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1. EXECUTIVE SUMMARY

Kriel Power Station comprises a vast number of civil engineering infrastructure. In these assets a variety of building materials are used, and they are often combined in the same structure. These materials, in turn, are subjected to diverse environmental and exposure conditions which may cause some deterioration of the structures over time. The great majority of the civil structures at Kriel Power Station are typically constructed with reinforced concrete and structural steel. These structures need to be regularly inspected to ensure that any structural defect or degradation will not compromise their structural stability and at the same time to allow intervening in time either to repair the problem or to follow up with a more stringent site inspection and laboratory tests.

This Scope of Works provides a methodology to undertake precautionary inspections to identify and rectify the defects of critical structures. The outside face of the boiler and turbine buildings and the boiler structure have also been included in this scope of works.

Following the survey, the condition of civil and structural assets must be reported and recorded. Remedial measures for each defect must be provided and quantified. The Scope of Works defines six condition categories, ranging from 0 (being excellent new condition) to 5 (being deterioration to the extent that the assets are unusable).

2. BACKGROUND

Kriel Power Station was completed in 1979, and at that time it was the largest coal-fired Power Station in the Southern Hemisphere. It has a capacity of 3000 MW with 6 units generating 500MW each with an installed capacity of 2850MW.

The critical civil structures, specifically Cooling Towers and Chimneys, have been in service for at least 40 years (design lifetime). These structures are exposed to factors such as highly corrosive environments, operational cyclic loads, and prevalent climate conditions. These factors have resulted in the deterioration of some of the structural elements which, if unattended, could impact the structural integrity.

A dedicated maintenance or monitoring program needs to be put in place to ensure the safe operation of the structures until the end of service of the Kriel Power Station.

3. ASSESSMENT PURPOSE

The purpose of the assessment is therefore to:

- evaluate the state of the structures (detailed inspection – to establish a reference point);
- identify dedicated remedial works to be performed (preventive and corrective maintenance and optimisation of maintenance cost);
- prepare a preventative action plan *(monitoring program, preventative maintenance strategy)* to be implemented to operate safely for the service life of Kriel Power Station: annual visit, routine procedure, further follow-up assessments, instrumentation if required; outage inspections and
- prioritise and identify urgent short-term activities that require immediate remedial action.

4. SUPPORTING CLAUSES

4.1 Scope

The ***Scope of Work for the Monitoring of Critical Structures in Kriel Power Station:*** includes the assessment of the Cooling Towers, Chimney Structures, Boiler Structure, coal staithes, and Turbine Buildings. The Employer requires the *Consultant* to perform detailed inspections and full structural assessment as well as providing a repair scope of work for the critical structures as defined above. The Critical Structures to be assessed include the following:

- Four (4) Cooling towers and the respective structural elements.
- Two (2) Chimney structures including and associated structural elements
- Two (2) Coal Staithes, concrete shell and supporting structural elements
- Six (6) Boiler Structures
- Six (6) turbine structures
- Six (6) Quenching and Blowdown Sumps
- Six (6) Boiler Bottom Ash sumps
- Twelve (12) Ash Pump bases

Based on the operations of the Kriel Power Station, several areas within the structures discussed above would either be inaccessible due to height limitations and normal generation processes or. During the detailed inspections and structural assessment, the *Consultant* is expected to perform the following tests:

- Readings of surface hardness.
- Depth of carbonation, tested at critical/ key points (Key points to be documented in method statement).
- Concrete strength by taking core samples.
- Concrete cover, tested at critical/ key points.
- Brick and mortar testing
- Potential half-cell method for corrosion testing.
- Sulphate/ Nitrate/Chloride attack.
- Environmental factors, as detailed below.
- Analysis of concrete samples (chemical analysis).
- Life expectancy under normal and abnormal conditions (e.g.: extreme chemical attack, major cracks, loss of concrete cover); and

3D laser scan survey and model to measure the deformations, possible settlement, and loading patterns of the as-built structures and report on the deformations found. Excessive deformations will be highlighted for further investigation.

The “Consultant” will be appointed for a period no longer than three (3) years.

4.1.1 Objective

Listed below are the main objectives of inspection/maintenance management of the critical structures at Kriel Power Station:

- To comply with the Occupational Health and Safety Act 85 of 1993 and the Construction Regulations 2014 inspections requirements
- To proactively prevent structural failures that may result in loss of life and financial loss.
- Providing a detailed reference point to be able to follow the ageing of the structure (periodical control) and warranty of their operability to end of asset life.
- From the list of recorded defects, prioritising the defects which should be repaired (remedial works) or monitored in short to medium term to plan and optimise maintenance costs.
- Based on the prioritised list of defects prepare a bill of quantities (BOQ) and cost estimates for immediate and urgent repairs.

4.1.2 Applicability

This document applies to Kriel Power Station.

4.2 NORMATIVE/INFORMATIVE REFERENCES

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

4.2.1 Normative References

(a) Civil and Building Works Strategic Report

(b) ISO 9001 Quality Management Systems

(c) Occupational Health and Safety Act 85 of 1998

(d) Construction regulations 2014

4.2.2 Informative References

[1] 240-105658000 - Supplier Quality Management Specification.

