OLRT

(Ottawa LRV Project)

Consolidated Safety File

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REVISIONS

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A	L. LEFER	05/10/2015		Creation
B	L. LEFER	13/04/2016	1) Chapter 2.4 2) Chapter 5.1 3) Chapter 5.2 4) Chapter 7 5) Chapters 8; 9; 10; 11	1) Update of Train driver incapacity failure rate 2) Update of critical events list 3) Update of hazard description 4) Update of results synthesis 5) Update of maintenance, operation, validation and design constraints
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1 INTRODUCTION

1.1 *Purpose and Scope*

This document has been created to establish the consolidation and summary for all the safety related activities on the OTTAWA project to demonstrate the vehicle is fit for intended use.

This first release of the document has been created at the outcome of the detailed design phase and relates all the lifecycle of the train for the definition and the targets allocation until the exploitation phase.

This document will be updated periodically as open safety analyses are completed and/or specific testing related to safety are completed. A final revision will be issued when the management of all the safety risks will be demonstrated through a hazard analysis and safety tests as required.

The references of the train hazard analysis, subsystems and parts as well as the safety test results are provided in this document.

Thus, this file is organized as follows:

- A LRV description of the major subsystems (traction, brakes, doors….), equipment and components. (Chapter 2)
- The complete safety requirements list with a presentation of the targets (Chapter 3),
- The management, planning and procedure apply for the safety. (Chapter 4)
- The relationship between inputs, outputs and safety documents. (Chapters 5)
- The results of the detailed studies associated with the safety management plan (Chapter 6)
- The results of the Fire Safety Design analysis and testing (Chapter 7)
- The general assessment of compliance to the technical specification (Chapter 8)
- The activities associated with audits, and reviews related to the overall Safety Assurance Program (Chapter 9)
- The summary and conclusions (Chapter 10)

1.2 *Reference and applicable document*

1.2.1 Reference documents

Table 1: Reference documents

No.	*Document*	*Doc. No*
[R1]	Project Management Plan	OLRT-PMP-001
[R2]	Quality Management Plan	OLRT-QMP-001
[R3]	Train Requirement Specification Fire Safety	DTD0000208475
[R4]	ALSTOM Railway Safety Management Manual	RSA-MLN-001
[R5]	Engineering Management Plan	ADD0000938670
[R6]	Train Software Management Plan	ADD0000938676
[R7]	Safety Assurance Management Plan	ADD0000938677
[R8]	Preliminary Hazard Analysis	ADD0000938861
[R9]	RSAD Train	ADD0000939425

[R10]	RSAD Brakes	ADD0000939433
[R11]	Validation Plan	ADD0000938671
[R12]	EMC Management Plan	ADD0000938681
[R13]	Hazard log	ADD0000939629
[R14]	Brake Calculation Note	ADD0000939578
[R15]	SSR - Traction	ADD0000939632
[R16]	SSR - Gauge	ADD0000939262
[R17]	SSR - Doors	ADD0000939630
[R18]	SSR – External Signalling	ADD0000939641
[R19]	SSR - Brakes	ADD0000939631
[R20]	Safety Plan	ADD0000938677
[R21]	Rolling Stock RAM Plan	ADD0000939639
[R22]	Safety Related Items List - SRIL	ADD0000939657
[R23]	Consolidated FMECA	
[R24]	Safety Related Documents List	ADD0000939281
[R25]	First Prefinal Design Review RAMS	ADD0000939480
[R26]	ILS Management_	ADD0000939475_
[R27]	Second Prefinal Design Review RAMS	ADD0000939547
[R28]	Type Test Procedure: Floor & Roof Fire Resistance	ADD0000939609
[R29]	Type Test Report: Floor & Roof Fire Resistance	DED0000460216
[R30]	Crashworthiness Analysis	ADD0000938715
[R31]	SSR – Gravity 1 feared Events	ADD0000939279
[R32]	Fire Safety Design Plan - Ottawa	ADD0000939633
[R33]	Fire Safety Design Report	ADD0000939244
[R34]	Railway dynamic Management Plan	ADD0000938682
[R35]	EMC Management Plan	ADD0000938681
[R36]	Environment Management Plan	ADD0000938684
[R37]	Noise Management Plan	AD0000938679
[R38]	Eco-design Management Plan	DTD0000208565
[R39]	Vibro-acoustic Management Plan	DTD0000212472
[R40]	Occupational Health and Safety Management Plan	OLRTC EHSP MP 001
[R41]	Brake System Clarification	ADD0000939505
[R42]	First Prefinal Design review - Brake System Details	ADD000939483
[R43]	Second Prefinal Design review - Brake System Details	ADD0000939550
[R44]	"White Paper" review on Ottawa LRV braking system	ADD0000939565
[R45]	Compliance Matrix	ADD0000938687

The Final Safety File is realized to the latest version of these documents.

