Eskom	Standard	Technology

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CONTENTS

1. INTRODUCTION

This document aims to provide the minimum requirements for welding activities for the construction and repair of Eskom's Primary Air, Induced Draught and Forced Draught fans. Generic actions and guidance for achieving successful weld repair are also provided.

2. SUPPORTING CLAUSES

2.1 SCOPE

2.1.1 Purpose

Defining uniform, fit-for-purpose requirements for performing any manufacturing, repair and/or maintenance welding and related activities on Eskom draught plant. The objective is to impose good basic welding practice while conforming to the construction code and welding specifications, thereby improving and preserving the integrity of Eskom draught equipment. Specifically, the document is designed to:

- Provide Eskom staff and contractors with rules for the manufacture and repair of primary air (PA), induced draught (ID) and forced draught (FD) fans designed and manufactured with high strength low alloy (HSLA) quenched and tempered (Q&T) structural steel
- Serve as a basis for the monitoring of repair work performed by contractors on fan components
- Itemise the parameters required for the successful repair welding
- Provide a basic and generic repair procedure from which more specific procedures may be derived as called for in particular situations
- Ensure basic good quality welding on safety critical draught plant components to contribute to a safe and healthy working environment as required by the Chief Inspector, Occupational Health and Safety Act

This document replaces the previous Eskom Procedure *OPP 2398 (1983): 'REPAIR WELDING OF INDUCED AND FORCED DRAFT FANS MANUFACTURED FROM ROQ-TUF AD 690*

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions. This standard is applicable when procuring, reviewing and placing manufacturing, maintenance and repair contracts with vendors working on Eskom draught plant by the relevant Eskom procurement departments. Routine weld repair and maintenance work by Eskom personnel also fall within the requirements of this document. It will serve as the standard to support Eskom's position on all welding related issues and disputes on the draught plants. Any disputes that fall outside this standard or that appear to be in conflict with it can be resolved with the necessary weld engineering and/or metallurgical inputs. Contractors that fail to meet the requirements of this standard may be evaluated to determine the nature and significance of the shortcomings, after which they may be considered for the contract with the necessary concessions.

This standard outlines the requirements, techniques and parameters necessary for obtaining satisfactory weldments on all high integrity Level 1 plant components, in particular the following areas located on the fan impellers:

2.1.2.1 Welds joining the blades and main drive plate of the impeller
2.1.2.2 Welds on the drive plate
2.1.2.3 Welds joining the impeller blades and shrouds (nose and tail ends)

2.1.2.4 Welds joining wear plate and the drive plate
2.1.2.5 Welds joining wear plates and blades
2.1.2.6 Welds joining separate wear plates (where applicable)
2.1.2.7 Balance weight to fan impeller welds

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

International Standards

[1] BS EN 10025 (2004): Hot rolled products of structural steels – Part 1: General technical delivery conditions
[2] BS EN 10025 (2004+ A1:2009): Hot rolled products of structural steels – Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition
[3] BS EN 10160 (1999): Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)
[4] BS EN 10163 (2004): Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections – Part 1: General requirements
[5] BS EN 10163 (2004): Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections – Part 2: Plate and wide flats
[6] BS EN 10204 (2004): Metallic products – Types of inspection documents
[7] BS EN 1011 (1998): Welding- Recommendations for welding of metallic materials – Part 1 General guidance for arc welding
[8] BS EN 1011 (2001): Welding- Recommendations for welding of metallic materials – Part 2 Arc welding of ferritic steels
[9] BS EN 287 (2004): Qualification test of welders - Fusion welding-Part 1: Steels
[10] BS EN ISO 15607 (2003): Specification and qualification of welding procedures for metallic materials - General rules
[11] BS EN ISO 15609 (2004): Specification and qualification of welding procedures for metallic materials-Part 2. Welding procedure specification – Part 1: Arc welding
[12] BS EN ISO 15614 (2004): Specification and qualification of welding procedures for metallic materials-Part 1. Arc and gas welding of steels and arc welding of nickel and nickel alloys
[13] BS EN ISO 15614 (2007): Specification and qualification of welding procedures for metallic materials-Part 7. Overlay welding
[14] BS EN ISO 15613 (2004): Specification and qualification of welding procedures for metallic materials – Qualification based on pre-production welding test
[15] BS EN ISO 5817 (2003): Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) – Quality levels for imperfections
[16] BS EN ISO 17663 (2009): Welding – Quality requirements for heat treatment in connection with welding and allied processes
[17] EN ISO 13916 (1997): Welding – guidance on the measurement of preheating temperature, interpass temperature and preheat maintenance temperature

