AFRO 4000 LOCOMOTIVES : INSPECTION AND VERIFICATION REPORT		
REFERENCE	**RSR/INSPECTION/AFRO 4000/MWC550**	
OPERATOR	**PASSENGER RAIL AGENCY OF SOUTH AFRICA (PRASA)**	
INSPECTION AND VERIFICATION	**INSPECTIONS AND TESTS FOR THE AFRO 4000 LOCOMOTIVES**	
INSPECTION AND VERIFICATION DATE	**November 2015**	
INSPECTION AND TEAM	**TEAM MEMBERS**	**SIGNATURE**
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Contents

Definitions

Abrasion:	Means a wear due to contact between two surfaces;
Anthropometric:	means a measurement of the human individual
Bogie:	Means a structure underneath a locomotive frame to which the wheels and axles are attached;
Cape gauge:	Means a railway track where the distance between the tracks is 1067 mm;
Derailment:	Means a disturbance between wheel and rail interaction which results in a train moving out of the track;
Flashover:	Means the near-simultaneous ignition of directly exposed material;
Hybrid/Dual locomotive:	Means a locomotive with two propulsion systems i.e. diesel and electric power or Direct Current (DC) and Alternating Current (AC) power;
MINIPROF:	Means a Wheel Profile Measuring System;
Rolling Stock:	Means a locomotives, wagons or coaches that travel on rail tracks;
Slack:	Means a weak area on the track where the formation is unbalanced;
Standard gauge:	Means a railway track where the distance between the tracks is 1435 mm;
Tamping:	Means a packing of the track ballast under railway tracks to make the track more durable;
Vehicle gauge:	Means a structure indicating the tolerances allowed for rolling stock operating in a network
Vossloh Espana:	Means a Spanish locomotive manufacturer

Acronyms

AC	Alternating Current
CEO	Chief Executive Officer
DC	Direct Current
HL	Hazard Log
kV	kilovolts
LCM	Life Cycle Management
MLPS	Main Line Passenger Services
OHTE	Overhead Traction Equipment
POC	Point of Contract
PRASA	Passenger Railway Agency of South Africa
Qr	Flanged Gradient or flange toe Radius
RA	Risk Assessment
RS	Rolling Stock
RSR Act	National Railway Safety Regulator Act 16 of 2002 as amended
RSR	Railway Safety Regulator
SANS	South African National Standards
SARCC	South Africa Rail Commuter Corporation
TCO	Train Control Officer
TE	Transnet Engineering
TFR	Transnet Freight Rail
TWR	Train Working Rules
URS	User Requirements Specification
YQ	Trip Authorisation Certificate

EXECUTIVE SUMMARY

The Railway Safety Regulator, (RSR) in terms of the National Railway Safety Regulator Act 16 of 2002 ("the Act") as amended, is mandated to oversee safety of railway transport, while operators remain responsible for such safety within their areas of responsibility.

This report covers the technology review process followed by the RSR as it pertains to the AFRO 4000 fleet of diesel locomotives. It also covers an investigation into the impact of a deviation in the form of the AFRO 4000 fleet exceeding the vehicle gauge height on South African networks. The purpose of the exercise is to ensure that the locomotives will operate safely in all the areas where they will be deployed by PRASA's Main Line Passenger Services (MLPS).

RSR processes include submission of documents from permit and non-permit holders from the conceptual stage of each and every project. This report details the submissions from PRASA which, in this case, did not follow the required processes during the procurement of the AFRO 4000 series of diesel locomotives. Notwithstanding that the RSR received a statement of intent from PRASA stating its plan to procure Euro 4000 locomotives on 13 March 2014, it has since become apparent that the locomotives had already been purchased by this date.

The RSR conducted inspections and testing of the 12 locomotives in the AFRO 4000 series. Such inspections and tests were conducted at different locations of the railway network. These inspections were limited to the 25kV lines. The findings of the inspection and verification exercise are as follows:

- Abrasion marks were found on the roofs of the locomotives, indicating that contact or flashover occurred during testing;
- The cabin design is deemed not suitable for the South African operating conditions based on the location of the seats;
- There is no evidence of an existing maintenance contract to support the locomotives during the testing and commissioning process and beyond deployment; and
- Of the 13 locomotives, only one is equipped with a radio communication system.

The results of the inspection and assessment confirm that the AFRO 4000 series of locomotives is designed and manufactured to a height of 4140mm above rail head. This height exceeds the vehicle structure gauge height of 3965mm as required in the Transnet Freight Rail track maintenance manual. The impact of this deviation is that there is a greater risk of interference between Overhead Traction Equipment and the locomotive.

Accordingly, the RSR approves the deployment of the AFRO 4000 series on the 25kV lines in the Free State, Northern Cape and Eastern Cape provided that the conditions highlighted in the assessment are met. The RSR reiterates that all the safety critical items identified and communicated with PRASA in this report must be addressed before an operating licence can be granted for the locomotives to be operated on the South African network. These include the successful completion of the tunnel tests and the acceptance of the results by the RSR, cab ergonomics analysis – all of which must be submitted to the RSR for evaluation and assessment purposes.

With the exception of locomotive height limitations in certain areas of the network and subject to the highlighted conditions in this report, the PRASA AFRO 4000 series locomotives posess acceptable performance capabilities to operate in the South African network.

1. INTRODUCTION

The AFRO 4000 series of diesel locomotives was purchased by the Passenger Rail of South Africa (PRASA) from Vossloh Espana. The first locomotive arrived in South Africa in December of 2014. To date, there are 13 AFRO 4000 locomotives that are in the country and it is expected that seven more will be delivered before the end of 2015. The locomotives are manufactured to a height of 4140mm above rail with new wheels and new springs. For this reason, the locomotives present a risk when travelling in areas where there is reduced height of the contact wires, given that the locomotives exceed the vehicle gauge height on South African railway networks.

2. SOUTH AFRICAN RAIL NETWORK LAYOUT AND LIMITS

The South African railway system comprises three main elements, namely the network, station and train operators or any combination thereof. The railway network comprises a total track distance of 30,400km according to the National Rail Policy Green Paper and there are four conditions which determine the type of locomotive required for haulage on that specific line. These conditions are broadly listed below and depicted in figure1:

- Non-electrified lines for use by diesel and hybrid locomotives only.
- 3kV DC electrified lines for use by 3kV DC electric locomotives, 3kV DC/25kV AC dual locomotives, diesel and hybrid locomotives.
- 25kV AC electrified lines for use by 25kV AC locomotives, 3kV DC/25kV AC dual locomotives, diesel and hybrid locomotives.
- 50kV AC electrified lines for use by 50kV AC locomotives, diesel locomotives and hybrid locomotives.