[2] 240-144332407 - Guideline for Eskom Power Stations Concrete Remedial Work

[3] 240-56364545 - Structural Design and Engineering Standard

[4] JN786-NSE-R-ESK-7953 Kriel Power Station Structural Inspection Report

[5] JN786-NSE-R-ESK-7956 KPS Coal Staithes Inspection

[6] JN786-NSE-R-ESK-7957 KPS Cooling Towers Inspection

[7] JN786-NSE-R-ESK-7958 KPS Smokestacks Inspection

[8] JN786-NSE-R-ESK-7959 KPS Boiler Units 1 to 6 Inspection

[9] ID 13888 – Quenching/ Blowdown Sump Report (Unit 3, July 2020)

4.3 ABBREVIATIONS

Table 1: Abbreviations

Abbreviation	Description
CoE	Centre of Excellence
ECSA	Engineering Council of South Africa
EDWL	Engineering Design Work Lead
OHS	Occupational Health and Safety
Pr. Eng.	Professional Engineer
Pr. Tech	Professional Technologist
QCP	Quality Control Plan

5. DEFINITIONS

For the purposes of this document, the following definitions will apply:

Employer: Kriel Power Station and, by extension, Eskom will be referred to as the Employer. The Employer will appoint a representative to manage and ensure the Employers interests are protected.

System Engineer: The person designated by the Employer as having engineering responsibility for the affected plant or infrastructure.

Plant Engineer: Is a person designated by the Client as having engineering responsibility for a specific plant.

Civil or Structural Engineering Designer: An Engineer specialising in the Civil or Structural Engineering field, having experience in the design and construction of Civil or Structural Engineering infrastructure.

Competent Person: A person who has in respect of the work or task to be performed; required knowledge, training; experience and where applicable; qualifications specific to that work or task (Construction Regulations, 2014).

Consultant: Refers to the service provider who has been appointed to provide professional services in the assessment of critical structures.

Registered Person: An Engineer or Engineering Technologist registered with ECSA, specialising in, and having experience in, the design of respective civil engineering assets.

Inspector: A civil or structural Designer, Plant Engineer or Plant Foreman who have been specifically trained in how to conduct structural inspections and has experience in structural inspections.

Safety Critical item: A safety item is any asset element where the deteriorated condition constitutes an immediate risk to the safety of personnel in the plant.

The Act: The act refers to the Occupational Health and Safety Act 85 of 1993

6. MOTIVATION AND OBJECTIVES

When civil engineering related infrastructure are designed, relevance is given to its stability and durability taking into consideration the life of the assets, its environment and maintenance. It is also assumed that it will be properly maintained during its life. As with any infrastructure within the built environment, during the service life of the structural assets, structures will be subjected to an array of factors that would generally affect the integrity of the structure if such effects are not timeously identified and addressed. These factors include, but not limited to, the following:

- Cyclic loading- this can result in material deformations
- Environmental factors – Exposure to extreme weather conditions and highly corrosive environments
- Impact loads – Deformations to structures due to impacts during regular maintenance.

The motivation for the monitoring of critical structures at Kriel Power station is to detect potential structural decay that could have adverse impacts on the health and safety of exposed persons, the environment, and production at Kriel Power Station. The objective of this scope of works is to ultimately identify maintenance requirements and provide the necessary preventative maintenance solutions for the critical structures at Kriel Power Station.

6.1 SAFETY AND LEGISLATION

By legislation, owners of structures are required to conduct inspections of all structures during the life of the plant asset in terms of the OSHA Construction regulations.

The OHS Act in Regulation R 1010 of 18/07/2003 states the following:

"(4) Any owner of a structure shall ensure that inspections of that structure upon completion are carried out periodically by competent persons in order to render the structure safe for continued use:

Provided that the inspections are carried out at least once every six months for the first two years and thereafter yearly and records of such inspections are kept and made available to an inspector upon request."

Construction Regulations (2014) with regards to existing structures Regulation 11(2) states that "An owner of a structure must ensure that:

(a) inspections of that structure are carried out periodically by competent persons in order to render the structure safe for continued use;

(b) that the inspections contemplated in sub-regulation (a) are carried out at least once every six months for the first two years and thereafter yearly;

(c) the structure is maintained in such a manner that it remains safe for continued use;

(d) the records of inspections and maintenance are kept and made available on request to an inspector."

6.2 INSPECTIONS OBJECTIVES

The primary objective of conducting inspections and the development of maintenance management strategy is to assess the current condition of civil engineering assets with reference to their strength and condition and to ensure that appropriate maintenance is carried out where significant deterioration has occurred. The secondary objective may be related to the development of civil and structural engineering maintenance budgets. This is done by comparing the current condition of the assets with its original condition (or reference point condition), and specifying what is necessary to maintain the safe structural integrity.

It is envisaged that the Consultant will conduct comprehensive inspections based on the requirements outlined in the ensuing subsections or guided by their experience, in the interest of meeting the requirements of “the Act”. The Consultant will be required to compile and submit a comprehensive annual report for the assessment of critical structures in Kriel Power Station for a period, no longer than three (3) years. In addition to the above, where the severity of deterioration of a structural element has reached critical levels, the Consultant will be required to provide interim reports that provide recommendations of the required repairs.