1.2.2 Applicable documents

These documents will be used as guidelines for the RAMS activities.

Table 2: Applicable documents

No.	Documents

[A1]	EN 50126 (CENELEC Standard Railway Applications) : The specification and demonstration of dependability, reliability, availability, maintainability and safety
[A2]	EN 50128 (2011): Railway Applications Software for Railway Control and Protection System
[A3]	IEC 812 : Analysis Techniques for System Reliability-Procedure for Failure Mode and Effects Analysis
[A4]	IEC 1025 : Fault Tree Analysis
[A5]	IEC 62278 : Railway Applications – Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)
[A6]	IEC 62279 : Railway Applications – Communications, Signalling and Processing Systems – Software for Railway Control and Protection Systems
[A7]	MIL-STD-882 : Standard Practice for Safety System
[A8]	Schedule 15-2, Part 4 Article 3 of the Project Agreement

1.3 *Abbreviations and definitions*

Table 3: Abbreviations and definitions

Abbreviation	***Explanation***
AC	Alternating Current
AGATE	Advanced Generic Alstom Traction Electronics (Alstom Trade Mark)
AGTU	
APS	Auxiliary Power Supply
ASU	Air Supply Unit
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATPM	Automatic Train Protection Manual
AW3	Assigned Weight 3 (seated plus 6 passengers per square meter of standing space)
CAID	Clim Aire Interface Driver
CAN	Control Area Network
CB	Circuit Breaker
CCTV	Closed Circuit TeleVision
CGR	Critical Gate Review
CVS	Convertisseur Voltage Statique (See APS)
DAT	Duct (Supply) Air Temperature
DC	Direct Current
DCU	Door Control Unit
DDU	Driver Display Unit
DFQ	Design For Quality
DRCS	
EAD	Emergency Access Device
EB	Emergency Brake

EBCC	Electronic Brake Control Card
EBCU	Electronic Brake Control Unit
EDR	Emergency Door Release
EED	Emergency Egress Device
EMC	ElectroMagnetic Compatibility
EMM	
EN	European Norms
ESG	External SiGnalling
EVR	Event Recorder
FAT	Fresh Air Temperature
FBS	Function Breakdown Structure
FMECA	Failure Mode Effects and Criticality Analysis
FQA	Final Quality Acceptance
FSD	Fire and Smoke Detection
FTA	Fault Tree Analysis
GAME	Globalement Au Moins Equivalent (overall at least equivalent)
GFV	Go For Validation
GSR	Go Serial Review
HPCO	High Pressure Cut-Out
HPU	High Pressure Unit or Hydraulic Power Unit
HSCB	High Speed Circuit Breaker
HV	High Voltage
HVAC	Heating Ventilation Air Conditioning
HW	HardWare
ICT	
IEC	International Electrotechnical Comission
IEEE	
IGBT	Insulated Gate Bipolar Transistor
IHA	Interface Hazard Analysis
ILS	Integrated Logistics Support
IMC	Intermediate Motor Car
IOS	Incorrect Operation Status
IQR	Internal Qualification Review
ISO	
LCC	Long Central Car
LCM	Least Common Multiple
LGR	Launch Gate Review
LHD	Latent Heat Detector

LLEPM	Low Level Emergency Path Marking
LMC	Long Motor Car
LPCO	Low Pressure Cut-Out
LRC	Thermo King HVAC Unit
LRV	Light Rail Vehicle
LV	Low Voltage
LVPS	Low Voltage Power Supply
MAS	Motor ASynchronous
MC	Motor Car
MIL-HDBK	MILitary HanDBooK
MIL-STD	MILitary STanDard
MPU	Main Processing Unit
MSB	Maximum Service Brake
MU	Multiply Unit
MV	Medium Voltage
MVB	Multifunction Vehicle Bus (train network)
NA	Not Applicable
NPU	Network Processing Unit
OCC	Operations Control Centre
OCS	Overhead Catenary System
OLRT	Ottawa Light Rail Transit
ONIX	ONdular Intégration eXceptionnel (Alstom Trade Mark)
PBEB	Push Button Emergency Brake
PBS	Product Breakdown Structure
PCB	Printed Circuit Board
PCE	Propulsion Control Electronics
PGR	Preliminary Gate Review
PHA	Preliminary Hazard Analysis
PHL	Preliminary Hazard List
PIS	Passenger Information System
PPS	Primary Power Switch
PTU	Portable Test Unit
RAMS	Reliability, Availability, Maintainability, Safety
RAT	Return Air Sensor
RIOM	Remote Input Output Module
RM	Restricted Mode
RS	Rolling Stock
RSAD	Requirement Specification and Architecture Description

