

	Standard	Generation Engineering
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1. INTRODUCTION

This standard details the process to be adhered to when performing metallographic replication on Eskom turbine and generator components. The document details how metallographic replication work must be performed on turbine and generator components. The standard also lists the roles and responsibilities of Eskom role players and suppliers of metallographic replica taking services.

2. SUPPORTING CLAUSES

2.1 SCOPE

The scope of this standard covers the process of taking metallographic replicas on Eskom turbine and generator components. The responsibilities of suppliers and Eskom role players are also stipulated in the standard. The correct selection and use of etchants for alloys is included to ensure consistency of results. A directive regarding minimum wall thickness constraints and post cleaning is detailed.

2.1.1 Purpose

The Purpose of this standard is to specify the in-situ metallographic replication technique used on turbine and generator components. The principles may also be applied on other components after consulting the Physical Metallurgy and Structural Integrity CoE.

2.1.2 Applicability

This document applies to all personnel involved in performing metallographic replication on turbine and generator components on Eskom Plant.

- a) The following standard details techniques of a surface examination in which a thin plastic film is used to non-destructively duplicate the microstructure of a component or a defect to determine the creep damage or mechanism of cracking.
- b) This technique is advantageous because of its suitability in locations where access is restricted or where the removal of the component is difficult and/or impossible. The main use of metallographic replication within Eskom is the in-situ inspection of highly stressed components on the turbine and generator, critical components, components with long replacement lead times and major leading components.
- c) This technique can also be carried out on the inside of the components where accessible, especially in areas where creep is suspected.

2.2 NORMATIVE/INFORMATIVE REFERENCES

2.2.1 Normative

- [1] 240-75109745: Metallographic Replication Standard Applicable to High Temperature High Pressure Components on Eskom Plant.
- [2] ISO 9001: Quality Management Systems.
- [3] 240-83539994: Eskom NDT Personnel Approval (NPA) for Quality Related Special Processes on Eskom Plant Standard
- [4] 240-56065041 Steam Turbine Life Assessment Guideline

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[5] 240-56063895 Minimum Outage Inspection Requirements for Steam Turbines

[6] 240-56357338 Life Management of Coil Retaining Rings in Turbo Generators Standard

2.2.2 Informative

[7] Metallography Principles and Procedures, Leco Corporation 1977

[8] ASTM E3-11

2.3 DEFINITIONS

Definition	Description
Replica Film	Acetate film 30 - 50-micron thickness is recommended
Replica	Replica film mounted on a glass slide and labelled as per this standard
Stainless Steel	All alloys containing > 12% chromium
Low Alloy Steel	CMoV steel, all alloys containing < 5% Cr, < 2% Ni, < 3% Mo
High Alloy Steel	CrMoV, all alloys containing >5% Cr but < 12.5% Cr
Site Metallurgist	An Eskom appointed Metallurgical Engineer/ Technologist/ Advisor that is responsible for advising a Power Station regarding remaining life assessment of high temperature high pressure components
Service Provider Company	A supplier/contractor approved by Physical Metallurgy and Structural Integrity CoE to perform the duties of taking metallographic replicas on Eskom plants
Section	Eskom Physical Metallurgy and Structural Integrity CoE

2.3.1 Disclosure Classification

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

2.4 ABBREVIATIONS

Abbreviation	Description
BMW	Bi-metallic weld
DM	Physical Metallurgy Departmental Manager
ESMQR	Eskom Metallographic Quality Representative
FA	Functional Administrator
HAZ	Heat Affected Zone
METALL	Metallographer
MT	Magnetic Particle Testing
NDE	Non-destructive examination
PSGM	Power Station General Manager
WT	Wall Thickness
UT	Ultrasonic Testing

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2.5 ROLES AND RESPONSIBILITIES

2.5.1 Action by the Power Station

- a) The Power Station General Manager (PSGM) will ensure that this standard is implemented on site.
- b) The applicable engineering and outage departments will ensure that only Eskom approved suppliers for replicating of turbine and generator components are used to perform metallographic replication. The list of approved suppliers will be available from the ESMQR.
- c) The applicable engineering and outage departments will ensure that all suppliers adhere to this standard.
- d) The relevant Power Station Outage Manager will ensure that the correct flow of replicas is followed.
- e) Quality related issues highlighted by the ESMQR, or Metallurgical Site Representative will be managed and addressed by the Power Station and the service provider company.

