaskets, oil.
 - Casing and doors: e.g. casing/shaft seals, flange seals, door-seals.
 - Compensators: e.g. rotor track compensator, bolts, special washers.
 - Pre-manufactured balance weights.
- iii. Suitably qualified and experienced Task Execution supervisor – Experience references should be available for similar applicable fans in accordance to Contract requirements.
- iv. Team – Skill and proof of training reference for applicable fans in accordance to Contract requirements.

2) Rotor swop Execution detailed preparation at T-1

- i. Insulation & cladding insulation requirements, specifications and control for removal & re-instatement.

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- ii. Scaffolding requirements & co-ordination for access, safety platforms and overhead (rain) protection installation.
 - iii. Access platform erection specification and co-ordination requirements with execution plan.
 - iv. Transport arrangement with 15-ton capacity, and resolution of routes to installation point (especially in the case of tight outage timelines and large Scopes of Work).
 - v. Permit requirements & testing co-ordination. The lubrication & hydraulic system is required throughout the task execution processes of Rotor turning, lube and control oil system flushing and commissioning testing activities.
 - It is recommended to provide an 'external' power source and control mechanism if Station electrical boards are subject to maintenance unavailability during the planned outage period.
 - x. Availability of the rigging equipment required for casing and Rotor lifting.
 - xi. Availability of a removed Rotor support stand/cradle.
 - xii. Quality documentation submission for review & approval.
 - vi. NDT Scope, specifications, execution requirements and reporting.
 - vii. On-line execution of testing for the casing/Rotor seals condition verification – this is particularly relevant to the Majuba fans due to the difficulty to replace/adjust seals.
 - viii. Availability of a 'dummy-rotor' or setting-jig if shaft-seal setting is required (MJ).
- 3) A comprehensive Rotor Swop execution procedure is required that covers the sequence of activities in detail, including prompts for critical hold and witness points and reporting details is required for approval (As a minimum, the following guiding pointers are provided below).
- i. Inspection method and details for capturing, clearly stipulated on designated recording sheets.
 - ii. Rotor & component protection with zero exposure to rain/dust contamination/damage.
 - iii. Casing ovality reporting.
 - Engineering assessment and action plan.
 - iv. Removal and re-instatement requirements for insulation & cladding.
 - v. Blade position/orientation requirements.
 - Rotor blades should be in the open position for inspections access.
 - Rotor blades must be in the closed position for tip clearance measurement and casing lift activities.
 - vi. Casing loosening, rigging & removal and placement requirements specific to each fan type.
 - Equipment health and rating of rigging equipment.
 - Extraction of locating dowels (MD/KS).
 - Horizontal Load control and manipulation.
 - Radio communication availability to both casing-sides and detailed rigging guides.
 - Placing surface and level survey.
 - vii. Blade position marking.
 - viii. Shaft seal assessment.
 - Recording of setting & condition.
 - Engineering assessment and action plan.
 - ix. Hydraulic hose assessment.
 - Condition/damage report with recommendation and approval.
 - x. Hydraulic actuator assessment and oil purge.
 - Reporting of leakage and travel rate/pressure.
 - xi. Control of oil leakage, dirt ingress on hydraulic equipment.
 - Mandatory blanking of all ports when maintenance work is undertaken on the lube and/or control oil systems and components.
 - xii. Blade NDT and repairs:
 - Pre-cleaning requirements.
 - Areas and screening.

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- Repairs, incorporating trimming guidance and permissions.
- xiii. Casing cleaning and NDT:
 - Pre-cleaning.
 - Reporting and reference marking verification.
 - Engineering assessment, verification and recommendation.
 - Repair controls and verification.
- xiv. Rotor rigging & removal requirements, cleaning, and transporting requirements.
 - Equipment health and rating.
 - Load control and manipulation methods to ensure safe task execution.
 - Supporting cradle, and bolt-down.
 - Rotor cleaning and protection.
 - Release condition inspection, verification & check-sheet sign-off.
 - Transport arrangements.
- xv. Casing repair documentation and controls.
 - Refer to the applicable sections below in this document.
- xvi. Rotor to casing (shaft seal) gap control and recording.
- xvii. Rotor installation preparation requirements.
 - Assessment & control of Rotor flange vs. casing gap – shimming methods.
 - Rotor cradle lubrication & sealing.
- xviii. Rotor rigging and installation precautions with control of:
 - Equipment health and rating.
 - Load control and manipulation techniques.
 - Verification of re-connected attachments.
 - Caution regarding pinch/contact-points.
 - Anchor bolt torque verification.
- xix. Lubrication/Hydraulic flushing requirements before applying connections to newly installed Rotor.
 - Witness and recording.
 - Verification of function re-instatement.
- xx. Blade fitting controls with appropriate details as noted in the applicable “Blade replacement” section below.
- xxi. Rotor alignment verification.
- xxii. Blade pitch stroking & testing methodology and verification.
 - Verify Rotor stop versus external mechanical stop and secure travel gap.
- xxiii. Hydraulic Actuator set-up & function.
 - Alignment verification and recording.
 - Function testing method and recording.
- xxiv. Sealing and preservation requirements.
 - Application of sealing on flange and bolt/pin-holes.
 - Application of preservation coating.
- xxv. Casing rigging and safe manipulation during installation.
 - Radio communication availability to both casing-sides and detailed rigging guide.
 - Briefing on observation points.
- xxvi. Casing tie-down requirements.
 - Torque control.
 - Compensator clamps & attachment verification.
 - Final Blade tip-clearance verification.
- xxvii. Hydraulic compartment verifications and closing.
- xxviii. Sealing air system health assessment and set-up verification.
- xxix. Final verifications & cleanliness inspection with door closure control.

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- e) Quality Control Plan for Rotor swops
- 1) The Contractor compilation, review and internal approval of the QCP is required before submission, incorporating control and improvements from previous revisions and review recommendations in accordance to Contract requirements.
 - 2) The Contractor-approved QCP must be submitted to the applicable System Engineer for compliance review and approval at least two months prior to the starting date of the planned outage.
 - 3) Scope additions identified and approved after the execution of Inspections and the SOW Rev.1 meeting is added to the approved QCP with an addendum page.
 - 4) Refer to the stipulated requirements for QCP's noted in the applicable section for "Inspection and Testing" below.
- f) Lubrication & Hydraulic system service requirements during Rotor swops
- 1) Comprehensive servicing is executed in conjunction with Rotor swops, while a clear guidance is needed on requirements for availability during the Rotor swop set of activities – the following activities during the Rotor swop require the availability of the Lubrication/Hydraulic-systems and the outage schedule should take cognisance of this:
 - i. Rotor turning for Blade tip clearance measurement and Blade removal.
 - ii. Blades pitching for inspection & casing removal.
 - iii. System flushing before connecting to new Rotor/Bearings.
 - iv. Rotor turning for Blade fitting and trimming.
 - v. Blade pitching & Hydraulic stroking before closing casing.
 - 2) As noted above, compulsory pre-flushing is required before connecting the lube/hydraulic system with Installed Rotor.
 - 3) Important details related to the servicing of these systems is covered in the appropriate section dealing with "Lubrication and Hydraulic Systems" below.
- g) Casing repairs during Rotor swops
- 1) Repairs are executed in conjunction with Rotor repairs/swop – and require effective coordination of NDT, repairs and Rotor removal in order to prevent delays with the total swop-duration.
 - i. Repairs on the top casing are prioritised as soon as the casing is removed.
 - ii. Repairs to the bottom casing are prioritised as soon as the blades are removed from the Rotor.
 - 2) Refer to the noted details in the applicable section for "Rotor track Casing" above.
- h) Rotor & Motor Alignment – refer to the complete details in the applicable section on "Alignment" below.
- 1) The Station is to prepare and approve a guiding procedure for the execution of Fan & Motor alignment.
 - 2) Implement a Quality Control Plan with associated check-sheet incorporating a check-list for verifications of prior-alignment requirements such as:
 - Rotor in Rotor-track alignment.
 - Bearing Housing alignments.
 - Motor magnetic centre verification.
 - 3) Stipulate motor axial location with coupling-gap specifications.
 - 4) Stipulate provision for thermal expansion.
 - 5) Alignment acceptance criteria and required verifications.
- i) Rotor dynamic Balancing
- 1) The Station is to prepare and approve a comprehensive procedure for the execution of in-situ Fan balancing, covering the following relevant aspects:
 - i. Preparation required for balancing start-up.
 - ii. Requirements for flow-path and permit arrangements.

- iii. Requirements and critical controls to be applied during the Balancing process and when dealing with electrical switchgear.
- iv. Balancing method and control.
- v. Balance weights and fitting control.
- 2) Implement a Quality Control Plan with associated check-sheets to control the execution of Balancing.
- 3) Alert and oversight of the cleanliness inspections before and after Fan starts.
- 4) Elevate readiness and clarity of staff regarding communication and rapid response should problems arise with first fan balancing start.
- j) Commissioning after Rotor swops – requires management of the following activities:
 - 1) Lubrication/Hydraulic set-up with approved Procedure and recorded critical performance parameters as part of the QCP.
 - 2) Lubrication/Hydraulic system on-load verification and recording of critical performance parameters.
 - 3) Balancing and Test-run monitoring aspects and reporting:
 - i. Coupling gap.
 - ii. Bearing temperatures.
 - iii. Bearing total overall vibrations, as well as confirming that balancing fault frequencies (1x rpm) are within specification in the vibration spectrum.
 - iv. Pitch response and flow balancing as per RTS procedure.
 - v. Seal Air setting (ID Fans) with base-line report of pressures as part of the QCP.
 - vi. Labyrinth seal dP setting/signature (ID Fans).
 - vii. Stall Protection Device testing/operation.
- k) Dispatch of removed Rotor
 - 1) The swopping Contractor is to perform 90% cleaning of ash/dirt deposits from the Rotor before removal from site.
 - 2) Hydraulic oil ports shall be blanked-off to prevent ingress of contaminants and prevent oil from leaking out.
 - 3) The Axial flow fan Rotor shall not be left in external environment for longer than one week, and shall be covered with a tarpaulin at all times.
 - 4) A Rotor despatch check-sheet shall be completed and signed-off with particular aspects checked and confirmed:
 - i. All hydraulic ports blanked-off and protruding actuator shaft protection shield fitted.
 - ii. Bearing journals preserved and protected with grease tape (FD Fans).
 - iii. Documenting of any visible external damage to the Rotor.
 - iv. Preservation and packaging of removed HAD components.
 - v. Serial number of the Rotor.
 - vi. Serial number of the Rotating union (KS/MD FD Fans).
 - vii. Serial numbers of the Servo valve and Rotating union (MJ FD Fans).
 - viii. Reason for removal – Engineering to be consulted for information requirements that must be recorded.
 - ix. Employer verification of dispatch conditions.
 - x. Transport tie-down control executed.
 - 5) In terms of the management of Strategic Spares, Eskom P&SCM shall ensure that the removed Rotor is actioned for refurbishment within one month from swop.
 - i. Removed Rotors are subject to the same mandatory preservation activities as established for Spare/Strategic Rotors, especially to prevent sagging/deflection of 'overhung' shafted impellers – refer to the applicable section on Rotor Storage & Preservation below.

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3.3.3 Rotor alignment

Rotor alignment is inter-linked with bearing housing alignment and main motor alignment – also refer to the applicable alignment details noted under the applicable sections for “Bearings housings” and “Main Drive Motors” below.

- a) The requirement for repetitive Rotor/Motor alignment on **FD Fans** is dependent on the Fan design and swop-methodology.
 - 1) Movement/disturbance of the NDE Bearing Housing positions due to the swop methodology for MJ, requires re-alignment of the Motor.
 - i. The DE-locating Bearing housing position is normally NOT disturbed with Fan Rotor-swops, unless anomalies are detected during the Housing inspection, justifying a Housing replacement.
 - 2) The Bearing Housing alignment position of the KS/MD fans is NOT disturbed during Rotor swops, unless necessitated through comprehensive inspection findings of deficiencies on the housing inner spherical seats.
 - 3) Considerations of conditions for the inclusion of alignment after a Rotor swop:
 - i. Bearing housing re-positing required, as detailed for the applicable swop-philosophy indicated above.
 - ii. Motor failure and replacement will require re-alignment from first principles.
 - iii. Looseness detected on Motor or Fan Bearing foundations.
 - iv. High thrust bearing temperature as a result of incorrect axial alignment.
 - v. Coupling inspections/servicing must be facilitated during the Rotor swop process (KS/MD & MJ) – refer to the applicable section for the Main Motor drive and Connecting shaft below.
 - 4) Methods and requirements
 - i. For FD Fans, any decision for movement of Bearing housing positions is to be approached with caution, as a pre-alignment of the Bearing locations is guided by a verification of the Rotor alignment within the Rotor-track casing – Blade tip-clearance is adjusted within OEM specifications of ± 0.25 mm (0.5 mm TIR) and movement of bearing housings can impact this.
 - ii. Re-alignment of the Bearing Housings must prompt for the verification of alignment in multiple directions: - refer to the applicable details noted under the section for Bearing Housings below.
 - Housing elevation is corrected to meet Rotor centralisation.
 - Housing tilt (front to rear) and square-ness (rotation).
 - If the heights of both bearings were disturbed, the final shaft level must be verified within 0.4 degrees horizontal accuracy.
 - iii. For FD Fans, the shaft is extended through the inlet casing with an easily accessible surrounding fairing, which is also acting as NDE bearing support, so the installation presents adequate line-of-sight for the use of Laser-alignment equipment.
 - 5) Important pointers for **FD Fan** Rotor & Motor alignment execution activities:
 - i. A pre-requisite for alignment is the confirmation of Rotor centralisation and Bearing Housing alignment as detailed above.
 - ii. CAUTION: NO MOVEMENT for re-alignment of the Fan Bearing Housings is allowed after boxing-up of the bearing.
 - iii. No allowance is made for thermal growth on casing/bearings on FD fans.

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- iv. Lubrication of bearings for turning of Rotor and Motor during the alignment process is mandatory.
- v. Safety precautions and training is required for hand-turning the Fan Rotor via the blades.
- vi. Motor magnetic centre and direction of rotation must be verified and/or corrected before coupling connection.
- vii. The flange to flange insertion gap for the Cardan shaft (with both couplings) is measured and recorded as part of the QCP, and setting should be in accordance to the relevant Power Station coupling specification to prevent excessive axial thrust on bearings.
- viii. Note that there is a requirement for using special compression-clamps when doing the Cardan-shaft installation.
- ix. The Turbo-flex coupling alignment tolerance is maximum 0.12 mm.

b) Repetitive post-swap Rotor/Motor alignment on **ID Fans** is generally not necessary.

1) Considerations of conditions that warrant the inclusion of alignment after a Rotor swap are:

- i. Motor failure and subsequent replacement - this would require re-alignment from first principles.
- ii. Looseness detected on Motor foundations.
- iii. Fan bottom-casing removal requires re-alignment from first principles. This alignment should carefully consider the limitation for Motor re-alignment movement – which is limited within the allowed motor flange-slots, requiring accurate re-positioning of the removed casing in accordance to pre-defined marking.
- iv. Coupling inspection/servicing as stipulated under the applicable section for “Connecting Shaft & couplings” below.
- v. High thrust bearing temperatures being observed – this is generally caused by incorrect axial alignment.
- vi. High vibrations on Motor detected - supported by clear coupling misalignment fault frequencies excited in the vibration spectrum.

2) Methods

- i. For ID Fans, the shaft extended through the inlet casing is covered/surrounded by a guard which could present challenges with line-of-sight and the use of laser-alignment equipment can therefore be problematic.
- ii. The use of conventional DTI's with special attachment brackets is suggested as the preferred alternative.
- iii. A detailed report demonstrating connections and alignments of alignment equipment is required.

3) Important pointers for **ID Fan Motor** alignment execution

- i. Thermal growth of the Casing on all ID Fans must be incorporated into vertical alignment calculations and activities, in accordance to Station-specific OEM specifications.
- ii. Lubrication of Bearings for turning of the Rotor and Motor is mandatory.
- iii. Safety precautions and training is required for hand-turning the Fan Rotor via the blades.
- iv. Motor magnetic centre and direction of rotation must be verified and/or corrected before coupling connection.
- v. Note that there is a requirement for the use of special compression-bolts, which is required for coupling compression in order to separate it from connected flanges.
- vi. Coupling gaps on both ends of the connecting shaft in accordance to the relevant Fan coupling specification must be verified in order to prevent excessive axial thrust on bearings.
- vii. Turbo-flex coupling alignment tolerance is maximum 0.12 mm.
- viii. The re-instatement of the shaft guard inlet seal should be done at this time to control cold air ingress for the cooling of the shaft in accordance to OEM.

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- ix. Witnessed sealing and closure of Rotor-side coupling guard/inlet-cone is required as part of the QCP.

3.3.4 Rotor balancing and Fan test-run

- a) The Station is to compile a comprehensive procedure to detail the flow-path and duct settings required for starting the fan for a test-run under partial boiler permit conditions.
 - 1) For **FD Fans**, with the fan discharge damper should be in closed/isolated condition to prevent disturbance inside Air Heaters and Boilers.
 - i. With the KS/MD discharge dampers located downstream of the Air Heaters, both the PA and FD fans flow paths into the Air Heater with open access doors should be used, but will require evacuation of workers and suspension of outage work activities in the Air Heaters during the balancing test run.
 - ii. With the MJ discharge damper immediately after the FD fans (before air Heater), the only option is to utilise the PA Fan flow path with all Primary fan/duct doors open, while ensuring that discharge is prevented through the Milling plant.
 - iii. The FD Fan suction path must be secured in the open position and safety cleared.
 - iv. The FD Fan blade pitch position must be increased to eliminate stall-vibration conditions to a minimum of 5%, depending of the size of the open flow-path, thus cautioning over-pressurisation of the Fan.
 - 2) For **ID fans**, the fan discharge damper is required to be operable to start and vent the fan.
 - i. ID fans are started against a closed discharge, and the damper must be fully opened after starting the fan.
 - ii. The ID Fan suction is the other important area to secure through the opening and locking of the inlet implosion system, or venting through the Fabric filter plant, which is an activity that requires a multitude of de-isolations and will impact on the scheduling and execution of other outage work.
 - iii. The ID Fan blade pitch position must be increased to a minimum of 20%, in order to eliminate stall-vibration conditions, after verifying full opening of the discharge damper.
- b) Control of fan and switchgear
 - 1) It is imperative with each balancing cycle that the following aspects are tightly controlled:
 - i. Fan internal cleanliness inspection verified.
 - ii. Blade pitch in the closed position for initial start-up.
 - iii. All Fan casing access doors closed.
 - iv. Blade pitch control for balancing set at the stipulated position to establish safe flow conditions.
 - 2) Strong and clear radio communications with both the control room and electrical switchgear operators are required.
 - 3) The starting of a fan via control of the electrical switchgear requires emergency alertness with the required immediate responses to de-activate the switch-gear if abnormal conditions are reported:
 - i. High vibrations detected on bearings or casing.
 - ii. Abnormal noises emitted from the fan.
 - iii. High or rapidly increasing bearing temperatures are detected during run-up.
- c) Application of balance weights
 - 1) Axial flow fan balance weights are applied by bolting – no welding is allowed.
 - 2) The station must prepare and manage a selection of pre-shaped weights and masses to be applied by bolting on predetermined bolting locations (defined PCD).