The report shall indicate, depending on the type of the asset to be inspected, how the inspection was carried out, supported by photographs and sketches; it must provide recommendations on possible repair methods. The investigation and report must be sufficiently detailed to allow for adequate maintenance to commence or to deem the structure structural sound and safe to operate. Where access is limited due to station processes, provision for further inspections during planned outages will be arranged.

7. GENERAL INSPECTION AND MONITORING REQUIREMENTS

The fundamental purpose of Power Station inspections is to confirm that the plant remains safe to use productively.

7.1 STRUCTURE HEALTH MONITORING STRATEGY

The main objective of preventive maintenance is to detect, quantify and localise any defects which can affect in a short, medium and long term the structural integrity of a structure. To meet this objective means recording and quantifying at the same time, **all the significant defects** as well as **any evolution of the defect.** It is only the evolution of a cracking pattern or corrosion mechanism that could alert and prevent any risk of structural impact which could occur in the next years. To be able to record this evolution, to compare one state with another, sufficient information should be captured (identification, location, and characterisation) of each defect.

Also, it is only with a full record of all the defects that a **structural health indicator can be established** for comparison with a structural zone, the whole structure or to benchmark with international reference data.

This full data system (identification, characterisation, location) will provide the required information to also quantify, specify and supervise any repair work.

To follow the ageing of a structure a **full and complete mapping and characterisation of each apparent defect** has to be performed. This means acquiring data of each defect in order to estimate the present structural health of the structure. These methods provide the opportunity to control any evolution of a defect of the structure from its current state and will provide a good support/reference for any preventive maintenance to be implemented. This means that:

- Inspections needs to be **"exhaustive"** and each defect **precisely localised** (in order to be able to look at them again in the next few years or decades), **well characterised and pictured** (in order to notice any evolution). Each visual inspection deliverable should include a reference map of defects.
- The methods should be based on inspection procedures to deliver a reference point with an accurate and exhaustive bill of defects (quantity, size, characteristics) in order to not only build a **robust and economical strategy for maintenance and repair work** but also further monitoring in order to save costs.

7.2 PREVIOUS REPORTS

Because it is only the evolution of a cracking pattern or corrosion mechanism that could alert and prevent any risk of structural impact it is important to study previous reports in order to establish which information, if any, could be used to track this evolution. It must be noted that there might be gaps in historical reports that the Employer will provide. Where reports are not available, the appointed consultant will be expected to treat the investigation as a new investigation with no historical data.

7.3 GEOGRAPHIC INFORMATION SYSTEM (GIS)

In order to detect, quantify and localise any defects which can affect in a short, medium and long term the integrity of the structure means that a comprehensive data management system should be established. Referencing spatial data with field data will further assist with the management of the system. A Geographic Information System (GIS) is an ideal tool to achieve this. The GIS system could then also be used to query, sort and abstract relevant data for the planning and development of maintenance programme going forward.

Should a GIS System be used then all the data could be merged with different layers. For instance;

- One layer could contain HD pictures adapted to become a scaled picture, also called "orthophoto"
- Another layer could contain all the defects as per the inspection.

Data should then be geo-referenced. This means that every defect is accurately located as well as its features (length, crack-width, etc.):

- Total length of cracks.
- Total length of corroded bars.
- Number of corroded bars.
- Number of cracks presenting a length superior to a given length.
- Total length cracks presenting a width superior to a given crack-width.

This information then allows conducting statistical evaluations and to calculate health indicators of the asset (to benchmarks with global reference database, etc.)

7.4 CONDITION CATEGORIES

In order to ensure consistency of reporting and common understanding of the severity of deterioration of plant structures, six condition categories are used, as defined in Table 2.

Table 2**: Condition Categories**

Category	**Description**	**% Original Strength**	**Typical Remedial Action**
0	The plant assets are in excellent condition with no deterioration evident. Safe use of the plant assets is assured.	100	None Required
1	The plant assets have slight evidence of surface deterioration, but to an extent that there is no reduction in strength.	100	None Required
2	The plant assets have some deterioration to an extent that there is slight reduction in strength. Safe use of the plant assets is assured.	95-100	Repaint, tighten bolts, other minor work
3	The plant assets show deterioration, to an extent that there is some reduction in strength. There is some compromise to safe use of the plant structure. Repair must receive attention in maintenance scheduling.	75-95	Repair, repaint, tighten bolts, other minor work
4	The plant assets show severe deterioration, to an extent that there is a major reduction in strength. Safe use of the plant is severely compromised. Urgent attention must be given to repair.	50-75	Repair or replace components
5	The plant assets show severe deterioration, to an extent that they have little useful residual strength. Safe use of the plant is impossible. Urgent attention must be given to repair.	< 50	Repair or replacement of components required urgently

7.5 VISUAL INSPECTIONS SPECIFIC SAFETY

The purpose of this section is to define safety requirements for a visual inspection.