SA	Surge Arrester
SCR	Specification Change Request
SGR	Specification Gate Review
SAMP	Safety Assurance Management Plan
SRIL	Safety Related Items List
SRV	Safety Relief Valve
SSHA	Sub-System Hazard Analysis
SSR	Safety Studies Report
SW	SoftWare
TBCU	Traction Brake Control Unit
TCMS	Train Control & Monitoring System
TCU	Traction Control Unit
TDSG	Train Design Sound Generator
TGR	Tender Gate Review
THR	Tolerable Hazard Rate
TSAM	Train Safety Assurance Manager
TSCC	Transit Services Control Centre
TTCUx	
TUV	Technischer UberwachungsVerein (German railway standards)
UIC	Union Internationale des Chemins de fer (International Union of Railways)
UMC	
UTO	Unmanned Train Operation
VCU	Vehicle Control Unit
VGR	Validation Gate Review
VMC	
VOBC	Vehicle On Board Controller
VPF	Alstom Valenciennes Petite-Forêt
WSS	Work Shop Socket

2 ROLLING STOCK DESCRIPTION

2.1 *LRV configuration*

The OTTAWA Project is based on the CITADIS Spirit product range (vehicle 404).

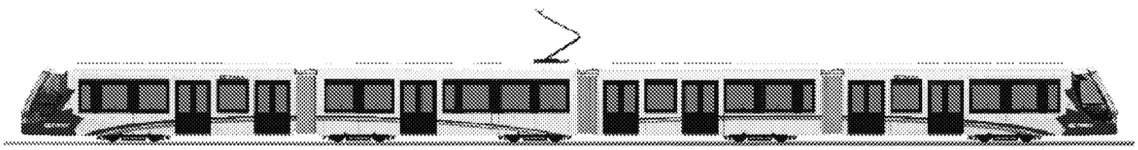


Figure 1: Train configuration

The whole train configuration is made up of 4 elements or car sections as follows:

- LMC_1/LMC_2: Long Motor Car
  - ✓ Two fully motored elements at the extremities of the LRV with a driver's cabin.
- IMC_1: InterMediate Car
  - ✓ One intermediate trailer element.
- Long Central Car
  - ✓ One intermediate half motor element.

The 404 vehicle is equipped with 14 passenger doorways, 7 per side, directly across from one another and has a total of 5 trucks (3 motor trucks and two trailer trucks).

Each motor truck has two traction motors and gear units, 1 track brake pair and one mechanical brake composed of 2 callipers and disks.
Each trailer truck has 1 track brake pair and one mechanical brake composed of 4 callipers and disks.

The energy is taken from the catenary in the LCC Car. The current collection is made by one pantograph. The nominal voltage on the catenary is 1500 V.

2.2 *Operating mode*

On the Ottawa Project, the train can be operated in several modes:

Table 4: Operating Mode

Mode	*Description*
Dead	There is not any power supply on the vehicle. The battery is cut off.
Unprepared	It's the minimum active state of the vehicle: everything is off except the red external lights for signalling and radio in sleeping mode.
Service Retain	This mode maintains HVAC, Lights, Doors, PA System, etc., for a period to allow for end-to-end changes, and upon cleaners/maintainers entering the car, time to clean or do some limited functions.
Layover	All the electronics are operational, but to save energy, train does a load shedding. The HVAC are configured in Layover Mode (heat set to maintain car at 4 to 8 degrees C), the

	Internal Lighting is in emergency mode and the PIS Display are off. The door push-buttons are inactive, and the door only opens with the Crew Key.
Active Cab	It's the mode to drive the train. The train drive chose a cab, and this one becomes active. It means all the commands come from this one, and the others are neutralized.
ATO (Option)	Automatic Train Operation Mode is a sub level of the active cab mode: the ATC takes the control with a driver.
UTO (Option)	Unmanned Operation: the ATC takes the control without a driver.

2.3 *Mission profile*

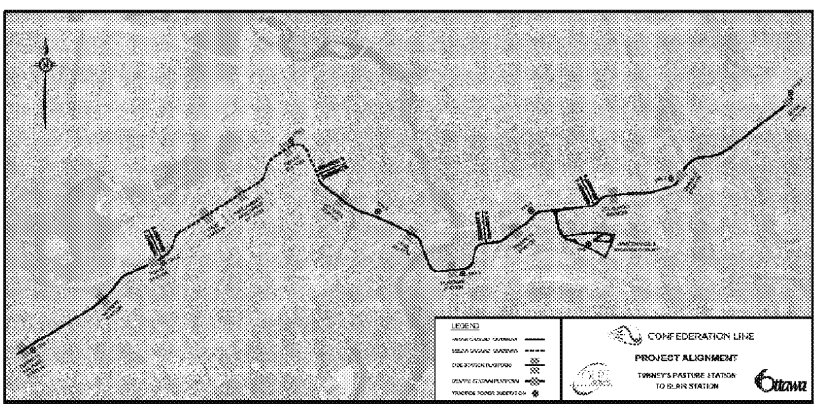
The Confederation Line is a light rail transit system which will operate in the City of Ottawa. The initial build will operate between Blair Station in the east and Tunney's Pasture in the west.
The line will be 12.5 km in length with 2.5 km running underground in a tunnel beneath Ottawa's downtown core.