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- 3) The use of balance weights thicker than 8 mm requires a re-assessment of the bolting thread depth and longer bolts.
- 4) For the MD/KS FD Fans, OEM designed balance weights are fitted onto a “balancing rail”, which is a machined taper-spigot on the Rotor.
- 5) The use of “Loc-tite” and torque control on the balance weight bolts is executed in line with each specific Rotor bolting specification.

d) Balancing results and reporting

- 1) In general Fans are balanced in accordance with the referenced Eskom Standard for “Balancing and Vibrations”, with the following exceptions applied to Axial flow fans re-balanced after swop installations:
 - i. For overhang **FD fan Rotors**, the balancing of the Rotor on the rotational frequency (1x) must be targeted as 0.5 mm/s (RMS), with an absolute maximum of 1 mm/s (RMS) on the NDE bearing.
 - ii. For **ID Fan Rotors**, the balancing of the Rotor on the rotational frequency (1x) must be targeted as 0.5 mm/s (RMS), with an absolute maximum of 1 mm/s (RMS) for both the DE and on the NDE bearings.
 - iii. Blade pass frequencies in excess of 4 mm/s is alarmed.
- 2) Clear justification to accept values outside of these tolerances requires approval by the Employer’s Engineer.
- 3) Records are required of each balance run and balance weight change, incorporating a clear indication of positions, weights and results. The final condition of Balancing is recorded and issued onto the Balancing Certificate with a recording of the final weight & location angles used and the resultant vibration level & phase angle observed.
- 4) Initial imbalances in excess of 2 mm/s requires an in-depth investigation and actions to rectify and improve initial Rotor imbalances, with a focus on the following aspects:
 - i. Blade moment-balancing accuracy and checking for correct sequence-fitting of the blades.
 - ii. Rotor pre-balancing should be specified as a requirement during Rotor overhauls and should be checked and signed off as acceptable by Employer’s Engineer upon return to the stores.
- 5) For the balancing of two-stage ID Fan Rotors, the following approach shall be adopted:
 - i. Correcting the imbalance through the fitting of balance-weights to be done first on the DE-side which has the largest bolting PCD (MJ Rotor).
 - ii. Fine-tuning of balancing is performed on the NDE-side using the accessible bolting location, which is on a smaller bolting PCD (MJ Rotor).
 - iii. Final balancing with a developed out-of-phase indication (“couple unbalance” condition) is not acceptable.

e) Fan and Draught Test-runs

- 1) The ultimate purpose is to secure faultless hand-over of the fans to Operating & Production, thus the aim of the test run should be to verify the operational response of the fans through its full range of operation.
- 2) The aspects to be investigated/monitored and reported on a formal check-sheet/report are as follows, and could be captured as part of the mandatory RTS (commissioning) procedure:
 - i. Start Control logic anomalies.
 - ii. Stall reporting and response during start-up.
 - iii. Blade pitch control response.
 - iv. Flow/pressure norm versus blade pitch control position.
 - v. Bearing temperatures at MCR load conditions, especially confirmation that the stabilisation of Fan Thrust bearing temperatures has taken place and are within the acceptable normal operating temperature response range.
 - vi. Monitoring all Process instrument responses.

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- vii. Fan bearing vibration responses through the load-spectrum.
- 3) Effective management of failure/deficiency resolutions secures the goal of achieving a “faultless handover”.
- 4) Stall device setting/verification and testing must be executed to an approved Power Station procedure.
- 5) Draught leakage verification is an optional cold-air test that may be required to be executed during the Draught Group test-runs to evaluate flow versus leakage which would highlight some leakage deficiencies on the Plant as a whole.

3.3.5 Spare Rotor storage and preservation

Storage and preservation requirements are stipulated in the referenced “Fan Storage Standard”.

- a) Rotors are stored under roof, and while subject to storage or outage swapping activities shall be covered under water-tight canvass.
- b) The longer term storage preservation for Rotors entails the following mandatory periodic tasks:
 - 1) The availability of a lubrication/hydraulic power pack, with associated connecting hoses and a nearby power supply source to enable rotor rotation & function testing.
 - 2) Preservation is executed on periodic intervals against an approved Site procedure and as per the stipulated time-frequency, and is witnessed via an approved QCP.
 - 3) Rotor rotation is done to prevent shaft deflections, with recording of execution dates and the rotated position.
 - 4) Rotor blade pitching mechanism activation in order to lubricate seals and moving components.
 - 5) Inspection of the FD Rotor shaft bearing-journal preservation.
- c) Requirements for storage and preservation of removed Rotors, as stipulated under ‘Rotor swaps’ must be adhered to.

3.4 BLADES AND ATTACHMENTS

3.4.1 Condition monitoring for Blades

- a) Blades are designed to render a service life in excess of 30 years – thus if standard operational conditions are managed (with specific focus on managing ash emissions), the condition monitoring of blade condition will be supported from a structured progression of wear trends and reporting.
- b) Undesired operational conditions must be detected, reported & managed on a critical Risk Assessment basis, and if left unattended, will result in both Fan/Unit capability losses with ultimate reduction of plant and system availability.
- c) Undesired operational conditions will drastically affect the wear-life of blades and requires the following actions:
 - 1) An active adaption of the condition monitoring regime.
 - 2) Focussed efforts to address the causes of ash/coal-dust leakages inside the Boiler House.
 - 3) An assessment of the wear-effects on the Fan’s Operational capability.
 - 4) Accelerated monitoring frequencies for Blade wear assessment.
- d) Blade wear assessment and trending.
 - 1) The wear-condition of Blades is assessed on a 3-yearly basis.
 - 2) Operational conditions leading to accelerated wear-conditions may dictate monitoring intervals to be changed to yearly intervals.
 - 3) Blade wear monitoring procedure:
 - i. Accuracy & repeatability of measurements must be ensured with control of correct equipment, consistent & trained personnel and an accurate execution procedure.
 - ii. A wear-location monitoring template to the Fan/blade OEM specification for each blade-type is required, with clear referencing to a non-wear position-locator in order to secure accurate repeat-measurements.

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- iii. Wear-progression is monitored on a sample of the same (repeated) blade-numbers/positions and a quantity of 4 blades per fan-stage is the norm. Rapid-wear with more frequent monitoring intervals, during short-duration shutdown opportunities may be reduced to perform only two sample measurements per stage of visually-judged 'worst-case' blades.
- iv. Chord-width measurements require the use of a similar (or same) template in order to ensure that measuring chords are perpendicular to the blade base centreline.
- v. Thickness-measurement, executed on ID Fan blade assemblies, with the use of a long-reach Vernier-calliper calibrated to a 0.1 mm accuracy is recommended. The use and accuracy of electronic sonic-type d-meters on varying profile thickness must be challenged and proven before accepted as a thickness measurement method.
- vi. Reporting of the wear-condition must be accurate – oversight and a verification of completeness is required from the relevant Task-supervisor before submitting the report for evaluation.
- vii. Engineering trending and analysis of wear readings taken is required, with a recommendation to be made on approval/rejection of the blade-set.
- viii. The installation of new/replacement blades require the mandatory recording of the blade-wear parameters and selected wear positions as a baseline to enable future wear-trend monitoring on the new blade set.

e) Blade wear-limits and Operational responses to Blade wear

- 1) Blades reported to exceed the allowable wear limits are replaced as a set.
- 2) A first-order evaluation of the Blade-wear, is done by comparison of the total Blade-width reduction of the leading-& trailing edges. An average of 10% accumulated wear between any two chords is an indication that the blade-set wear-condition will result in operational deficiencies.
- 3) Blade-width reduction, associated with a diminished "trailing-edge" thickness to 0mm is recommended for discard, based on the rapid-depletion of chord-widths with further erosion.
- 4) Blade thickness – assessed on ID Fan Blades only – is subject to comparison with a prescribed minimum thickness, and the thickness reduction below a minimum specified value of more than 4 monitoring positions per blade requires Engineering assessment and OEM recommendations on whether it can be re-used or should be discarded.
- 5) Any reporting of wear-limits being exceeded in the bottom third (from the base) of the Blade is treated as critical wear conditions and must inform the removal of the blade-set.
- 6) The reduction of the Blade pressure-side surface with more than 10% will diminish the fan-margin capability, and the addition of other systemic capability reducing deficiencies will result in the Fan being operated beyond its design-base. These conditions require a re-assessment of fan and system protection with consideration and monitoring of the following process conditions:
 - i. Fan pressure overload – reduced/limited fan loading may be required.
 - ii. Fan Stall threshold – which requires some additional risk mitigation actions and considerations:
 - Warnings based on pressure/flow thresholds will be ineffective.
 - A direct Stall Protection Device activation based on a warning and operator-response presents a major risk of failure to the Fan if the alarmed response is not adhered to.
 - iii. Motor overload – will require reduced motor load-limits, with the consideration that coal quality, air-demand and firing conditions may lead to rapid changes in air-flow (and thus motor power) required, thus requiring the retention of at least a 15% margin to prevent motor thermal overload.

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- f) Mechanical damage to Blades
- 1) While mechanical damage to the blades should not be the norm, it is possible, thereby justifying a requirement for visual Blade inspection as frequently as possible – maximum 18-monthly frequency – and during any other opportunity short-shutdowns if possible.
 - 2) Mechanical damage can be caused through undetected debris in upstream ducts, and in the case of ID Fans through failure of upstream plant items such as vent fans or damper rods – thus making controlled inspection of these areas mandatory.
 - 3) The servicing and repair of damage to blades is detailed in the applicable section for “Blade in-situ servicing” below.
- g) NDT and reporting of findings
- 1) The execution of NDT on blades is performed on 3-yearly intervals, and requires the establishment of a clear procedure to detail the important areas, processes and recording.
 - i. The Dye Penetrant (DP) crack testing method is used for FD Fan (Aluminium) Blades.
 - ii. The Magnetic Particle (MP) crack testing method is used for ID Fan (Cast Iron) Blades.
 - 2) The cleaning & visual Inspection of blades is a pre-requisite following any decision to perform NDT.
 - 3) NDT for Blades scheduled during Rotor swops is executed with rotor blades removed.
 - 4) NDT scheduled between Rotor swops is executed in-situ with the following key requirements:
 - i. NDT is executed on the BOTTOM third portion of the impeller’s blades to prevent ingress of testing substances into the impeller.
 - ii. Rotor rotation will facilitate complete testing of the blade set. As with other maintenance tasks, rotation of the rotor requires the lubrication oil system to be available and operating during the time of rotating the rotor.
 - 5) Reports of deficiencies are recorded with photographic details of the affected areas per Blade and included into the NDT inspection report.
 - 6) Note that the cast blades often have “approved” manufacturing porosity defects which must not form the focus of the reporting.
 - 7) With erosion of Blades, some initial sub-surface defects may be revealed and should be reported for further investigation as well as future testing and tracking of defect progression.
- h) Blade-pass vibration
- 1) The execution of post Rotor-swap or Blade-swap balancing activities requires the monitoring and reporting of Blade-pass frequencies in the vibration spectrum.
 - 2) Blade-pass frequencies with amplitudes in excess of 4 mm/s must prompt for further investigation and elimination, as excessive Blade-pass vibrations leads to Casing fatigue.
 - 3) The investigation and elimination on causes of excessive Blade-pass vibrations hinges around addressing the following aspects that are generally the causes for such high vibration levels:
 - i. Failure to adhere to requirements for casing ovality and tip-clearance control as stipulated in the relevant Fan specification.
 - ii. Blade pitching and stroking irregularities – some blades may not be pitching.
 - iii. Casing fixed vane alignment or repair deficiencies.
 - iv. Blade manufacturing and/or installation deficiencies in terms of the blade-set leading-edge alignment.
- i) Fan Stall operation
- 1) Stall occurrences must be reported, and the time it was in stall condition should be logged for accumulated trending of the Stall duration time per fan.
 - i. The aluminium blades generally have a threshold of 15 minutes of accumulated Stall duration with an OEM recommendation to discard/replace the Blades once this time duration is reached.
 - ii. Stations with a direct Trip-protection on Stall (MJ FD) do not require monitoring or logging.
 - iii. Stations with a trip delay on the Stall warning (KS/MD FD) must accumulate the incidents.

- 2) Stations with only a Stall Warning configured for Operator intervention requires the establishment of clear Operator Intervention/reaction Instructions (Alarm Response Procedure).
- 3) CAUTION: It is very important to note that the reduction of blade “pressure” surfaces due to wear leads to a change (lowering) of the Fan stall threshold.

3.4.2 Blade servicing

a) In-situ servicing

- 1) Blades are subject to NDT crack testing as noted in the applicable section for “Blade Condition monitoring” above.
- 2) Mechanical damage (notches) may be blended by grinding with a gradual radii up to a maximum depth (from the leading edge) of 15 mm and requires the execution of NDT (crack-testing) to confirm complete removal of the affected area.
- 3) Investigation and further action is prompted if excessive repairs are required to a quantity of more than 4 blades per service – in such cases this would justify the replacement of the blade set and subjecting the set of blades to a factory assessment and repair and re-balancing (should the blades still be use-able).
- 4) Blade trimming requires a re-assessment and correction of the balancing of the Rotor.
- 5) Mechanical damage caused to the bottom 1/3 (from the base) of the blade requires Engineering assessment for replacement.
- 6) The decision for replacement of single blades is made with Engineering advice, after assessment and consideration of the spread of installed blade-masses on the impeller, which is used to reduce the effects of out-of-balance conditions on the Fan.
- 7) Severe pitting erosion must be critically evaluated to preserve blade-life – replacement or blade repair is prompted from a blade availability and economical point of view (cost for life-extension versus cost of replacement).
- 8) The evidence of material cracks is treated as a critical actionable outcome from the inspection (visual or NDT/E), and must be controlled with the following limits:
 - i. Blending of cracks require re-assessment NDT for proof of removal.
 - ii. Remaining crack-evidence after blending to the maximum allowable depth, will require removal of the blade.
- 9) Welding or weld-striking on blades is not permitted – caution and preventative plans are required when Casing weld-repairs are executed.

b) OEM factory servicing – applicable to ID Fan blades

- 1) The conditions noted above for “site-servicing” also applies for Factory (OEM/AEM) servicing.
- 2) Additional methods of repairs must be considered, and requires the OEM development of proposals and specifications, while applying the following principles:
 - i. Minimisation of Blade surface irregularities:
 - The focus is to minimise blade surface removal while eliminating accelerated erosion due to aerodynamic surface irregularities.
 - Severe leading-edge surface irregularities are reduced by trimming techniques in order to remove 75% of the damaged surface.
 - Remaining surface irregularities are plug-welded or removed by alternative innovative means as approved by the OEM.
 - ii. Removal of crack-forming risks.
 - iii. NDT inspection and clearance.
 - iv. Application of an Erosion protection coating (optional) - refer to the applicable section on “Blade Erosion protection” further on in the document.
- 3) Manufacturing history-reference should be kept intact – this requires maintenance of original Blade serial numbers despite repairs being undertaken on them.

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- 4) Baseline control and reporting of wear-condition.
- 5) Blade set Moment balancing with position/fitting-sequence certificate.
- 6) Delivery storage preservation & packaging.

3.4.3 Blade replacement (Flanged/bolted connections)

a) Philosophy & Planning

- 1) Blade swaps are preferred during Rotor swaps when the top casing is removed, and unless necessitated through Technical evaluation, the following applies:
 - i. For FD Fans, Blades can be removed & replaced with the casing in-situ, through the provided 'Blade-removal hatch'.
 - ii. For ID Fans, lifting of the top-casing is mandatory.
- 2) Partial Blade replacement can be facilitated on most installations through a casing Blade-removal hatch (excluding the MD/KS ID fans).
- 3) Spares and control
 - i. Blade removal and replacement requires the planning for and assurance of availability of spares – including peripherals like the attachment bolts and seals.
 - ii. Blades currently provided through the OEM's do not contain any form of erosion protection, requiring Power Stations to implement specific actions to apply the required protection in order to obtain some improvement on blade-life - refer to the applicable section on "Blade erosion protection" below.
 - iii. Blade attachment bolts:
 - Re-use of Bolts is permitted if the Power Station has a controlled record per fan of replacement history. Re-use for up to 3x torque-cycles may be allowed.
 - If no control register is kept, the mandatory replacement of Bolts is required after one torque-cycle.
 - Re-used bolts should be punch-marked with the number of torque-cycles indicated on the Blade-bolts in Impeller port position 1 for each stage.
 - The criteria for inspection and acceptance of Bolts is detailed in the section for "Procedure and Execution" below.
 - iv. Blade bolt-head seating/protection bushes (KS/MD ID Fans) may be re-used subject to controlled inspection and rejection of erosion-damaged bushes.
 - v. Blade base flexible seals should NOT be re-used.
 - vi. Blade base scraper (steel) seals (ID Fans) may be re-used subject to controlled cleaning and inspection to ensure there are no visible signs of damage, while excessive cleaning through sanding/scouring is not permitted.
- 4) Equipment
 - i. Torque control of blade-attachment bolts is required:
 - Mechanical leverage may be used, subject to proper control for the prevention of bolt damage.
 - The use of Hydraulic torque-control for the KS/MD ID fans, with a high bolt-torque requirement, is preferred.
 - ii. Valid calibration verification certificates for Hydraulic equipment is a critical requirement and must be checked at the start of conducting these activities.
 - iii. High-quality hex-drive tools for high-torque applications are critical for prevention of bolt-damage.
 - iv. Excessive damage to bolts is unacceptable, and must prompt for fitting procedure evaluation and a staff training review regarding methods applied.
- 5) Replacement methodology
 - i. The lubrication system must be in service to facilitate rotation of the Rotor.