7.5.1 Accompanying Person

When the visual inspection is carried out by any person who is not normally employed on the plant, the "Employer" will provide an Engineer; who is familiar with the plant being inspected. The Engineer provided by the Employer will be required to accompany the "Consultant" to areas that have restricted access on the first inspection. For the preceding inspections, it would be assumed that the Consultant has adequately familiarized themselves with the site. The "Consultant" will be required to undergo inductions and adhere to all safety requirements applicable to Kriel Power Station and Eskom in general. All necessary permits are to be obtained prior to accessing any restricted area, in line with the Kriel Power Station requirements.

7.5.2 Induction

Where an induction is required, the "Employer" will advise the "Consultant" of all induction requirements and processes within a reasonable time. The "Employer" will communicate requirements for personal protective equipment to the "Consultant" for the various areas to be accessed.

7.5.3 Risk Assessment

The "Consultant" conducting the visual inspection must also conduct a risk assessment prior to commencement of the inspection, to identify any hazards and risks that may be encountered, and to develop risk mitigation measures.

7.5.4 Access and Lighting

The visual inspection will generally be conducted from the ground or from easily accessible floors, stairs, and walkways. Where access is required to inspect inaccessible or hidden areas, the "Employer" will provide safe access in line with Kriel Power Station requirements and "the Act". All inspections conducted to be conducted will commence only with prior notification of the "Employer" by the "Consultant". No inspection will commence where the necessary safety requirements are in doubt or have not been confirmed.

Where access is required during outages, the Employer will make provisions for the necessary permits to be provided to the appointed Consultant. The lighting provided by the client will be based primarily on outage requirements. Additional lighting requirements will be agreed upon with the Employer once such areas have been accessed.

8. STRUCTURAL INSPECTIONS

8.1 COOLING TOWERS

The cooling tower system comprises of the following structures:

- Cooling Towers 1 and 2, located on the northern side of the power station
- Cooling towers 3 and 4, located on the southern side of the power station

The cooling system also comprises 2 cooling pump houses, with 1 pumphouse located on either ends of the station.

8.1.1 Description

The cooling system in use at Kriel Power Station is a wet cooling system. A wet-cooling system follows the counter-flow concept in which air flows upward through the fill section and interfaces counter-currently with falling hot water.

Typically cooling towers are measured at the foundation annular ring beam. The foundation ring beams are typically supported on augered reinforced concrete piles as in the case of Kriel Power Station. In other cases they may be supported by mass concrete bases under diagonal columns taken to the bedrock.

Typically pond floors, in areas of made-up or back-filled ground, are supported on augered piles.

Based on the age of the Power Station and the deficiencies in storage of historical records, drawings will be issued based on their availability. Typical layout and elevation of the power station's cooling towers will be made available on building plans/contract drawings, if available. Power Station reinforcement drawings, which illustrate the typical reinforcement arrangement both at the columns and the shell, can be made available on request.

8.1.2 Typical Problems in Cooling Tower Structures

The mode of operation will certainly have an effect on the structural performance. Frequency of starting and shutdown as well as low-load operation has an impact on the concrete exposure conditions and will influence the long-term performance of the concrete.

The reinforcement on the cooling tower shell contributes to factors such as crack control of due to temperature differential, lateral loads such as wind and seismic loads. Severe reduction in the steel area due to corrosion, or a drastic decrease of the concrete section because of spalling, which would ultimately compromise the integrity of the structure.

It is relevant to highlight some of the possible stress-related problems in cooling tower structures.

The hyperbolic shape of a cooling tower is rather a constructional than a thermal parameter. Membrane forces essentially take up the self-weight and the wind loads. The cooling towers are, therefore, very sensitive to geometric imperfections. These imperfections disturb the stress pattern and result in high local compressive and tensile stresses, which may cause cracking.

The skirt of a cooling tower's shell is only supported at concentrated points. High local stresses will cause edge shearing strain, which may lead to a state of distress, if disregarded.

The hyperbolic shell is also very sensitive to differential settlement of the foundations. Differential settlement will induce partial edge effects, which, according to research in cooling towers of this magnitude, could spread up to 1/20 to 1/5 of the height of the tower.

Temperature variations, and in particular differential temperatures across the thickness of the shell wall, can also cause considerable stresses. Apart from exposure, the degree to which these stresses result in structural problems will also depend on the quality of the concrete and, in particular, on the type of aggregate employed.

8.1.3 Inspections

Visual inspections should be performed on all cooling towers up to a height not exceeding 10m; above this height, mechanised systems, such as drones, should be used. The visual inspection shall comprise of:

(a) Inlet structure

(b) Shell

- Outer and Inner surface for the first;
- Where access is limited, the consultant must implement mechanisms such as drones to capture images of the shell's structural conditions.

(c) Supporting columns.

(d) Cooling pond wall

- Water distribution channels.
- Packing and drift eliminators supports.
- Outlet structures

(e) Walkways.

(f) Cooling Pond floor – only applicable in cases where production is reduced, and ponds are emptied.

(g) Assess Crawl beam and supporting structure for structural integrity and advise on loading adequacy

Photographic records should be compiled to assist and document the inspection. Observations should be referenced to the photographs.