The right-of-way of the initial build is completely segregated and there are no at-grade road/rail crossings. Public intrusion onto the system is prevented by means of right-of-way fencing.
There are 13 stations on the initial system.

The maintenance and storage facility will be located in Belfast Yard which is approximately 600 meters south of the mainline between Tremblay and St. Laurent Stations, connected to the main line by dual connecting tracks.

There will be a Transit Services Control Centre (TSCC) located at [redacted] from which operation of the system will be controlled and coordinated.

The system is designed to have an ultimate capacity of 24,000 passengers per hour per direction.



Some mission profile elements are given below (**Error! Reference source not found.**), they will constitute common data to all analyses.

Table 5: Mission profile parameter

Mission profile parameter	Value
Train consist	LMC1-IMC1-LCC-LMC2
Lifetime of material	30 years
Minimum ambient temperature	-40°C
Maximum ambient temperature	+40°C
Ottawa train fleet	34
One Vehicle consist length	49 m
Passenger capacity per vehicle	300
Station length	90 m
Global line length	12,5 Km
Line length underground	2,5 Km
Number of stations	13
Number of stations underground	4
Average number of days in use per year	310 days/year
Average time in circulation/operation per day	13 hours/day
Time in circulation/operation per day	24 hours/day
Annual distance per train	100 000 Km
Maximum speed	100 km/h
Service average speed	24,8 km/h

2.4 *Hypothesis of safety calculations*

For the fault tree analysis basic events, we have used the following data.

Those data come from the IEC 62380, the MIL-HDBK 217F, RAMS tools and the mission profile.

To represent some particular situations that may impact the boundary hazards, Alstom Transport uses the following events and probabilities:

- Train driver incapacity : 5.56×10^{-7} (1 every 20 years over the fleet)
- No reaction of the driver in case of drift/rollback of the train: 1×10^{-3}
- No reaction of the driver in case of untimely traction: 1×10^{-3}
- Failure/incorrect response of the driver: 1×10^{-3}
- No respect of maintenance procedures by a maintainer: 1×10^{-3}

Safety calculations are realized taken into account those hypotheses:

- Step of maintenance plan are respected and well done
- Drivers, control operators and maintainers are trained and know and apply the operating rules and maintain rules
- Infrastructure is in accordance with specifications.

2.5 *Latency Time*

Latency time defines the elapsed time between the last instant when the component was monitored as operating correctly and the moment when the failure is repaired or isolated to put the train in a safe operating condition.

The most common latency times are:

- 0,1 h: for all components whose failure is detected at each station and where the failure can be repaired or isolated immediately to put mitigate the problem
- 24 h: for all components whose failure is detected and repaired after the service
- Maintenance interval in days based upon maintenance schedule: for Failures which are not monitored but are detected only during inspection
- 262 800h (30 years) : Failures which cannot be detected have a latency time equal to the train lifetime
- 1h: for all components whose failure is detected, or isolated at the end of tour by train removal

The intervals of inspection which are used to demonstrate the safety are included in the chapter 6.5.1.1 of this document "Maintenance task summary links to the safety". These intervals cannot be modified without revalidation of the hazards that the tasks are mitigating.

In order to take the "worst case", the latency time is the Least Common Multiple: LCM.

2.6 *Train subsystems, equipment, component descriptions*

2.6.1 Carbody Structure

The carbody is composed of one underframe, sidewalls, roof and end ring as shown in the picture below:

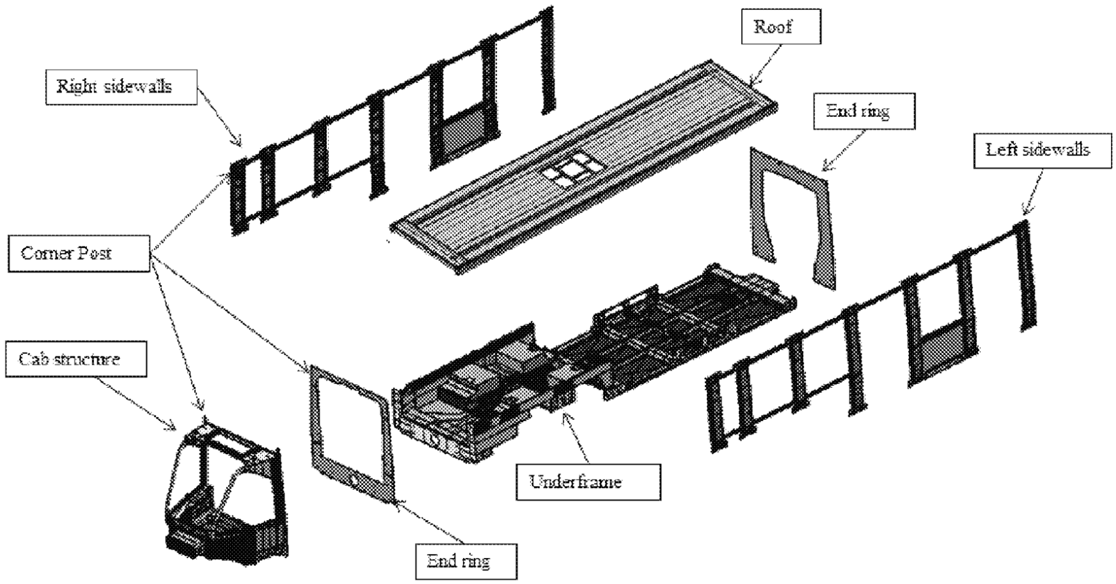


Figure 2: Carbody Structure

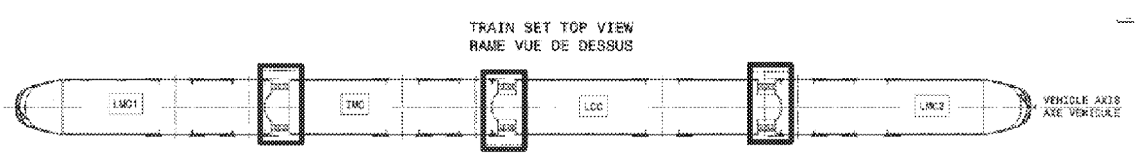
Each carbody element shell consists of 4 subassemblies:

- one welded underframe
- two sidewalls (left/right)
- one welded roof assembly
- two end rings.

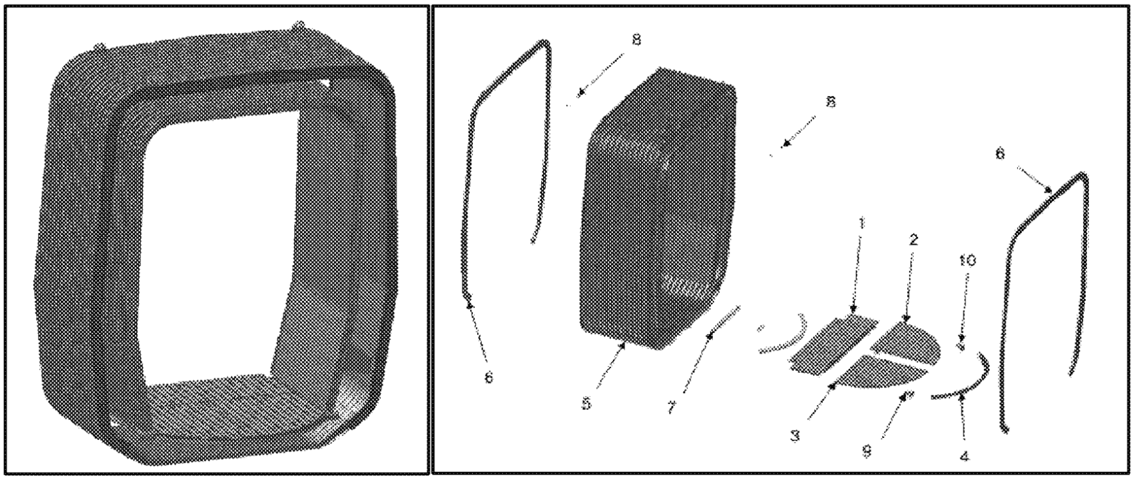
The carbody structure is made of aluminium and steel parts.
The connections between carbody subassemblies are done by the means of HRC bolts.

2.6.2 Intercar equipment

2.6.2.1 Gangway



Gangways are made of metal components and polymer material to form an inter-connecting passage way from one vehicle to another enabling passenger to walk with safety and security.



Number	Item Description
1	Floor Plate Equipped
2	Left Rotating Equipped
3	Right Rotating Equipped
4	Bended Threshold Plate
5	Bellows
6	Equipped Frame
7	Inferior Fixing Plate Equipped
8	Centering Pin
9	Right Folded Sheet
10	Left Folded Sheet

Figure 3: Gangway Description

2.6.2.1.1 Design Evolution

It is important to note that the intercar bellows is not flush to the vehicle sides, as required by specification. During the design and styling this point was discussed and the colour of the fabric was selected so that the visually impaired could distinguish it from the doorways.

During the production phase, the platform gap at the gangway was reassessed with a potential hazard of a person being trapped between the platform and the vehicle at the gangway, and the decision was made to add a third side layer to the bellows, to minimize the gap at the platform.