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- ii. Opposite blade versus sequential blade removal must be facilitated by clear Risk Assessment and procedure, and the decision on the method used should be guided by personnel skill versus efficiency.
- 6) Outage Program – typical acceptable planning duration for activities:
 - i. MJ FD Fans – removal 4 hours, new-blade replacement 6 hours.
 - ii. MJ ID – removal 8 hours (casing already open), new/serviced blade replacement 8 hours.
 - iii. MD/KS ID – removal 16 hours (casing already open), new/serviced blade replacement 16 hours.
 - iv. Casing removal, blade cleaning & NDT and casing replacement on the guided durations above would require additional time that must be planned for in the outage schedule.
 - v. Contractors must use efficient rigging methods and a multiple blade-lifting procedure together with the use of a lifting-cage as an efficient dismantling practice.

b) Procedure and Execution

- 1) A detailed sub-procedure for Blade removal and replacement is required, highlighting the stipulated critical hold and witness points.
- 2) Critical inspection and component rework requirements should be clearly described, e.g. bolt inspection & blade repairs.
- 3) An access platform is required to mitigate to risk of injury and to prevent damage to installed instruments, piping and other equipment – NO climbing and trampling on top of bearings is allowed. The need for scaffolding should be indicated, and time allowed for its installation/removal in the outage plan.
- 4) Position referencing of Blades before removal is mandatory with clear un-erasable marking.
- 5) Casing opening and closing verifications are executed in accordance with stipulations for Rotor swops.
- 6) Torqued Blade-bolt removal for ID Fans is clearly noted for Quality Control, in order to prevent damage to bolt-drives.
 - i. Note that incorrectly angled leverage and damaged drive tools are the main causes of bolt-damage, requiring critical oversight and quality controls.
 - ii. Bolts presenting difficulty to remove due to damaged hex-drives must be removed by local heating to elongate the bolt for easy removal – bolts are subject to controlled marking and must be discarded after removal.
- 7) The removal of Blades from the impeller requires thorough cleaning, rigging and mandatory controls as follows:
 - i. Dust deposit is hand-brushed and vacuum cleaned BEFORE lifting out of blades.
 - ii. Additional vacuuming is required after each individual blade-removal to prevent ash-ingress into the impeller blade ports.
 - iii. A safe-work method statement is required for the handling of blades for which the weight is in excess of 50 kg per blade.
 - iv. The “transport” of blades from the removal platform to ground-level is best and safely executed through the use of blade transport cages. The executing Contractor must provide this facility for efficient and safe execution of the task.
- 8) Blade preparation and fitting
 - i. The thorough cleaning and QC verification of the base with seal-grooves is mandatory – ash-deposit and debris in seal grooves causes seal-fouling and consequent wear on the impeller sealing area resulting in costly repairs.
 - ii. Wet MoS2 Lubrication of blade seal & grooves is mandatory.
 - iii. Dry MoS2 lubrication of Impeller ports is mandatory for all fans.
 - iv. Caution is applied that NO lubrication is applied to DU bushes.
 - v. Blade orientation (leading versus trailing-edge) and sequence of fitting should be critically controlled, verified and documented as part of the QCP.
 - vi. The fitting/tightening of Blade-attachment bolts requires stringent torque control and recording as part of the QCP.

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- 9) Tip clearance control and reporting
 - i. The initial assessment of casing and clearances is used for decision on verification of tip-clearances after the re-fitting of blades.
 - ii. Open top-casing verification and blade trimming is best practice and mandatory for ID Fans.
 - iii. Closed top-casing verification is mandatory.
 - 10) Casing ovality is reported and corrected in accordance to the details stipulated in the applicable section dealing with the “Rotor track casing” above.
 - 11) Verification & set-up of blade synchronisation & stroking is mandatory, and must be incorporated as part of the QCP for verification.
- c) Quality Control
- 1) A detailed QCP for a Blade Swap shall be presented and approved, with accurate control details of the stipulated aspects above.
 - i. Controls applicable to casing removal & installation.
 - ii. Casing ovality assessment.
 - iii. Casing shaft-seal assessment.
 - iv. Cleaning – for the prevention of dust ingress into impeller.
 - v. Blade-base seals – cleaning, fitting and lubrication.
 - vi. Bolt re-use selection and control.
 - vii. Blade fitting-sequence control & verification.
 - viii. Blade-attachment torque-control.
 - ix. Blade tip-clearance recording and reporting.
 - 2) Refer to the requirements for QCP’s noted in the applicable section for “Inspection and Testing” below.
- d) Rotor balance verification is mandatory with Blade replacements.
- e) Scrapped blades are discarded through an approved station procedure, considering that the applicable materials can obtain a “refund” superior to scrap steel.

3.4.4 Blade replacement (threaded spigot connection) (MD/KS FD)

- a) Relevant aspects noted above for “Flanged blades” above also apply to the “spigot-attached blades” – only aspects unique to these types of fans and their blade configurations are detailed below.
- b) Philosophy and Planning
- 1) Spares and control
 - i. Replacement blades should be provided complete with a securing pall/key and sealing plug.
 - 2) Equipment
 - i. Special tools are required for the removal of the blade-securing pall/key.
 - ii. A special blade-synchronising gauge is required for the setting/verification of blade angles and should be available when any work is carried out on the blade configuration of these fans.
 - 3) Outage Program – typical acceptable planning duration for activities:
 - i. MD FD Fans – removal 4 hours, new-blade replacement 6 hours.
- c) Procedure and Execution
- 1) Special task requirements apply for the cleaning and lubrication of the threaded connection, and must be noted on the QCP for verification.
 - 2) Special task requirements apply for the alignment and screwing initiating point when mounting the blade.

3.4.5 Blade erosion protection

- a) Severe wear is generally encountered on the Blade leading-edge and pressure flank.

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- b) Erosion protection methods for Axial Fan blades is not a defined science, and proposed current methods is applied as described, and is based on experimentation and testing.
- c) Any alternative proposals must be submitted and approved through the relevant Eskom Engineering SCOT committee for the applicable plant, in order to avoid duplication and/or repeat of failed testing.
- d) Any evaluation of proposals is subject to equitable operating conditions – specifically considering the environmental severity of exposure to wear.
- e) Erosion protection for Aluminium Blades
 - 1) Leading edge protection:
 - i. Hard-wearing materials – HVOF coating. First trials conducted only provides for a life-doubling extension.
 - ii. Polyurethane coating – cast-on layer. First trials conducted, material failed to adhere to the predicted prolonged period.
 - iii. Steel shield, bolt-on. Trials by other Fan users have yielded positive results.
 - 2) Pressure flank (Concave side) protection:
 - i. Hard-wearing materials – HVOF coating. Currently deemed best practice, providing 3x longer wear-life.
- f) Erosion protection for Spheroidal Cast-Iron Blades
 - 1) Leading edge protection options are under investigation:
 - ii. Hard-wearing materials – HVOF coating. First trials failed to adhere to predicted wear-life extension expectations.
 - iii. Polyurethane coating, cast-on. Not suitable for high temperature applications.
 - iv. Hard-wearing materials – Welding technique. Trials to be conducted.
 - 2) Pressure flank (Concave side) options are under investigation:
 - i. Hard-wearing materials – HVOF. First trials failed to adhere to the anticipated wear life extension predictions, and based on results achieved for Aluminium blades, tests may have to be repeated.
 - 3) Bolt bush/washer
 - ii. Hard-wearing materials – Electrolytic coating. These are generally an OEM supplied components.

3.5 BEARING HOUSING AND BEARING SLEEVES

3.5.1 Bearings, Compartment and access door (FD Fans)

- a) On-line Inspection and access:
 - 1) The KS/MD FD Fans do not permit access into the Bearing Compartment due to tunnel entrance covers.
 - 2) The MJ Fans permit access into the Bearing Tunnel with the use of access platforms.
 - i. Care and supervisory control is to be applied during access so as to avoid interference with instrumentation.
- b) On-line monitoring, maintenance and inspections (MJ & Motors):
 - 1) Daily logging of operating temperature and vibration.
 - 2) Observation of bearing housing secureness/movement.
 - 3) Reporting of observed leaks on housings, seals or connecting pipework.
 - 4) Marking of standstill versus running oil level on non-circulating bearings.
 - 5) Observing oil level during operations and also checking for oil discolouration over time which may be indicative of oil quality deterioration that would prompt oil replacement.
 - 6) Condition of Bearing housing breather.
 - 7) Cleaning of oil/ash contamination if evident, while observing operational risks/precautions when performing this task.
- c) On-line monitoring of other Fan bearings (KS/MD fans):
 - 1) Daily logging of operating temperature and vibration levels.
 - 2) Reporting of observed leaks on external oil supply/return connecting pipework.

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- 3) Motor bearings are all accessible and can be dealt with as per MJ FD Fans noted above.
- d) Off-line inspection and cleaning.
 - 1) Initial SOW inspections are conducted with plant in the “dirty” condition.
 - 2) Inspection reporting must prompt for exact observation of each individual maintenance components/elements on the Bearings.
 - 3) In cases of extreme external contamination, if high-pressure washing is selected as the cleaning method, precautions should be taken to prevent contamination and water ingress through the labyrinth seals.
- e) The tightness of Bearing housing attachment bolts to casings or pedestals shall be periodically verified by means of checking and recording the torque setting.
 - 1) Uncontrolled flogging of bolts is not allowed.
 - 2) Bolt torque must be done with the use of a controlled torque-applying tool and torque setting recorded on the maintenance work quality control check-sheet.
 - 3) Bolts and threads must be protected against corrosion.
- f) Bearing breather filters are inspected and cleaned/replaced with annual shut-down opportunities.
- g) Oil leakage inside the bearing compartment must be avoided and cleaned, as casings are not sealed to prevent seepage into the fan flow area – failure to address leakages can result in contamination of blades and the fan flow area.
- h) Shaft guards and access cover-plates are inspected to ensure sturdy fixing, and control is exercised to ensure that no contact is made with rotating shafts.

3.5.2 Bearing housings and alignment (FD Fans)

- a) Housing health and alignment is controlled and corrected during Rotor swaps, with proof & sign-off on final set-up.
 - 1) Opened bearings during Rotor-swaps, justify a verification and reporting of the spherical Inside Diameter (ID) sizes and any signs of fretting/damage observed during the inspection.
 - 2) The provision of an alignment jacking mechanism for housings is essential and correct functioning must be maintained if defective.
 - 3) Removal of Bearing housings should be carefully executed with accurate control & recording of its positions relative to the motor, as well as the shimming conditions.
 - 4) With re-installation of bearing housings, the positioning is established against the Blade-centering positions as references, and will require controlled sideways movements & vertical shimming, in order to achieve the applicable specification of 0.5 mm TIR.
 - 5) The availability of “trim-shimming” must be secured for outage tasks on the bearing housing, with the limitation of adding no more than three shims to the main pedestal (main insert/packer with two trim-shims allowed).
 - 6) Rotation of the Bearing housing around its horizontal & vertical axes must be controlled and reported to a maximum of 0.2 mm difference between opposite sides, in order to secure correct fit of the labyrinth seals/housings.
 - 7) The axial position of bearing housings must be controlled and reported as part of the QCP, while considering various influencing aspects that will dictate the correct position, such as motor adjustment slots, motor magnetic centre, and allowable gaps on the Cardan-shaft couplings.
- b) Rotor swop re-alignment (MD/KS)
 - 1) Bearing positions are normally NOT disturbed with Fan Rotor-swaps, so re-alignment would only be required in the case of detected bearing housing faults or seal fitting problems.
- c) Rotor swop re-alignment (MJ)
 - 1) The NDE Bearing position will be disturbed with Fan Rotor-swaps, and therefore requires re-alignment from first principles as detailed above.

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- 2) The DE-locating Bearing housing position is normally NOT disturbed with Fan Rotor-swaps, unless anomalies are detected during the bearing housing inspection which justifies a Housing replacement.

3.5.3 Bearing internals and seals (FD Fans)

- a) Bearing-bore journals, manufactured from 'White-metal' are designed for minimum 6-year lifetime, and must be comprehensively inspected at these intervals.
- b) Bearing inspections must coincide with Rotor swaps, thus optimising the need to open the bearing in accordance with the Rotor swap philosophy. If the Rotor swap interval exceeds the 6-year period, the bearing inspection will be postponed to the planned swap-event, unless there is an Engineering report of elevated temperatures, vibration bearing fault frequency indicators in the spectrum or other reported operational problems.
- c) Servicing of bearings require detailed inspection & reporting of critical aspects and shall be presented to Eskom Engineering for assessment of all wear observed and the return-to-service set-up verifications, referenced to a unique identifier (serial) of the specific bearing/sleeve as part of the QCP.
- d) Bearing health is assessed by means of objective measurements and observations, considering the following aspects, while replacement instructions should be authorised by Engineering:
 - 1) Crown clearance measurements.
 - 2) Observation and reporting of abnormal pressure points or defective lay on the bearing.
 - 3) Wear of a 20% increase on the original maximum crown clearance is acceptable.
 - 4) Shaft condition assessment – and alarming deficiencies like scoring and disturbed surface finish.
 - 5) Thrust pad visual wear and report of scoring or damage.
- e) The Site Service Contractor shall utilise personnel with bearing-specific training and provide a comprehensive inspection procedure that requires approval from Eskom, which will cover the following sensitive areas as a minimum:
 - 1) External washing procedure and cautions.
 - 2) Opening cleanliness and control.
 - 3) Rigging practice to prevent damage to equipment and instrumentation.
 - 4) Requirements and methods to retain clean working precautions.
 - 5) Seals condition, clearance and sealing methods.
 - 6) Bottom Bearing sleeve removal control.
 - 7) Record of any shaft/journal damage observed.
 - 8) Measuring, recording and evaluation of the "crown clearance"
 - i. Assessment and reporting of the bore-clearance with the aid of "plasti-gauge" in accordance to the original installation tolerance.
 - ii. The objective reporting on the condition of the shaft journal, with consideration of scoring marks and disturbed surface finish.
 - 9) Measuring and recording of the "lip clearance".
 - 10) Measuring and recording of thrust pad clearance.
 - 11) Thrust-pad damage/scoring, flush installation and clearance control.
 - 12) Bearing sleeve anti-rotation locator.
 - 13) Control of run-down installation where applicable.
 - 14) Bearing sleeve splits, locating-dowel installation & verification and spherical OD condition/size verification/recording.
 - 15) Labyrinth seal fitting precautions.
 - 16) Sealing and preservation.
 - 17) Housing cleanliness, sight-glass and access-cover sealing.
- f) The Site Service contractor, and shall present a detailed QCP for Witness verification of the following minimum aspects:
 - 1) Internal and split-bearing "dirty" inspection.

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- 2) Component wear assessment – crown clearance, with a recommendation requiring a decision on re-use of sleeve.
 - 3) Control of cleanliness and verification of internal installation aspects, which is best performed with the use of a detailed inspection check-sheet before bearing/housing closure.
 - 4) After closure, a final inspection with check-sheet to secure start-up readiness.
 - 5) Commissioning with verification reporting on oil levels and bearing operating temperature.
- g) Lubrication of Bearings
- 1) Installations with forced-lubrication systems (KS/MD) are inspected and serviced on 6-yearly intervals, or in conjunction with Rotor-swopping.
 - 2) Oil pressure and flow of lubricating oil to bearings is monitored on a daily basis.
 - 3) Lubrication condition monitoring is performed from an oil sampling point on the lube oil system, and is dealt with in the applicable section.
 - 4) The run-down lubrication for (KS/MD) fans:
 - i. The primary system is via installed emergency pumps and operation must be proven/tested with 3-yearly maintenance shutdown opportunities.
 - ii. The secondary system is via installed bearing-internal oil rings and are inspected and cleared with bearing servicing, while observing the following:
 - No signs of wear on the oil rings, and maximum ovality of 1 mm allowed.
 - Split dowels and attachment screws inserted and locked with no steps of misalignment on lubricating ID-surface.
 - 5) Rundown lubrication (MJ Fans):
 - i. The flinger disc installation requires additional care and assessment during bearing inspections and installation.
 - ii. Verification of critical aspects shall be controlled and recorded as part of the QCP:
 - Flinger- disc attachment secureness verified on split faces and grub-screw.
 - Oil scoop attachment and secureness.
 - Oil scoop radial clearances should not exceed 1mm and lateral clearance must be centralised.
 - The shaft should be rotated for verification of non-contact conditions before closing the bearing.
- h) Housing Labyrinth seals are maintenance items and require a review of the wear-condition and cleanliness on 3-yearly interventions. This is applicable to all FD Fans and Motor bearings.
- 1) MD/KS Fans and Motors:
 - i. Fixed-lip Labyrinth seals must be inspected with reporting of any leakages and other possible damage observed, the setting-clearance measured & recorded during the initial inspections.
 - ii. Recording of set-up clearances after re-installation should be part of the QCP.
 - 2) MJ Fans and Motors:
 - i. Floating Labyrinth seals should be inspected with reporting of any leakage observed, the wear-clearance measured, and possible distortion – generally, healthy fitting clearances are not more than 0.3 mm, with no gap on the seal-split-ends.
 - ii. Note that in the case where shaft damage is observed, it will be possible to revert to a fixed-seal installation as a temporary solution (MJ Fans).
 - iii. Ensure that the seal-installation incorporates a verification of correct orientation, leakage/drain holes and anti-rotation pins as part of the Quality checks.
 - iv. Where additional weather-proof IP55 seals are fitted, record of clearances shall be recorded (MJ FD & all Motors) as part of the Quality check.

3.5.4 Bearing compartment and access door (ID Fans)

- a) MJ Fans - No inspection or maintenance is possible after closing the Fan casing, therefore adherence to thorough inspection and testing protocols before closing the casing is of utmost importance, while noting the following areas to be controlled:
 - 1) Verification of all oil and vent-pipe connections with a centralisation of vent-pipe connecting couplings.
 - 2) Verification of connection of the seal-cavity drainage connections.
- b) KS/MD Fans - Inspection access is available but care should be taken to ensure proper sealing and controlled closure of the access doors after inspections.
- c) Ash-contamination of the bearing room is not the norm, but if it is evident, this must be reported, investigated and resolved – also refer to the maintenance requirements for the Seal Air fan.
- d) The inspection, and verification of the compartment and flange alignment, must be adhered to for pre-opening and post-closure of casings – especially after executing weld repairs on the fixed-vanes.
- e) Bearing compartment sealing must be controlled, in order to secure air-tight sealing on all horizontal flange contact-surfaces. The sealant thickness may have to be adapted if small machining or distortion clearances are evident.
- f) Bearing room cooling, pressurisation & venting is of prime importance and must be managed in accordance with requirements stipulated under the applicable section for Seal air fans.