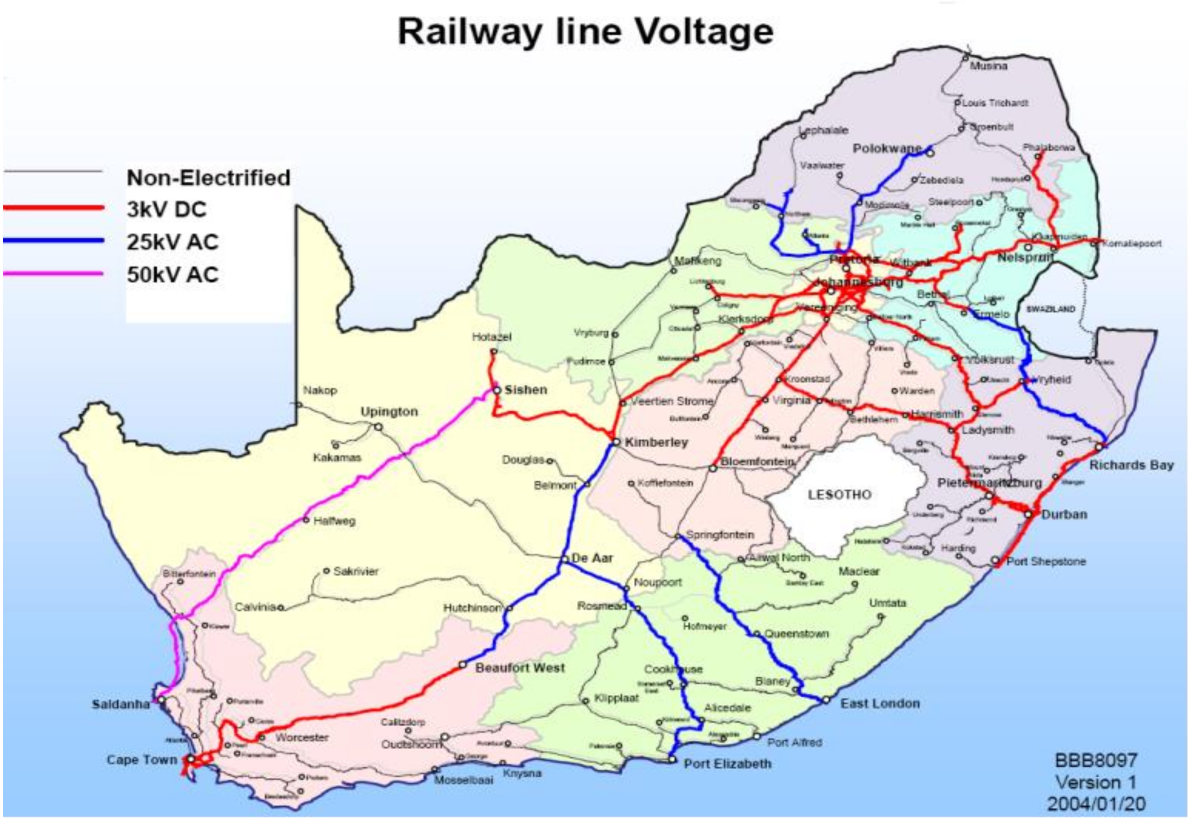


Figure 1: SA Rail Network (Transnet BBB8097)

2.1. Problem statement

The AFRO 4000 series of locomotives is designed and manufactured to a height of 4140mm above rail head. This height exceeds the vehicle structure gauge height of 3965mm as required in the TFR track maintenance manual for diesel locomotives.

3. RAILWAY SAFETY REGULATOR PROCESSES

The RSR uses a life cycle management approach when conducting safety assessments on new works and technology developments. It follows that the RSR should evaluate this rolling stock acquisition project from concept phase to disposal. Throughout the life cycle phases, the operator is required to inform the RSR of the risks involved in moving from one phase to the next phase and how such risks will be eliminated or mitigated, with the ultimate goal of ensuring safe railway operations. The RSR must be satisfied that the operator has considered all risks involved in moving from one phase to the next when evaluating the submissions, as stipulated in SANS 3000 series of standards. This process is presented in figure 2 below:

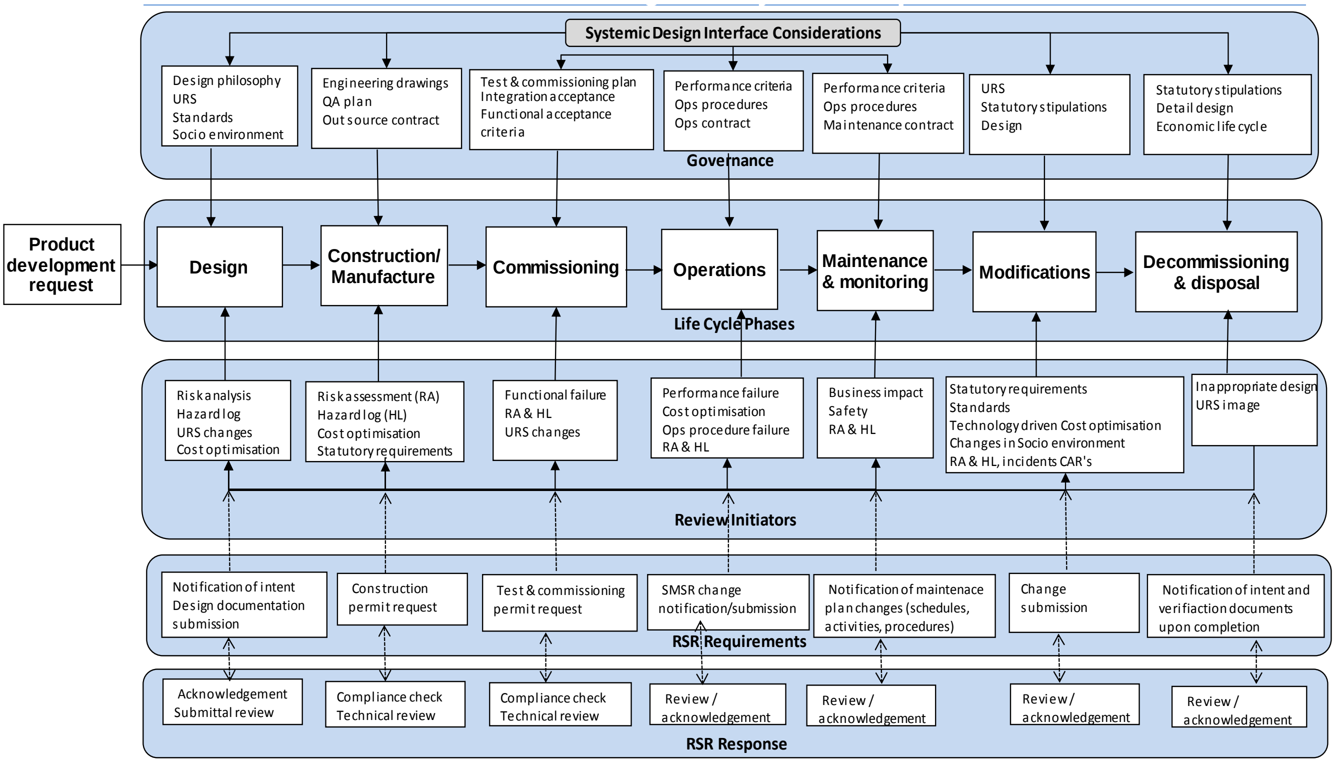


Figure 2: RSR processes for Life Cycle Phases (SANS 3000 Standards)

PRASA did not follow the process as outlined above in respect of the AFRO 4000 project. PRASA notified the RSR in March 2014 of its intention to purchase the diesel locomotives from Vossloh Espana, at which time the locomotives were already in production. As a result, the RSR was not privy to information and decisions that were taken during the design phase of the project which would have safety implications for the South African railway network. This timeline is substantiated by the arrival of the locomotives in South Africa in the first week of December 2014 after a lengthy sea journey from Spain.

PRASA made a presentation to the RSR in November 2014 to seek approval to test and commission the locomotives. The approval was granted subject to certain conditions being met prior to the commencement of the tests.
PRASA then made a follow-up presentation to the RSR in February 2015 on the progress of the project and to confirm that the issues that were raised in the November 2014 submission had been addressed. The approval for testing and commissioning was granted end of February 2015. Some test results, analysis and evaluation like the tunnel test were still continuing when this review report was compiled.