National Standards:

[18] SANS ISO 3834-1:2005, Quality requirements for Welding Part 1 Guidelines for selection and use
[19] SANS ISO 3834-2:2005, Quality requirements for Welding Part 2 Comprehensive quality

Eskom Standards:

[20] 32-632 Non-Destructive Testing (NDT)
[21] GGS0462, Quality requirements for engineering and construction works in generation
[22] 240-56241933 Control Of Plant Construction, Repair And Maintenance Welding Activities Standard
[23] 240-56246601, Personnel and Entities Performing Welding Related Special Processes on Eskom Plant Standard

2.2.2 Informative

None

2.3 DEFINITIONS

Definition	Description
Eskom Welding Co-ordinator	Personnel performing weld related duties as defined by Eskom standard 240-56246601.
Welding Procedure Qualification Record (WPQR)	A record comprising all relevant data from the welding of a test piece needed for the approval of a welding procedure specification as described in the welding specification BS EN ISO 15614:2004.
Welding Procedure Specification (WPS)	A document compiled as per BS EN ISO 15609 and derived from the WPQR/PQR that sets out in detail the required variables for a specific application to assure repeatability.
Welder Qualification Record (WQR)	A document compiled to the requirements of BS EN 287 that presents the results of the approval testing of a welder to perform a fusion welding process.

2.3.1 Classification

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

2.4 ABBREVIATIONS

Abbreviation	Description
BS EN	British Standard European Norm
ISO	International Organization for Standardization
IWE	International Welding Engineer registered with the International Institute of Welding.
IWT	International Welding Technologist registered with the International Institute of Welding.
OHS Act	Occupational Health and Safety Act of 1993
TPI	Third Party Inspector employed by an Approved Inspection Authority

2.5 ROLES AND RESPONSIBILITIES

None

2.6 PROCESS FOR MONITORING

None

2.7 RELATED/SUPPORTING DOCUMENTS

None

3. REQUIREMENTS

3.1 MATERIAL

For the construction of new components material properties shall conform to Specification BS EN 10025 Parts 1 and 6. As-delivered surface condition of plates shall conform to the requirements of BS EN 10163 Parts 1 and 2 Class B, and inspected for lamination type defects in the through thickness direction by ultrasonic testing (UT) to the requirements of BS EN 10160. All material intended for use on structural members subjected to fatigue loading during operation shall be delivered with BS EN 10204 type 3.2 inspection certification.

Table A1 in the annex shows various HSLA Q&T steels used on Eskom plant.

3.2 STEEL MAKING PROCESS:

The steel shall be made by vacuum degassing electric furnaces as defined by EN 10025-1. The steel shall be roller quenched and tempered and shall have a fine grain structure. The steel shall be weldable and capable of forming by cold working. No hot working is allowed. New material shall be ordered with a maximum carbon equivalent limited to 0.65 as per calculation by the formulae in EN 10025-1.

3.3 WELD PREPARATIONS

3.3.1 Welding shall be performed to the requirements of the Eskom Welding Standard 240-56241933 which reference BS EN 1011 Parts 1,2 and 3 for guidance on how to achieve and control basic good quality weldments.