3.5.5 Bearing Housings and alignment (ID Fans)

- a) Bearing housings are integrated with the Rotor, and require no maintenance intervention during the normal operational service period, unless operational problems are experienced.
- b) On-line inspections
 - 1) Only external casing access is available for on-line inspections.
 - 2) Inspections should be conducted for signs of external leakage through bearing compartment drains below the casing, and should be conducted and reported on a weekly basis.
 - 3) Bearing performance parameters like temperatures, vibrations and oil condition should be regularly executed and monitored as for other Bearings.
- c) Off-line inspections require the monitoring of the following aspects internal to the casing:
 - 1) Any signs of oil leakage between Fan impeller and Bearing housings must be reported.
 - 2) Any signs of leakage reported on the external casing drains must prompt for a controlled internal inspection of the bearing-compartment (KS/MD).
 - 3) Signs of severe leakage on the external casing drains (MJ) must prompt for inspection by lifting the top-casing, while minor leakage may potentially be tolerated up to the next scheduled Rotor swop.
- d) Alignment of Bearing Housings inside the Fan casing is controlled through a fixed locating spigot, and the following aspects must be controlled (also refer to the applicable details noted under the section for Rotor swops on other related important aspects to be considered):
 - 1) Axial fit shimming must be documented with Rotor-removals, and again recorded with re-installation as part of the QCP.
 - 2) Fixing bolt torque control.
 - 3) Alignment deviations measured through blade-tip clearance must be reported and documented as part of the QCP.
 - 4) Housing to Rotor “shaft-seal” clearances must be validated and controlled as per prescribed specifications.

3.5.6 Bearing internals and seals (ID Fans)

- a) KS/MD – Bearings are serviced and factory tested during Rotor overhauls – no intrusive opening or maintenance is allowed on site. Bearing problems or failures are reported to the Rotor OEM, and the resolution to severe bearing deficiencies is most likely done through Rotor replacement.

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- b) MJ – A requirement to perform intrusive inspections and repairs on bearings is strongly recommended for execution by the Rotor OEM, especially if Rotor overhaul warranties are still applicable. Specific control is required on several sensitive aspects on Bearings when opened:
 - 1) Pre-trip cleanliness.
 - 2) Stripping sequence – procedure.
 - 3) Gas seal slide-fitting (carbon-seal).
 - 4) Labyrinth seal alignment and gaps.
 - 5) Sealing cavity oil drainage.
- c) The monitoring of Bearing thrust-pad performance for initial start-up is mandatory and care should be taken of factors that can affect the operational performance of the thrust (also take note of items listed as risks under the section for alignment and Rotor swops):
 - 1) Correct installation of temperature measuring probes, especially on thrust pads.
 - 2) Motor and coupling axial alignment.
 - 3) Lubrication oil supply quantity.
- d) Lubrication of Bearings
 - 1) Forced-lubrication pressure and flow of oil to bearings should be monitored on a daily basis.
 - 2) Lubrication condition monitoring is performed from an oil sampling point on the lube system, and is dealt with in the applicable section.
 - 3) The run-down lubrication for KS/MD Fans:
 - i. The primary system is via installed emergency pumps and correct operation must be proven/tested with 3-yearly maintenance shutdown opportunities.
 - 4) The run-down lubrication for MJ Fans:
 - ii. The primary system is in the form of internal oil-rings for which the installation and correct functional operation is verified and reported on during Rotor overhauls.

3.5.7 Commissioning

- a) Best-practice for the fitting of a new bearing sleeve is to verify the lay/contact-pattern. With the shaft fully seated on a pre-oiled bearing, and the Rotor turned up to 3 full turns, the bottom bearing sleeve is removed for a lay-assessment, and the desired contact surface should be in excess of 60%.
- b) As health-protection for all bearings, the execution of any intrusive work on lube-systems and oil-supply piping requires the pre-flushing of the oil supply-system prior to connection of oil supply to the bearings.
- c) Flushing is executed to a documented procedure and should be done for a minimum of 2 hours and at an elevated system oil flow through manipulation of the lube-system control settings. With standard flow-settings, the flushing duration must be increased to 4 hours.
- d) Start-up of machines without forced lubrication (MJ motors) after a standstill of more than 2 weeks require the addition of start-up lubrication, which is achieved by pouring 100 ml of oil on top of the bearing while doing 1 manual rotation of the shaft.
- e) Opened and/or replaced bearings are subject to a machine test-run prior to the RTS of a generating unit.
 - 1) All bearing temperatures are to be closely monitored during and after start-up to observe and record the temperature profile up to a point of stabilisation. The required emergency response procedure and actions should be in place for cases where the bearing temperature rapidly increase at start up or does not stabilise at the prescribed operating temperature.
 - 2) Thrust bearing (pads) temperatures are monitored after start-up to observe and record the temperature profile up to a point of 80% of Fan capacity.
 - 3) Bearing vibrations must also be monitored and recorded during balance runs or health-proving test-runs.
- f) Bearings with oil-sump lubrication require the marking/recording of both standing and operating oil levels.

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3.6 HYDRAULIC ACTUATING SYSTEM

The key components – Hydraulic actuator, Servo positioner valve and the Rotating union – are present for all Axial flow fans with some variations in design and layout between manufacturers and models.

3.6.1 Rotating union (FD Fan)

a) Medupi/Kusile

- 1) The expected leak-free service life of the Rotating union is minimum 4 years. The possibility for extension of useful operating life is yet to be evaluated and will be evident on the performance of the Medupi Unit 6 installations. The expected service life of the hydraulic hoses is currently maximum 4 years, unless any deficiency is detected before the recommended replacement interval and in comparison with other hydraulic hoses, these require to be reviewed.
- 2) Failure modes:
 - i. Internal failure through seal fatigue & damage on the shaft seal landing is a potential failure mode, and can be exacerbated through the use of incorrect components & repair techniques.
 - ii. General fatigue of component and linkages caused through incorrect fitting or misalignment.
 - iii. External leakage-failure due to incorrect handling or installation of the flange seals.
- 3) Service inspections must be executed on 18-monthly intervals and must report on leakage, fitting alignment, the condition of the control linkages & hydraulic tubing.
- 4) Replacement of Rotating unions require the following actions:
 - i. A fully serviced and tested exchange unit with new sealing gasket should be used – as on-site stripping and servicing is not permitted.
 - ii. Control and recording of the seal gap and alignment as part of the QCP.
 - iii. Recording of replacement history for each individual fan, incorporating asset tracking.
 - iv. Control of the refurbishment and testing must be undertaken by a suitably qualified and acknowledged Axial fan OEM/AEM.
- 5) Detailed engineering failure analysis for units requiring replacement before its targeted 6-yearly service, is required.

b) Majuba

- 1) The expected leak-free Service life of the union is minimum 3 years and the connecting linkages are subject to the same life expectancy. The expected service life of the hydraulic hoses are minimum 12 years, unless any deficiency is detected before the recommended replacement interval.
- 2) Failure modes:
 - i. Internal failure through seal fatigue & damage on the shaft seal landing, and can be exacerbated by the use of incorrect components & repairs techniques.
 - ii. Internal wear of mechanical shaft seals, leading to excessive internal bypass with ultimate failure to provide sufficient flow for blade pitching purposes. This aspect must specifically be investigated and assessed during the service & testing of the component.
 - iii. General fatigue of component and linkages caused through incorrect control of fitting alignment. The fitting alignment must be verified within maximum 0.2 mm, and deviations must be reported to Engineering for resolution.
 - iv. External leakage failure due to the use of incorrect sealing O-ring size.
 - v. Caution: The use of an incorrect ('too large') flange sealing O-ring size will result in functional failure.
- 3) Service inspections are executed on 18-monthly intervals and must report on leakage, fitting alignment, the condition of the control linkages & hydraulic flexible hoses.
- 4) Replacement of Rotating unions require the following actions:

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- i. A fully serviced and tested exchange unit with new sealing gasket should be used – as on-site stripping & repairs on these items are not permitted.
 - ii. Verification of the required installation parameters should be done as part of the QCP, and must include a full verification of the control linkage installation set-up.
 - Caution: The condition and restoration of the connecting rod-ends & pins is a very important aspect during the process of verification.
 - The position (exact location), and adjustment of the mid-support with restored condition of the linking rod is of critical importance and must be verified.
 - Refer also to the applicable section below on the Connecting linkages.
 - iii. Recording of replacement history for each individual fan, incorporating asset tracking, should be implemented.
 - iv. Control of the refurbishment and testing activity must be undertaken by a suitably qualified and acknowledged Axial fan OEM/AEM.
- 5) Detailed engineering failure analysis for units requiring replacement before its 3-yearly service cycle, is required.

3.6.2 Servo valve (FD Fan)

a) Medupi/Kusile – Servo valve and Hydraulic actuator

The MD & KS Servo positioner valve is an integrated unit with the Hydraulic actuator and rotates as an assembly with the actuator while controlling the transfer of hydraulic oil through accurately timed oil ports and tight hydraulic clearances to accommodate the axial/linear movements required for oil-port alignment.

With the Servo positioner valve integrated with the Hydraulic Actuator, only the Servo-valve spool (shaft) is extractable.

- 1) The targeted Service life for the Servo positioner-valve is to coincide with the Rotor service-life for replacement on 4 to 6 yearly intervals.
 - i. Caution: The Servo valve spool & sleeve has been reported to accumulate and display severe fretting wear on the mutual contact surface which may require replacement or service intervention on 3-yearly intervals.
- 2) The only known Failure mode is at this point in time is limited to the Servo positioner valve as noted above. No other failure modes have been detected for the Hydraulic actuator, except the obvious risk of sealing element wear which would be subject to a predetermined service life (to be assessed).
- 3) Service inspections on the Servo-valve spool must be executed on 3-yearly intervals, until such time as a method for improvement is found to counter the fretting-wear anomaly.
 - i. Fretting damage on the spool (OD) is to be removed/smoothened by appropriate methods and by skilled personnel.
 - ii. Fretting damage to the mating sleeve (ID) should not be attempted in-situ, due to the risk of dirt-ingress.
- 4) A complete replacement of the Hydraulic unit is possible, but not recommended from a philosophy point of view. If, through Engineering assessment, a replacement is justified, the following actions are required:
 - i. A fully serviced and tested exchange unit must be available.
 - ii. Control and recording of the installation alignment.
 - iii. Several points of control must be managed, requiring a comprehensive procedure & QCP covering the following: (as a minimum)
 - Actuator rear shaft support bush assessment.
 - Regulating disc attachment bolt torque.
 - Actuator/Hub support-cover bolt torque and alignment.
 - Rotating union attachment and alignment.
 - Actuator air bleeding and functional testing.

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- Balancing/vibration verification.
 - iv. Recording of replacement history for each individual fan, incorporating asset tracking.
 - v. Control of the refurbishment and testing activity must be executed with a suitably qualified and acknowledged Axial fan OEM/AEM.
- 5) Detailed engineering failure analysis for units with forced replacement before its targeted 6-yearly service, is required.

b) Majuba

The MJ Servo positioner valve is a rotating component, generally referred to as the “distribution sleeve”, and is rigidly mounted onto the Hydraulic actuator. The Servo valve consist of a spool shaft and sleeve, which is a matched pair with small hydraulic clearances and matched oil ports to achieve the desired functionality through limited and relative linear movement.

- 1) The expected service life of the Servo positioner valve is 6 to 9 years, and is generally subject to the quality of refurbishment & testing. Some external components do require a review on 3-yearly intervals.
- 2) Failure modes constitute the following:
 - i. Fretting-wear of the keep plate, with oscillating linear movements inside the Servo spool key-slot. The fitting of a replacement keep-plate (non-wear material) must be controlled with specific installation requirements. Replacement of a damaged Servo valve spool is not recommended due to it being a matched set with the sleeve.
 - ii. Oil Leakage on front/shaft seal, generally as result of incorrect seal specification or installation. On-site replacement of the seal is justified.
 - iii. Oil leakage on the rear mounting face/flange, generally as a result of incorrect seal or fitting interfaces, and such instances must be investigated.
- 3) Service inspections are executed on 18 monthly intervals to detect any of the known failure modes, and repairs may be required on 3-yearly basis in the following areas:
 - i. Oil leakage of front or rear seals.
 - ii. Fretting of keep plate and key slot.
- 4) Replacement
 - i. The replacement of the Servo valve requires skilled site-support and is only executed with thorough Engineering assessment.
 - ii. A fully serviced and tested exchange unit must be available if replacement is recommended as an outcome of the Engineering assessment.
 - iii. Several points of control must be managed, requiring a comprehensive procedure & QCP covering the following: (as a minimum)
 - Servo valve rear-flange seals fitting and port alignment/orientation.
 - Servo valve spool keep plate fitting.
 - Rotating union attachment seals, fitting and alignment.
 - Control linkage health and set-up.
 - Actuator air bleeding and system functional testing.
 - iv. Recording of replacement history for each individual fan, incorporating asset tracking.
 - v. Control of the refurbishment and testing activities must be executed with a suitably qualified and acknowledged Axial fan OEM/AEM.
- 5) Detailed engineering failure analysis for units requiring repair or replacement before its minimum 6-yearly service-life, is required.

3.6.3 Hydraulic actuator (FD Fan)

a) Medupi/Kusile

The Hydraulic actuator for these fans has been dealt with under the Servo valve section above.

b) Majuba

- 1) The Service life of the Hydraulic actuator is 6 to 8 years, and is generally subject to the quality of refurbishment & testing, and the correct specification of seals.
- 2) Known failure modes for Hydraulic actuators are classified as internal or external:

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- i. Internal failure modes such as failed piston seals or loose piston are rare if effectively dealt with during the refurbishment phase.
 - ii. External failures are detected with visual inspection, and should be reported to Engineering for further investigation & potential replacement.
 - 3) Service inspection for Hydraulic actuator is executed on 18-monthly intervals and possible defects are as follows:
 - i. Leakage of rear seals is a hidden random failure and becomes evident through hydraulic oil loss and possible seepage out of the impeller – which will be observed as oil on the Blades & rotor track of the casing.
 - ii. Excessive drag or friction on the Actuator Support bush caused by excessive dirt ingress or incorrect/eccentric fitting tolerances.
 - iii. Leakage on front seal or blanking plugs.
 - 4) Replacement
 - i. The replacement of the Hydraulic actuator is not the norm and requires extensive & skilled site-support. A replacement should only be executed after thorough Engineering assessment.
 - ii. A fully serviced and tested exchange unit must be available.
 - iii. Several points of control must be managed, requiring a comprehensive procedure & QCP covering the following (as a minimum):
 - Regulating disc control and attachment bolt-torque.
 - Actuator shaft seal and shaft entry into main shaft.
 - Hub cover alignment and attachment bolt torque.
 - Deva-bush fitting and clearance.
 - Actuator centre-bolt torque procedure: cold & hot conditions.
 - Servo-valve and Rotating union fitting, sealing and alignment.
 - Control linkage condition and set-up.
 - Actuator air bleeding and system functional testing.
 - Balancing/vibration verification.
 - iv. Recording of replacement history for each individual fan, incorporating asset tracking.
 - v. Control of the refurbishment and testing activities must be executed with a suitably qualified and acknowledged Axial fan OEM/AEM.
 - 5) Detailed engineering failure analysis for units requiring replacement before its minimum 6-yearly service-life, is required.

3.6.4 Servo valve and Hydraulic Actuator (ID Fan)

a) Medupi/Kusile

The MD & KS Servo positioner valve is an integrated unit containing both the transfer of hydraulic oil and the blade-position functionality into a combined and non-rotating (static) unit.

The Servo positioner valve is further integrated with the Hydraulic Actuator – OEM assembled & tested, and should thus be stored and replaced as a complete unit.

- 1) The Hydraulic actuator assembly is subject to a full Service when the Rotor is swapped on 3 to 4-yearly intervals. A service-life beyond the OEM-recommended 3 years needs to be investigated and proven before frequency is changed to longer duration.
- 2) Failure modes on the Hydraulic actuator:
 - i. From a site-maintenance point of view, failures and causes are outlined as follows:
 - Incorrect alignment – minimisation of vibrating movement on the furthest point of the actuator is important and the verification of alignment is mandatory with each Rotor or blade swop.
 - Incorrect adjustment or synchronisation of actuator movement - specifically setting of extreme-positioning mechanical limits/stops.

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- Oil leakage due to failed seals – requiring a hydraulic-unit replacement if found to be excessive.
 - Incorrect positioning of the oil-supply hydraulic hoses – this requires clear stipulation of the required hose-positions as part of the maintenance procedure.
 - Extreme blade wear would exceed the limit of sufficient available hydraulic pressure/force to be exerted, resulting in a failure to pitch the blades as required – thus not to be seen as an Actuator failure.
 - Evidence of possible internal Servo-valve failure is detected when a mismatch of relative position is observed between the mechanical feedback indication (sensor CG001) versus the electric actuator position-indication (sensor AS001).
 - ii. Service/overhaul failure-modes related to internal labyrinth sealing members have been identified, and are possibly caused by high vibrating movements – a condition to be avoided through correct site set-up.
- 3) On-line (external) Service inspections for the Hydraulic actuator are executed on a weekly basis to detect anomalies with the position indicator and to identify excessive vibrating movements.
- Off-line (internal) Service inspection for the Hydraulic actuator is executed on minimum 18-monthly intervals and possible defects are as follows:
- i. Leakage of rear shaft-seals is a hidden random failure and becomes evident through hydraulic oil loss and possible seepage out of the impeller – this would be observed as oil deposits in the discharge casing and may also be evident through leakage on the rear access door.
 - ii. Leakage on external seals or blanking plugs.
 - iii. Signs of fatigue on control-rod sleeve & flexible coupling, or loose bolts.
- 4) Replacement
- i. The verification of alignment/movement on the servo-unit in compliance with the fan specification is mandatory with each opening of the Fan casing – either for a blade-swop or a Rotor swop.
 - ii. The in-situ replacement of the Hydraulic actuator is not a norm, and requires extensive and skilled site-support. A replacement is only executed after thorough Engineering assessment.
 - iii. A fully serviced and tested exchange unit should be available.
 - iv. Several points of control must be managed, requiring a comprehensive procedure & QCP covering the following minimum requirements:
 - Regulating disc attachment bolt-torque.
 - Actuator supporting cover alignment and attachment bolt torque.
 - Servo positioner-unit alignment set-up with recorded QCP verification.
 - Verification of internal mechanical limit-setting, synchronised with the external indicator.
 - Verification of the correct hydraulic hose positions and sealing.
 - Verification of the stabiliser attachment.
 - Verification of the control rod coupling connection and setting.
 - Application of controls relating to the lifting and re-positioning of the casing
 - Inspection of hydraulic compartment details like pressure & temperature measuring points.
 - Balancing/vibration verification.
 - v. Recording of replacement history for each individual fan, incorporating asset tracking.
 - vi. Control of refurbishment and testing activities must be executed by a suitably qualified and acknowledged Axial fan OEM/AEM.