Typically inspections of cooling towers should include, but not limited to, the following:

(a) Check for major geometrical imperfections in any of the cooling tower shells. Edge shearing strain effects will generally be noticeable in cooling towers and manifested in the form of hairline bending cracks at the skirt level. These may be of lessor concern.

(b) Check for signs of cracks in the shell. Cracking at the skirting is usually specifically ascribed to temperature from solar radiation. Shells are generally provided with reinforcement at both faces (some of the old cooling towers are reinforced with a single layer of reinforcing placed in the centre of the shell) to cater for horizontal bending moments that could be caused by the distribution of wind pressure and/or an uneven rise in temperature. Localised bulging; meridianal bulging; as well as circumferential bulging due to bad setting out of shutters during construction; may be evident. Large meridianal or vertical cracks in the shell will be cause for concern. Cracking on the outer surface of the shell, attributable to inadequate concrete compaction, may also be evident. In addition, during concrete casting, large aggregate may have been retained between the upper shutter and the diagonal reinforcement and, as a result, voids could have formed underneath it. From these voids hairline cracks might develop and propagate to the surface.

(c) Check for water seeping through the shell. This takes place where grout leakage has occurred, and generally occurs at the horizontal construction joints at the concrete casting lifts. It can be particularly noticeable on the negative slopes.

(d) Check for any signs of localised spalling. Spalling is typically more evident lower in the shell and up to the sixth construction ring. The probable cause is reduced cover in parts of the shell where the reinforcement is very congested. The typical concrete cover on the outer surface of the shell should be established from the drawings.

(e) Check the cooling tower components for signs of biochemical attack by algae or other micro-organisms.

(f) Check the condition of the shell-supporting columns. Where scale deposits (presumably calcium sulphate) are evident on the surface; this is caused by wind-driven falling water. It may then be necessary to scratch the surface with a sharp instrument in order to reveal the quality of the concrete underneath. Concrete samples are usually sent to a laboratory to analyse the percentage of sulphate in the concrete. Check for cracks in the columns and plinths or column blocks. Some columns may display minor cracks. Concrete spalling may be evident because of the small cover provided to the hoop steel.

(g) Check the joints between the foundation and the cooling water duct inlets for spalling. Check for visible signs of sandpaper texture formation as a result of condensate attack.

(h) Check water-distribution channels and drainage trenches for blockages by grass, leaves and other debris.

(i) Check the condition of the packing support structure. Check the condition of column and beam system supporting the drift eliminators for any awkward eccentricities or movement caused by the volume changes in the louvers. Check damage to the fill, distribution pipes or sprayers. Misalignment can result from a best-achievable fit at the time of construction. In such cases, check for visible sliding movement at the interface. Also swelling of asbestos components can push the ribbed beams away from their original position. Check for blockage of drift eliminators because of algae growth. Check for localised spalling in the precast columns. Check for cracks in the connections of bracing components. As the drift eliminators expand during the normal operation of the cooling tower, and contract when not in operation, check whether the allowance for expansion has been reached and whether the drift eliminators bear directly onto the eliminator support beams. (Any movement in the drift eliminators may then result in a lateral push on the support beam and over a period, especially during periods of rapid expansion immediately after an outage, and the induced force may be sufficient to push the support beam from its support.)

(j) Check safety of walkways, handrails and cat ladders, even though safety issues are regarded as a part of the normal plant operating procedures. Check whether walkway support beams rest fully on their supports, or whether they slide on them. If in timber, deterioration is usually the result of the intermittent dry and wet conditions experienced.

(k) Assess the pond wall and the precast packing supports. If the cooling pond is emptied for the purpose of inspection, check the pond walls for shrinkage cracks. Pond wall expansion joints generally require replacement at certain intervals. Check the pond floor slab for cracks.

8.1.4 Vertical cracks — Possible causes

Vertical cracks in the top third of cooling towers tend to occur as a consequence of wind-induced vibration; foundation movements; and thermal conditions inherent in the operation of the towers.

There are many unknown factors affecting a Cooling Tower, which could in fact affect the integrity and result in of the collapse of the structure.

The principal factors are:

- The wind speed on its own is already an uncertainty:
- The wind uprating factor, which is applied to the tower, may be different. The Design Engineer normally decides on this value from certain values, which are given in the Code.
- The distribution of the wind around the tower could be influenced by the position of the towers and the materials of the tower could differ from those accepted i.e. the crushing and tensile strength of the concrete; the effect of the reinforcing on the concrete; and the reinforcing on its own.
- The lengths, depths and spacing of the existing vertical cracks in the shell.

8.1.5 Non-destructive Testing (NDT)

A representative sample of NDT testing is required for each structure. These tests shall comprise of but not limited to the following:

- Concrete Surface Hardness
- Concrete cover to reinforcement
- Depth of Carbonation
- Sulphate attack
- Concrete Strength of Cored Samples
- Chemical Tests on the Cooling Water and Condensate
- Chemical tests of concrete samples.
- GPR Scanning, or similar approved.