3.3.2 Welding on fan components shall be in accordance with the requirements and application ranges of a WPS supported by a valid WPQR. The WPQR shall be *approved* by a registered IWE or IWT.

3.3.3 The contractors suitably qualified welding supervisor / coordinator shall verify that the information on the WPS accurately reflects the parameters reported on the WPQR before use on Eskom equipment. Although approval of this document by an IWE/IWT is not mandatory, it is recommended practice.

3.3.4 The contractor shall prepare quality control documents as required by Eskom Quality Standard GGS0462 and submitted to the Eskom responsible person for approval before commencing with any contract or welding job.

3.3.5 All weld quality related activities on Eskom draught plant (which is rated as an Eskom Level 1 plant) shall be in accordance with the requirements of SANS ISO 3834 Parts 1 and 2. This by implication requires the contractor to be an SANS ISO 3834 Part 2 certified company.

3.3.6 Welding personnel requirements shall be as prescribed by Eskom Standard 240-56246601.

3.4 WELDING PROCEDURES

Welding procedure qualification shall be in accordance with the appropriate combination of EN and ISO/EN family codes of specification; BS EN ISO 15607, BS EN ISO 15609, BS EN ISO 15614-1, EN ISO 15614-7and BS EN ISO 15613; as is applicable to the Eskom quality Level requirements stipulated in Table A1 of 240-56241933. Any possible exceptions shall be motivated for approval by the Eskom welding coordinator.

3.4.1 Construction of new components shall be performed to welding procedures qualified to the requirements of the latest version of the applicable construction code.

3.4.2 Weld repairs to be performed on old plant shall conform to the latest version of the construction code. Any deviations from the requirements resulting from technological advancement of equipment, processes and techniques shall be noted and submitted for approval by Eskom. For this type of application the original welding procedure can be used but must be re-written to reflect the latest weld specification format. Only old procedures with the required supporting documents such as the heat treatment chart and report from the mechanical test laboratory will be eligible for use.

3.4.3 Modification work to existing plant shall be performed to welding procedures qualified to the requirements of the latest version of the applicable construction code.

3.4.4 Refurbishment work on existing plant that require non-standard weld preparations shall be supported by suitably qualified welding procedures that accommodate the geometry of the intended repairs. In the majority of cases this will require weld built-up / overlay type welding techniques. It is recommended that the basic rules stipulated in BS EN ISO 15614 Part 1 be complemented by elements of BS EN ISO 15614 Part 7 and BS EN ISO 15613. For this approach the welding procedure will closely reflect the geometry, sequence and technique required for the production weld.

3.4.5 Quality levels for imperfections as described in BS EN ISO 5817 for metallic wldments shall be prescribed to the contractor before production commences, preferably at the inquiry or order stage. For special purposes additional conditions and details may be prescribed. The applicable flaw acceptance level B, C or D shall be agreed between contracting parties before any welding commences. The quality levels refer to production quality and not to fitness-for-purpose of the situation.

3.4.6 Pertinent to welding procedure qualifications, the following information shall always be recorded in addition to the basic requirements of the weld specification:

3.4.6.1 Heat input: the speed of weld progression shall be recorded in mm/s; the weld current range shall be measured with a clip-on gauge/ tong tester; the open circuit voltage of the welding machine and the weld voltage range shall be measured with a volt-meter (multi meter).

3.4.6.2 Specification, size and commercial trade name of the welding consumables

3.4.6.3 The yield strength and tensile strength and elongation of the coupons shall be recorded during the tensile tests

3.4.6.4 The heat treatment chart (where applicable) shall form part of the permanent record of the WPQR

3.4.6.5 Material certificates for both filler and parent material(s) shall be part of the permanent record of the WPQR

3.4.6.6 The mechanical test samples shall be retained after completion of the tests for evaluation/examination by Eskom

3.5 WELDER AND WELDING OPERATOR QUALIFICATION

WQR testing for metallic materials shall be performed in accordance to BS EN 287.