4. THE REVIEW APPROACH

Sections 2 & 3 above outline the rail network and the RSR requirements for life cycle management of new technology such as new rolling stock. Of critical importance to the railway operator (network, station or train operator), when planning to introduce the new rolling stock into the railway environment, is an understanding of overall conditions in which the rolling stock will be operating. This implies that, at concept phase, the operator must determine the areas where the rolling stock (RS) will be operating in the SA rail network, who will be operating the RS, and how it will be maintained. This will assist the RS operator to know what type of communication will be required, as well as the required human/machine interface and deployment plan. Figure 3 below highlights the various areas the operator must consider when purchasing new rolling stock.

On this basis, audits and inspections were conducted on the AFRO 4000 series locomotives which are currently undergoing testing and commissioning. The assessment included physical inspections; measurements and compatibility verification on other features of the railway network.

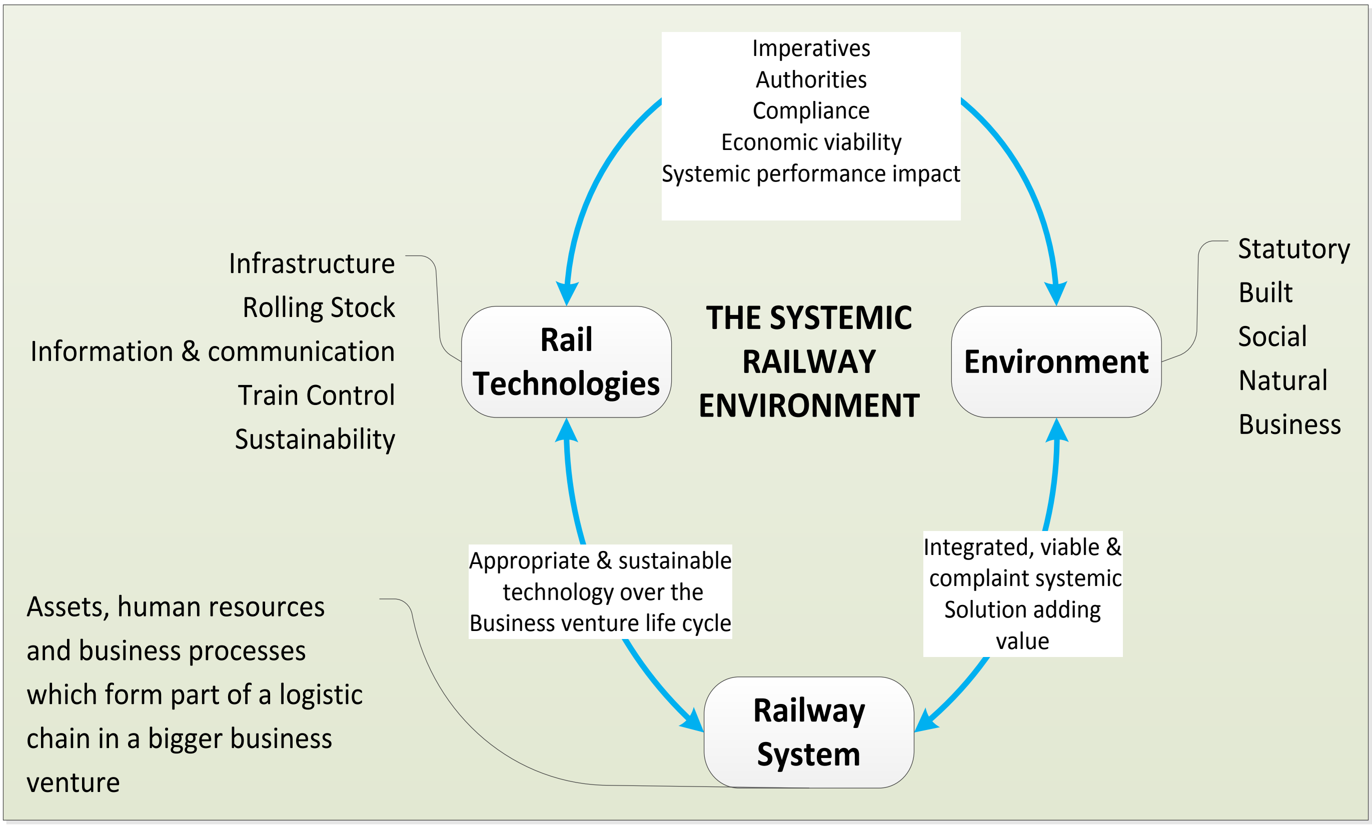


Figure 3: Whole Systems Approach

5. INSPECTION OF AFRO 4000 LOCOMOTIVES

5.1. General description of the locomotive:

The locomotives are provided with an EMD 16-710-G3B turbo-charged diesel engines. The engine supplies the main generator with the mechanical power necessary for generating electrical power for traction. The traction power is distributed by the transmission system to each traction motor fitted on the bogies. Each traction motor is directly geared to a number of driven wheels. There are two cabs in the AFRO 4000 locomotive. The cab located next to the electrical cabinet is considered to be the front cab. The AFRO 4000 is a modified version of the EURO 4000. It was modified to run on Cape track gauge (1067mm) as the EURO 4000 locomotive is based on the standard track gauge (1435mm).

The operational control of the locomotive system is performed by a computer (EM2000 microprocessor). The computer detects and gives warnings of most locomotive fault conditions through messages on the display (located on the desk) and audible alarms. It also records failure messages and significant information in a file memory.

5.2. Locomotive Communications

In accordance with train working rules, a radio communication system is required to facilitate communication between the train driver and the train control officer (TCO) as there may be instances where the driver is required to communicate with the TCO.

Of the 13 locomotives, only one is equipped with a radio communication system. The absence of an appropriate communication system results in the use of unreliable communication methods and sometimes no communication at all. The picture below shows where the radio communication system should have been fitted

Picture 1: AFRO 4000 Cab Layout

5.3. Locomotive Inspection

A summary of the inspection report in tabular format was developed and a copy is included in Appendix C of this report.

5.3.1. Inspection Findings

As part of the inspection, the locomotives' heights were measured and found to be 4140mm from the highest point (over the exhaust) to the top of the rail. The measurement was made by laser and straight edge so it may include a margin of error of about 2mm. The diagram contained in the Vossloh manual for the AFRO 4000 confirms the height of 4140mm. Given that all the locomotives are built to the same design and production specification, it was not necessary to measure all of the locomotives.

A visual inspection confirmed that the locomotives have the following correct equipment for South African operations:

I. Cape gauge bogies (1067mm)
II. The standard No. 22 wheel profile is used on the locomotives
III. Composition brake blocks are installed
IV. Air and vacuum brake equipment, including all piping, emergency valve in cab and compressor/exhauster are installed
V. AAR automatic couplers are installed
VI. Vossloh fuel level sensor is installed
VII. Except in the AFRO 4001 Cab 2, communication radios are not installed in the cab consoles of the other locomotives. Communication with the TCOs could therefore be compromised.

All the locomotives have already covered significant mileage, with AFRO 4001 and AFRO 4004 having travelled the most at over 12000 km each.

What appears to be electrical burns from overhead traction equipment are present on some locomotives on the exhaust silencer and the dust blower (see inspection sheets in Appendix A for details). Photo evidence (see Appendix B) shows this to be fairly minor at this stage.

There is minor damage to some of the locomotives components below deck, namely:

a. AFRO 4008 and AFRO 4012 have sustained damage on an overflow pipe. This pipe protrudes beyond other equipment to the side of the locomotive. It is recommended that the overflow pipe be shortened so that it does not protrude.
b. AFRO 4001, AFRO 4004, AFRO 4006 and AFRO 4012 have broken sand pipes on the right-hand side with Cab 2 leading. AFRO 4012 has bent brackets enclosing the air brake pipes on both ends of the locomotive. On the one end, the actual air brake pipe is bent and the cock is broken.

