Eskom	Standard	Technology

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1. INTRODUCTION

Variations in material properties are a significant contributor to scatter in material behaviour for various failure mechanisms and a major cause of premature failures and exhaustion in the power generation industry. To allow for safe and reliable operation within design limits, and plant life management within predictable boundaries of material scatter, it is important to adhere to international manufacturing standards when material is ordered.

It is Eskom's preference not only to approve suppliers of high pressure (HP) pipework components but also the manufacturers. Globalisation and growth of developing economies has created access to numerous manufacturers, who can compete on cost but are not always capable of repeatedly delivering quality HP pipework and boiler tubing components. Without careful control of technical quality, Eskom is at risk of receiving substandard material that can lead to premature failures on safety and availability critical plant. To limit this risk, it is necessary to standardise the specifications for HP pipework components in Eskom within the limits of international standards as well as engineering best practice.

These will, in some cases, result in special requirements for material procurement in Eskom which will be more stringent than those contained in standard code requirements. Eskom does not have a mechanism to approve manufacturing plants and to ensure material is procured from plant with proven capabilities; technical gatekeepers are introduced as a special requirement, which if not supplied with the tender documents, will result in disqualification of the supplier from the tender process. No concessions with respect to the technical gatekeepers will be considered for HP Pipework operating in the creep regime (design temperature > 450ºC) or any other safety critical plant

This standard covers the materials that can be ordered both via the European Norm (EN) or American Society of Mechanical Engineers (ASME) Standards. It must be noted however that the material to be ordered must be in accordance with the design base of the station in question. Most Eskom plant is designed and built to EN codes while some (Kendal) are designed and built according to ASME codes.

2. SUPPORTING CLAUSES

2.1 SCOPE

This standard covers the ordering of all seamless tubing and piping material to be used in high pressure applications.

This standard does not cover medium and low pressure applications. This is covered by Eskom standard 240-86546783 – Procurement Standard for Material Certification Requirements Applicable to Metallic Products Used on Low and Medium Pressure Applications

2.1.1 Purpose

The purpose of this standard is to ensure that the material purchased by Eskom for HP pipework and boiler tubing purposes is of the highest quality.

2.1.2 Applicability

This document shall apply on high pressure pipework and boiler tubing throughout Eskom Generation, Technology and Procurement Divisions.

2.2 NORMATIVE/INFORMATIVE REFERENCES

2.2.1 NORMATIVE

[1] ISO 9001 Quality Management Systems.

[2] EN 764-5: Pressure Equipment – Part 5: Inspection Documentation of metallic materials and compliance with the materials specification.

[3] EN 10216: Seamless steel tubes for pressure purposes – Technical delivery conditions – Part 1-5.

[4] EN 10204: Metallic Products – Types of inspection documents

[5] ASTM A106/106M: Seamless Carbon Steel Pipe for High-Temperature Service

[6] ASTM A178/178M: Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes

[7] ASTM A192/192M: Seamless Carbon Steel Boiler Tubes for High-Pressure

[8] ASTM A209/209M: Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

[9] ASTM A210/210M: Seamless Medium-Carbon Steel Boiler and Superheater Tubes

[10] ASTM A213/213M: Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat Exchanger Tubes

[11] ASTM A335/335M: Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service

[12] BS EN 12952: Water-tube boilers and auxiliary installations

[13] BS EN 13480: Metallic industrial piping

[14] 240-56239129: High Energy Pipework Standard for Power Generation Plants

[15] VdTÜV WB560/2 (03.2009) - *VM 12*

[16] VdTÜV WB547 (06.2003) – *DMV 347 HFG*

Note: In all cases the latest version of the code/standard/procedure shall be applicable

2.2.2 INFORMATIVE

[17] VGB Specification VGB-R 109

[18] VdTÜV WB511 (03.2009) - *for X10CrMoVNb9-1 and T/P 91 impact properties only*

[19] EPRI Guideline: Best Practice for Manufacturing and Construction of Grade P91 Steel Components (Report No: 1023199)

2.3 DEFINITIONS

Definition	Description
High Pressure Pipework and Tubing	Pipes and fittings in such systems for the conveyance of steam, water, gases or other fluids whose design pressure equals or exceeds 4.0 MPa **or** whose design temperature equals or exceeds 250 °C.
Technical Gatekeepers	Information pertaining to the quality management system of the material manufacturer which must be supplied with the tender documents
Safety Critical Plant	Level 1 plant according to Eskom Standard 240-72273656 – Power Generation Asset Criticality Classification

2.3.1 Disclosure Classification

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

2.4 ABBREVIATIONS

Abbreviation	Description
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
EN	Euro Norm
EPRI	Electric Power Research Institute
HP	High Pressure
MPa	Mega Pascal
PED	Pressure Equipment Directive

2.5 ROLES AND RESPONSIBILITIES

The Power Station Manager is accountable for the implementation of this standard.