3.6 WELDING PROCESSES

All recognised welding processes for the construction of rotating equipment may be considered for construction, repair and maintenance work on the draught plant.

Application of the different processes in particular areas will however take into consideration of the limitations of such processes. At areas of high loading such as for structural joints especially those the involves the impeller drive plate only processes with good track records for high integrity welds such as shielded metal arc welding may be considered. At positions that requires special skills to manipulate weld arcs consistently such as around the impeller blade nose to drive plate welds, gas metal arc; flux cored and metal cored processes will not be allowed. Only tungsten inert gas and manual metal arc welding may be applied here.

3.7 WELDING CONSUMABLES

Welding consumables shall be stored in a dry storage area with temperature controlled at least 30ºC above atmospheric dew point. Only low hydrogen potential welding consumables rated at below 5g diffusible hydrogen per 100 ml weld metal shall be used.

Electrodes showing signs of flaked and cracked flux layers shall not be used. The supplier's recommended drying procedures for electrodes shall be strictly adhered to. After baking the electrodes shall be kept in a holding oven at a minimum temperature of 120ºC. Only sufficient electrodes for a shift's work shall be issued to welders from the holding oven and transferred directly to a pre-heated hot box / quiver which shall be kept at a minimum temperature of 100ºC at all times. Electrodes not used during any one shift shall be returned to the consumable storage area and considered for re-baking as per the contractors established marking and maximum allowable re-baking works procedure.

Wires with flaking protective coatings or showing traces of rust, oil and other carboniferous contamination shall not be considered for use on HSLA metal Q&T steels. Correct storage of flux cored and metal cored wire products in a sufficiently dry environment are of particular importance due to possible moisture pick-up through non-tight long wire seams.

Submerged arc flux products shall be stored and dried strictly as per supplier's recommendations. Baked flux shall be kept in a dispenser maintained at a minimum temperature of 100ºC. Recycled flux is to be re-baked as recommended by the supplier.

Weld shielding gas regulators and transmission tubes shall be kept dry and free of any traces of oil and grease on the inside surfaces.

3.8 PREHEATING

The preferred heating method will be resistance heating pads as far as practically possible. Alternatively a flame heating technique with a neutral flame gas mixture may be considered. The flame for gas heating must not be concentrated at one point. It is preferable, where possible, that preheating be done on the reverse side of the plate. To ensure adequate soaking of hat throughout the area to be welded, the heating source must be removed two minutes prior to the temperature being checked by an approved method for meeting minimum preheating temperature. The welder must ensure that the correct preheating temperature is achieved before tack welding or welding commences.

Measurement of preheat temperature shall be in accordance with EN ISO 13916.

3.9 TACK WELDING

Areas to be tack welded must be preheated to the same temperature (as specified for welding in the WPS) up to 150 mm away minimum. The length of the tack welds shall be minimal of 25 mm and be cleaned of slag prior to welding the main runs. The leg length shall be a maximum of 6mm and the minimum distance between tack welds shall be 200 mm as far as practically possible. All tack welds must be ground prior to completion of the weld runs.

3.10 REMOVAL OF WEAR PLATES AND LINERS

Removal of the liners with the fan in-situ is not generally recommended other than in the exceptional circumstances, where an individual wear plate or liner needs replacement, in which case the following shall be observed:

3.10.1 Prior to any preheating being applied for gouging or welding purposes, a small hole of 3 mm diameter must be drilled near the blade trailing edge weld (minimum 20 mm from the weld). The hole must enter the air space between the blade plates. These shall be closed welding after completion

3.10.2 Preheating before gouging or welding is essential and must conform to the applicable WPS

3.10.3 Liners to liner welds may be removed by argon arc air gouging. All other liner to fan impeller welds shall be removed by abrasive grinding where practically possible

3.10.4 Once all the required wear plates are removed, the previously welded areas must be ground to a smooth profile.

3.10.5 100% MT inspection must be carried out on all the ground areas as well as the adjacent material

3.11 HEAT TREATMENT

Heat treatment procedures shall be based on the guidelines provided in BS EN ISO 17663

3.12 INSPECTION OF WELDMENTS

All NDT shall be performed to meet the requirements of Eskom NDT Standard 32-632

Final inspection of welds shall be delayed and performed at least 48 hours after cooling down from welding and PWHT (where applicable).