8.2 CHIMNEY STRUCTURES

8.2.1 Description

Kriel Power Station has two chimney structures, referred to as the north and south smokestacks, that service three generating units each. The Chimney Structures consist of a concrete shell, with an interior brick-lining supported at regular intervals on corbels on the shell. A non-accessible air space exists between shell and lining. Kriel Power Station has two chimneys (referred to as South and North) each serving three generating units. Each structure has a total height of 213m above the ground level.

At Kriel Power Station access to the top of chimneys is provided by means of a cat-ladder attached to the external concrete shell. Many of Eskom's chimney shells were cast in rings by means of a climbing formwork system in 1.20m high sections. The shell has a cylindrical shape at the base and rests on a ring-shaped foundation. The annular ring beam is founded on a piled foundation.

The brickwork lining was constructed in free-standing cylindrical lifts. These lining lifts are supported directly on concrete corbels in the shell. Where the quality of the brick is not specified on drawings, it is assumed that high quality acid resistant bricks laid in acid resistant cement mortar were used. The minimum space between the lining and the shell differs from station to station and typically varies between 60mm and 115mm. Cast-iron capping rings are provided at the top of the chimneys. The chimneys are also equipped with lightning protection.

8.2.2 Typical Problems in Chimney Structures

Some of the specific problems as well as the possible problems that may be encountered in chimney structures are:

(a) A sudden high rise in flue gas temperature leads to a fluctuating transmission of heat through the brick lining. As a result of uneven heating and large temperature gradients through the brick lining, ultimate stress values can be exceeded and cracks may develop.

(b) Should flue gas temperature drop below its dew point, acid attack of the bricks, and especially the mortar, may take place. The severity of the attack depends on operating conditions and particularly on the frequency of start-ups and shutdowns.

(c) During certain operating conditions, especially during start-ups, over-pressure in the flue can result. Flue gases can penetrate the structure through corroded spots in the brick lining; gaps at expansion joints; or through cracks; and cause excessive thermal stresses in the shell.

(d) Fly ash may also enter the space between lining and shell and cause cold spots, which can lead to acid condensation and subsequent deterioration of the concrete.

(e) Under certain operating conditions, a flue gas plume is blown onto the concrete windshield and, as a result, downwash of flue gasses occurs on the top portion of the windshield. Acid attack at the outer surface of the concrete on the top 20m to 30m of the windshield may then take place as a consequence off this downwash.

(f) Cracking of the windshield, as a result of uneven distribution of temperature or ovalisation due to the harmonic motion of the wind, may occur.

(g) Signs of distress in the windshield as a result of local stresses at the corbels, or at other concrete sections weakened by corrosion, are also traditional problems.

(h) Flaking or scaling of the brick lining could indicate that serious corrosion is in process.

8.2.3 Inspections

The aim of this inspection is to locate all possible degradation peculiar to chimney structures and their operational environmental conditions.

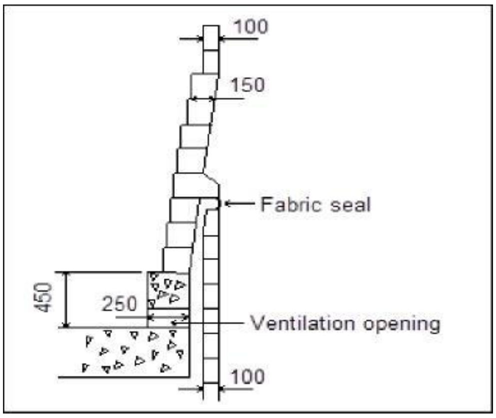

Figure 1: Typical cross section of a flue lift at support slab level

The following elements are generally included in the visual inspection:

- the concrete windshield;
- the brick cap;
- the lightning protection system;
- the steel inlet duct into the chimney;
- the brick lining.

Both external and internal inspections are undertaken.

8.2.3.1 External Inspections

The external structure can be visually inspected up to 10m at most. Due to the age of the structure and the need to ensure that there is adequate information for any remedial works to be conducted, the Consultant will be required to provide mechanised alternatives, such as remote-controlled drones or other mechanism approved by the Employer.

8.2.3.2 Internal Inspections

The Chimney structures service three units each and the only time internal inspections can be carried out, to the full extents of the internal structure, is during half station shutdown. These are generally undesirable and rare shutdowns that provide a small window of opportunity to inspect the internal structure.

Based on the possibility of unreasonable time frames to obtain resources; inspections during half station shutdown, will be at the Consultant's discretion, if the Employer could not notify the Consultant within a reasonable time frame.

The Consultant is still required to carry out internal inspections where access is not dependent on outages or half station shutdown.

8.2.4 Testing

NDT, as detailed in Section 8.1.5 above, will be required for the accessible areas of the Chimney structure. Where information on concrete strength is not available, the Consultant will be required to carry out concrete coring for sampling purposes.

8.3 BOILER AND TURBINE HOUSE: EXTERNAL FACE MAPPING

In addition to the critical structural assessment, and to assist the maintenance department with repairs, a general panoramic view of the external facing of the main building (boiler and turbine house) will be conducted. A coloured laser-scan cloud points should be used to detect any disconnections, rupture or corrosion of outer metal cladding, windows and external elements (current maintenance quantification). Turbine house structures.

8.3.1 Boiler Structure

The assessment of the boiler structure must be conducted in two phases. These phases include the following:

- External boiler structure.