The final design of the 3rd bellows layer is still under development. See 6.1.2.1 for description of the complete issue and photographs of the changes

2.6.2.2 Articulations description

The movement between each carbody element is permitted by different types of articulations (upper and lower articulation) at each inter-car connection.
At the level of inter-car, corridors gangway linking each car allow passengers access from one car to another.

Each vehicle is composed of:

- lower articulations
- longitudinal dampers (reduce movement between two car "gallop")
- dip-hump rods and anti-yaw dampers (allow circulation on vertical curve)

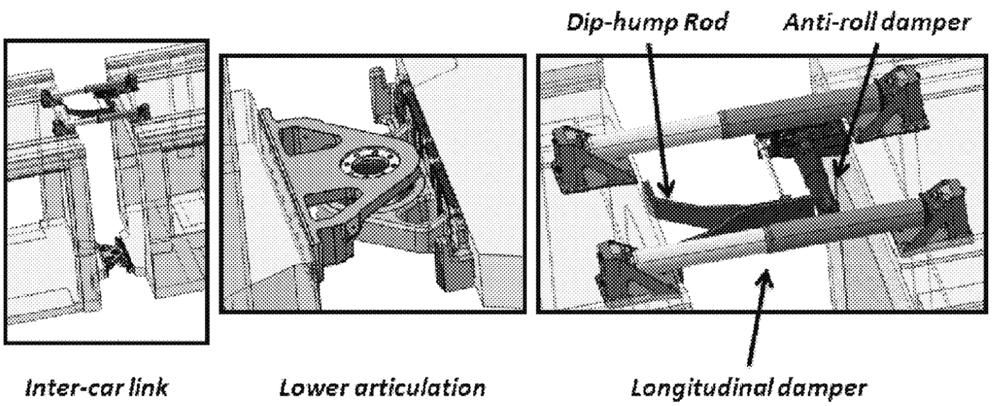


Figure 4 : Articulations - Different Types

Please find below a geographical position of each articulation type:

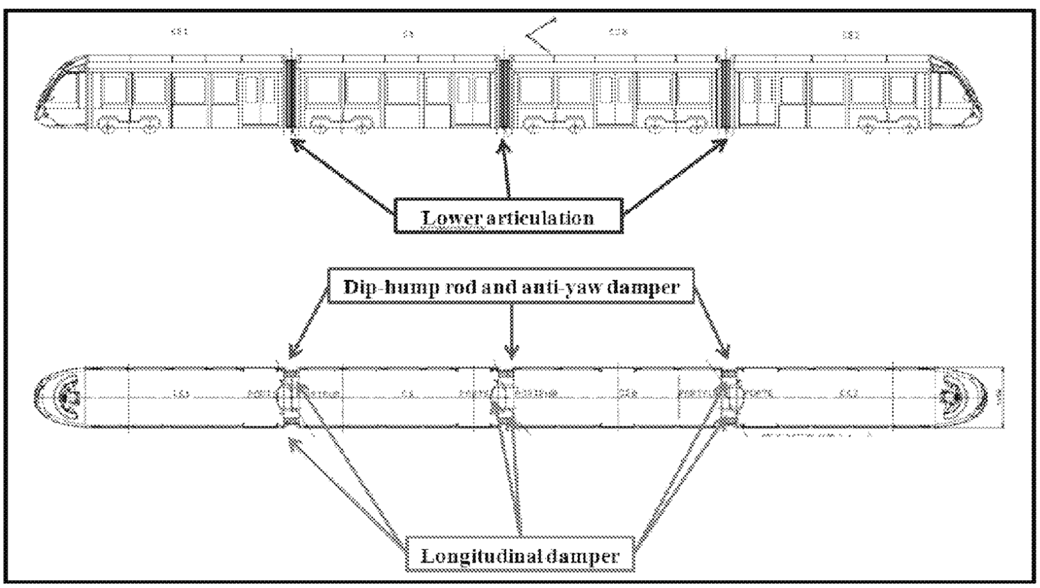


Figure 5 : Geographical Position of Articulations

2.6.2.3 Coupler

A coupler is installed at the extremity of each LMCx to connect two LRVs.

For operational reasons (multiple unit operations or towing pushing), the coupler equipment allows both mechanical and electrical connection between two LRVs. This equipment is composed of one mechanical and two electrical coupler heads.

The coupler is foldable in underframe after a uncouple operation. Once the cover is attached, the coupling system is no longer visible.
The coupling status indicator at the front face can check the coupling status of two couplers during the coupling process, and send electric signals to the diver desk to show the on-line status.