Exemption for delayed inspection:

- Only the balancing weights to the side plate attachment welds shall be exempted from a minimum of 48 hours waiting time before final inspection by MT surface crack detection techniques.
- This exemption is only valid when the welding preparations and special techniques as described in Paragraph 3.13 of this document are adhered to.
- The time between completing the weld or PWHT (if applicable) and performing final inspection shall be as long as possible within the time constraints of the outage.

3.13 REQUIREMENTS FOR WELDING BALANCING WEIGHT TO THE SIDE PLATE WHERE DELAYED INSPECTION IS WAIVED

3.13.1 Background information

Manufacturing and maintenance processes involving high strength low alloy quenched and tempered steels have to take cognisance of potential complications inherent to this type of material. This material has a tempered bainitic microstructure when processed correctly. The most likely welding problem expected with this type of alloy is hydrogen induced cracking (HIC) also known as delayed cold cracking, hydrogen cracking for short that can occur in an un-tempered bainitic microstructure. Even though this phenomenon is well understood and extensively studied for many years, it still occurs often when the right combination of factors preside namely when a hardened microstructure charged with hydrogen is stressed at sufficiently low temperature. Correct welding principles and techniques will minimise the risks associated with welding on these types of materials. Due to the propensity for cracking to occur even long after welding ended, it is essential to delay final NDT as long as practically possible to be able to detect the presence of such cracks. Academic institutions, specialist weld consultation companies and material suppliers have studied the HIC phenomenon in depth and have consequently recommended minimum waiting periods before final NDT for different strength grades of construction materials while several construction codes adopted these recommendations.

For the 690 MPa yield strength material (of which ROQ-tuf AD690 and Weldox 700 are well known examples) the general industry consensus is a minimum waiting time of 48 hours for the worst cases scenario based on material properties that conform to specification ranges.

3.13.2 Weld technique

The following basic minimum required steps needs to be followed:

3.13.2.1 For the preheating and bake-out, resistance heating mats are preferred if practically possible, propane flame heating by hand will not be desirable but will be allowed.

3.13.2.2 Apply only stringer weld beads

3.13.2.3 Check for weld indications with the hot magnetic particle testing technique using iron powder after each welded layer

3.13.2.4 Under normal circumstances a purpose designed 690 MPa yield strength rated consumables are required to match the yield strength of the base material, but for some applications such as for welding of balance weights a so-called under-matching consumable will be more appropriate.

3.13.2.5 Clean out the areas where welding will be applied by grinding to remove all traces of rust or surface contaminants.

3.13.2.6 For a pre-weld hydrogen bake-out, the area around welding must be subjected to controlled heating with resistance heating pads insulated with wool insulation material to the maximum interpass temperature of about 200ºC then dwell for 3 hours before gradually lowering to the minimum weld preheat temperature stipulated in the WPS. A gas heating technique may be used if resistance heating methods are found to be impractical (upside down applications). This relative high preheat and interpass temperature level facilitates hydrogen removal and reduces cooling rates and thermal gradients induced by the welding process which might lead to high hardness values in the completed weld

3.13.2.7 Use either the SMAW or GTAW welding process with WPS and a welder qualified for the fan material. A minimum of two weld layers are required to fill the butt weld or complete a fillet weld, which ensures tempering on the first layer by the subsequent layer.