6. HUMAN FACTORS AND DRIVER'S CAB ERGONOMICS

6.1. Human Factors Approach on Technical Reviews

The Human Factors Management Standard requires that human factors in design (ergonomics) and the physical environment in which the task will be operated be considered during the introduction of new designs. Ergonomics can be defined as the study of human abilities and characteristics which affect the design of equipment, systems and jobs, with the aim of improving efficiency, safety, and well-being (Clark and Corlett, 1984). It is therefore essential to consider man's limitations and abilities when looking at the interface between people and machines in systems.

The human factors assessment process includes a verification and validation phase as described by van der Weide et al, 2013. During the verification phase, it must be confirmed, by examination and provision of objective evidence, that the specified requirements have been fulfilled. The validation phase includes a confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use have been fulfilled. Based on the Human Factors management standard, the assessment process for the AFRO 4000 considered the following three elements:

- Physical environmental factors
- Human factors in design
- Training and development

6.2. Assessment / Inspections

6.2.1. Verification phase

As explained earlier, the verification phase relies on two legs, mainly, examination and the provision of objective evidence that a specific requirement has been met. These were some of the observations that were made with regards to the cab as it relates to the train driver during the examination by the RSR:

6.2.1.1. Access provisions

Several notable shortcomings were identified in the AFRO 4000 related to the ease of entry into and exit from the locomotive cabin. The first shortcoming noted was the distance between the rungs. Although the spacing between the rungs could not be verified during the site visit, the RSR team observed that there were spatial inconsistencies between the rungs of the ladder used to gain access into the cab. While the AFRO 4000 is equipped with handrails for the driver to hold when moving in and out of the cab, the driver may experience difficultly gripping the handrails in wet conditions. An additional factor that could limit ease of exit from the locomotive cabin is the potential change in platform height in relation to the last rung the driver steps on when exiting. If the platform and the height of the first set of rungs are not perfectly aligned, the driver would have to jump to reach the platform.

6.2.1.2. Seating

The seat for the train driver was found to be adjustable; the seat could move back and forth and had an adjustable back rest. The driver also had a foot rest which was within easy reach. The typical practice within the South African rail industry is for a driver’s cab to include a driver’s assistant seat. In keeping with this practice, PRASA included a driver’s assistant seat within the cab that was not originally part of the AFRO 4000 design.

No evidence was submitted to the RSR to indicate whether the addition of the assistant's seat would pose an additional risk. Since the assistant's seat is placed in a cab that was not originally designed to accommodate it, there is limited space behind the seat at the back of the cab. Based on the activities that the train driver and train assistants are required to execute, the RSR is of the view that the train assistant's seat was placed too close in proximity to the driver's seat. The space restriction caused by the placement of the assistant's seat means that should an emergency evacuation be necessary, the assistant would struggle to exit the cab safely and quickly.

The seats on the AFRO 4000 series locomotives were also found to have insufficient lumbar support and the backrests of both the train assistant and driver's seats were not vertically adjustable. The seat pan (seat base) on the train assistant's seat was tilted at an acute angle, resulting in the assistant sitting in a position where their hips would not rest at a 90° angle.

PRASA had indicated that the train drivers and train assistants indicated that they were happy with the current position of the seat. However, no formal report has been submitted to the regulator to state how the responses from the drivers were obtained. It is not clear whether the responses were gained through the use of questionnaires or interviews. No information has also been provided detailing the sample size as well as the percentage of drivers who actually preferred the layout of the cab.

6.2.1.3. Body posture and orientation

It was found that both the train driver and train assistant adopted awkward body postures to perform the required tasks safely, effectively and comfortably. This was caused by the location of the controls in relation to the seat position; the current design set up is likely to force some drivers (based on their anthropometric dimensions) to sit forward in the seat, in order to comfortably reach the controls. Any driver who is forced to sit forward in the seat would necessarily forgo the use of the available back rest for support.

6.2.1.4. *Workspace*

The legroom inside cab was found to be restrictive, especially for train assistant, due to the cab size and layout.

6.2.1.5. Controls and displays

Control and display layout coding and stereotype were found to be inconsistently applied to the design of the locomotives. Physical reach to controls and labelling were also identified as deficiencies.

6.2.1.6. Visual access

While the train driver and the assistant had a clear view of the tracks, rear view was not possible as the cab does not have mirrors.

6.2.1.7. Other hazards identified in the cab

The ashtray should be removed from the locomotive as the cab is not a designated smoking area it is an accident hazard as its placement makes it possible for the driver to bump against it when exiting and entering the cab.

The emergency hand brake next to the driver seat poses as a hazard, especially when the driver seat has been adjusted to the forward position, and its placement makes it likely for the driver to easily hit their leg against it. It advisable that a rubber bracket is placed against the break to prevent accidental activation of the emergency break.

6.2.1.8. Training and development

PRASA indicated that there have been some individuals who have been trained on the new locomotive. A list of all the individuals who have been trained as well as the depot where they are stationed has been made available to the RSR. Information regarding the training for the AFRO 4000 was also provided to the RSR.

6.2.2. Validation phase

The validation phase of the assessment has not been completed yet. This requires that a proper task analysis of the tasks performed by the train drivers and train assistants be conducted to determine whether particular requirements for a specific intended use have been fulfilled.

PRASA is required to provide this results once this phase is completed.

7. LOCOMOTIVE AND INFRASTRUCTURE HEIGHT ASSESSMENT

7.1. Locomotive Height Assessment

The height of the AFRO 4000 locomotive was measured at 4140mm which is 175mm higher than the track maintenance manual requirement of 3965mm. By exceeding the vehicle gauge, the clearance safety margin between the top of the vehicle and the Overhead Traction Equipment is reduced. Thus, any reduction in height of the TFR contact wire height from its minimum allowed height as a result of tamping actvities, will pose a greater risk of contact with this locomotive than any other type of locomotive in the country. This also increases the likelihood of a flashover.

As a result of the AFRO 4000's deviation from TFR vehicle gauge height,a greater risk of interference between Overhead Traction Equipment and the locomotive exists. This risk is greater on DC overhead lines, as the minimum allowed height of DC equipment is less than on AC overhead lines. The most critical height restriction is the case of DC electrification lines, which, according to the TFR *Infrastructure Manual for Track Maintenance*, Clause 8.2.1, may be a minimum of 4220 mm above the rail top, and this minimum may occur in old tunnels and old bridges due to track maintenance or due to construction standards.

Thus, in the worst case scenario, on DC lines, the clearance between locomotive and overhead traction equipment could be 80mm. This is a static clearance. The motion of the locomotive over vertical track geometric variations, variations due to super-elevation in curves, or for whatever other reason, may cause dynamic reduction of this clearance.

PRASA instituted an investigation in collaboration with Stellenbosch University in August 2014. The investigation report, titled *Calculation of Contact Wire Gap,* states that arcing occurs at 70mm gap under the worst conditions and with 25kV overhead. The minimum gap at which arcing (flashover) occurs decreases approximately linearly as voltage decreases, to below 20mm for 3kV. The report concludes that "The data obtained is in no way a safe design value and the distances need to be increased to allow for variances in height, altitude as well as other factors."

7.2. Infrastructure Height Assessment

The 25kV AC lines at Kimberley station and south of the station that were inspected had no impact on the clearances of the locomotive(s). However, the evidence of marks on top of the exhaust chamber suggests that the locomotive might have also traversed the 3kV DC lines.

8. IDENTIFICATION OF OPERATIONAL RISKS

Operational risks exist where the AFRO 4000 series locomotives run on lines with reduced Overhead Traction Equipment clearances. The risks are of contact with the contact wire or flashover which can result in overhead power trips, with resultant delays to train services and associated costs.