- 5) Detailed engineering failure analysis for units requiring replacement before its minimum 4-yearly service-life, is required.

b) Majuba

The Majuba Servo positioner valve is integrated into the Hydraulic actuator, which also facilitates the transfer of hydraulic oil from a non-rotating servo valve spool to a rotating servo valve sleeve. The hydraulic oil is connected onto a non-rotating manifold with dedicated ports matching with the Servo-valve ports to guide oil into achieving the desired function.

- 1) A fault-free Service-life of 6 years is the norm – thus the Hydraulic actuator assembly would be subjected to a full service when the Rotor is swapped and overhauled on 4 to 6-yearly intervals.

- 2) Failure modes on the Hydraulic actuator:

i. From a site-operational point of view, failures and causes are outlined as follows:

- Incorrect adjustment or synchronisation of actuator movement – incorrect setting of extreme-positioning mechanical limits.
- Oil leakage due to a failed gasket on the connecting-manifold – with in-situ replacement through basic controls possible should this be the case.
- Oil leakage due to failed seals on the front-cover scraper seal and O-ring – in-situ replacement requiring detailed skill and special tools for seal-replacement would be required if this failure mode is identified.
- Oil leakage due to a failed rear shaft-seal would be evidenced by a major oil leakage observed through a leak-detection hole in the actuator mounting flange, and manifesting as oil leakage from the hydraulic compartment into the flow-area.
- Incorrect positioning or damage of the oil-supply hydraulic hoses – this requires clear stipulation of the required hose-positions as part of the maintenance work instruction, as well as avoidance of contact with the rotating actuator.

ii. Service/overhaul failure-modes are related to internal bearing and spool-contact damage caused through high vibration movements – a condition to be avoided.

- 3) External service inspection for the Hydraulic actuator is executed on a weekly basis to detect anomalies with the position indicator and to identify any excessive vibrating movements observed from the movement of hydraulic piping and linkages.

Internal Service inspection for the Hydraulic actuator is executed on a minimum 18-monthly interval and possible defects are as follows:

i. Leakage of rear shaft-seals is a hidden random failure and becomes evident through hydraulic oil loss and leakage from a leak-hole on the actuator flange and manifesting as oil leakage from the hydraulic compartment into the flow-area – in-situ seal replacement is an extremely sensitive task and should only be executed by a suitable skilled & trained service team.

ii. Leakage on external seals or blanking plugs.

- 4) Replacement

i. The replacement of the Hydraulic actuator is not the norm and requires extensive and skilled support from the OEM. A replacement should only be executed after thorough Engineering assessment.

ii. A replacement rear seal set, or a fully serviced and tested exchange unit, should be available.

iii. Several points of control must be managed, requiring a comprehensive procedure & QCP covering the following minimum requirements:

- Tight/exact lifting controls should be in place to stabilise the unit for connection & alignment purposes.
- Connecting-shaft attachment alignment verification and bolt-torque.
- Actuator attachment and bolt-torque.
- Servo positioner-unit alignment set-up with recorded QCP verification.

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- Verification of internal mechanical limit-setting, synchronised with the external indicator.
 - Verification of the correct hydraulic hose positions and sealing.
 - Application of controls relating to the lifting and re-positioning of the casing.
 - Inspection of hydraulic compartment details like pressure & temperature measuring points.
 - Balancing/vibration verification.
- iv. Recording of replacement history for each individual fan, incorporating asset tracking.
 - v. Control of refurbishment and testing activities must be executed by a suitably qualified and acknowledged Axial fan OEM/AEM.
- 5) Detailed engineering failure analysis (RCA) for units requiring replacement before its minimum 6-yearly service-life, is required.

3.6.5 Blade pitch Hydraulic System testing and setting

- a) Pre-swap assessment
 - 1) The testing and recording of the minimum pressure required to pitch the blades in the stationery condition provides guiding information on the general condition of the system – static pitching pressures above 6 Bar must be reported to Engineering for further investigation.
 - 2) Hydraulic oil is purged-out with a dedicated air-fitting before disconnecting the oil return flexible piping.
- b) Installation & testing
 - 1) A pre-connecting & testing requirement for all lube and hydraulic systems is to perform bypass circulation with the aid of dedicated bypass/flushing connections, before connecting the piping onto the respective bearings or hydraulic actuators.
 - 2) Most Hydraulic actuators require the correct positioning of air-bleed points, and removal of captured air with the initial oil fill after installation.
 - 3) The execution of air-bleeding is witnessed and prompted for reporting on Commissioning and/or QCP documentation.
- c) In-service failure assessment
 - 1) Failure of the Hydraulic Actuator to perform its intended function is the result of internal leakage, inadequate system supply-pressure or increased mechanical friction.
 - 2) The manifestation of failures requires intensive investigation and recommendation of proposed actions involving Engineering, and often requires the input from the OEM.
 - 3) The testing and verification of failure causes require the re-establishment of pitching pressures and correct oil-volume flow in accordance to an approved Engineering procedure as per OEM specifications.

3.7 LUBRICATION AND HYDRAULIC SYSTEMS

3.7.1 Configurations and lay-out

- a) Lubrication and Hydraulic systems for these large fans are distinguished by the large operating pressure differences between them, and therefore require separate pumping and control mechanisms.
- b) While for different stations, OEM's and design layout configurations there may be a slight variation of components, they all require the same basic Inspections and servicing activities. Commissioning of each respective system requires a unique approach per type of system.
 - 1) Integrated Lubrication & Hydraulic systems – All ID Fans & KS/MD FD Fans.
 - i. The KS/MD FD Fan Lube/Hydraulic pressure is provided from electrically driven, fully immersed tandem gear-pump sets for in-service & standby application. The separate

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- pressure paths are each equipped with its own pressure relief, flow control, duplex filter and compact-plate-type oil coolers.
 - ii. The KS/MD ID Fan Lube/Hydraulic pressure is provided from electrically driven, fully immersed tandem gear-pump sets for in-service & standby application. The separate pressure paths are each equipped with its own pressure relief, flow control, duplex filter and tube & shell-type oil coolers.
 - iii. The MJ ID Fan Hydraulic pressure is provided from electrically driven, in-service & standby, fully immersed screw-type pumps with a tap-off pressure reducing valve for the lubrication oil supply. The common path is fitted with a duplex oil filter and tube & shell-type oil cooler, but with separated path pressure & flow control functions.
- 2) Individual (separated) Lubrication and Hydraulic systems – MJ FD Fans
 - i. The Lubrication system is equipped with immersed in-service & standby electrically driven, gear-type pumps, and a supply-line tube & shell-type oil cooler. The supply-path is fitted with a duplex filter, and adjustable pressure relief & pressure control valves.
 - ii. The Hydraulic system is equipped with immersed in-service & standby electrically driven, gear-type pumps, and a return-line tube & shell-type oil cooler. The supply-path is fitted with a duplex filter, and adjustable pressure relief & pressure control valves.
- c) Fan rundown system – total power failure rundown protection.
 - 1) The MJ ID Fans have bearing-internal oil rings and MJ FD Fans have bearing-internal flinger discs that provide adequate rundown lubrication.
 - 2) The KS/MD FD Fans are equipped with an electrical (DC) emergency lubrication pump, and a secondary mechanism with Bearing-internal oil rings.
 - 3) The KS/MD ID Fans are equipped with an electrical (DC) emergency lubrication pump.
- d) Braking system – shutdown & standstill Rotor brake
 - 1) The MJ Fans have manual brakes only for standstill conditions to prevent Fan “wind-milling”.
 - 2) The KS/MD Fans have hydraulic brakes for rundown from <150 rpm to standstill.

3.7.2 Site monitoring and maintenance

- a) The individual monitoring components on typical hydraulic/lube systems can experience several modes of failure, and general monitoring of system health is assessed with daily walk downs and weekly reporting cycles.
- b) Refer to the details noted under the applicable section for “Online Inspection – Plant walk verification” below.
- c) Duplex filters
 - 1) Action should be taken when filter dP warning is activated, as this indicates blockage and replacement of the filter element should be done.
 - 2) Selection positions are marked in order to pick-up on switch-overs executed outside of normal working hours.
 - 3) A clear procedure on the execution of filter replacements is required, with care taken to use the correct tools, doing pressure relief before opening the filter and correct environmental disposal of the filter element and oil removed/drained during the exercise.
- d) Flow sight glass and flow-switch
 - 1) Observe strength of flow through the sight glass.
 - 2) Observe and record visibility through glass (stained) and signs of oil leaks.
 - 3) Flow-switches are screened-off when washing activities are executed.
- e) Pressure Relief and Control functions
 - 1) Observe and report for fluctuations, pressure settings and leaks.
 - 2) Observe and report dumping to tank.

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- 3) On-site crews must possess the ability & procedure to replace defective components, and perform setting from first-commissioning principles.
- f) Instrumentation
 - 1) Provides an essential link for the evaluation of deficiencies on pressure setting & control.
 - 2) Mechanical crews perform hand-cleaning and monitoring, with reporting to the supervisor of any detected deficiencies.
- g) Pumps and drive-motors
 - 1) Performance of the pump must be judged by a change in system pressure – after also evaluating other affecting factors – as well as with pump switch-over responses.
 - 2) Pump switch-overs – for alternative exercising of standby pumps should be facilitated on a monthly basis.
 - 3) Subjective monitoring of vibrations with a hand-held monitoring device on a monthly basis to detect possible developing deficiencies is recommended.
 - 4) Observe leaks and cleanliness and report any anomalies identified during the visual inspection.
 - 5) Replacement of pumps and drive-motors would be dictated from the results indicated by the inspections and vibration data, following the dedicated and prescribed procedure on various pump-types (as per station design).
- h) Oil Coolers and temperature control
 - 1) Monitoring and reporting of leaks and temperature deficiencies when identified.
 - 2) Cooler internal leaking is normally manifested by a change in oil-tank level – increasing if water-pressure is higher than the oil operating pressure, and visa/versa.
- i) Flexible piping
 - 1) Inspection and reporting of leaks and deficiencies, and performing cleaning as/when required.
- j) Oil tank
 - 1) Tank level monitoring and top-up when required. Investigation should be done on reasons for notable oil level-changes during daily visual inspections.
 - 2) The use of a control register is recommended in order to secure the use of the correct oil type for the system in question.
 - 3) Inspect the condition of the tank vent-filter and facilitate filter replacement on at least annual basis – dependant on plant conditions and temperature cycling frequency.
 - 4) Facilitate sampling of oil and initiate remedial action based on the analysis outcome (as required).
 - i. Oil sampling and analysis should be performed on minimum 3-monthly basis.
 - ii. Oil should ideally be sampled from a bearing-return location or from the tank – sampling after filtration only demonstrates the ability of the filter.
 - 5) Perform bypass filtration if/when the oil analysis report indicates contamination by water or particulate matter. The source of ingress must be investigated if/when detected.
- k) General maintenance & reporting
 - 1) On-line cleaning is performed by hand & brush methods – this requires the deployment of skilled personnel to prevent incorrect practice with resultant risk of damage or tripping the plant.
 - 2) Monitoring, fault identification and repair skills are required for site-crews deployed for maintenance work on these fan lubrication systems.
 - 3) Clear capability on the setting-up of the lubrication & hydraulic system pressure and flow control valves is required, in line with details covered in the section for “Commissioning” below.
 - 4) The servicing and set-up of most components is done as part of the Outage SOW and in conjunction with Rotor swop activities.

3.7.3 Site Servicing during Outages

- a) The individual components on typical hydraulic/lube systems can experience several modes of failure, and components are to be comprehensively assessed and replaced/repared on minimum 3 yearly intervals.
- b) In-line filters are serviced by routine crews in accordance with dP-alarm reporting, and tank vent-filters are replaced by routine crews on predetermined intervals.
- c) Flow sight glass and flow-switch
 - 1) Stripping, cleaning and re-sealing when deficiencies are reported.
 - 2) Flow-switches are screened from water-damage when cleaning is executed.
- d) Flow control
 - 1) The KS/MD systems are fitted with flow-measuring instruments for ensuring correct oil-supply to Fan and Motor bearings, thus requiring clear and controlled set-up procedures.
 - 2) The MJ ID systems are fitted with flow-measuring instruments requiring servicing & cleaning on 6-yearly intervals.
- e) Pressure Relief and Control functions
 - 1) The cartridge-type PRV & PCV's generally operate maintenance-free, and a strip, inspect and clean task should be scheduled on 12-yearly intervals.
 - 2) For the MJ ID Fans, the following apply:
 - i. PRV's are pre-tested and set – requiring replacement of calibrated valves on 6 yearly intervals – proposed during Rotor swops.
 - ii. Large-volume PCV's are sensitive to wear and calibration drift and require stripping, cleaning and replacement inspections on 3-yearly intervals. This task must be executed by an adequately experienced person.
 - 3) Outage crews must possess the ability and use the correct/approved procedures to replace defective components, and perform setting from first-commissioning principles.
- f) Instrumentation
 - 1) Outage instrumentation maintenance is performed by the C&I department, requiring clear co-ordination on execution-timing to facilitate Fan maintenance activities and bypass-flushing.
 - 2) Mechanical crews performing cleaning are responsible for instrument protection when performing tasks in order to prevent damage to the instrumentation.
- g) Pumps and drive-motors
 - 1) Gear-pumps are subject to a run-to-failure philosophy, but requires coupling and leakage inspections on 6-yearly intervals.
 - 2) The screw-pump on MJ ID Fans requires a strip and inspection service on 6-yearly intervals.
 - i. Serviced and tested Pump sub-assemblies are required for modular swop-out on 6-yearly intervals.
 - ii. A comprehensive procedure is required to facilitate the swop taking care to deal with the following sensitive aspects:
 - Execution sequence with clean working conditions.
 - Sleeve-coupling gap.
 - Turning-direction commissioning.
 - Handling and dispatch of pump sub-assemblies.
- h) Oil Coolers and temperature control
 - 1) Tube & shell-type oil coolers are inspected for contamination (oil-side) and corrosion-damage (water-side) on 6-yearly intervals.
 - 2) Inspection findings should be used to determine the cooler service interval – these are generally scheduled for a complete strip-down inspection, chemical clean and pressure testing on 12-yearly intervals.
 - 3) Cooler replacement requires system flushing when starting the re-commissioning.

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- i) Oil supply & return piping
 - 1) Flexible piping should be inspected for signs of leakage and signs of rubber-cracking, and generally require replacement on 12-yearly intervals, coinciding with scheduled Rotor swops.
 - 2) Flexible piping with high UV-exposure requires more frequent replacement.
 - 3) Rigid piping with flanged connections requires gasket replacement on 6-yearly intervals, while observing the quality control requirements associated with the task.
 - 4) Rigid piping with fitted throttle-valves, require cleaning of the needle-valve by purging, especially during each flushing event, with recording and control of the normal set-position.
 - 5) Opened piping requires system flushing as part of the re-commissioning process.
- j) Oil tank
 - 1) Tank internal cleaning is required on 3-yearly intervals to remove settled debris and sludge, and pending findings of good cleanliness, the interval could be extended to 6-yearly intervals.
 - a. It should however be observed that tank-internal rusting is associated with progressing years in operation.
 - 2) Systems fitted with pump suction strainers require inspection and cleaning on 3-yearly intervals.
 - 3) Oil drainage for tank -internal inspections is facilitated through the use of a bypass filtration system – refer to the applicable requirements noted under the section “general execution standards” below.
 - 4) Tank-internals inspections require a detailed check-list based assessment to assess the tank for cleanliness; signs of internal corrosion, checking internal piping condition, correct piping/pump termination, suction strainer cleanliness, etc. Cleaning should be done with lint-free materials, and door seal condition should be evaluated.
 - 5) Oil is re-used, pending the tribology report analysis findings and recommendation.
 - 6) Care should be taken to use a formal control register to secure the use of the correct oil type in cases of top-up or replacement of oil.
 - 7) Opened piping requires system flushing as part of the re-commissioning process.

3.7.4 Commissioning

- a) Intrusive work on the piping and tank requires the maintenance task of bypass-flushing, especially as noted in the applicable section for “Rotor swop” above.
- b) The execution of flushing with accelerated flow, and cleaning of throttling needle valve, will require that the flow-volume set-up of each bearings oil-consumption requirements are undertaken from first principles and according to the required flow specifications as set by the OEM.
 - 1) The MJ FD Fans are not fitted with in-line flow-devices and would require the temporary fitting of such a flow control device to assist with set-up (recommended), or the use of a volume-flow bucket-test should be used as an alternative.
- a) The Outage maintenance crews deployed must possess the skill and capability for setting-up of the lubrication & Hydraulic system pressure and flow control configurations for the applicable station.
- b) Maintenance teams are required to submit a detailed schedule with check sheets in order to report on actual pressure/flow set-points and operating temperatures observed during inspections and/or after maintenance work was performed.
- c) Post Outage test-runs also require the on-line monitoring, verification and recording of settings in accordance with the site-specific specifications.

3.8 MAIN DRIVE MOTOR AND CONNECTING SHAFT

3.8.1 Main drive Motor

- a) While the Main drive Motor is perceived to be the responsibility of the Electrical Department, the Fan Mechanical contractor has specific involvement in assisting with the management of motor health, specifically in the following areas of importance:
 - 1) Motor internal inspection for possible oil and water ingress on a 3-yearly basis.

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- 2) Motor replacement (swop), as required by the Electrical Department.
- 3) Motor piping connections for oil and water supply.
- 4) Motor coupling health.
- 5) Motor to fan alignment.
- 6) Motor bearing health as detailed under the section for bearings below.

b) Motor internal Inspections

- 1) Internal health inspections require the lifting of the cooler on minimum 3-yearly intervals.
- 2) Precautions are required to maintain “clean working conditions” when Coolers are lifted from the motor:
 - i. Canvass protection must be used to prevent possible undrained water spillage.
 - ii. Tool and debris control when working in overhead positions on top of the open motor.
- 3) Care should be taken to secure and maintain the cooler mounting pads.
- 4) Internal inspections from a mechanical point of view focus on specific equipment and observations such as:
 - i. Oil ingress and bearing vacuum seal health.
 - ii. Cooler leakage and general cleanliness condition.
 - iii. Motor internal fan condition.
 - iv. Re-sealing when cooler is re-positioned.

c) Motor replacement (swop)

With a service life of up to 18 years and potential earlier failures, motor swops are facilitated by the Mechanical contractor with a responsibility for the following aspects:

- 1) Coupling dis/re-connection and removal/replacement.
- 2) Coupling guard maintenance & fitting.
- 3) Mounting plinth & pad cleaning and preservation.
- 4) Alignment & shims and tightening of mounting bolts, taking care to not introduce “soft foot” conditions due to incorrect tightening or shimming methods.
- 5) Motor direction checking and verification of the magnetic centre indicator.
- 6) Motor re-alignment with details noted in the applicable section below.

d) Motor auxiliary connections

- 1) Inspection, maintenance and replacement of bearing oil supply & return piping connections – in most cases this would be flexible hoses. Replacement intervals vary from 12-yearly intervals, depending on UV-exposure.
- 2) Cooling water piping connections to the Cooler and/or bearings, including checks on the flow-restricting orifices in the return piping that is used to manage motor operating temperatures and CW consumption.
- 3) General observation and reporting on the external condition of Electrical & Instrumentation connections.
- 4) Management of bearing temperature thermocouple installation interfaces.

e) Motor alignment

- 1) The alignment of the Motor is interlinked with the alignment of the fan – refer to the details of Alignment, noted under the applicable section for “Rotor swop” above.
 - i. For FD Fans, the Rotor position and shaft-elevation is first confirmed, while considering the limited available adjustment-movement of the motor mounting flange and fixing-locations.
 - ii. For ID Fans, the fan Rotor position is fixed, thereby requiring independent adjustment of the Motor, except if major fan bottom-casing repairs or movements were executed. The Fan casing position must be determined with consideration and referencing of the limited available adjustment-movement of the motor mounting flange and fixing-locations.
- 2) Magnetic centre verification is principle vital first step in the alignment process.
- 3) The provision & cleaning of rust-free alignment packers and shims is mandatory.