The Engineering Manager is responsible for ensuring that the relevant system engineers include the provisions of this standard in all procurement requests for HP piping and boiler tubing.

The procurement manager is responsible for ensuring that the provisions of this standard are adhered to when an order for HP pipework and boiler tubing is placed.

2.6 PROCESS FOR MONITORING

Not applicable

2.7 RELATED/SUPPORTING DOCUMENTS

Not applicable

3. TECHNICAL REQUIREMENTS

3.1 GENERAL REQUIREMENTS

3.1.1 APPLICABLE MATERIAL STANDARDS

Materials codes and standards used frequently in Eskom for boiler tubing and HP Pipework are referenced as process governing documents. When materials codes and standards required are not referenced here, a detailed specification must be developed for the particular order, based on the principles contained in this standard. The following material standards shall be used when ordering material for HP pipework and boiler tubing purposes:

(a) EN 10216: Seamless steel tubes for pressure purposes – Technical delivery conditions – Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties

(b) EN 10216: Seamless steel tubes for pressure purposes – Technical delivery conditions – Part 5: Stainless steel tubes

(c) ASTM A106/106M: Seamless Carbon Steel Pipe for High-Temperature Service

(d) ASTM A178/178M: Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes

(e) ASTM A192/192M: Seamless Carbon Steel Boiler Tubes for High-Pressure

(f) ASTM A209/209M: Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

(g) ASTM A210/210M: Seamless Medium-Carbon Steel Boiler and Superheater Tubes

(h) ASTM A213/213M: Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat Exchanger Tubes

(i) ASTM A335/335M: Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service

(j) VdTÜV WB560/2 (03.2009) – *VM 12*

(k) VdTÜV WB547 (06.2003) – *DMV 347 HFG*

(l) EN 10204: Metallic Products – Types of inspection documents

In addition the following specifications will be used as reference documents:

(a) VGB Specification VGB-R 109

(b) VdTÜV WB511 (03.2009), - *for X10CrMoVNb9-1 (T/P 91) impact properties only*

(c) EPRI Guideline: 1023199 Best Practice for Manufacturing and Construction of Grade P91 Steel Components Rev 1 – *Chemical analysis and heat treatment requirements for X10CrMoVNb9-1 (T/P 91) only*

NOTE: Material standards and specifications must be utilised according to the design base of the particular plant/plant area. NO mixing of codes (i.e. ASTM material on an EN designed station) will be permitted without an approved design modification being in place.

3.1.2 QUALITY GATEKEEPERS

The information listed below must be included in the tender submission for each material grade and dimension group. Failure to supply the information (known as the quality gatekeepers) will result in automatic disqualification of the tenderer.

(a) Certified quality management system in accordance with EN 764-5 Clause 4. The certificate should have been valid for a minimum of two years for materials being supplied.

(b) Name, street and postal address, contact names and telephone numbers of the plant (*site of manufacturing, inspection, testing, and release – if any activity is done at a different plant it must be listed*) where the material will be manufactured, must be supplied with the tender submission. Note that Eskom reserves the right to audit the facilities (or arrange for it by a third party). Under no circumstances can material be manufactured elsewhere without Eskom's written approval.

(c) Third Party/Notified Body *certification* that the plant has been audited and authorised having a quality assurance system for material manufacture in accordance with PED 97/23/EC or 2014/68/EU (Pressure Equipment Directive) to produce the material grades and dimension ranges tendered for. For materials operating in the creep regime (>450°C) certificates to prove that material of the same grade as the tendered or quoted material, was manufactured at the plant and subjected to actual creep testing of at least 40kh is required, no extrapolation is permitted (e.g. similar material appraisal info as in VdTÜV data sheets). In the event this cannot be supplied during the tendering process a signed declaration confirming the above point and allowing access to this documentation at any stage during the tendering process must be submitted.