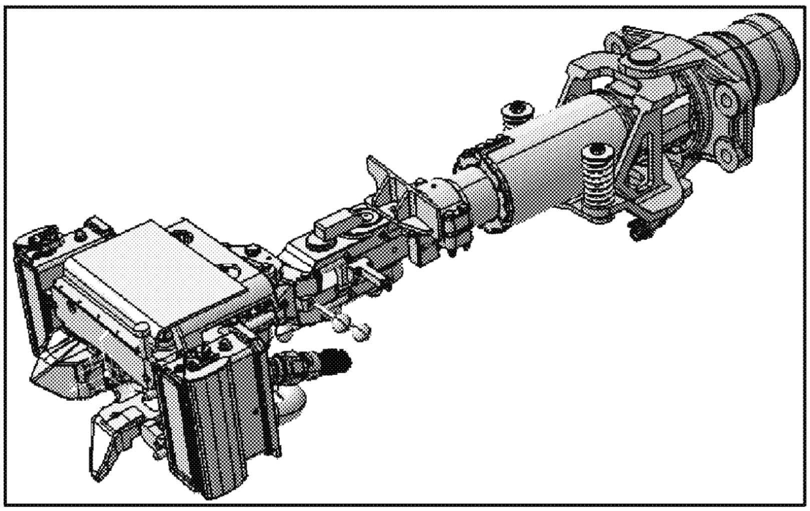


Figure 6 : Coupler

2.6.3 Underframe Equipment

2.6.3.1 Snow Plough

The aim of the snow plough is to remove the snow accumulations between two train passages to protect to the extent possible, antenna, cables and motors from snow accumulation on the track. It is composed of two different parts one rigid part in steel and one flexible in polymer. This large deflector is mounting across the width as shown below:

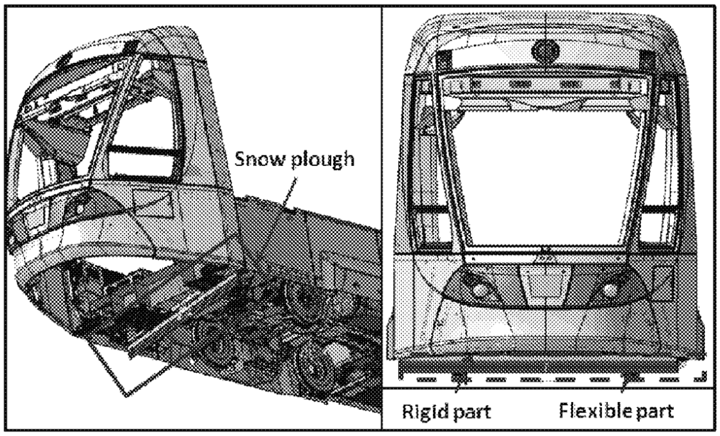


Figure 7: Snow Plough

2.6.3.2 HPU

The HPU is a self-contained unit which is used to supply hydraulic pressure to the accumulator and the callipers. It consists of a reservoir, pump, motor and a hydraulic valve manifold. The motor drives the pump which builds pressure in the accumulator. The pressurized fluid is routed through the valves in the manifold and delivered to the callipers in order to regulate the forces necessary to stop the vehicle. The HPU is a compact unit designed to mount under the carbody or on the truck frame. There is one HPU per truck mounted underneath the vehicle, in a wheel arch above each truck.

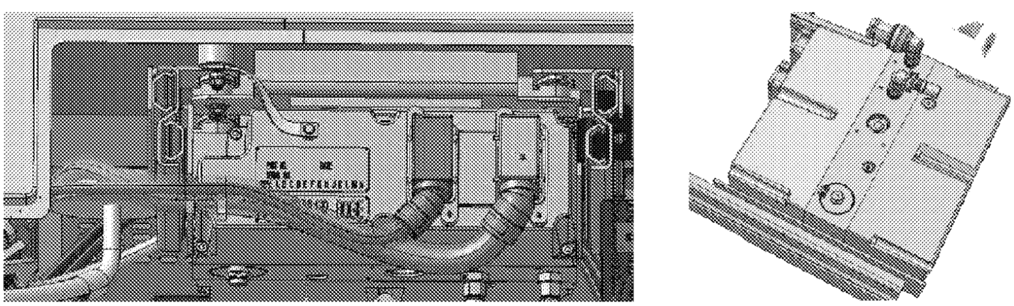
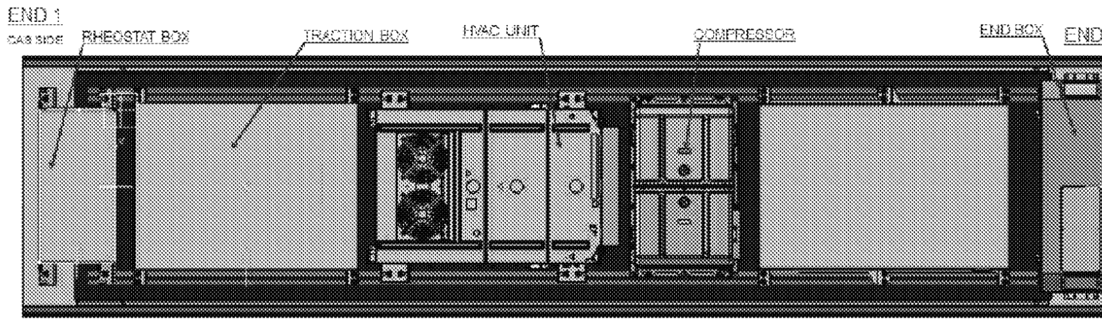