2.5.2 Action by the Physical Metallurgy Section

- a) Give the Power Station advice on area/SOW where replication should be carried out.
- b) The Materials Care Group shall ensure that all relevant staff in the Physical Metallurgy and Structural Integrity CoE implement this standard in full.
- c) The Materials Care Group is responsible for maintenance of this standard.
- d) An Eskom approved Metallurgist (ESMQR) shall be responsible for ensuring that the metallographic replica technique is performed according to this standard.

2.5.3 Action by Site Metallurgist

- a) Confirm the geographical area (Middelburg/Rosherville) where the replicas should be delivered with the Power Station and the service provider company. Arrange with the functional administrator (FA) regarding the date and the time replicas will be received. The Site Metallurgist is responsible for correct flow of replicas between the service provider company and FA as well as feedback between FA and the Power Station/ service provider company.
- b) Action all concerns from METALL to the system engineer or Power Station project management.
- c) Involve the ESMQR in resolving replica quality or work-flow problems with the replica taking company.
- d) Carry out remaining life assessments on replicated components.
- e) Assists the ESMQR in ensuring that the metallographic replica technique is carried out according to this standard.
- f) Reviews high damage/defects in replicas through own evaluation.

2.5.4 Action by the Eskom Physical Metallurgy and Structural Integrity CoE quality representative

- a) Perform replication training of the Service Provider staff.
- b) Ensure the replication standard is adhered to by all Service Providers (SPs).
- c) Approve all replica taking SPs. Ensure that the list of approved replication SPs is kept up to date for record keeping purposes.

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- d) Keep record of all the replicas evaluated and record all rejected replicas as a percentage of total replicas evaluated per supplier.
- e) Liaise with SPs in case of quality problems.
- f) Perform round robin studies on a yearly basis to ensure continuous high quality replica evaluation.
- g) Site visits to power stations to ensure compliance to the procedure.

2.5.5 Action by Functional Administrator (Principal Clerk)

- a) All replica boxes must be received by one of the Principal Clerks at Rosherville or Middelburg.
- b) No replicas will be accepted without a transmittal sheet and the transmittal sheets will not be accepted without wall thickness measurements.
- c) The Principal Clerk must check the number of replica boxes against the transmittal sheets received.
- d) The transmittal sheets must be signed by both parties and the date and time at which the boxes are received must be on the transmittal sheets.
- e) The service provider company must keep the copy of the transmittal sheets signed by the Principal Clerk.
- f) The Principal Clerk must keep the copy of the transmittal sheets signed by the service provider company.
- g) The Principal Clerk will check the labelling of the replica boxes and slides and confirm the number of slides in the boxes against the transmittal sheet.
- h) If boxes are found to have been labelled incorrectly, they will be rejected, and the service provider company must re-lift those replicas.
- i) The service provider company must correct any faulty transmittals immediately.
- j) The replica boxes must then be taken to the Replica Evaluators.
- k) When the service provider company wants to deliver replica boxes after hours or over weekends it must contact the Site Metallurgist supporting that Power Station to make special arrangements for the time and place deliveries will take place as well as how the signing of transmittal forms will be executed. The replicas dropped-off at the Security Office will only be checked and signed off when FA or Site Metallurgist receives them from the Security Office.

Note: Archiving via Microsoft Outlook and external hard drives is implemented in the interim while Hyperwave is down and archiving via the new platform Open Text shall be implemented once the system becomes fully functional.

2.5.6 Action by the service provider company

- a) The service provider company is responsible for the quality and integrity of the replicas lifted by their technicians and ensuring that the replicas are taken and labelled in accordance with this standard. A competent supervisor/metallurgist who will be responsible for quality of replicas must be appointed by all service provider companies.

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- b) The service provider company shall ensure that its employees have been approved to replicate turbine and generator components by Eskom and ensure that all quality control is done at a magnification of 400/500:1 by the supervisor.
- c) The supervisor must ensure that the service provider company staff adheres to this standard. Any deviation from this standard must be communicated and approved by the Eskom Site Metallurgist.
- d) The service provider company is responsible for the delivery of all the replicas to the Rosherville and/or Middelburg offices. The service provider company will be advised by the Site Metallurgist regarding where the replicas must be delivered.
- e) The service provider company will ensure that all replicas sent to Eskom will be of the required quality with respect to:
 - i. Level of scratches (no scratches are acceptable).
 - ii. Level of etching (under- and over-etching will not be accepted).
 - iii. Size of film that can be evaluated – minimum size of 10 mm x 40 mm.
 - iv. At least 15 mm Parent Metal and 10 mm Weld Metal is visible on weld replicas.
 - v. Replicas are correctly labelled.
 - vi. Transmittal forms are correct and complete with wall thickness readings before and after replication.
 - vii. Lines are walked with drawings and all components are correctly labelled (confirm with the system engineer).
- f) The service provider company must provide a delivery or transmittal sheet with all replicas. It is also recommended that the service provider company take note of any visual anomalies such as macro cracking, weld anomalies or any geometric anomalies and report to the ESMQR or the Site Metallurgist.
- g) The service provider company must provide a list of all the areas replicated with the wall thickness measurements taken before and after replication.
- h) Should a service provider company use an in-house procedure, the procedure must be approved by the ESMQR. In case of any disputes, this Eskom standard shall prevail.