According to the *Handbook of Vehicle Dynamics* page 205, 'Clearance is about risk management. The larger the clearance provided, the smaller the risk, and thus the need for control measures is minimised. Modern standards specify clearance according to risk regime, where the available clearance dictates what control measures are required.'

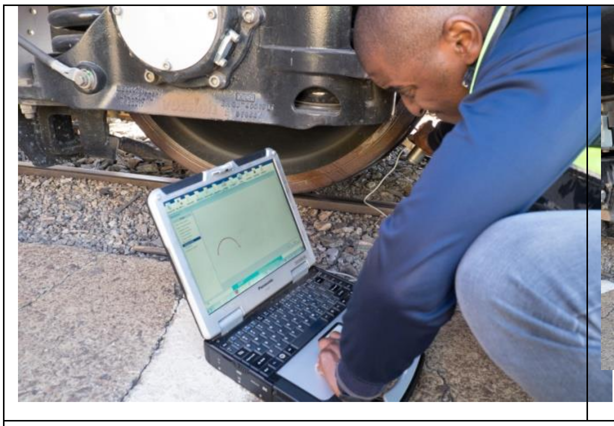
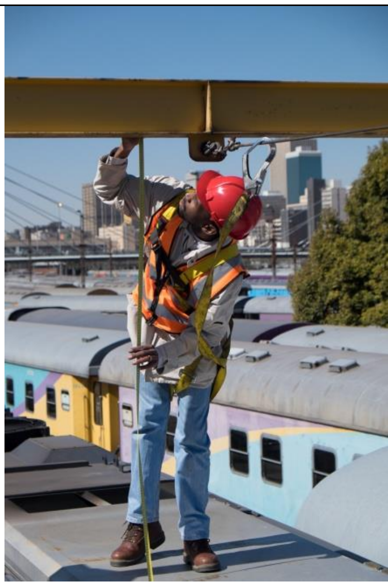
To mitigate against operational risk, there should be a full and detailed survey and joint mitigation plan by PRASA and TFR to ensure that the contact wires are not below minimum heights and to identify lines, if applicable, where the AFRO 4000 is not permitted to travel due to an unacceptably small gap between the overhead and the locomotive.

It is recommended that TFR and PRASA regularly measures overhead height, and reviews these heights for new deviations on all electrified lines where AFRO 4000 is granted permission to operate.

9. ANALYSIS OF LOCOMOTIVE HEIGHT IMPACT

9.1. Vehicle Envelope

The vehicle static envelope as per the SARCC Manual for Track Maintenance is shown in Appendix D. The maximum allowable height of the vehicle without load and with new wheels and new springs is 3965mm and the allowable width is 3050mm. The Vossloh AFRO 4000 diesel electric locomotive is 4140mm high and 2850mm wide as noted in the descriptive manual of the locomotive, the highest component being the top of the exhaust silencer. The height figure is consistent with the physical measurements which were conducted using a steel tape measure during the inspection of these locomotives. It1 0 0 1 520.18 675.34 Tm1 0 0t 0 1 2Cen95.2insp10 0T35TJo

	
Mini Prof performed by PRASA, see attached separate report of the results.	
	
Roof marks on the exhaust silencer indicate some interference with the catenary wires	
	
Wheel and sand pipe dispatch point	Battery packs clearance from the top of rail

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<tr><td>Front view</td><td>Cab view with the locomotive mileage indication</td></tr>
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<tr><td colspan="2">Engine room</td></tr>
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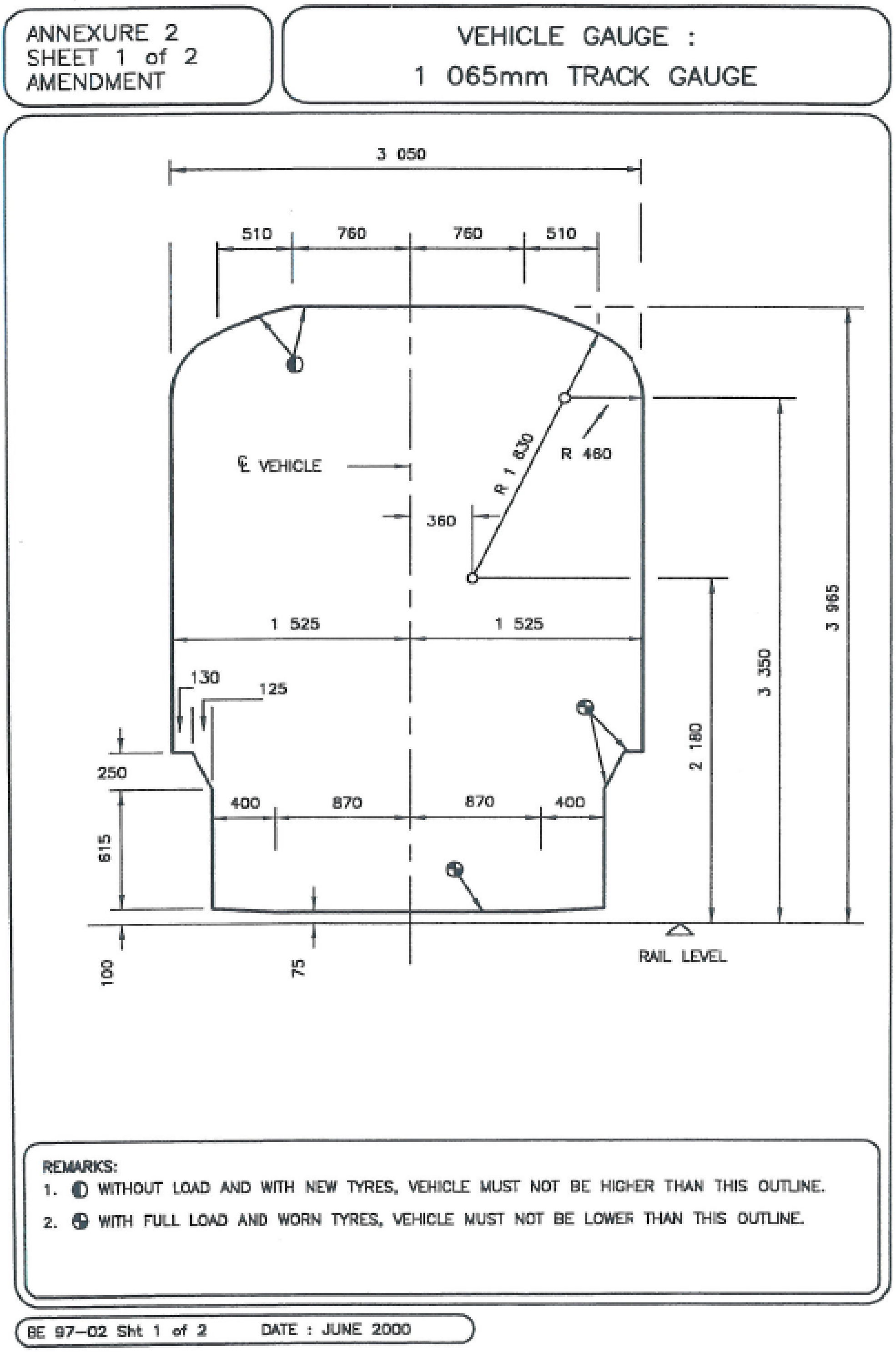
APPENDIX C: RSR Locomotive Inspection Report