3.13.2.8 Perform a post-weld hydrogen bake-out (minimum of 300 mm from the weld edge) around the weldment area, by controlled heating with resistance heating pads insulated from the environment to the maximum interpass temperature of 200ºC then dwell for 3 hours before gradually reducing to 80ºC. A gas heating technique may be used if resistance heating methods are found to be impractical (upside down applications).

3.13.2.9 Remove heat and slowly cool down weldment to ambient under thermal blankets .

3.13.2.10 Perform surface replication at a minimum of two pre-selected positions across the weld heat affected zone of the repair to determine the possible presence of micro-cracks, followed by hardness traverse checks on the same positions

3.13.2.11 Post-weld hydrogen bake-out at 200°C may be omitted if the following technique is followed:

- Complete the welding using austenitic stainless steel consumables
- Apply insulation to the local area to slow cooling rate
- Monitor metal temperature on the inside of the plate using a thermal crayon
- When cooled to about 120°C, gently apply heat with a gas flame for two hours to sustain temperature before cooling to ambient temperature, still with insulation
- Follow-up with appropriate NDE when cooled to ambient temperature.

3.14 INSTALLATION OF BALANCE WEIGHTS

Balance weights shall be manufactured from a certified low carbon steel grade as used for pressure vessel applications. Material shall be adequately certified and stamped before cutting and proof to demonstrate positive material identification is made available when required. Weights must be attached to the fan impeller at positions of lowest possible stress using a low strength (500MPa yield maximum) and low hydrogen potential carbon steel welding consumable, circumferentially not closer than 20 mm to the periphery of the impeller. The use of austenitic stainless steel or nickel based consumables is not preferable due to the added difficulty of interpreting surface crack detection results on dissimilar welds.

Balancing weights shall be of thickness not in excess of 75% of the thickness of the base plate where the weight will be attached and shaped to follow the surface radius profile of the base plate. Weights shall be chamfered at 45 degrees at ½ t and corners radiused to a minimum of 10 mm to facilitate continuous welding. The weight shall also have a 5 mm hole drilled in it before welding. When closer than 50 mm to the tail of a blade. if the pads are to be welded within the 50 mm restriction area, they are to be narrowed and centered evenly over the tail of the blade.

Balance weights shall be welded in position in accordance with an approved welding procedure specification. Before tacking the balance weight onto the impeller, pre-heat as prescribed in the WPS shall be applied. Confirm correct pre-heat temperature with an approved technique such as temperature indicating crayons. Only electrodes baked in accordance with the approved welding procedure and kept in a hot box may be used. Welding will be continuous around the perimeter of the weight and the leg length of the fillet weld shall be of the order of ½ t of the balance pad being welded.

After welding, the profile shall be ground, leaving a small groove at the toe of the weld, roughly, 0,5 mm deep the groove have to a smooth transition from the weld to the base plate surface with a width of about 5 mm

4. RECORDS

A data package shall be compiled by the contractor for each job and submitted to Eskom for approval before work commence and this data package with a release certificate must be handed over to Eskom for safe storage and record keeping at completion of the project. It shall contain the following documents as a minimum:

4.1 WPQR ; WPS and WQR register

4.2 Register with calibration certificates for welding, measuring and recording equipment

4.3 Welding consumable and material test certificates

4.4 Heat treatment recorded data

4.5 NDE certificates/records and radiographs stored in accordance with Eskom requirements.

4.6 Weld record sheet/weld map relating all the above records to each individual weld, for example, which welder performed the welding to which WPS with which batch of consumables and what were the NDT results for that joint.

4.7 Record of concessions and non-conformances.

4.8 Records of the position, size and procedure followed of any repairs carried out

4.9 QCP / ITP and or repair procedure

5. AUTHORISATION

This document has been seen and accepted by:

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	Document Approved by TDAC ROD 16 July 2013
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6. REVISIONS

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November 2012	0.1	P Doubell	Draft Document for review created from
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7. DEVELOPMENT TEAM

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

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8. ACKNOWLEDGEMENTS

None