The service provider company through the Replica Supervisor must ensure:

- a) Grinding, polishing, and etching steps as per this standard are known and followed.
- b) A standardised list of etchants for various materials must be provided by the Site Metallurgist when and if required.
- c) Work instructions are prepared for sensitive areas (rotor bodies, rotor attachments and generator clean areas) and agreed upon by the system engineer and Site Metallurgist to prevent contamination of critical components and grinding too deep on critical components.
- d) Replication is carried out on a clean area and the areas replicated are left dry and free from any contaminants (swab etching in critical areas must contain all chemicals on the replicated area and the replicated area must be cleaned and dried with acetone and polished with 1000 grit to leave the area free of any etchant or rust marks).
- e) The work area is always clean and safe.

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- f) The replica quality is good and acceptable to Eskom and the Original Equipment Manufacturer (OEM).
- g) The replicas are labelled correctly and transmitted to Eskom with agreed transmittal sheet and to the agreed destination.
- h) Replication happens according to a pre-arranged schedule.
- i) Concerns regarding replicas are understood and handled effectively.

Also see section 4.5 for post replication cleaning

2.6 PROCESS FOR MONITORING

It is the responsibility of the ESMQR (on behalf of and as appropriately delegated by the Materials Care Group), to monitor performance of replica lifting (by service provider) companies by arranging quality spot checks as and when required. It is expected that the Service Provider company will do its own process monitoring in the form of spot checks, the results of which are to be shared with the ESMQR.

2.7 RELATED/SUPPORTING DOCUMENTS

Document Code	Document Title
24075109745	Metallographic Replication Standard Applicable to High Temperature High Pressure Components on Eskom Plant
240-71443868	Standard for Evaluation of Surface Microstructures Using the Metallographic Replication Technique.

3. STANDARD FOR METALLOGRAPHIC REPLICATION

3.1 METALLOGRAPHIC REPLICATION PROCESS

Although steam turbines have mostly been conservatively designed, mechanical components used in these machines experience various damage mechanisms. Creep damage, fatigue, or a combination of the two are some of the damage mechanisms that affect these components. Inspection and life assessments of turbine components are conducted to ascertain the amount of damage accumulated to date, the rate of damage accumulation as well as the predicted remaining life under a given set of operating conditions. The components examined will ultimately be governed by a holistic approach, as directed by the Site Metallurgist and scope of work (SOW) development team.

- a) The scope of the inspection shall be done by the system engineer and agreed to by Site Metallurgist prior to inspection. Recommendations from the OEM and other relevant stakeholders and the specific plant design must also be considered when compiling the final scope of inspection.
- b) When a component is re-replicated the area that is examined shall be as near as possible to the area of the previous examination (subject to minimum wall thickness not being violated or component clearances/tolerances and dimensions not being compromised). Note that the Structural Integrity CoE must be involved in the minimum wall thickness calculations of complex components.
- c) In all cases the depth of grinding to remove the oxide layer shall be restricted to the minimum. The minimum wall thickness must not be violated. During investigative grinding, frequent thickness measurements must be taken. The maximum allowable depth of grinding and minimum allowable

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thickness in the replication/replicated area shall be clarified through consultation with the system engineer and Site Metallurgist in charge.

- d) NDE inspection reports will reveal where additional replicas must be lifted, and these areas must be confirmed with the Site Metallurgist. Additional areas examined are those where geometry changes occur, where the component is thinnest, and where there is a possibility of external loading on a component.
- e) Only personnel qualified according to this standard are allowed to carry out any replication duties on Eskom sites.

3.2 LEVELS OF APPROVAL FOR PERSONNEL

The following personnel, in accordance with their specified qualifications are allowed to perform metallographic replica lifting on turbine and generator components on Eskom plant.