- Internal boiler structure

The internal boiler structural assessment requires the respective unit to be offload. The Consultant is therefore required to make provision for inspections during planned outages. The Employer will provide the Consultant, within reasonable time, the planned outage schedule.

Should an unplanned outage occur for a unit that has not been inspected or is not scheduled for outage within the required annual inspection, the Employer will advise the Consultant of such an outage. Based on the possibility of unreasonable time frames to obtain resources, inspections during unplanned outages will be at the Consultant's discretion

8.4 Coal Staithes

A detailed structural investigation of the coal staithes will be required from the appointed Consultant. The Consultant is required to provide NDT tests as detailed in Section 8.1.5 of this scope of works. In addition to the NDT, the Consultant will be required to obtain concrete cores for sampling purposes on various sections of the Coal Staithes. The Consultant "must" also provide conditional assessments for the structural steel elements within the Coal Staithes.

9. QUALITY REQUIREMENTS:

9.1 Method Statement

The "Consultant" must develop a detailed Method Statement for each component of the work to be assessed. The method statement must be approved by the "Employer" prior to the commencement of any activity.

9.2 Quality Control Plan

The Consultant must develop a detailed quality control plan for the complete *works.* The Employer will approve the quality plan before any work commences. The quality control plan should also contain a detailed programme for all the identified activities to complete the inspections within the annual inspection. A revised programme is to be provided at the beginning of each calendar year.

The Employer will witness all tests and inspections and sign of the relevant documentation before the next phase of work commences.

9.3 Documentation and Record Drawings

The Consultant shall submit a signed (by competent person) detail inspection report in PDF and hardcopy format to the Employer*.* The *Service Provider* shall also submit the captured data together with the data management system (GIS) to the Plant Engineer.

10. SHE REQUIREMENTS

(a) The *"Consultant"* is required to ensure safety awareness at all times through continuous training.

(b) The *"Consultant"* is appointed to act on behalf of the *"Employer"* in terms of "the Act" for this contract.

(c) The staff of the "Consultant" are required to comply with the Eskom health and safety requirements specific to Kriel Power Station

(d) The *"Consultant"* is required to comply with the "SHE Requirements for the Eskom Commercial Process", 32726 Rev 1.

(e) The *"Consultant"* is also required to comply with the Eskom "SHE Specification Template", 32-524 Rev 0.

(f) The *"Consultant"* and all his personnel are required to attend a Health and Safety Induction Course prior to starting with the *Works.*

(g) In carrying out its obligations in terms of this contract; in providing the *Works;* in using Plant, Materials and Equipment; and while at the Site for any reason, the *"Consultant"* is required to comply and ensure compliance by its employees, agents, Sub -Service Providers and mandatory with:

- The provisions of "the Act" (as amended) and all regulations in force from time to time in terms of that Act; and
- The Eskom "Safety, Health and Environmental Requirements for *Service Providers"* document attached to the *Works* Information (as amended from time to time) and such other Eskom Safety Regulations as are applicable to the *Works* and are provided in writing to the *"Consultant"* (collectively "the Eskom Regulations"). The Eskom Regulations may be amended from time to time by the *"Employer"* and all amendments will be provided in writing to the *"Consultant".* The *"Consultant"* must comply with the provisions of the latest written version of the Eskom Regulations with which it has been provided; and
- The health and safety plan prepared by the *Service Provider* in accordance with the SHEQ Requirements.

(h) The *"Consultant",* at all times, consider itself to be the *"Employer"* for the purposes of "the Act" and does not consider itself under the supervision or management of the *"Employer"* with regard to compliance with the SHEQ Requirements. The *"Consultant"* furthermore does not consider itself to be a subordinate or under the supervision of the *"Employer"* in respect of these matters. The *"Consultant"* is, at all times, responsible for the supervision of its employees, agents, subcontractors and mandatory's and takes full responsibility and accountability for ensuring that they are competent, aware of the SHEQ Requirements and execute the *Works* in accordance with the SHEQ Requirements.

(i) The *"Consultant"* ensures that all statutory appointments and appointments required by any Eskom Regulations are made and that all appointees fully understand their responsibilities and are trained and competent to execute their duties. The *"Consultant"* supervises the execution of their duties by all such appointees.

(j) The *"Employer";* or any person appointed by the *"Employer",* may, at any stage during the currency of this contract:

- Conduct health and safety audits regarding all aspects of compliance with the SHEQ requirements, at any on-site place of work.
- Refuse any employee, subcontractor or agent of the "*Consultant"* access to the premises if such person has been found to commit an unsafe act or any unsafe working practice or is found not to be qualified or authorised in terms of the SHEQ Requirements;

- Issue the *"Consultant"* with a stop order should the *"Employer"* become aware of any unsafe working procedure or condition or any non-compliance with any provision of the SHEQ Requirements.

(k) The *"Consultant"* immediately reports any disabling injury as well as any threat to health or safety of which it becomes aware at the *Works* or on the Site.

(l) The *"Consultant"* is required to appoint a person, qualified in accordance with the SHEQ Requirements, as the liaison with the Eskom Safety Officer for all matters related to health and safety.