(d) A list must be supplied of all material supplied over the past two years, with particular attention paid to the material required as part of the order. This should include both the material type and size. Additionally a reference list with contact details of the end users (Utilities) should be supplied with tender submission for evaluation by Eskom. The reference list must include dates of delivery, material grade, dimensions, tonnage and user contact details. Eskom reserves the right to audit the manufacturing plants or arrange for an audit by a third party without any obligation to give reasons for executing this right. Should a plant be unable to prove manufacturing of a specific grade of material, proof should be provided that the mill has produced pipes in a material grade of similar chemical composition and manufacturing complexity in the past.

(e) Heat treatment dummy charts for all the materials being tendered for and furnace packing plans are to be supplied with tender documents.
(f) A declaration form must be signed to confirm that all the requirements of this specification can be met. If there are requirements that cannot be met, these should be listed on the declaration form. Supporting documents should be attached for evaluation and as proof. This is required for each plant where tubes will be manufactured and must be included with the tender submission. Failure to do so will disqualify the tenderer.

3.1.3 CERTIFICATION

Certification shall preferably be in accordance with the latest version of EN 10204: “Types of Inspection Documents” for both EN and ASME materials. Should this not be possible in the case of ASME materials, a certificate of compliance in accordance with the relevant material code shall be supplied.

For tubing applications (OD < 100mm) an EN 10204 3.1 certificate shall be acceptable in all cases.

In the case of piping applications (OD > 100mm) the following materials require EN 10204 3.2 certificates:

15NiCuMoNb5-6-4 (WB 36)

7CrWVMoNb9-6 (P/T 23)

7CrMoVTiB10-10 (P/T 24)

X20CrMoV11-1

X10CrMoVNb9-1 (P/T 91)

X10CrWMoVNb9-2 (P92)

XCrNi19-11 (DMV 347 HFG)

X12CrCoWMoVNb12-2-2 (VM12 – SHC)

Exceptions to this requirement may be made for manufacturing plants that have undergone an audit conducted by Eskom specialists in which the facility is declared competent to manufacture these materials with 3.1 certification.

EN 10204 3.1 certification is required for all other grades of steels.

3.1.4 STEEL MAKING PROCESS

The foundries used to supply cast billets for HP pipework and boiler tube manufacturing shall be listed in the tender documents.

The manufacturer shall provide Eskom with a short technical description of its process to ensure the production of “clean” steel. Raw material and scrap control by foundries must demonstrate low contamination levels of trace and dangerous (poisonous and radioactive) elements. Only fully killed steels will be acceptable.

For Austenitic Stainless Steels, only Argon-Oxygen-Decarburisation (AOD) or Vacuum-Oxygen-Decarburisation (VOD) processes are allowed.

Manufacturers shall also provide details of raw material suppliers and their PED certification.

3.1.5 HEAT TREATMENT

The following requirements shall apply and must be demonstrated and listed on both the tender evaluation documents (if omitted, the tenderer will fail technical compliance and cannot be considered) and material certificates for each order after contract award. For evaluation purposes information for a previous order may be submitted. For the material certificates for the particular order actual data is required.