3.2.1 Preparation Technician

An individual approved to this level:

- a) Shall be qualified to carry out grinding and/or polishing of surfaces as per the approved service provider company standard.
- b) Shall be qualified to conduct wall thickness measurements throughout the replication process.
- c) Shall understand drawings allocating positions where replicas must be taken.

3.2.2 Wall Thickness Technician

An individual approved to this level:

- a) Shall have a minimum requirement of UT Wall thickness at an NDT approved training facility.
- b) Shall be approved by Eskom's NDE Level III.
- c) Results reported by Level I must be countersigned by a Level II/III in that discipline.

UT wall thickness shall not be conducted, under any circumstances, by non-approved personnel.

3.2.3 Replication Technician

An individual approved to this level:

- a) Shall be qualified to perform all replication tasks as per the approved service provider company procedure excluding evaluation of replicas. They must mark replicas correctly by writing component and position information on each slide.
- b) Shall supervise, train, and assist the replication surface preparation technicians.
- c) Shall complete report forms for evaluation (sketches showing replica positions included).

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3.2.4 Replica Supervisor

An individual approved to this level must be a Metallurgical engineer or technologist and:

- a) Shall be qualified to undertake full responsibility concerning taking of replicas for and on behalf of Eskom.
- b) Shall be responsible for:
 - i. the correct marking of components (in consultation with the Site Metallurgist and the System Engineer) and areas to be replicated as per the drawings. All deviations must be agreed on between the Site Metallurgist and Power Station Systems Engineer and drawings must be updated to reflect the correct and/or current plant status.
 - ii. ensuring that etchants are prepared correctly, and correct etchants are used.
 - iii. ensuring that minimum wall thickness tolerances are not violated during the replication process.
 - iv. the evaluation of all replicas to ensure correct quality before delivery.
 - v. the correct labelling of replicas, boxes, and transmittals with correct wall thickness readings.
 - vi. report on the preparation technique with respect to the quality and integrity of the replicas taken prior to transmittal of replicas for further evaluation.
 - vii. regularly assessing the performance of all replica personnel during the actual replication operations, to establish whether the correct operating procedures are being adhered to.
 - viii. ensuring that replicas are delivered on time and at the agreed location and that the transmittal forms are signed off correctly.
 - ix. arranging to resolve enquiries and re-works.
- c) Shall be accountable for the choice of etchants, communication with Eskom's Chief Metallurgists, workflow, quality control, cleanliness, and safety of replication activities on the turbine components.

Note: It is preferable that supervision is direct; however, Eskom recognises that this is not always possible. A supervisor's presence is mandatory at the beginning and at the completion of an inspection activity.

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3.3 POSITIONS TO BE REPLICATED

Positions to be replicated should be determined from recommendations by the Original Equipment Manufacturer (OEM) analysis, Finite Element Method (FEM) analysis and other relevant analysis done. All involved stakeholders' experiences and the specific plant design must also be considered when compiling the final scope of inspection.

The critical positions that need to be replicated should be decided by the relevant turbine engineer and Site Metallurgist. The critical areas should be marked on the drawing and assigned a unique number. The drawing with critical areas' unique numbers should be archived with the outage report and it should serve as a record of the components inspected. The SOW drawing should exist for turbine rotors/blades, inner casings, outer casings, and steam chests.

Areas to be replicated must be clearly defined in the scope of work. Marking out of areas should be performed by the relevant turbine engineer, Site Metallurgist, a Rotek works engineer, the replica supervisor from the replication service provider company and the replica technician during the NDE phase of the project.

The size of the areas that are prepared for replication must be polished and etched, and should not have any defects to ensure that the following metallographic evaluation is possible on a slide/film:

- a) Size of film that can be evaluated – minimum size of 10 mm x 40 mm.
- b) At least 15 mm parent metal (PM) and 10 mm weld metal (WM) must be visible if the replica is taken across a weld.

3.4 SURFACE PREPARATION

When a decision has been made regarding which components are to be replicated, the appropriate areas shall be marked by the replica supervisor (agreed upon by the Systems Engineer and Site Metallurgist) and then prepared using the following procedure:

3.4.1 Depth of Replication

The following replication depths must be adhered to:

3.4.1.1 Turbine Rotor/blades and generator components

- 0.3 mm maximum on all areas replicated.

Note: Replication must only take place in acceptable areas, some areas e.g., pull faces in serrations, grinding and polishing shall not be replicated.

3.4.1.2 Steam chests, casings, and valves

- a) 0.5 - 0.8 mm on all low alloy areas not yet replicated.
- b) 0.5 - 1.0 mm on all X20 components with WT less than 25 mm, for areas not yet replicated.
- c) 1.0 - 1.5 mm on all X20 components with WT greater than 25 mm, for areas not yet replicated (NOTE: Decarburised layer must be removed and is thicker on thicker wall components).