(m) The *"Consultant"* confirms that it has been provided with sufficient written information regarding the health and safety arrangements and procedures applicable to the *Works* to ensure compliance by it and all employees, agents, subcontractors or mandatory with the SHEQ Requirements while providing the *Works* in terms of this contract. As such, the *"Consultant"* confirms that this contract and the relevant Eskom Regulations referred to in this contract constitute written arrangements and procedures between themselves and the *"Employer"* regarding health and safety for the purposes of section 37(2) of "the Act".

(n) The *"Consultant"* agrees that the *"Employer"* is relieved of any and all of its responsibilities and liabilities in terms of Section 37(1) of "the Act" in respect of any acts or omissions of the *"Consultant",* and their employees, agents or subcontractors, to the extent permitted by the "the Act"..

(o) The *"Consultant"* hereby indemnifies the *"Employer"* and holds the *"Employer"* harmless in respect of any and all loss, costs, claims, demands, liabilities, damage, penalties or expense that may be made against and/or suffered or incurred by the *"Employer"* (as the case may be) as a result of, any failure of the *"Consultant";* its employees, agents, subcontractors and/or mandatory to comply with their obligations in terms of this clause, and/or the failure of the *"Employer"* to procure the compliance by the *"Consultant",* its employees, agents, subcontractors and/or mandatory with their responsibilities and/or obligations in terms of or arising from *"the Act"*.

11. SCHEDULE OF QUANTITIES

ITEM NO.	DESCRIPTION	RESOURCES								
		Project Director (hrs)	Rate/hr	Senior Structural Engineer (hrs)	Rate/hr	Structural Engineer (hrs)	Rate/hr	Civil Technician (hrs)	Rate/hr	**Total Amount (R)**
1	**PROJECT INCEPTION**									
1.1	Initial Site visit	6		6		6		6		
1.2	Project planning	4		18		18		0		
	Sub-Total A		R		R		R		R	**R**
2	**COOLING TOWER INSPECTIONS**									
2.1	Visual inspection	0		0		96		96		
2.2	Testing Supervision	0		6		6		12		
2.3	Proposed Remedial measures including costing	0		6		18		3		
	Sub-Total B		R		R		R		R	**R**
3	**CHIMNEY INSPECTIONS**									
3.1	Visual inspection	0		0		48		48		
3.2	Testing Supervision	0		0		6		12		
	Proposed Remedial measures including costing	0		12		32		3		
	Sub-Total C		R		R		R		R	**R**
4	**BOILER & TURBINE HOUSE: EXTERNAL FACE MAPPING**			`						
4.1	Visual inspection	0		0		144		144		
4.2	Testing Supervision	0		0		24		24		

4.3	Proposed Remedial measures including costing	0		6		48		12		
	Sub-Total D		R		R		R		R	**R**
5	**COAL STAITHES**									
5.1	Visual inspection	0		0		48		72		
5.2	Testing Supervision	0		0		24		24		
5.3	Proposed Remedial measures including costing	0		48		24		6		
	Sub Total E		R		R		R		R	**R**
6	**BOILER STRUCTURE**									
6.1	Visual inspection	0		12		108		144		
6.2	Testing Supervision	0		0		24		24		
6.3	Proposed Remedial measures including costing	0		12		36		6		
	Sub-Total F		R		R		R		R	**R**
7	**REPORTING**									
7.1	Compilation of Annual Report	2		24		72		18		
7.2	Internal Review	8		24		24		24		
7.3	Client Review	6		6		24		24		
7.4	Incoporating Client Comments	6		12		24		24		
7.5	Final Submission	3		3		3		0		
	Total Hours	**35**		**201**		**1073**		**906**		
	Sub-Total G		R		R		R		R	**R**
7	**DISBUREMENTS**	**UNIT**	**QUANTITY**	**RATE**						
7.1	Travelling	km	2500							R

7.2	Accommodation within 100km of site	day	75			R
7.3	Subsistence	day	75			R
7.4	Printing and binding	Sum	3			
7.5	Specialist Testing (NDT and DT)	Sum	3			
7.6	Specialist monitoring Equipment (incl. drones)	Sum	3			
					Sub-Total	**R**
					Contingencies (10%)	R
					Sub-total 1	R
					VAT (15%)	R
					Total	**R**

12. AUTHORISATION

Name & Surname	Designation
Sanele Msibi	Senior Civil Engineer – Kriel Power Station
Neo Muthavhine	Auxiliary Plants Engineering Manager- Kriel Power Station
Rofhiwa Nelwamondo	Engineering Manager - Kriel Power Station

13. REVISIONS

Date	Rev.	Compiler	Remarks
March 2023	0.0	S Msibi	Revised document for review
March 2023	1.0	S Msibi	For signatures
August 2023	1.1	S. Msibi	Scope reduction and activity schedule amendments

14. DEVELOPMENT TEAM

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

Sanele Msibi

15. ACKNOWLEDGEMENTS

FJ Olivier for the Kriel Power Station Monitoring of Critical Structures: Cooling Towers, Chimney Structures and Outside Face of Boiler and Turbine Buildings scope of works document EAP0386