Locomotive Number	AFRO4003		AFRO4008		AFRO4009		AFRO4001		AFRO4004		AFRO4007	
	Odometer: 3,702 km (Kimberley-Mafikeng)		Odometer: 3,861 km (Kimberley-Mafikeng)		Odometer: 3,280 km (Kimberley-Mafikeng)		Odometer: 12,356 km (Bloemfontein-PE/EL)		Odometer: 12,042 km (Bloemfontein-PE/EL)		Odometer: 3,898 km (Kimberley-De Aar)	
Damage/abrasion/flashover marks	No signs of damage below deck or on the sides. Slight abrasions on top end of cab polyester fairing. Abrasions/overhead burn marks on exhaust silencer		Below deck: overflow pipe has been struck and bent. Bolt on the air conditioner on the top / roof seems to have been struck Abrasions/overhead burn marks on exhaust silencer		No signs of damage below deck or on the sides.		No signs of damage on the deck or from the sides, other than broken sandpipes on the right-hand side with a Cab 2 leading. This damage was reportedly due to cow collision. Abrasions/Overhead burn marks on exhaust silencer, electrical arc/burn marks on an extractor fan vent		No signs of damage on the deck or on the sides, other than broken sandpipes on the right-hand side with a Cab 2 leading. This damage was reportedly due to cow collision. Abrasions/overhead burn marks on exhaust silencer		No visible signs of damage below deck or on the sides. No visible signs of damage on top.	
Technical requirement	*Yes/no*	*Comment*	*Yes/no*	*Comment*	*Yes/no*	*Comment*	*Yes/no*	*Comment*	*Yes/no*	*Comment*	*Yes/no*	*Comment*
Axle modified for gauge reduction	Yes		Yes		Yes		Yes		Yes		Yes	
Wheel profile to SA Standard	Yes	Visual inspection only. Mini prof profile measurements provided by PRASA showing standard 22	Yes	Visual inspection only. See a mini pro.	Yes	Visual inspection only. See PRASA mini pro showing 22	Yes	Visual inspection. No signs of undue hollow wear or flange wear	Yes	Visual inspection. No signs of undue hollow wear or flange wear	Yes	Visual inspection. No signs of undue hollow wear or flange wear
Brake shoes	Yes		Yes		Yes		Yes		Yes		Yes	
Vacuum brake valves	Yes		Yes		Yes		Yes		Yes		Yes	
Compressor/ exhauster	Yes		Yes		Yes		Yes		Yes		Yes	
Vacuum piping	Yes		Yes		Yes		Yes		Yes		Yes	
Vacuum flexible hoses	Yes		Yes		Yes		Yes		Yes		Yes	
Vacuum emergency brake valve	Yes		Yes		Yes		Yes		Yes		Yes	
AAR Automatic couplers	Yes		Yes		Yes		Yes		Yes		Yes	
Radio	No	Slot provided in the cab, but no radio installed	No	Slot provided in the cab, but no radio installed	No	Slot provided in the cab, but no radio installed	No	A radio installed in Cab 2 only	No	No radios in either cab	No	A radio installed in Cab 2 only
Fuel sensor	Yes		Yes		Yes		Yes		Yes		Yes	
Roof height measured	No	PRASA arranging verification measurement.	No	PRASA arranging verification measurement.	Yes	Measured by tape. Height = 4,140 mm. PRASA arranging verification	No		No		No	
Primary suspension height options	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension
Battery box clearance	Yes	Adequate clearance	Yes	Adequate clearance	Yes	Adequate clearance	Yes	Adequate clearance	Yes	Adequate clearance	Yes	Adequate clearance

Locomotive Number	AFRO4002		AFRO4005		AFRO4013		AFRO4006		AFRO4012		AFRO4011	
	Odometer: 3,608 km (Kimberley-De Aar)		Odometer: 758 km (Kimberley-Braamfontein)		Odometer: 508 km (Kimberley-Braamfontein)		Odometer: 9415 km (Port Elizabeth-Bloemfontein)		Odometer: 10,630 km (East London-Bloemfontein)		Odometer: 7,637 km (East London-Bloemfontein)	
Damage/abrasion/flash over marks	No visible signs of damage below deck or on the sides. No visible signs of damage on top.		No visible signs of damage below deck or on the sides. No visible signs of damage on top.		No visible signs of damage below deck or on sides, except a minor notch and paint chip on the battery box toward Cab 1. No visible signs of damsges on top of the loco roof.		**Minor chip on the battery box. Broken sandpipe on the right side no. 2 cab leading. Abrasiom/overhead burn marks on exhaustsilencer**		Overflow pipe struck. Bent air brake pipe brackets both ends, with air brake pipe also bent on one end. The sand pipe is broken right side on no.2 cab leading. No vissible signs of damage on top		No visible signs of damage on the deck or on the sides. Unable to view top from above due to locomotive position and weather, but no sign of damage from a side angle of the top.	
Technical requirement	***Yes/no***	***Comment***	***Yes/no***	***Comment***	***Yes/no***	***Comment***	***Yes/no***	***Comment***	***Yes/no***	***Comment***	***Yes/no***	***Comment***
Axle modified for gauge reduction	Yes		Yes		Yes		Yes		Yes		Yes	
Wheel profile to SA Standard	Yes	Visual inspection. No signs of undue hollow wear or flange wear	Yes	Visual inspection. No signs of undue hollow wear or flange wear	Yes	Visual inspection. No signs of undue hollow wear or flange wear	Yes	Visual inspection. No signs of undue hollow wear or flange wear	Yes	Visual inspection. No signs of undue hollow wear or flange wear	Yes	Visual inspection. No signs of undue hollow wear or flange wear
Brake shoes	Yes		Yes		Yes		Yes		Yes		Yes	
Vacuum brake valves	Yes		Yes		Yes		Yes		Yes		Yes	
Compressor/exhauster	Yes		Yes		Yes		Yes		Yes		Yes	
Vacuum piping	Yes		Yes		Yes		Yes		Yes		Yes	
Vacuum flexible hoses	Yes		Yes		Yes		Yes		Yes		Yes	
Vacuum emergency brake valve	Yes		Yes		Yes		Yes		Yes		Yes	
AAR Automatic couplers	Yes		Yes		Yes		Yes		Yes		Yes	
Radio	No	No radios installed	No	No radios installed	No	No radios installed	No	No radios installed	No	No radios installed	No	No radios installed
Fuel sensor	Yes		Yes		Yes		Yes		Yes		Yes	
Roof height measured	No	At Kimberley Station about 400-500 mm clearance	No		No		No		No		No	
Primary suspension height options	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension	No	There is limited opportunity to reduce height over suspension
Battery box clearance	Yes	Adequate clearance	Yes	Adequate clearance	Yes	Adequate clearance. The Minor	Yes	Adequate clearance. Minor	Yes	Adequate clearance.	Yes	Adequate clearance.