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d) 0.3 - 0.5 mm on previously replicated areas if replicating again.

Note: Replication is only acceptable in areas that will not affect the mechanical functionality.

Depth of replication on components with a wall thickness less than 15 mm must be provided in writing and specified by the Site Metallurgist.

Depth control grooves or punch marks must be made over the entire replication area before any grinding, to ensure a homogeneous and correct depth.

Wall thickness (WT) measurements or measurements of allowable grinding depth must be taken on thinnest areas before replication of the area and after replication, to indicate approximate depth and minimum WT remaining. On areas where before and after replication wall thicknesses are not possible due to geometry, grinding should only be done after consultation with Site Metallurgist.

The wall thickness and depth measurements must be recorded on the transmittal sheets and submitted with the replicas, including all deviations and or concessions. The Replication Technicians may use the profiling technique to manage the material removal during grinding.

3.4.1.3 Generator coil retaining rings

Care should be taken in the shrink fit areas that the shrink fit tolerances (to be discussed with the Site Metallurgist and the turbine engineer) are not compromised. Ensure that not more than 0.2 mm of material is removed in an area not greater than 30 x 30 mm.

Any marking or writing on the coil retaining rings should only be done using pre-approved marking pens.

Wall thickness measurements must be recorded prior to, and after replication.

Note: No replication must be performed on landing areas.

3.4.2 Rough Grinding

- a) Before grinding, the actual and calculated minimum wall thickness or allowable grinding depth must be established, and during preparation the minimum wall thickness may not be violated without prior approval in writing by the Site Metallurgist in charge.
- b) Rough grinding on rotors, coil retaining rings and other turbine components with tight tolerances is not permitted. Tolerances to be discussed with the Site Metallurgist and the turbine system engineer.
- c) Rough grinding is to be carried out using a light angle grinder to remove heavy oxide deposits from the surface and to expose bare metal. Care must be taken to ensure that the surface is not over heated or burnt, and that sufficient material is removed to eliminate residual oxide.

3.4.3 Intermediate and Fine Grinding

- a) This operation is generally carried out in two steps: firstly, using an electrically powered tool with fanned grinding segments (flap wheels) of successively finer particle sizes from 80 to 320 grit, followed by silicon carbide grinding (using a "transpol" or other light grinding unit) paper of successively finer particle sizes i.e., 320, 500, 800 and 1200 grit. It is important to use at least 6 progressively finer grinding steps to ensure ease of removal of previous deformed layer. More steps can be advantageous.

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- b) To ensure optimum quality, it is important to use light pressure and speed during grinding. A speed of no more than 3000 rpm is recommended for intermediate grinding and a speed of not more than 600 rpm is recommended for fine grinding. The direction of polishing or grinding must be changed (preferably by 90°) after each grinding step to ensure that the old and deformed layer is removed each time. It is also important to clean the area before successive grinding or polishing step. It is recommended that high quality metallographic preparation products, especially polishing media be used.
- c) Ensure an adequate area is cleaned and free of dust and white background paint (if MT was carried out prior to replication).
- d) Care must be taken to ensure that all grinding marks from the preceding grit are removed before moving to the next grit.
- e) Adequate lighting is essential for satisfactory results.

3.4.4 Polishing

The polishing operation is aimed at producing a smooth, uniform, mirror-like surface finish like that produced in a metallographic laboratory.

- a) The procedure describes the use of Struers “transpol” unit. Though other power units and polishing methods may be employed, the basic procedure shall remain the same.
- b) In each instance the polishing step is lubricated with a suitable polishing extender (most diamond paste solutions already contain polishing extender).
- c) Thoroughly clean the surface with methanol and a cotton wool swab and flush the surface with methanol.
- d) Polishing cloths should be changed on a regular basis. Old and slightly worn cloths introduce artefacts that lead to uneven polishing and under-polishing.
- e) Using a polishing cloth (mol or felt type cloth), moderate pressure and 6 µm diamond paste/suspension, all polishing marks from the preceding 1200 grit (equivalent to 15 µm surface finish) grinding step should be removed (3 minutes of polishing is a good guide to achieve this).
- f) Flush and swab the area clean using methanol; ensure that it is dry before proceeding.
- g) Using a polishing cloth (mol or felt type cloth), light pressure and 3 µm diamond paste/suspension to remove any marks from the preceding 6 µm diamond paste/suspension (2 minutes of polishing is a good guide to achieve this).
- h) Flush and swab the area clean using methanol to ensure that it is dry before proceeding.
- i) Using a suitable etching solution (3 - 5% Nital for low alloy steels) the area shall be etched using a swab or by continuously wetting the area with the etchant for approximately 20 - 30 seconds and methanol should then be used to flush and dry the area. This is to check for scratches which must not be carried over to the subsequent stages.
- j) Using a polishing cloth (felt type cloth), moderate pressure and 1 µm diamond paste/suspension, all polishing marks from the preceding 3 µm step should be removed (1 - 2 minutes is a good guide to achieve this). The etched structure should be removed at this stage.