(a) The calibration status of the furnace, temperature sensors (thermocouples) and monitoring instrumentation loops must be verified before heat treatment commences.
(b) The control thermocouple shall maintain the target temperature within 2ºC (+/- 1°C)
(c) The horizontal, vertical and diagonal temperature differentials of the furnace must be less than 20°C (+/- 10°C) over the areas where the tubes will be positioned during heat treatment.
(d) This must be demonstrated by placing a calibrated thermocouple blocks per furnace control area distributed over the entire loading area and to include the extremes. The plan to show how this was or will be achieved must be supplied and agreed on before the tender is awarded and the results to prove that it was achieved must be included in the furnace calibration certificates. Thermocouples must be used to demonstrate that the correct heat treatment process has been followed through the entire process. This should include the transformation process where applicable. For tubes and pipes that are not sensitive to heat treatment (low alloy steels) Eskom Engineering may waive the requirement to place thermocouples in the furnace if proper temperature control is demonstrated by the supplier.
(e) Pieces must be packed and separated to avoid non-uniform heating and cooling rates (especially during austenitizing, hardening and tempering of CSEF steels) and associated non-uniform material properties.
(f) The heat treatment plan (heating and cooling rates and mediums, with holding temperatures, times and sequence) for each material type and dimensions batch must be supplied with the tender documents. These heat treatment plans and the actual heat treatment charts of each batch should be included in the data books
(g) For X10CrMoVNb9-1 (T91) and X10CrMoWVNb9-2 (P92) the following limits must be adhered to:
    - Austenitizing should be done at 1060ºC. The minimum temperature on any component should be 1050ºC and the maximum 1080ºC. Soaking starts once the full thickness reaches the desired temperature and must be controlled within 2ºC of the required temperature. The soaking time is left to the discretion of the manufacturer but must be stated to Eskom as part of the heat treatment plan at the time of enquiry and/or order. The soaking must be carried out for at least 10 minutes at the austenitizing temperature.
    - After austenitizing, the hardening process requires cooling to temperatures <100ºC, to be reached by the through-thickness of the product. The rate of cooling through the temperature range of 900ºC - 480ºC shall be controlled to be at least 5ºC/minute, not slower (EPRI guideline). The choice to quench thicker components to achieve the required microstructure and hardness is left to the discretion of the manufacturer but must be stated to Eskom at the time of enquiry and/or order (and indicated as QT).
    - Tempering should be done at 760ºC (± 2ºC) observing strict control between limits of 750ºC - 770ºC. Soaking starts once the full thickness reaches the desired temperature. Tempering temperature and soaking time (which must be reported to Eskom at the time of enquiry and/or order) must be chosen to provide the required hardness limits (215HV – 260HV). The aim must be to achieve hardness in the centre towards the higher range to allow a minimum hardness of >205HV after bending and welding heat treatment processes.
    - Cooling must be in air after tempering. Note that the upper and lower limits specified must not be exceeded at all, even including measurement tolerances. Impact properties of X10CrMoVNb9-1 (T91) specified in VdTÜV datasheet 511/2 06.2001 must be achieved for acceptance (also on welds)

3.2 ADDITIONAL REQUIREMENTS

The following requirements are intended to be more stringent than the code requirements. No contraventions of the code, either on the upper or lower limits, will be accepted in the application of these additional requirements. No contraventions of these additional requirements will be accepted. While the materials listed refer to the Euronorm materials, the additional requirement limits apply to the ASME equivalent materials as well.

3.2.1 CHEMICAL COMPOSITION

(a) Cast/melt analysis is required for all materials. In addition, product analysis (on the same sample used for mechanical testing) is required on the following materials:

15NiCuMoNb5-6-4 (WB 36)

7CrWVMoNb9-6 (P/T 23)

7CrMoVTiB10-10 (P/T 24)

X20CrMoV11-1

X10CrMoVNb9-1 (P91)

X10CrWMoVNb9-2 (P92)

XCrNi19-11 (DMV 347 HFG)

X12CrCoWMoVNb12-2-2 (VM12 – SHC)

(b) Trace elements must be controlled and reported (on mill material certificates) for the chemical analysis of *all* materials. The following limits must be adhered to:

Phosphorus (P) ≤ 0,015%

Sulphur (S) ≤ 0,005%

Arsenic (As) ≤ 0,010%

Antimony (Sb) ≤ 0,003%

Tin (Sn) ≤ 0,010%

Lead (Pb) ≤ 0,001%

In addition the following equation as a target will apply and must be reported in the material certificates: As + Sn + Sb + Pb < 0.01%.

(c) The following special requirements, for both cast and product analysis, within but more stringent than the code limits, must be adhered to for the steels listed in Table 1:

Material	Ni (%)	Al (%)	N (%)	N/Al Ratio	Si (%)	Cu (%)
X20CrMoV11-1	0,40 max					0,10 max
X10CrMoVNb9-1	0,20 max	0,015 max	0.035 min	> 4	0,40 max	0,10 max
X10CrWMoVNb9-2	0,20 max	0,015 max	0.035 min	> 4	0,40 max	0,10 max
VM12-SHC	0,20		0.035	> 4		0,10 max

	max		min			
7CrWVMoNb9-6						0,10 max
7CrMoVTiB10-10						0,10 max

Table 1: List of Special Chemical Requirements.

(d) Control of Delta Ferrite will be maintained by adherence to the following formulas:

X20CrMoV11-1:
(Cr + 6Si + 4Mo + 1,5W +11V + 5Nb + 9Ti + 12Al) – (40C +30N + 4Ni +2Mn +1Cu) < 12

X10CrMoVNb9-1 (P/T91), X10CrWMoVNb9-2 (P/T92) and VM12-SHC:
(Cr + 6Si + 4Mo + 1,5W +11V + 5Nb + 9Ti + 12Al) – (40C +30N + 4Ni +2Mn +1Cu) < 12

The chemical analysis results and techniques used shall be reported for the above elements on the respective test certificates.