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- 4) The Motor Axial position must be verified with consideration of both Motor- & Fan-side coupling gaps in accordance to OEM specifications and measurements must be recorded as part of the QCP.
- 5) For ID Fans, the following aspects must be considered
 - i. The vertical alignment and shimming must be done with incorporation of the required motor-elevation measures to counter the Fan-casing thermal growth and in accordance to the prescribed OEM specifications.
 - ii. If an out-of-schedule Motor-alignment is required, the removal of the Fan-side “inlet cone” will be required in order to perform coupling-alignment, thus requiring the incorporation of this activity into the program.
- 6) Horizontal alignment must be executed considering both Motor & Fan-side coupling halves.

f) Motor bearings

- 1) The requirements for inspection, condition monitoring and maintenance of Fan bearings are also applicable to Motor bearings. It should be clear from the details below, that bearings and seals require a well-defined maintenance plan.
- 2) The monitoring of operational bearing temperatures is not the only measure of bearing health – securing reliable operation for a 6-yearly period requires the execution of maintenance & condition-inspections.
- 3) Depending on the bearing lubrication system lay-out, the servicing intervals, based on operational experience, may be different:
 - i. Oil sump with oil ring design.
 - Oil change with sump cleaning is mandatory on 3-yearly intervals – adverse external conditions and internal wear may result in severe contamination of oil and should prompt for reporting and shorter replacement intervals. Discolouration of oil (visual) or oil sample analysis would be typical indicators of oil quality issues.
 - ii. Circulating oil design.
 - This configuration allows for continuous “replacement” of oil through the Fan bearing lubrication system and justifies postponement of maintenance interventions to 6-yearly intervals.
- 4) Additional features related to the inspection & maintenance of Motor bearings are as follows:
 - i. Leakage gutter: severe leakage from the gutter located between the bearing housing and the motor end-shield should result in an investigation and review of the internal Labyrinth seals.
 - ii. Inner Labyrinth seals: The maintenance requirements for these seals require the opening of the bearing housing cap.
 - iii. Vacuum seal: The seal is located on the motor end-shield and inspection for verification of health is important to prevent oil ingress into the motor internals.
 - iv. Bearing sleeve insulation: Bearing sleeves are insulated and 3-yearly electrical insulation-health checks should be conducted and may require renewal/repair of the insulation. Care should be taken not to impact insulation-health when servicing/replacing bearings.
 - v. The DE-bearing earth-connection: The sleeve (internal) is earthed to the housing (external), requiring interface management when opening/closing these bearings.
 - vi. The servicing of bearings: The spherical design of sleeves facilitates self-alignment, ONLY if both DE & NDE bearing-sides of the shaft are open and properly seated. No boxing-up of any one bearing is allowed while the other is still in the raised/jacked condition.
- 5) Service of labyrinth seals
 - i. Labyrinth seals are generally of the ‘floating’ type, and depending on the material-selection, are subject to deformation, wear and shrinkage. Inspections and possible replacement justifies 3-yearly inspection intervals.
 - ii. Labyrinth seals are wearing and duct-blocking maintenance items.

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- iii. The fitting of seals require special care on correct sizing, orientation and fitting of the anti-rotation location pin. All seal verifications are to be recorded.
- iv. Motor Labyrinth seals should be carefully sealed around the circumferential rim with a non-setting sealant to limit bypass leakage of oil.
- v. The recording of set-up clearance on motor bearing IP55 seals is required as part of the Quality control measures.

3.8.2 Couplings and Connecting (Cardan) shaft

- a) Due to the different Rotor configurations, different types of shaft connecting configurations are used between FD Fans and ID Fans, and described as follows:
 - 1) The FD Fan overhang Rotor has a long shaft with the Impeller positioned on the outside of the NDE bearing. The connection between Motor and Fan shaft is thus a short removable shaft (Cardan shaft), containing two coupling sets which are located on the outside of casing or partly inside the accessible bearing tunnel.
 - 2) The ID Fan two-stage Rotor has a short shaft between impellers, thus requiring a long connecting shaft extending through the inlet box with coupling mounting spigot flanges on either side of the connecting shaft. The Motor-side coupling is external to the casing and only removable if either the Motor or the connecting shaft is moved away, while the Fan-side coupling can be separated and removed with the Rotor.
- b) Cardan shaft and Couplings
 - 1) Coupling cleaning & visual inspection for signs of deflection & cracking is required at 3-yearly intervals.
 - 2) For FD Fans, the couplings are located on the two ends of a relatively short and removable "Cardan shaft", which is flange-connected to the coupling hub/adaptor on the motor output shaft and similarly on the Fan-shaft.
 - i. The Cardan shaft with Couplings can be removed and must be subject to a mandatory strip-down and NDT inspection on 12 to 16-yearly intervals, ideally coordinated with the Rotor swops – refer to the servicing details for the coupling in the applicable Rotor-swap section above.
 - 3) For ID Fans, the coupling flex-packs form an integral part of the Motor-side coupling-hub and similarly on the Fan-side is integral to the connecting adaptor.
 - i. The Motor-side coupling flex-pack NDT is mandatory if/when motors are removed – and if the motor serves its full potential 18-year service period, a 12-year service intervention for the flex-pack must be arranged which may require the re-location/moving of the motor to create sufficient maintenance space.
 - ii. The Fan-side coupling NDT and servicing is coordinated with Rotor swops – refer to the servicing details for the Fan-side coupling in the applicable Rotor-swap section above.
 - 4) Connecting bolts must be replaced with coupling replacements on 12-yearly intervals and the bolt-torque activities must be controlled to OEM specifications with QCP check-sheet recording.
- c) For Coupling and Shaft Alignment – refer to the alignment details for the coupling under the applicable section for "Rotor- swap" above.
- d) Brake assembly – The assembly is located adjacent to the motor-side coupling, with the brake-disc attached to the coupling, and requires a thorough inspection and clean-up on 3-yearly intervals under normal operating/environmental conditions. In adverse conditions this activity must be performed more frequently to avoid ash deposit and ingress between the disc and brake-pads.
 - 1. Brake-pad wear is associated with the number of fan stops and environmental conditions, which requires the measurement and trend-reporting of pad-thickness on 18-monthly intervals.
 - 2. Disc damage must be prevented through frequent cleaning, and a minimum thickness of 4 mm should prompt for the replacement of brake-pads. Disc-damage will accelerate pad-wear, and disc repairs could be coordinated with Rotor swap scopes of work.

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3. The braking-system operation and functional testing is incorporated into the scheduled Lube-system testing
 4. Rotational speed instrument function and calibration settings must be checked with Outage shutdown and Fan RTS test-runs.
- e) Coupling guard – Inspection on sturdiness is incorporated with weekly routine walk-downs. It is also covered in the initial outage SOW inspection and re-installation is verified with final inspection before RTS test-runs.

3.9 SEALING AIR FANS (ID FANS ONLY)

3.9.1 Seal Air Fan Filter

- a) The monitoring and replacement of the fan suction filter is of prime importance to the health of the ID Fan. Debris entering this seal-air system will find direct access into the Bearing- & Hydraulic compartments.
- b) Filter cleaning and replacement frequencies are established and adapted from the general environmental condition, i.e. more adverse conditions must prompt the adaption of a typical monthly filter inspection/replacement routine to a weekly task.
- c) Caution must be applied when replacing & inspecting the fan suction arrangement to ensure that no ingress of environmental debris (ash) is possible.
- d) If it is observed that the filter elements are exposed to wet conditions due to rain, this should be reported and actions implemented to avert.
- e) Adverse operating conditions requiring excessively frequent cleaning should prompt for review the system for multiple tiers of cleaning elements.

3.9.2 Seal Air Fan Ducting

- a) Ducting consisting of support/fixtures, duct clamps, and hangers must be inspected and their condition or any observed defects reported on a 3-monthly basis with plant walk-downs.
- b) Specifically observe sources of leakage and corrosion or physical damage, and report if detected.

3.9.3 Seal Air Fan, casing and support

- a) Operational switching between Online and Standby fans must be facilitated on maximum 3-monthly intervals.
- b) The Fan Impeller & Casing, if exposed to severely contaminated operating conditions, must be subject to 3-yearly NDT crack and wear inspections.
 - 1) Less severe operating conditions requires an assessment on 6-yearly intervals.
- c) Corrosion of the fan-external structure and supports must be inspected and reported on 3-monthly intervals
- d) MJ Fans are shaft-mounted, requiring a taper-coupling inspection on 6 yearly intervals.
- e) KS/MD Fans mounting - to be assessed for any signs of wear, deterioration or damage on 3-yearly intervals.

3.9.4 Seal Air Fan System Commissioning (MD)

- a) The set-up, testing, and continued correct functioning of this system is of prime importance to the health of the fan, for the following reasons:
 - 1) To prevent the loss of oil from the bearings due to high vacuum on the bearing seal-cavity.
 - 2) To prevent ash ingress into the bearing seal-cavity.
 - 3) To prevent ash-contamination of the Bearing- & Hydraulic compartments.
- b) A comprehensive RTS commissioning procedure is required to ensure that the pressure set-points, and damper positions have been achieved, and verifications are required for both low (balance test-run) and high (<70% MCR) load conditions.

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- c) The setting of compartment pressures is heavily dependent on the health of casing/Rotor labyrinth seals, which is dealt with in the next section.
- d) The Labyrinth Seal (Rotor seal) health can be evaluated as an optional condition-assessment activity. The monitoring of pressure differentials on externally located pressure tapping points is strongly recommended, with correct task execution details contained in the applicable sections for the “Rotor-track casing details” above and the section on “Inspection and Testing” noted below.

3.9.5 Seal Air Fan System Commissioning (MJ)

- a) The focus with the set-up of the Fans is to ensure that the leakage-path is not excessive to prevent the fan from reaching its minimum operating pressure set-point, which would result in engaging the standby fan.
- b) Smooth operation of the selection flap-valve must be verified, in order to prevent loss of pressure.
- c) The setting of compartment pressures is heavily dependent on the health of casing/Rotor labyrinth seals.
- d) The Labyrinth Seal (Rotor seal) health can be evaluated as an optional condition-assessment activity and is strongly recommended.
 - 1) Due to the complexity to verify the correct adjustment of the top-casing mounted seals, it is advised to perform the setting as a once-off activity during a Rotor swop, and then monitor the performance via this mechanism on a 3-yearly basis to establish any drift in the seals leakage performance.
 - 2) Testing execution details are noted in the applicable sections for the “Rotor-track casing details” above and the section on “Inspection and Testing” below.

3.10 ELECTRIC POSITIONER AND CONTROL LINKAGES

The blade-angle positioner otherwise known as the electric actuator is a key item for controlling the fan load. The positioner is used to operate the Hydraulic Servo valve, which in turn channels high pressure hydraulic oil to the hydraulic ram, which executes the force required for changing the position/angle of the fan blades.

3.10.1 Electric actuator

- a) The Electric actuator is a reliable controlling element but requires a number of checks in order to secure a maintenance-free service for minimum 12 years, after which it is recommended to be subject to a thorough service and re-sealing. The following key-elements must be taken into account in defining the service scope of work:
 - 1) Position-feedback limits are sensitive and prone to failure with frequent pulsations.
 - 2) The Braking mechanism is prone to failure with frequent operating pulsations.
 - 3) The applicable Torque-setting is sensitive so as to protect the fan-connections from excessive force-inputs.
 - 4) Sealing and checking correct functioning of the dehumidifier/heater (if applicable) is very important, as this is used to eliminate internal moisture due to atmospheric temperature cycles.
- b) The operation of the Electric actuator is dictated by the need to control the furnace pressure, and incorrect optimisation of the control system may require too frequent operating cycles – actuator operating cycles more frequent than 2x per minute must be investigated and corrected.
- c) Incorrect ratio's, i.e. a change of leverage or actuator characteristics may result in over-pitching, thus leading to a pattern of “hunting” – and as a result the operating cycles will increase.
- d) Based on the above observations it is important to ensure that on removal and re-installation of electric actuators that the lever-position radius from actuation shaft remains unchanged. Original position/radius should be documented and post installation should be checked against the originally documented value.

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- e) On completion of the linkages set-up, the Electric actuator mechanical limits must be set in order to prevent excessive travel in the case of a loss of the electronic stops, which will result in excessive force being applied on the Fan mechanism. Settings must be executed by experienced personnel in accordance to the electric actuator OEM instructions.

3.10.2 Blade pitch position indication

- a) All Axial flow Fans have a blade position indicator external to the Fan, and is required to be set in accordance to the internal position & linkages – the positioner is the prime reference used for C&I stroking.
- b) The indicator references blade angle position & range in accordance to OEM design and/or an indication of control angle from 0% to 100%.
- c) In addition to the external set-position indicator, the KS/MD ID Fans have a physical blade position feedback position indicator – demonstrating a possible error if there is a variation between set-position and feedback position – this is a variation that must be reported and investigated as potential failure.

3.10.3 Lay shaft and internal connection

- a) The Lay-shaft forms the link between the external indicator & actuation point and the Fan internal linkages and contains several components which are subject to thorough inspection on a 3-yearly basis and servicing on a 6-yearly basis:
- 1) Support bearings and seals.
 - 2) Greasing points that require 3-yearly servicing.
 - 3) Hub key and grub-screw connection secureness.
 - 4) FD Fans have a servo-valve protection mechanism with flexible deflection springs requiring monitoring, inspection and cleaning.
 - 5) The KS/MD FD Fans have an excessive torque indicator requiring set-up verification.
 - 6) The MJ FD Fans are regularly presented with vibrating wear patterns on linkages and as such must be managed through correct replacement & set-up.
 - 7) It should be clear from the above that comprehensive spares planning are required for shutdown maintenance.
- b) Connecting push-rods are set-up to a comprehensive OEM procedure – and in most cases are traced back from the physical blade or servo-motor positions.
- c) The KS/MD ID Fans have actuating pushrod and feedback shaft couplings that must be reviewed for tightness and health on a 3-yearly basis.
- d) ID Fans have internal mechanical stops/limits requiring set-up verification before final stroking.
- e) The MJ FD Fan has a push-rod mid-support requiring the use of a comprehensive OEM procedure for setting-up.
- 1) It is cautioned that for all FD Fans – the incorrect set-up of the linkages will result in excessive wear of mating components, and final setting is QCP Witnessed for verification.
- f) Any signs of excessive wear on linkages or looseness must be reported and corrected.

3.10.4 Positioner stroking and limits

- a) The mandatory “Stroking” of the blade positioner system is required to achieve balanced flow between the two sides of the Draught plant, and to prevent damage to internal hydraulic components.
- b) It is important to note that the Rotor internals allows a predetermined range of blade-position extremes, and by forcing the movement beyond the internal extremes can damage the Rotor internal components

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- c) Stroking from first principles involves mechanical / hydraulic stroking before final electrical actuator stroking and is performed on the following intervals:
 - 1) Verification of set-up - minimum 3 yearly.
 - 2) Stroking from first principles should be done with any change/replacement of blades, linkages or electric actuator.
 - 3) Should be done from first principles with report of flow-imbalance between the two Draught Fans and exhaustion of instrument accuracy verification.
 - 4) Executed comprehensively and from first principles with any Rotor swops.
- d) The Stroking activity requires a mechanical set-up and a QCP witnessed set-up verification, followed by electrical stroking.
- e) The position extremes for all Axial flow fans originates from the blade position, which is normally traced from indications on the impeller, unique to each Fan or application.
- f) FD Fans mechanical set-up process
 - 1) Generally FD Fans do not have internal indicators or stops, and the Fan blade position is obtained with the use of a special tool, used to reference blade position and the set-up of linkages.
 - 2) The internal linkages are set-up in accordance with a comprehensive OEM procedure with care to be taken on correct set-up considering lengths and support heights.
 - 3) The external indicator and stops are set in accordance to the internal feedback position.
- g) ID Fans mechanical set-up process
 - 1) Generally ID Fans have internal stops to be set-up by mechanical personnel in accordance with the prescribed OEM procedure:
 - i. The MJ ID Fans require a set-up of internal mechanical stops with a 1 mm non-contact gap-margin.
 - ii. The KS/MD ID Fans have internal servo-motor mechanical stops, which are factory pre-set to prevent over-pitching of the blades, but requires verification with each new installation in order to secure and confirm a 1 mm non-contact gap-margin.
 - 2) External indicator and actuator stops are set-up in accordance to internal positions.
 - 3) The KS/MD fans require additional stroking/set-up of the electronic position feedback (through the Kinex transmitter).
- h) Due to the dual rotational activation on linkages – resulting in non-linearity of pushrod movement – setting up from correct first principles is required to ensure that the mid-position of the actuating levers is vertical, so as to allow symmetric linkages travel to minimum and maximum positions.
- i) The electric actuator mechanical stops are set-up in accordance to the external position indicator for all Fans.
- j) The electric actuator C&I stops and feedback is set-up in accordance with external mechanical stops and/or external position indicator.