APPENDIX D: Locomotive Clearance References

Vertical Static Clearance



APPENDIX E: Tests Conducted by PRASA

Static Test

Tests Register	Report Comfirmed	Test Type	Local Tests	Comment	Resolution	Process	Criteria	Document Reference
Dimensional Test	Y	Type and Routine	Not Done	MetroRail do not have the ability in the maintenece facilities. Cape Town GO contractors did not have the ability/opertunity to do. Static testing will be done in TE Koedoespoort for 1st Sept 2015.	Request fro proposal issued to Contractors to provide the service. To be completed by 20 September 2015	Physical Measurements	Vehicle Gauge Structure, Loco GA	BB14601201001
Weighing tests	Y	Type and Routine	Not Done			Weigh Bridge	tender Specification	HC/CS QU1460000000
Water tests	Y	Type and Routine	Not Done			Water test procedure	As per the procedure (Vosloh protocol used)	QE14600000000
Slew Test	Y	Type and Routine	Not Done			Traveser Test and 90m radius curve	Vosloh report and Prasa validation	QI14600000000
Electromagnetic Compatibilty Test	Y	Type	Done	Vossloh to provide the report. PRASA to provide the test results	Certificate and results avaiable, see Ref documentation	Testing and Reporting	Vosloh report and Prasa validation	PRASA AFRO4000EMCReport; PRASA AFRO4000RF Report; PRASA_AFRO4000_EMC&RF_C onformance Report
Electrical Insulation tests:	Y	Type	Done	To be done at the end of the Vossloh tests which will only include the mission critical components.		Physical Measurements and validation	As per the procedure	ET14600000000
Brake System (pneumatically) tests	Y	Routine	Done	Awaiting raw data and analysis		OEM procedure	As per the procedure	TA40420/710 (EN14600000000)
Brake System (vacuum) tests	Y	Routine	Done	Awaiting raw data and analysis		OEM procedure	As per the procedure	TA40420/711
Sanding tests	Y	Routine	Done	250ml in 20 sec and is deemed to be acceptable.	There were issues that were noted which will be part of the design improvements	OEM procedure	300 to 366ml/half a minute	ET14600000000
Air system tests	Y	Routine	Done	To be discussed with Vossloh whether they are done and when they are going to be done.		OEM procedure	As per the procedure	HC/CS EM14600000000
Auxiliary power supply system tests	Y	Routine	Done	Included as part of Pre Commisioning test		OEM procedure	As per the procedure	ET14600000000
Battery charging tests	Y	Routine	Done	Included as part of Pre Commisioning test				ET14600000000
EM2000	Y	Routine	Done	Included as part of Pre Commisioning test				ET14600000000
Electrical Functional tests (Cab1&2)	Y	Routine	Done			OEM procedure	As per the procedure	HC/CSER1461/2000000
Engine Tests	Y	Routine	Done					
Noise Tests	Y	Routine	Done	Standard Routine tests. Verification planned to be done under controlled condition at TE Koedoespoort	To be Tested during static testing at Koedoespoort	Noise level meter	Below 75db in Cab and 105 db in Engine room	To Be Developed
Safety related system (automatic emergency brake, automatic vigilance equipment, drivers safety device)	Y	Routine	Done	Vigilance and emergency included in standard Commitioning tests on all locos	Design improvements	Functional test: Dynamic and Static		
Lifting Ability and procedure	Y	Type test	Done	Documentation available.		Vosloh lifting procedure	As per the procedure	
RAMS	Not part of C&T		Not Done	Normally not required as part of T&C. Risk analysis was done.		Prasa Maintenance Standards (incl FMECA)	As per MS	
Visibility Test	Y	Type test	Done	Report submitted		Signal visibility (driver and assistant)	Signals to advice	
Train Control System (Software EM 2000)	Y	Type test	Done	The functionallity was verified. PRASA do not currently have the interface software, but access is available for through the Driver display unit (DDU)		Demonstrate functionality		

Dynamic Test

Tests Register	Report Confirmed	**Local Test Progress**	Process	Criteria	Acceptance	Comment	Document Reference
Traction performance tests	Y	Done	Vosloh test procedure	as per procedure	Tractive Effort Curve		ET14600000000
Braking tests (electrical)	Y	Done	Vosloh test procedure	as per procedure	Brake Effort Curve		
Braking tests (mechanical)	Y	Done	Vosloh test procedure	as per procedure	Stopping distances		EP14600000000
Wheel slip	Y	Not Done	Demonstrate functionality, during final Dinamic valuation with the delivery of the last 7 Locomotives in Oct 2015	Prove slip control with and without sanding	Povide full traction effort	Not formally done and recorded but the single Locomotive was used to pull a 51 car train, proving that the wheel slip is working within the Shosholosa Meyl Operational environment.	HC/CS ET1460000000(
Traction and Braking Thermal capacity	Y	Done	Demonstrate functionality, during final Dinamic valuation with the delivery of the last 7 Locomotives in Oct 2015	No brake 'fading' during brake applications	Within acceptabel braking distance	During the final Dinamic testing, the Braking and Traction effort curves will be evaluated against the URS	
Automatic train protection (Overspeed protection)	N	Not Done	Demonstrate functionality	Automatic limitation of maximum speed to 90 km/h as per SA network	Limit to max of 90 km/h	This funtionallity was not yet implimented during T&C phase but will be done the moment these locomotives are approved for operational use.	HC/CS ET1460000000(
Vehicle/track interaction	N	Done	Demonstrate functionality	As per procedure and testing protocol	Compliance to norm	Completed	
Emergency braking	Y	Done	Demonstrate functionality	As per procedure and testing protocol		Done as the norm during Commission tests on loco only. Test reports available on each loco delivery file	
Operation of wheel lubricators		Done	Demonstrate functionality				
Aerodynamic Tests	N	Not Done	Demonstrate functionality			Not Required	
Air system - compressor duty cycle	Y	Done	Demonstrate functionality				EM14600000000
Noise tests	Y	Prasa	Noise level meter	Below 75db in Cab and 105 db in Engine room		PRASA confirmed that the noise test results are submitted with all loco data packs	C/072397I2/1
Stability tests	Y	Done	Vossloh test procedure	As per procedure and testing protocol	Compliance to norm. Certified to 90km/h		
Stability tests	N	Not Done	Vossloh test procedure as per IEC61133	As per procedure and testing protocol	Compliance to norm. Certificate of compliance	To be validated during final Dinamic valuation with the delivery of the last 7 Locomotives in Oct 2015	
Engine Emergency Stop	Y	Done	Demonstrate functionality	Stop engine		Done as the norm during Commission tests.	EM14600000000

APPENDIX F: Human Factor Design considerations

In line with international practice (Muller *et al.*, 1998) physical environmental factors take the following into consideration:

CAB PHYSICAL ENVIRONMENT HEATING

- If a heater is installed, the minimum temperature maintained should be 17.8˚C at a point that is about 610mm above the center of each seat (in cabs which can be occupied for more than 3 hours).
- Glazing of the windows should be designed in order to reduce heat loss by radiation, conduction and by air infiltration at poor seals.
- Cab floors should be insulated to eliminate the loss of ambient heat and conduction from feet when standing and the walls should be insulated to reduce radiation.
- Cabs should provide a means to add humidity to the heated air to improve comfort, reduce skin and membrane drying and aid dust settling.

VENTILATION

- Air from outside should be filtered to remove dust, insects and other debris. The introduction of fumes and vapors must be eliminated.
- The noise from the ventilation system should be controlled.
- The cab pressure should be positive and should be maintained to reduce infiltration of outside contaminants and drafts.

NOISE

- A maximum continuous noise level of 75 dBA is a desirable goal.

VIBRATION

- With regards to loss of comfort, the human body is sensitive to vibration in the 0.4 to 20 Hz range. With regard to vertical vibration, the area of greatest sensitivity is between 4 and 10 Hz. Very low frequency vertical motions (0.1 to 0.5 Hz) are not experienced as vibration but may result in motion sickness.

- Active systems can provide greater vibration control than passive systems. They can potentially be applied to locomotive suspension, cabs, or seat posts.

The Human Factors in Design considers the following factors:

CAB LAYOUT

GENERAL DESIGN

- User population sizes should be used to design the cab with the male 95th percentile dimensions used to set clearances and the female 50th percentile dimensions used to set reach envelopes.
- Enough space should be allocated for each cab occupant: 6 square meters is a minimum amount of floor space. Comfort facilities (toilet, water cooler, storage, refrigerator, etc.) should be located out of the main area of the cab and not counted as crew space.
- The height of the cab ceiling should be at least 1930mm (European designs use 2006 mm).
- Other items, such as first aid kits, flares and fire extinguishers, should be mounted where they are accessible, but do not impede movement in the cab.
- Changes in floor levels in the cab, e.g. raised seat platform, should be minimised in order to prevent tripping hazards.
- Interior surface finish should be light colored, of low reflectance and easy to clean.
- Designing for extremely large individuals is appropriate when a design feature must accommodate most of the population (such as a doorway).
- Designing for an adjustable range is permissible when features can be easily tailored to the individuals who use them (such as seats, keyboards).