3.2.2 MECHANICAL PROPERTIES

(a) All mechanical testing shall be carried out in accordance with the relevant codes or standards.

(b) Tensile Testing

Tensile testing shall be done at room temperature and in the transverse direction except where the dimensions do not allow. The sample direction must be noted on the test report. Tensile properties shall comply with the respective codes. Yield strength (or 0,2% proof strength), ultimate tensile strength, elongation and reduction in area shall be reported.

High temperature tensile tests shall be carried out for all materials used in time-independent designs. A temperature of 600°C shall be used (or 550°C where the values at 600°C are not contained in the relevant code/standard). Testing shall be in the transverse direction except where the dimensions do not allow. The sample direction must be noted on the test report. Tensile properties shall comply with the respective codes. Yield strength (or 0,2% proof strength), ultimate tensile strength, elongation and reduction in area shall be reported.

(c) Hardness Testing

Hardness testing (macro-Vickers with 10kg load) shall be carried out on a cross section, close to the outside surface (0,5 - 1mm), in the centre and close to the inside surface (0,5 - 1mm) of each sample. Care must be taken to polish away the cold work effects from cutting of the samples.
For X10CrMoVNb9-1 (T/P91) and X10CrWMoVNb9-2 (P92), manufactured tubes/pipes must be in the hardness range of 215HV – 260HV. The hardness range after bending and forming must be 210HV – 260HV and after final site welding processes must be 205HV – 260HV.

(d) Impact Testing

All impact testing shall be done in the transverse direction except where dimension do not allow. The sample orientation must be noted on the test report. In addition longitudinal impact testing of 15NiCuMoNb5-6-4 is required. In the case of X10CrMoVNb9-1, X10CrWMoVNb9-2 and VM12-SHC the values contained in the latest VD TÜV data sheets shall be applicable. In all other cases impact properties shall comply with the relevant codes.

3.2.3 NON-DESTRUCTIVE TESTING (NDT)

(a) *ASME materials:*

All non-destructive testing shall be carried out as per the relevant ASME V code

(b) EN materials:

All testing shall be carried out in accordance with EN 10216 – 2 Table 13 Test Category 2 (TC 2).

In material to be used in piping applications, additional NDT in the form of ultrasonic testing (UT) must be carried out in the transverse direction, and for the detection of laminar imperfections.

Magnetic particle (MT) shall be carried out on all tubes/pipes. Should electromagnetic testing be used (in the case of tubing) it must be fully capable of detecting longitudinal defects.

In all cases (ASME and EN) leak tightness testing shall be by electromagnetic testing for ferritic steels and eddy current testing according to EN ISO 10893-1 for austenitic steels.

3.2.4 PROTECTION AGAINST CORROSION

All pipes and tubes must be dry, free of corrosion, and a temporary protective coating must be applied on each tube to protect it for long term storage in outside atmospheric conditions (open storage). Tube ends must be covered with tight fitting end caps and desiccant bags or suitable inhibitor must be placed in the inside of each tube to protect it for long term storage in atmosphere (outside storage). The manufacturer must supply details of the coating and desiccant /inhibitor that will be applied.

3.2.5 MARKING

Standard and clear legible marking must be applied to all on both ends of each tube/pipe. All marking shall be in accordance with the relevant code.

3.2.6 SURFACE CONDITION

The surface of all tubes/pipes shall be of such a nature that all required NDT testing can be carried out without restriction.

All pipes/tubes shall be delivered free of external and internal scale.

3.2.7 DELIVERY

Upon completion, technical data books shall be supplied containing as a minimum:

(a) Order requirements and specifications (including declaration of conformity)

(b) PED certification

(c) Signed quality control documentation

(d) Steel making processes and foundry material certificate.

(e) Certificates according to EN 10204 (3.1; 3.2) including all detailed results for destructive and non-destructive testing.

(f) Heat treatment charts (austenizing and tempering) and/or a detailed explanation of the processes including ramp rates, hold times and temperatures.

(g) Surface finish and corrosion protection applied.

(h) All concession correspondence if applicable.

4. AUTHORISATION

This document has been seen and accepted by:

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5. REVISIONS

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March 2016	0.1	A. Downes	New standard governing the procurement of HP pipework material in the Generation Division
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6. DEVELOPMENT TEAM

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

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7. ACKNOWLEDGEMENTS

- None