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- k) Flush and swab the area clean using methanol, ensure that it is dry before proceeding to final etching.
- l) The area is now ready for final etching.

3.5 ETCHING

Etching is a controlled preferential attack on the material surface for the purpose of revealing the microstructure. For optimum etch quality, fresh etchant must be mixed every two days and chemicals used in the preparation of etchant must be kept constant to avoid varying quality. Vilella's etchant must be freshly made every day.

Etching time depends on several variables namely, material temperature, material composition, etchant concentration, etchant age and quality of the polished surface. Hence it is not always possible to assign a fixed etching time. Etching can be done using a fixed time as a guide; however, the time should still be decided upon based on visual examination of experienced technicians. The surface is etched until it is an even, dull, blue/grey colour.

The following two stages of etching are recommended as a guideline for low alloy steel as explained partly in the polishing section (times stated below should be used as a guideline and must be subjected to the judgement of an experienced technician):

- a) Etch for at least 30 seconds after the first 3 µm diamond paste/solution polishing step.
- b) Final etching to last 30 - 60 seconds after the 1 µm diamond paste/solution polishing step.

The following three stages of etching are recommended as a guideline for X20CrMoV11-1 (X20) and X10CrMoVNb9-1 (P91) material (times stated below should be used as a guideline and are subject to the judgement of an experienced technician):

- a) Etch for at least 30 seconds after the first 3 µm diamond paste/solution polishing step.
- b) First etch for 45 - 60 seconds after the 1 µm diamond paste/solution polishing step. Proceed to take the replica, clearly marking it as the first etch.
- c) When the acetate film of the first etch has dried, remove film and clean area using methanol.
- d) Progressively etch for 10 -15 seconds after removing acetate film placed on first etch and lift the second set of replicas. Proceed to lift replicas clearly marking them as second etch.

When a bimetallic weld (BMW) is replicated it is important to first etch the low alloy side (etch with Nital), take first replica then the X20CrMoV11-1 side (double etch with Vilella's reagent), and take the second replica on the X20CrMoV11-1 side only.

After replication, no evidence of any polishing consumables or etching solutions must remain in the polished area. Marks must be removed by light grinding with 400 grit paper and cleaning with alcohol. The entire component should be clean and dry from any etching and polishing consumables. Also see section 4.6 for post replication cleaning.

Note: See the constituents of Nital and Vilella's reagent below.

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3.5.1 Etchants

Ensure that the polished area is clear of any polishing compounds or oils by cleaning with acetone.

The etchant to be used will be determined by the material requirements and is not restricted to the list below. The etchants listed below are the standard etchants to be used on the various steels. Any deviations from this list must be discussed with the Chief Metallurgist. Damage mechanisms such as pitting and stress corrosion cracking can be initiated when incorrect chemicals are used, the components are not properly cleaned, and the etching process is not controlled such that the etchant is not only contained on the area of interest. Past incidences have shown pitting induced by aggressive etchants on coil retaining rings on Eskom plant.

a) For Low Alloy Steels

3 - 5 % Nital = 3 – 5 ml Nitric Acid (HNO₃) + 97-95ml Methyl Alcohol

b) For High Alloy Steels X20CrMoV11-1 (X20) & X10CrMoVNb9-1 (P91)

Vilella's reagent = saturated solution of picric acid in high purity propanol mixed with HCl. Saturation is obtained by stirring the picric acid in propanol (at least 10 g picric for 100 ml propanol) at a temperature of 30 - 40°C for at least 2 hours. For every 100 ml of saturated alcoholic picric solution, 5 ml of HCl should be added. A good indication to ensure that a saturated solution of Picric acid has been achieved is when a thin gel forms when HCl is added.

c) For Stainless Steel (Get Site Metallurgist approval before using this)

Mixed acids = 1-part Hydrofluoric Acid (HF), 1-part Nitric Acid (HNO₃), 2 parts demineralised water (H₂O).