3.11 FAN PROTECTION SYSTEMS

- a) Lubrication system start-up temperature – this measurement is accompanied with alarm-reporting and compulsory engagement of oil heaters to increase temperature in order to provide the start-release.
- b) Lubrication tank oil level – fitted with control system alarm-reporting on low level, and pump-protection on minimum level set-point.
- c) Lubrication-oil pressure settings and condition – alarm-reporting on oil flow- and pressure condition with switching to standby lubrication-oil pump, and trip-action on persistent low oil-pressure.
- d) Hydraulic system settings and condition – alarm-reporting on oil-pressure with switching to standby hydraulic-oil pump, and blade-pitch freeze on persistent low hydraulic oil pressure.
- e) Bearing temperature – alarm-reporting on high journal & thrust temperature with trip function on defined maximum set-point – generally this point is not more than 85 °C.

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When downloaded from the EDMS, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorised version on the system.

- f) Bearing or Casing Vibration – alarm-reporting on high vibration with trip function on defined set-point – generally this set-point is not more than 7.5 mm/s RMS overall.
- g) Fan Stall indication
 - 1) CAUTION: The Stalling of a Fan can cause catastrophic failure with severe damage to the Fan.
 - 2) An indication of Stall conditions is integrated with the fan performance curve and flow/pressure measurements – control system alarm-reporting with controlled prevention of blade pitch increase.
 - 3) Absolute Stall-measured value is obtained through installed probes - with high-value alarm-reporting and ultimate trip-protection.
 - i. For FD Fans – direct pressure-differential measurement of stall-condition before the blade.
 - ii. For ID Fans – pressure before blades is compared to inlet duct absolute pressure.
- h) Hub cooling/sealing fans operating pressure – alarm-reporting of Hydraulic compartment low pressure with switching to standby fan, as well as trip-protection when no sealing/cooling fan is available.
- i) Hydraulic compartment temperature – alarm-reporting when high temperature control set point is reached.
- j) ID Fan intake maximum temperature – trip protection set-point linked to the Fabric Filter Plant.

3.12 FAN INSTRUMENTATION

Reference is made to the requirements stipulated in the Draught Plant “Minimum Protection Requirements” applicable to Fans.

- a) The purpose with listing the critical instrumentation is to:
 - 1) Compile a Draught Plant RTS (Return to Service) procedure with critical instrument verifications for reliability.
 - 2) Guide the Operating and Maintenance Engineers regarding the purpose and application of the provided instrumentation.
 - 3) Provide input on special requirements for Mechanical and C&I maintenance interaction.
- b) Note: Fan Maintenance personnel are urged to take the required actions to test and verify the accurate functioning of instrumentation in order to facilitate the appropriate condition and performance assessment of the machine.
- c) Specific details related to maintenance of instrumentation, requiring the intervention by C&I and Mechanical personnel is noted under the applicable “Fan Casing sections” above, and also in the detailed section on “Fan instrumentation” below.

3.12.1 Process and Protection Instrumentation

- a) Flow & Pressure
 - 1) FD Fans – Piezo rings with multiple measuring points on 3 tiers/positions on Fan casings.
 - 2) ID Fans – Dual selectable measuring points for 3 measuring tiers/positions on Fan casings.
 - 3) Absolute pressure – single inlet-casing measuring point.
 - 4) The above instruments, as well as the Fan inlet temperature, provide input to the Fan performance & stall curve.
- b) Process (Fan) Temperature
 - 1) Intake ducting, used to calculate flow/density.
 - 2) Hydraulic compartment temperature – ID Fans.
- c) Rotor Vibration probes
 - 1) KS/MD FD Fans – Bearing housing mounted, accessible only during shutdowns.
 - 2) MJ FD Fans – Bearing housing mounted, accessible on-line.

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- 3) KS/MD ID Fans – Casing mounted, accessible on-line.
- 4) MJ ID Fans – Bearing housing mount, accessible only with Rotor swops.

d) Bearing temperatures

- 1) KS/MD FD Fans – Bearing housing mounted, accessible only during shutdowns.
- 2) MJ FD Fans – Bearing housing mounted, accessible on-line.
- 3) KS/MD ID Fans – Bearing housing mounted, accessible during shutdowns and Rotor swops.
- 4) MJ ID Fans – Bearing housing mount, accessible only with Rotor swops.

e) Blade pitch position indication

- 1) Local blade angle indicator
- 2) Electronic position feedback – mounted in the electric positioner controlling the fan.

f) Fan Stall Protection Device

- 1) FD & ID Fans – Internally mounted before blades, accessible only during shutdowns.
- 2) Flow & Pressure measurements covered above.

g) Lubrication & Hydraulic system instruments

- 1) Several instruments are commonly provided for process & protection – accessible only during shutdowns.
 - i. Oil tank Temperature.
 - ii. Oil tank level measurement.
 - iii. Oil supply-pressure measurement for lubrication & hydraulic systems.
 - iv. Flow measuring devices.
 - v. Local Flow observation devices.

h) Maintenance – Mechanical and C&I interface

- 1) The importance of thorough pre-checking & commissioning of Instrumentation where no in-service access is available, is vital.
- 2) Pressure tapping points FD Fans
 - i. Piezo-rings require specific instructions for cleaning – due to the multiple connection points linked to a single ring, proper off-line purging procedures requires internal confirmation of flow, and/or sequential plugging of ports to purge each individual connecting line.
 - ii. Specific verification of health is required following oil leaks and Rotor swops.
- 3) Pressure tapping points ID Fans
 - i. Casing tapping points require special instructions and inclusion into the task list for cleaning – due to their exposure to flue gasses and acid dew.
 - ii. Tapping points require mechanical rodding to clean – blockage cannot be cleared with the standard C&I purging procedure used for impulse pipes.
 - iii. On-line cleaning is facilitated through selectable valve positions, and service frequencies are adapted with seasonal temperature variations – these vary between 3-monthly to 6-monthly intervals.
 - iv. Communication with the Control-room is essential for safe switching & execution when performing this task.
- 4) Stall protection device on the FD Fans
 - i. De-plugging of the device ports require specific verification of condition, especially with oil leaks and following Rotor swops.
 - ii. Test & adjustment of the Stall device require the referencing of a comprehensive procedure, which includes response verification & reporting during post-outage test-run start-ups.
- 5) Stall protection device on the ID Fans

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- i. The device requires a verification of acceptable condition and performance during shut-downs, due to exposure to erosion-wear and plugging.
 - ii. The availability of OEM provided replacement spares should be catered for in the Bill of Materials, as it incorporates an erosion-protection coating
 - iii. Installation instructions against the prescribed OEM drawing must be applied.
 - iv. Condensate vessels require 6-monthly draining & cleaning servicing (KS/MD).
- 6) Vibration probes
- i. Care should be taken not to damage these probes during Rotor swops with Rotor-installation, bearing and blade maintenance activities – instrument removal & re-fitting to be facilitated.
 - ii. Care should be taken with probe re-installation in order to ensure correct attachment & secureness.
 - iii. Specific checks should be made to ensure that probes comply to the correct temperature rating, and for ID Fans with casing-mounted probes, to ensure the thermal protection is correctly fitted.
 - iv. Thorough testing and commissioning of the probes are required for internally mounted probes before closing the fan compartment/casing.
- 7) Bearing temperature measurement
- i. Care should be taken against damage of these devices during Rotor swops with rotor re-installation, bearing and blade maintenance activities – in these instances instrument removal & re-fitting to be facilitated under supervision of the site C&I section.
 - ii. Care should be taken with probe-installation on Thrust bearings in order to control the depth of insertion, and to avoid mechanical thrusting into the thrust pads which will result in elevated temperature measurement. For ID Fans, the required probe insertion depth is reported/noted on the Rotor delivery notification documentation.
 - iii. Thorough testing and commissioning is required for internally mounted probes before closing the fan compartment/casing.
- 8) Stroke-checking of blade position & feedback
- i. The erection of scaffolding for Rotor and/or blade swop execution requires the verification of free movement of the external linkages, which is required for operation during the maintenance activity.
 - ii. The setting of the electric actuator must be preceded by Hydraulic and Mechanical stop position checking, and requires verification before facilitating C&I stroking.
 - iii. Adjustment of the external blade-position indicator requires verification for correctness between Mechanical and C&I personnel.
 - iv. The KS/MD ID Fans are equipped with a physical feedback rod and electronic indicator, requiring protection from damage during Rotor/blade swops.
 - v. Specific action is required to ensure correct installation of the drive-rod, and verification of synchronisation with the electric positioner feedback signals.
- 9) Lubrication & Hydraulic system maintenance & testing
- i. Mechanical personnel are cautioned on the requirement for oil temperature start-release interlocks, requiring management during RTS situations.
 - ii. The execution of C&I maintenance must be co-ordinated with Rotor swop activities, which requires the availability of the Lube/Hydraulic systems during the swop-out activity.
 - iii. Mechanical personnel must exercise due care around field instrumentation during maintenance and repair activities, and must inspect and report any observed damage to instruments.
 - iv. The use of an external power source is recommended for operation of the Lube/Hydraulic systems, requiring a Control & Protection system and the commissioning must be coordinated with Electrical and C&I personnel for the issuing of a Certificate of Compliance.

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- v. The replacement and/or reconnection of motors & power supply cabling require the physical verification of coupling settings and confirming the drive-motor direction of rotation.
- vi. Functional testing of protection functions require a witnessed coordination between Mechanical and C&I personnel and must be clearly indicated on the QCP:
 - Care should be taken to prevent simultaneous two-pump operation and immediate action should be taken in the case where both pumps are started simultaneously.
 - Testing of pump switch-over function should be undertaken.

3.12.2 Condition monitoring and trending instrumentation

Reference is made to the details contained in the applicable section for “Rotor health assessment” above.

- a) Fan flow & pressure measurement
 - 1) These measurements are inter-related and are used to assess demand requirements and possible leakage indications.
 - 2) Flow accuracy is less dependent.
 - 3) Pressure accuracy is more dependent.
 - 4) Co-ordination with blade pitch position assists with identification of measuring deficiencies.
 - 5) The Performance curve plot provides cautionary indications related to stall-risk.
 - 6) Serviceability of instruments and reporting/repair of deficiencies identified is important.
- b) Motor Current (Amps)
 - 1) The reading is dependent on flow & pressure parameters and is an indication of system resistance changes.
 - 2) Accurate and reliable comparison for load-level and balancing.
 - 3) Motor thermal overload warning/alarm requires a rapid response for de-loading.
 - 4) Actual Stall conditions result in rapid fluctuations in motor current.
- c) Bearing vibration
 - 1) On-line trending provides general overall RMS vibration level indication.
 - 2) Additional support with external device measurement/monitoring on a monthly basis provides more detailed frequency and time waveform analysis data to assist with root-cause determination of high vibrations.
- d) Bearing temperatures
 - 1) Observe start-up spikes in temperature are an immediate indicator of bearing fault conditions.
 - 2) A gradual increase in temperature generally provides indication of a healthy bearing condition, though continued increase in temperature above the normal expected operating temperature would be indicative of an abnormal shaft contact area or cooling water deficiencies.
 - 3) Rapid increase or fluctuations in bearing temperatures is generally indicative of instrument problems or failure that can result in spurious trips.
- e) Blade pitch position feedback
 - 1) If a lag with up/down pitching is observed, this would be indicative of some looseness on the feedback positioner.
- f) Lubrication system pressure, oil-flow, temperature and level measurements
 - 1) These measurements provide a general indication of health of the Lubrication system and are supported with upper and lower alarm/warnings.
 - 2) Oil sampling analysis would provide justification for oil replacement decisions.

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4. INSPECTION AND TESTING

4.1 ONLINE INSPECTION

4.1.1 Plant-walk verification

The list of Maintenance plant inspections to be monitored with daily/weekly plant walks are important reporting activities to flag potential failure, detect early signs of failure and the monitoring of changing process conditions and are summarised below:

Recording and reporting of observations is made to the Employer's Maintenance supervisor, and load-affecting deficiencies are elevated directly to the plant System Engineer.

- a) Flow & Pressure snapshot against unit load.
 - 1) Observe tapping points selection and changes.
 - 2) System performance and balance.
- b) Motor Amps snapshot against unit load.
 - 1) Detect anomalies on system resistance or demand.
 - 2) Detect draught flow un-balancing.
 - 3) Detect incorrect instrumentation readings.
- c) Bearing temperatures.
 - 1) Detect weekly trend/rise.
 - 2) Observe cooling water deficiencies.
 - 3) Observe and record oil leaks and ash contamination.
- d) Vibration monitoring snapshot.
 - 1) Detect weekly trend/rise as tell-tale for looseness or erosion wear.
 - 2) Observe bearing base movement.
- e) Lubrication system health.
 - 1) Report instrument deficiencies, leakages and risks of water contamination.
 - 2) Record system settings & performance.
 - i. Pressure set-point and fluctuations.
 - ii. Flow set-point and fluctuations.
 - iii. Temperature level for tank and supply oil to bearing.
 - 3) Tank oil level.
 - 4) Oil tank vent filter condition.
 - 5) Visual oil condition.
 - 6) Cooling water flow – temperature.
 - 7) Oil return sight-glasses.
 - 8) Servo motor return leakage (ID Fans).
 - 9) Piping flange/connection leaks.
 - 10) Duplex filter dP and swop control – position of lever.
 - 11) Pump-in-service and switch-over control.
 - 12) Pump drive system anomalies – Drive system vibrations are not specifically monitored on any system, but subjective observation or handheld device measurement must be available and can be reported on for initial detection of developing anomalies.
- f) ID Fan seal air fan.
 - 1) Filter condition.
 - 2) System pressure.
 - 3) Ducting health.
- g) Casing & Insulation.
 - 1) Flange leaks or holes.
 - 2) Shaft seal condition.
 - 3) Compensator leaks.
 - 4) Insulation defects – damage, looseness, leaks.

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- 5) Observe noise and subjective feel of casing and pipes shaking.
- h) Fan & Motor bearings.
 - 1) Marking and monitoring of oil sump levels for standing and rotating conditions.
 - 2) Oil level and oil leaks – labyrinth seals, gaskets.
 - 3) Ash contamination.
 - 4) Accessible housing breathers.
- i) Blade pitch operation.
 - 1) Control ‘hunting’ with frequent operating cycles.
 - 2) Position feedback.
- j) General alarming of observed ash emissions.
- k) Note that specific maintenance requirements involving Mechanical personnel have been noted and should be read in conjunction with each applicable Plant section and details above.

4.1.2 Engineering on-line operational assessment and incidents

Some machines are adversely affected when exposed to process or system excursions.

The purpose of elevating the importance for awareness of operational incidents is that it provides knowledge for root-cause analysis and decision-making on changes required to operational, maintenance and design deficiencies.

Engineering plant inspections are aimed at identifying, recording and reporting of plant health-affecting incidents. Typical aspects to be considered are:

- a) Operational assessment factors
 - 1) Fan temperature excursions.
 - 2) Blade wear assessment and effect on performance & loading.
 - 3) System resistance changes affecting Fan performance & loading.
- b) Operational incidents
 - 1) Ash emission excursions and durations.
 - 2) Single draught operation – loading of fans - logging of conditions arising from this mode of operation can result in changing the thermal behaviour of the machine with severe consequences to blade wear.
 - 3) Fan stall incident duration & logging.
- c) Apart from the on-line vibration trending report, an additional vibration analysis trending report with alarming of changing conditions, executed from external casing/bearing monitoring on a monthly basis:
 - 1) Analysis and support to identify cause and action:
 - i. Full spectrum analysis - radial/horizontal, 1x, 2x & multiples.
 - ii. Blade-pass frequencies, defined as number of blades times running speed.
 - iii. Axial vibration trend.
 - 2) Bearing housings vertical vibration profile when a raised base on spectrum is detected.
- d) Lubrication oil tribology reporting:
 - 1) Oil health analysis for evaluation of filter efficiency and depletion of life and oil lubrication parameter deterioration must be executed on a 2 to 3-monthly basis.
 - 2) The correct sampling and detection of metal particles in oil that can be indicative of white metal bearing deterioration.
- e) Seal air System set-up parameters and performance – ID Fans
 - 1) Monitoring precaution for adverse conditions developing into severe problems with bearing room and bearing oil contamination or even a loss of lubrication-system oil if incorrect setting/conditions develop. Important control-factors are as follows:

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- i. Monitoring and verification of system pressures, controlled through damper settings (KS/MD).
 - ii. Correct set-up of shaft-seal gaps, which is recommended for evaluation as detailed in the next paragraph.
- f) Rotor to casing (shaft seals) sealing performance evaluation (ID Fans).
 - 1) Shaft-seal health, assessed on 3-yearly intervals and especially before outages to assess probability for extended measurement, repair or replacement of seals during a Rotor swop activity.
 - 2) Condition monitoring is performed through the measurement of pressure-drop across each seal, by comparing seal upstream and downstream pressures, measured on externally mounted tapping points.
 - i. Note that the shaft-seals are subject to the extreme negative pressures created through the Induced-function of the ID Fans.
 - 3) Mano-meter measurements must be recorded and compared with initial set-up measurements in order to establish leakage-drift.

4.1.3 Contractors documentation for on-line inspections

- a) On-load plant walk-down/inspection documentation should be developed, containing effective reporting processes for trending, and flagging of anomalies or critical failures.
- b) Report format, layout and content is approved for use with the Eskom Engineer, and is subject to practicality changes and learning points.
- c) A comprehensive report is issued on weekly basis with verbal reporting on a daily basis in the case of urgent anomalies.
- d) Records are retained for the duration of the contract and are handed over to Eskom at termination of the contract.

4.2 OUTAGE CONDITION AND SOW INSPECTION DOCUMENTATION

4.2.1 Preventative maintenance SOW

- a) The Employer System Engineer compiles and submits the basic proposed Outage Scope of Work, based on known life-cycles and condition monitoring of individual components, as stipulated in the applicable sections of this document. These items are typically:
 - 1) Fan Rotor swop-life schedule.
 - 2) Known philosophy component with limited wear-life.
 - 3) Blade wear-life trending and monitoring.
 - 4) Bearing temperature profiles.
 - 5) Vibration signatures reporting.
 - 6) Reported plant defects.
 - 7) Previous outage reported omissions or tasks not performed due to time constraints or shortage of spares.
- b) The Scope of Work format must preferably be issued on a templet that supports a back-to-back issuing of the Contract Task Order.
- c) Contractor Engineer reviews the Scope of Work, and proposes written additions to the Scope of Work based on observed defects reported during the operational period as well as omitted Scope of Work from previous outage interventions.
- d) Contractors procedures are subject to its own evaluation against the stipulated criteria in this document, as well as Eskom Engineering scrutiny, and there may be prompts for correction and improvement to such procedures.