- Designing for the average individual is appropriate in noncritical situations, where designing for an extreme is inappropriate and where adjustability is impractical (such as a toilet seat).

- To provide good visibility while minimising fatigue due to poor neck and head posture, regular viewing tasks should be within a 30-degree cone around the normal line of sight (Grandjean, 1988). The normal line of sight is 10-15 degrees below the horizontal plane. Displays should be placed within a viewing angle between 5 degrees above and 30 degrees below the horizontal plane in establishing the height of the seat in relationship to the windows and the visual displays in the cab.

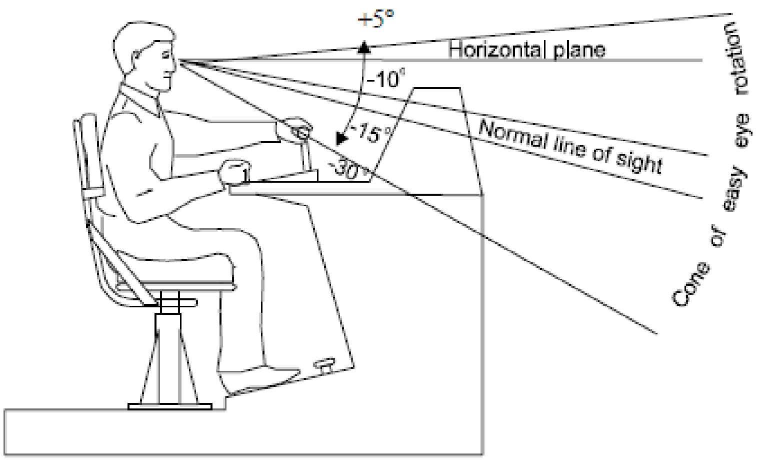


Figure 4-2. Area within which Primary Displays Should be Located

CONTROLS AND DISPLAYS

- Primary displays and controls should be placed so that the driver may view them without having to change his/her eye or head position from the normal line of sight.

- Secondary controls and displays may be located so that eye movements are necessary, but head movements are not.

- Non-critical displays and controls may be located outside the normal line of sight.

- Angled work surfaces should be considered when there are many controls and displays to arrange in the workstation as the controls on an angled surface allow for the placement of a greater number of controls within easy reach.

- Control size and spacing should permit the engineer to operate the controls without accidentally activating neighboring controls.

WORK-SPACE ENVELOPE

- Controls should be placed so that the operator's hands do not have to reach frequently or be elevated above the shoulder for substantial periods.

- Padded forearm supports should be used to relieve pressure at the shoulder and elbow.

- The workstation should be designed such that the driver's elbows remain flexed (bent) and allow for control activation.

- Sufficient clearance should be provided for the driver's thighs under the work surface.

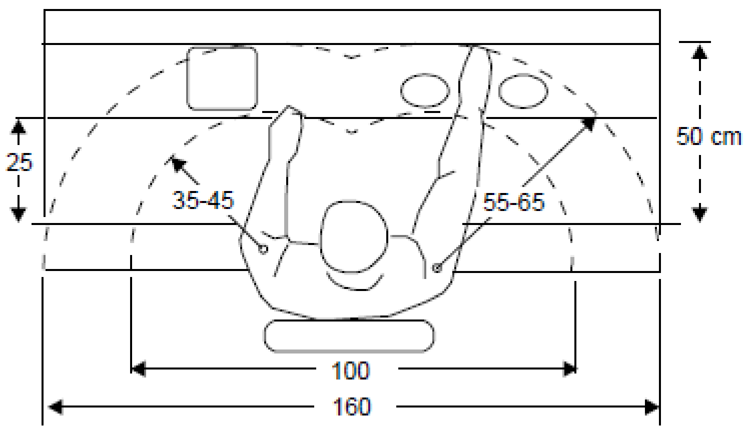


Figure 4-3. Area of Normal and Maximum Reach (Etinne Grandjean, *Fitting the Task to the Man: A Textbook of Occupational Ergonomics, 4th edition*, p. 51, 1988. Used with permission from Taylor & Francis, Inc., Washington, DC.)

ACCESS

- The placement of the doors should take accident scenarios into account, e.g. cars piling on and around the locomotive may block some exits in some circumstances
- Doors should open outward to permit easier pre-accident exits. This also eliminates the need for a clear area in the cab to allow an unobstructed inward swing.
- Door latches should be examined for potential hand pinch areas in their range of motion.
- The door should include a small sight glass to see if there is somebody that could be struck when opening the door.

VISIBILITY

- The windows should permit the operator to see a track level object as close as 15 m away and an overhead object (e.g. Signal Bridge) as close as 16 m away.
- Lateral field-of-view should be at least 180˚ and preferably 220˚.
- Too much window area can have drawbacks. Examples are radiant heat gain, heat loss, glare, reflections, vulnerability to thrown rocks and gunshots.

SEATING

- Locomotive seats should be cushioned at least 76 mm thick, use the buttocks for primary support, exert little pressure on the thighs especially at the front edge, support the lower back and have arm rests 101 mm wide and 330 mm long.
- Seat height should be adjustable from 406 to 482 mm in steps no larger than 25 mm.

- Seat should adjust forward and back at least 101 mm from the 50th percentile position.

- The seat cushion should be contoured for buttocks and the back for spinal curves in order to even pressure and provide support. It should provide adjustable lumbar support to increase support and comfort level.

- The seat's backrest should recline between 95 and 115 degrees, the seat pan should tilt back between 1 and 5 degrees from horizontal, front edge higher.

- A backrest curved on a radius of 457 609 mm or with lateral support will help during side sway.

- A rectangular seat pan with elevated sides is preferable to a round seat pan.

- The ideal seat adjustment mechanism is easy to use, reliable, and wear resistant. A swivel may be needed to access the seat and to accommodate the need to turn to look to the back and sides.

- The seat covering should be made of fabric or perforated leather to reduce perspiration and heat buildup.

- Non-seat characteristics can have a direct or indirect impact on the seated position or use of the seat and need to be considered to determine seating comfort.

- Non-seat factors include: leg room, knee room, availability of footrests, clearance from sidewall, vibration levels, ease of entry/exit, clearance when swiveling, visibility, and reach-to-control distance.

WORKSTATION DESIGN

CONTROLS

- Motion controls should be placed directly in front of the driver.

- The radio hand control should be place on the left hand side to allow the driver to operate the locomotive motion controls with his right hand while using the radio with his left hand.

- Controls for the whistle, horn, headlights and radio should be located within the zone of reach and preferably within the zone of comfort, if possible.
- Controls should be consistent with normal limb motions. This means that where arm motions are needed they should be forward and back, not sideways.
- Controls that have a similar function or purpose should be grouped together.

AUDITORY DEVICES

- A vigilance detector system with a time constant that varies based on both speed and control activity should be installed.
- Additional displays associated with a warning advisory panel that indicates which locomotive in a multiple consist is experiencing a particular problem can also be installed.
- For the vigilance system, an audio alarm and visual alert should be placed near the windshield as the drivers attention should be directed towards the outside.
- The use of sounds that could be confused with operational or malfunction noises (e.g., air brake releases, pump operations, sand discharges, etc.) should be avoided.