Marble's Reagent = 4 g of copper sulphate, 20 ml of hydrochloric acid (HCl) & 20 ml of water (H₂O).

Other electrolytic etching techniques will most likely be preferred by the Site Metallurgist and must be prescribed in writing when stainless steels and other materials are replicated.

d) Generator Coil Retaining Rings

18Mn 5Cr - 3-5 % Nital = 3 – 5 ml Nitric Acid (HNO₃) + 97-95ml Methyl Alcohol.

18Mn 18Cr - Mixed acids = 1-part Hydrofluoric Acid (HF), 1-part Nitric Acid (HNO₃), 2 parts demineralised water (H₂O).

Since replication of turbine components is riskier and more involved than pipework, the choice of etchants is strictly the responsibility of the replica supervisor (as specified on this procedure) and it must be discussed with the Chief Metallurgist.

3.6 APPLICATION AND REMOVAL OF THE REPLICATION FILM

Ensure that all etchants have been cleaned from the surface by cleaning with methanol (a wet cotton wool swab is normally required). Cleaning etchants with acetone is not recommended prior to replication film removal because it is aggressive and can cause surface contamination and poor washing.

a) Prior to use, the acetate film must be cut into suitably sized pieces. (Minimum 50 mm x 15 mm). The acetate film must be dust-free.

b) To apply the film, a strip is dipped into acetone for approximately 2 seconds. The film is then applied without pressure to the polished surface. Care shall be taken to minimise the amount of air trapped

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under the film. The replica is carefully peeled off after it has completely dried, and secured impression face upwards to a glass microscope slide.

- c) The film must be applied in a way that will prevent bubbles and ripples on the edges of the replica. It is known however that with the usage of 30 - 50-micron acetate film, and due to the porous nature of some castings, ripples and some small bubbles cannot be avoided and are formed on the replicas.
- d) The film must be correctly mounted on the glass slide (not upside down) and care should be taken not to touch the impression side of the replica at any time during the mounting process (the structure and voids can easily be flattened leading to a non-representative sample).
- e) After mounting the replica, the minimum information must be written in pen on mounting tape (e.g., Sellotape) to correctly identify the replica.
- f) The area and component replicated should be left clean and dry.

Note: It is possible that the film will detach from the surface which might lead to a loss of the replica, depending on the ambient or material temperature.

After polishing and etching it is critical that the replicas are lifted immediately to prevent pitting of the surface. Once polishing starts, a break cannot be taken by the technician until the replica is lifted. If a break was taken, commence at least with fine grinding and ensure that the area is left dry during the break.

3.7 POST REPLICATION CLEANING

The polishing and etching compounds can be detrimental to components replicated and the environment. The service provider company should ensure that their employees do not leave any traces of metallographic preparation consumables after replication on the components. Polishing media and consumables as well as etchants should be cleaned with methanol and acetone immediately after the replication has been completed. Marks must be removed by light grinding with 400 grit paper and cleaning with alcohol. The entire component should be clean and dry from any etching and polishing consumables.

The service provider company should ensure that the cleanliness is consistent with each component replicated.

3.8 COMPONENT IDENTIFICATION, LABELLING & TRANSMITTALS

Before work commences, the systems must be walked through and visually examined by the System Engineer, Site Metallurgist and Replica Supervisor. All the components must be correctly marked as per the inspection drawings supplied. If anomalies exist between the system and the drawings, the latter must be updated to reflect the correct plant condition before replication commences. The Site Metallurgist must be informed of such changes.

The component numbers on the replicas must always be correct and be reflected on the updated drawing used during the replication process. The drawing must be supplied after the outage.

To avoid a mix-up of areas, if replication is done on a previously replicated area, the replica label and transmittal must indicate "old" after the replicated position unique number to clearly identify the history of the area.

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Care must be taken not to touch the replica film during labelling and to work meticulously to ensure correct numbering.

The replicas shall be stored in conventional microscope slide storage boxes away from dust, moist conditions, and extreme variations in temperatures.

When a replica is lifted, the component, area, and the unique number, i.e., Inner Casing RT 3, must be written in ink on the mounting tape. During this step absolute care must be taken to use the correct component and area description.

The following information must be shown on each slide:

- e) Power Station, Unit, System - e.g., *Duvha, U6, TC*.
- f) Date – e.g., *Sep 2022*.
- g) Component Serial No/Name. – e.g., *Inner Casing*.
- h) Replica unique No – e.g., *RT 3*.