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4.2.2 Compulsory Inspection/assessment

- a) The purpose of the inspection is to assess the real condition of the Axial Flow Fans and to confirm the actual Outage Scope of Work, conducted and captured as noted below.
- b) The Contractor must be in possession of detailed procedures and specifications guiding accurate inspection and repairs as stipulated in the descriptive sections in this document.
- c) The inspections are coordinated with compulsory QCP Hold point intervention with the Eskom System Engineer, for urgent completion in order to facilitate the Scope review meeting and continuation of other agreed and scoped outage work.
 - 1) The Contractor's key experienced personnel conducts and reports on inspections.
 - 2) The initial visual walk-through inspection is performed with the involvement of the Employer's Engineer (as a minimum).
 - 3) The Inspection content is tailored and defined for each specific outage type, e.g. all the stipulated measurements cannot be scheduled for a limited-duration shut-down opportunity.
 - 4) Continued detail inspections that form part of the initial SOW inspections, incorporating measured wear of components and the status of adjustable settings is performed and documented by the Contractor.
 - 5) The inspection is guided by a pre-formulated and approved Inspection Check-sheet document, ensuring that all possible visual damage is assessed and reported in walk-through sequence.
- d) Measured Inspection of components condition and reporting
 - 1) CAUTION – All rotating "Control" measurements must be done with rotation in the motor NORMAL direction of rotation.
 - 2) The continued detail inspection of measured details, as stipulated for the individual items contained in this document, is recorded on an individual sheet per component, detailing what is measured, the measured results, reference specifications, and recommended actions.
 - 3) Complex inspection results (such as blade wear and casing ovality), requiring an increase of Outage Scope, is analysed by the Contractor's Engineers and recommended actions are recorded on the data-sheet.
 - 4) The reports are submitted to the Employer's Engineer as a controlled, edited, indexed and complete document for evaluation and planning a review of the Scope of Work – referred to as the Rev. 1 SOW.
 - 5) The outcome of the Rev.1 Scope of Work Review evaluation meeting would be a finalised Scope, requiring minimal to zero further changes, and results in the finalisation of a detailed Contractual Task Order with associated updated program and Quality Control documentation.
- e) The inspection sheets shall cover all the aspects as detailed in each scope/plant section of this Specification, and as applicable to each individual Station/Fan – it is thus not a 'generic' document.

f) Off-line Inspection list

The purpose of an action-list is a prompt to ensure that no component or aspect of the installation is overlooked, and facilitates presentation in a concise & logical sequential layout to enable adjustments to the summary of Scope-of-work, and covers the following (but not limited to) aspects.

- 1) Rotor and Casing condition:
 - i. Alignment and clearances relative to casing.
 - ii. Sealing gaps.
 - iii. Ash contamination.
- 2) Internal oil leaks, clearly identifying the exact nature and origin:
 - i. From Impeller internal.
 - ii. Bearings & seals.
 - iii. Between casing & Impellers.
 - iv. Hydraulic control equipment condition and oil leaks.
- 3) Assessment for Casing deficiencies:
 - i. Structural cracking & erosion.
 - ii. Flange leaks.

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- iii. Deformation.
- iv. Anchor bolts.
- v. Access doors and seals.
- 4) Blades condition assessment:
 - i. Attachment elements like bolts, bushes and seals.
 - ii. Rotational movement.
 - iii. Visual wear & crack assessment (NDT crack testing is listed under scoped work).
 - iv. Mechanical damage.
 - v. Measured wear reporting.
- 5) Blade position actuating mechanism:
 - i. External positioner, indicator & connecting rods.
 - ii. Internal connecting rods.
 - iii. Hydraulic actuating equipment.
- 6) Lube-/Hydraulic supply systems:
 - i. Critical control elements/components.
 - ii. Oil and tank leaks.
 - iii. Pipework & flange-gaskets.
 - iv. Flow sight glasses.
 - v. CW flow control & setting.
- 7) Fan peripherals:
 - i. Seal air fan, ducting & filter condition (ID Fans).
 - ii. Brake disc and brake pad wear.
 - iii. Drive couplings visual inspection, guards and shaft.
 - iv. Compensators.
 - v. Shaft seals condition & clearances.
 - vi. Insulation & cladding.
- 8) Fan bearings and housings:
 - i. Oil leakages.
 - ii. Labyrinth Seal gaps.
 - iii. Anchor bolts.
 - iv. Lube-oil supply/return piping.
- 9) Fan Motor and bearings:
 - i. General motor and cooler condition.
 - ii. Leakages & oil levels.
 - iii. Labyrinth Seals and gasket joints.
- 10) Supporting structure & access platforms.
- 11) Field Instrumentation:
 - i. Stall device blockage & wear.
 - ii. Setting and testing of Stall device.
 - iii. Pressure/flow tapping points blockage.
- 12) General housekeeping

e) Extended intrusive inspections

Further detailed inspections required are specifically listed as Outage Scope of Work.

- 1) Inspection on components that are to be stripped for complete assessment and maintenance, are separately scoped for execution, and are typically as follows:
 - i. Fan bearing and/or labyrinth seals internal inspections.
 - ii. Bearing-room enclosure (MD ID Fans).
 - iii. Servo motor internals (if required).
 - iv. Motor bearings internal inspection.
 - v. Intrusive lube/hydraulic system inspection and servicing.
 - vi. Fan Blades NDT inspection.
 - vii. Couplings NDT inspection.

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viii. Casing wear survey and NDT inspection.

- 2) The condition and recommended scope for these items is reported as per the stipulated technical reporting & Engineering evaluation requirements.

4.2.3 Scope of Work execution management

- a) The effective translation of plant inspection observations and measured recordings is a key element to providing the assurance of reliable RTS performance.
- b) The following aspects are designed for implementing continuous improvement to processes and performance (as per ISO 9001).
- c) The key role-players required to execute every element of the defined management process are the following personnel:
 - 1) Employer and Contractor System Engineers.
 - 2) Maintenance execution manager or supervisor.
 - 3) Employer and Contractor Contract's manager/controller.
- d) Failure to provide detailed input and management of the activities, results in wasteful expenditure and performance degradation.
- e) The key mandatory management activities to provide the above assurance are as follows:
 - 1) Scope clarification and provisional formulation of the Contracted Scope.
 - 2) Complete submission of inspection report.
 - 3) Report analysis and recommendation.
 - 4) Scope of Work review (Rev.1) and Task order finalisation.
 - 5) Issue of Scope variations and approval.
 - 6) Issue and approval of amended Quality Control Plans.
 - 7) Execution of repairs in accordance to approved procedure.
 - 8) Commissioning & testing of plant in accordance to approved procedure.
 - 9) Post mortem consolidation meeting, addressing the defined content detailed in the applicable section below.
 - 10) Issuing and approval of the Task execution data-book, addressing the defined content detailed in the applicable section below.

4.2.4 Spares and Management of Spares BOM

- a) Management of Spares requires the dedicated effort of continual improvement of the details, in order to secure effective execution of Maintenance.
- b) Spares lists are to be structured in accordance to plant layout and SOW Task list headings – for quick access referencing.
- c) Spares availability cannot be measured and managed on main items alone. The success of Spares management lies in the provision of accurate details and availability of each spare-able item.
- d) Due to the unpredictability of scope, resulting from operational changes, prolonged operational periods, and the interrelated effect of failures, spares-holding must be complete – meaning that it should make allowance for the maximum scope applicable to the scheduled outage. Partial stock-availability will result in partial repairs, with a spiralling decline in performance, and extreme increases to plant unreliability.
- e) The System Engineer is responsible to ensure that a consolidated list of spares is available, with continuous improvement of content.
- f) The Maintenance Contractor is responsible to contribute towards the population of the list, and to confirm the spares BOM, after evaluating the outage Scope of Work submission.

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4.2.5 Quality Control and Documentation

The complex and multitude of verifications required to secure effective execution of repairs of the Axial Flow Fans require detailed and tightly controlled Quality Control Plans (QCP's). The following important aspects are to be incorporated into planning and execution of QCP's:

- a) Inspections are executed by the correctly skilled persons, trained on the execution procedure, required assembly lay-out, and critical points of evaluation (Hold and Witness Points).
- b) The Contractor shall make use of well-formulated Pre-Job-Briefs in order to ensure task-execution is effectively planned and safely executed with re-enforcement of critical points.
- c) Inspection Interventions are consolidated and guided by the use of detailed check-sheets, in order to ensure that multiple inspection items (points of importance) are covered.
- d) The method of consolidating small inspection points into one witness check-point (with associated check-sheet), is considered good/mandatory practice.
- e) All Inspection Pre-job-briefs, check-sheets and measurement recording sheets are referenced on the QCP and attached for approval.
- f) Inspection of adjustments or settings is presented for verification, with the prescribed setting criteria/specifications, and recorded results-sheet attached.
- g) Measured inspection results are verified by the Contractor's Engineer, especially when recommendations based on the results require the addition of repair scope.
- h) Scope activities involving the "closing-up" of an item (meaning no further witness of the internal condition is possible), shall always be a Witness Hold point intervention involving the Employer.
- i) Control check-sheets shall be utilised prior to the execution of major activities, such as casing installations or closures, in order to prompt for the verification of quality control checkpoints.
- j) All final inspections (before closing doors) shall be guided by a documented check-sheet and signed-off by relevant delegated persons stipulated on the QCP. Check sheets shall cover typical items such as internal cleanliness, scaffold/internal ladder removal, door seals & latches, bolts fitted, final set-up measurement reports compiled, commissioning executed, and doors closure.
- k) Critical hold/check-point witnessing, is accompanied with assessment sheet and specification.
- l) Bolt-tightening of Fan rotors are controlled and recorded/signed-off on a referenced torque check-sheet.

4.2.6 Outage Post-mortem Records

- a) Documentation requirements and details to be supplied by the Contractor for the planning and attendance of the Outage Post-mortem meeting:
 - 1) Final assessment of the executed task order.
 - 2) Record of tasks not completed in accordance to the SOW.
 - 3) Record of recommended repairs not executed – to be incorporated into future SOW.
 - 4) Quality report, incorporating QCP completeness, QCP changes required, NCR Reports.
 - 5) Refurbishable spares, incorporating a reason for rejection and required repair notification per item.
 - 6) Excess list of (unused) spares to be returned to Eskom.
 - 7) Notification of the official Spares List updates that is required.
 - 8) Notification of the official SOW Task list updates that is required.
- b) The Outage Post-mortem meeting is arranged by the Eskom Outage Controller, and is attended by the Employer & Contractor Contracts, Engineering and Quality personnel within one month after completion of the work.

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4.2.7 Outage Data Book

- a) Notwithstanding the defined pre-submission of inspection findings (working documents), the Contractor shall compile a complete history file (Data book) for the overhaul/repairs executed to the plant for submission upon completion of the project or opportunity repair.
- b) The Data-file shall contain as a minimum (and not limited to), the following:
 - 1. Index of contents and transmittal cover sheet.
 - 2. All documents relating to SOW, Task order – initial, additional, not executed, recommendations for future work.
 - 3. Inspections and finding reports.
 - 4. Plant final commissioning settings, records, alignments & balancing.
 - 5. Quality records – QCP's, NCR's, requests for inspections.
 - 6. NDT records, reports.
 - 7. Repair execution records.
 - 8. Replacement & shortage spares.
 - 9. Manpower qualification & training records.
 - 10. Planning/program documents – bar chart.
 - 11. Post mortem records, reports.
- c) The repair history data-file should be submitted in both Hard-copy and an agreed electronic (scanned) format for Station use and filing.

The completed and approved Data-file shall be submitted within 1 month after completion of the Post Mortem outage meeting for evaluation and approval by the relevant Eskom System Engineer.

4.3 GENERAL SERVICE QUALITY AND EXECUTION STANDARDS

4.3.1 Bolting Arrangement

- a) The size and grade of replacement bolts & washers shall be in accordance to prescribed OEM/AEM design and drawing standards. The contractor should include checks as part of the Quality Inspection program and should detect and report any instances where bolts different from the standard grade, or specification were found during the inspection.
- b) Flame cutting for the removal of bolts on Bearings, Impeller Rotors, Pedestals, Bases, Flanged Components, and Fan casings is not permitted. If required under extreme conditions, this practice may only be utilised after approval by Site Engineering. The Contractor Supervisor shall take the utmost care that personnel have been adequately trained so as not to damage base components with flame cutting.
- c) No unauthorized welding, or weld build-up in an effort to repair components, is allowed.
- d) Where bolt tightening has been specified, the execution shall be accompanied with a torque check sheet and Witness record as part of the QCP.
- e) Previously used/removed bolts to be re-used, shall be properly binned per application and retained in a clean and dry environment until re-fitting.
- f) Foundation and bearing pedestal bolt arrangement shall be monitored against controlled torque specifications, and continuous tightening/testing by means of uncontrolled flogging is not permitted (unless physical access prevents the use of a torque wrench, in which case permission is to be obtained from the Employer's site representative after agreement with the Employer's Engineering staff).

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4.3.2 Rotating and alignment of fan drive trains

- a) Any off-line rotation of fan Rotors shall be controlled by the *Contractor* by ensuring the availability of lubrication and jacking systems (Where applicable).
- b) Care shall be taken on non-force-lubricated fan/motor bearings to manually lubricate the bearings following standstill periods in excess of two weeks. Appropriate training and care shall be taken when bearing filler plugs are opened, to prevent dust ingress.
- c) Drive train alignment shall be precluded with a witnessed confirmation and consideration of the motor magnetic-centre position. Once alignment is concluded, the test run of motor shall include the required test and vibration analysis to ensure that the magnetic centre position post-alignment activity is correct.
- d) Drive train alignment shall incorporate the requirements for casing thermal growth and stipulated coupling gaps.
- e) Alignment results shall be presented for witnessing confirmation to comply with each applicable coupling requirement.

4.3.3 Flanged Joints

- a) Gaskets shall be correctly sized in order to centralize the gasket between the flange bolts on the sealing landings.
- b) The contractor shall always verify that fitted gaskets are correctly specified for the applicable process parameters.
- c) Quality measures shall be implemented to ensure that the correct bolts for the application is used, and that joints are parallel bolted.
- d) All flange gaskets are to be made part of the spares list for the fans and kept in the correct storage conditions for outage/maintenance work – on-site cutting of gasket material is to be eliminated.

4.3.4 Lubrication Systems

- a) Transferring of lubrication system oil – to facilitate internal tank cleaning/servicing – shall be done via a pumped and filtered system with minimum 25 micron (nominal) filtration quality.
- b) Storage containers shall be cleaned before use, ensuring NO remnant dirt or alternative oil is present.
- c) Any extensive tank and oil supply pipe intrusive work shall be followed with bypass flushing before passing oil through bearings. The contractor shall provide the appropriate flushing connections.
- d) Passing of oil through bearings shall require the prior completion of all intrusive and/or component replacement work on the oil supply system.
- e) Lube tank internal condition shall be thoroughly inspected and reported for settled dirt and corrosion.
- f) The re-starting of lube system pumps shall be witnessed and monitored for leaks.
- g) Setting-up of control & pressure relief and valves shall be executed with an approved guiding procedure.

4.3.5 Sleeve Bearings

- a) Standard practice regarding proper cleaning of the component and working area shall be observed before stripping a bearing.
- b) The execution of any bearing work shall be supported with extensive effort to screen off the working area against ash/dirt ingress during the 'cleaning and close' period.
- c) Sleeve bearings shall be thoroughly cleaned, oiled and oil ports purged prior to installation.

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- d) The opening of a sleeve bearing is to be included as a witness point on the QCP for the Contractor and Employer appointed QC, and the general condition or failure mode analysed & reported.
- e) Serial numbers of sleeve bearings are to be recorded onto the inspection records.
- f) All serviced or installed bearings and associated oil rings, and seals shall be included on the QCP for the Contractor and Employer appointed QC and measured clearance verified, immediately before replacing the top housing/cover.
- g) All gaskets and split surfaces shall be sealed with a non-hardening sealant (e.g. "Hylomar").
- h) Unauthorized scraping of bearings is not permitted without the explicit instruction from Eskom Engineering.
- i) The bearing maintenance service provider shall be responsible to ensure that the removal and installation of instruments is coordinated, and that all open holes are blanked-off during the service period.
- j) For motors with sleeve bearings, the bearing maintenance service provider shall be responsible to verify and maintain the internal housing spherical insulation and earth wire connection (where applicable).
- k) Bearings are to be manually lubricated for turning if an operational lube-system is not available.

4.3.6 Open Lube Piping

- a) Any opened piping or vessel shall be screened off for prevention of dirt ingress.
- b) The contractor will ensure that open holes for piping or instrumentation is closed/blanked off to prevent dirt ingress on serviced bearings/components.

4.3.7 Stripping of Plant

- a) Any plant to be opened (stripped) shall be thoroughly CLEANED prior to exposing sensitive internals to dirt-ingress.
- b) Particular caution and control is to be applied with bearing oil top-up to secure the cleanliness of plant & oil and the filling operation.
- c) Applicable match-marking (where appropriate) shall be applied to facilitate the re-assembly process.
- d) Stripped components & bolts shall be safely marked and stored in appropriate containers.

4.4 DOCUMENTATION OF PROOF FOR TESTS AND INSPECTIONS

4.4.1 Important "proof of functioning or compliance" tests

The mandatory tests and verifications are documented and submitted for assessment, acceptance/approval, & record-keeping are as follows:

- a) Blade wear trending and analysis, accommodating unique set tracking.
- b) Blade NDT records and analysis, accommodating location and unique set tracking.
- c) Casing NDT and repair history.
- d) Lubrication and Hydraulic system set-up and performance verification.
- e) Bearing & Hydraulic compartment pressuring (seal air) set-up (ID Fans).
- f) Final internal inspection and Internal & external Door closing verification and sign-off before balancing and before RTS.
- g) Return to Service monitoring and recording of critical components.
- h) Stall protection system function verification.

4.4.2 Document acceptance requirements

The relevant Power Station shall maintain records to certify that proof tests and inspections were completed as required. These records shall include the following information as a minimum;

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- a) Description of the test and inspection performed.
- b) Stipulation of Station, Unit, Fan where tests are executed.
- c) Dates of the tests and inspections.
- d) Name of the person(s) who performed the test and inspections.
- e) Calibration certificates for test/inspection equipment used.
- f) Results of the tests and inspections.
- g) Actions recommended for rectification.

5. AUTHORISATION

This document was reviewed and accepted by:

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6. REVISIONS

Date	Rev.	Compiler	Remarks
January 2020	0	W. Garnett-Bennett	Defined the minimum requirements for Axial flow Fan Maintenance
April 2020	0.1	W. Garnett-Bennett	Addition of Service details and requirement
August 2020	0.2	W. Garnett-Bennett	Final Draft Document after Review process
August 2020	1	W. Garnett-Bennett	Final Document for Authorisation and Publication

7. DEVELOPMENT TEAM

N/A

8. ACKNOWLEDGEMENTS

- Site System Engineers for facilitation of plant inspections and failure assessments.

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