The areas of a specific component must not be mixed between boxes.

The replicas of different systems/components (Rotor & Steam Chest) must not be placed in the same box.

Each box must have a unique number and must contain the following information:

- a) Unique Box No., Date – e.g., *Box TC1, 12 September 2022*.
- b) Power Station, Unit, System – e.g., *Duvha, U6, TC*.
- c) Component/ Component Serial No. – e.g., *Inner Casing*.

The boxes in which repeated replicas (either due to poor quality or additional work) are submitted should reflect the box number of the original component. For example – if unique No RT3 from Box TC26 was rejected due to dust, the replica box should be labelled TC26-R1, and if additional work was requested on unique No RT3, the replica box should be labelled TC26-E1.

Each box must be indicated on a transmittal sheet. Transmittal sheets must contain the following information:

- a) Power Station, Unit, System – e.g., *Duvha, U6, TC*.
- b) Date – *16 September 2022*.
- c) List the following in table format:
 - Box No.
 - Component type (Rotor, Steam chest, casing, etc)
 - Component/ Component Serial No.
 - Area description/unique No (RT3).
 - WT before replication.
 - WT after replication.
 - Depth of replication.
 - Comments (no access due to flange, MT defect, etc.),

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The boxes of different systems (Rotor & Steam chest) must not be listed together on one transmittal.

3.9 FLOW AND DELIVERY OF REPLICAS

All replicas taken on day 1 must be labelled and transmittals prepared on day 2. The replicas, with **fully completed** transmittals (WT included) must be handed over to Rosherville or Middelburg not later than 7:00 am on day 3 (it can be done on day 2 if it is ready).

It is the service provider company's responsibility to hand over the labelled boxes together with the transmittals and wall thickness results to the Rosherville or Middelburg offices.

Daily records of areas replicated, handed over and not yet replicated areas must be kept by the service provider company. Daily progress must be reported in the morning meetings.

Quality problems will be handled via the system engineer and must be addressed immediately after the problems are detected. All rework due to poor/unacceptable quality will be retaken at the service provider company's expense.

Boxes and slides that are incorrectly labelled or requested for re-labelling during or after the outage will not be accepted. Should this happen, boxes and slides will be rejected and quarantined, and the issue will be addressed as a quality deficiency (service provider company to re-take all replicas at own cost).

Safety, environmental and quality control of the replication process is the full responsibility of the replica service provider company. Project management of the replication process is also the service provider company's responsibility, as well as attending daily meetings to discuss and solve problems.

See paragraph 2.5.6 for more details.

3.10 REJECTION OF REPLICAS

Metallographic replicas can be rejected for the following reasons:

1. Bubbles – treated case by case.
2. Dust – limited to 10 particles/mm².
3. Scratches – none accepted.
4. Etching and cleaning artefacts – none accepted.
5. Size of film - refer to minimum size of PM visible.
6. Incorrect marking – not acceptable.
7. Replicas not mounted correctly (upside down) – not acceptable.
8. Replica not flat – not acceptable.
9. No transmittal sheet – not acceptable.
10. No evidence of WT measurement – not acceptable.
11. Damaged slides – not acceptable.
12. Under and over-polishing or etching – not acceptable.

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4. AUTHORISATION

This document has been seen and accepted by:

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5. REVISIONS

Date	Rev.	Compiler	Remarks
November 2013	0.1	O Netshifamadi	Draft document developed
January 2014	0.2	Tshidi Ngoasheng	Draft Document for Comments Review
February 2014	1	Tshidi Ngoasheng	Final Document for Authorisation and Publication
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April 2017	1.2	Tshidi Ngoasheng	Draft Document for Comments Review
May 2017	2	Tshidi Ngoasheng	Final Rev 2 Document for Authorisation and Publication
May 2022	2.1	Aluwani Mabada	Draft Document for Comments Review
June 2022	2.2	Aluwani Mabada	Additional updated Completed
November 2022	2.3	Aluwani Mabada	Final Draft completed after Review Process
November 2022	2.4	Aluwani Mabada	Additional updates completed
May 2023	2.5	Aluwani Mabada	Additional Changes made, Final Draft
May 2023	2.6	Aluwani Mabada	Final Draft after Review Process Completed
May 2023	3	Aluwani Mabada	Final Rev 3 Document for Authorisation and Publication

6. DEVELOPMENT TEAM

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

- Thendo Mphaphathi
- Tshidi Ngoasheng
- Felicia Ramela

7. ACKNOWLEDGEMENTS

Special thanks to everyone who contributed to the compilation of this document.

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