Figure 8: HPU

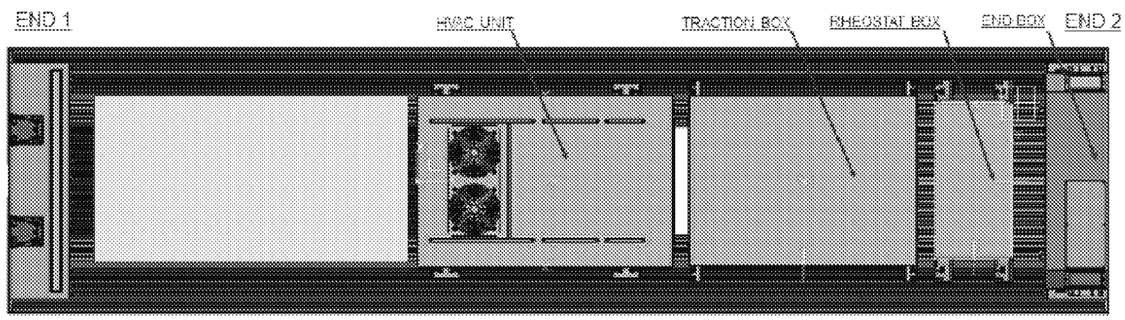
2.6.4 Roof Equipment

Here after description of equipment implemented on roof:

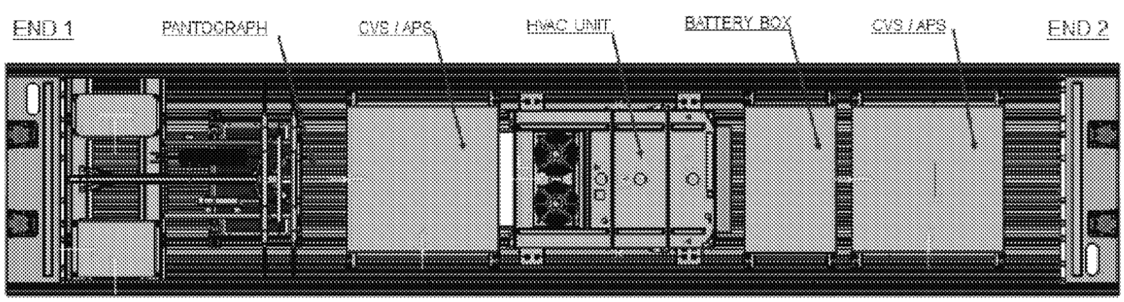
<u>On LMCx Roof</u>



On IMC Roof



On LCC Roof

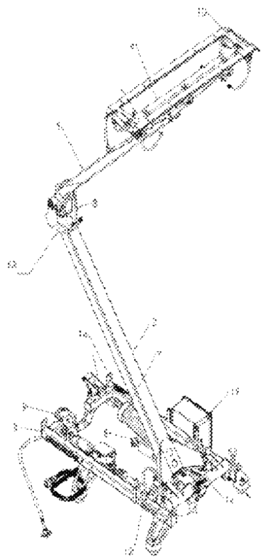


2.6.4.1 Pantograph

Pantograph provides power from the catenary to the car. Electricity is conducted through the carbon assemblies on the collector head, via the shunts, to the members of the pantograph and ultimately to the power take-off plate(s) on the base frame.

The pantograph is spring-raised and lowered by an electric motor drive with a shear pin release. The collector head includes a suspension that allows for optimal wire tracking of the catenary and absorption of obstructions. An adjustable dampening system is utilized to ensure proper wire tracking and smooth pantograph raising and lowering.

1	Base frame assembly
2	lower arm assembly



3	4th bar assembly
4	A.D.D. component assembly
5	upper arm assembly
6	head levelling assembly
7	spring pack assembly
8	damper assembly
9	motor drive assembly
10	head assembly
11	nameplate
12	decal, high voltage
13	warning, M16 type A SST
14	warning label, shear pin
15	tag, shipping bolt
16	washer, M16 type SST
17	bolt, hex head, M16 x 20mm, SS
18	nut, M16 hex HD elastic stop
19	heater kit

Figure 9 : Pantograph

2.6.4.2 Traction Box

The role of the traction control system is to control and monitor one electric traction/brake system (PCE or TBCU). The electric traction box is composed of the following equipment:

- Traction Inverter module
- Line contactor and filter charging contactor
- Control Electronics
- Line filter inductor and capacitor
- Inverter cooling fans

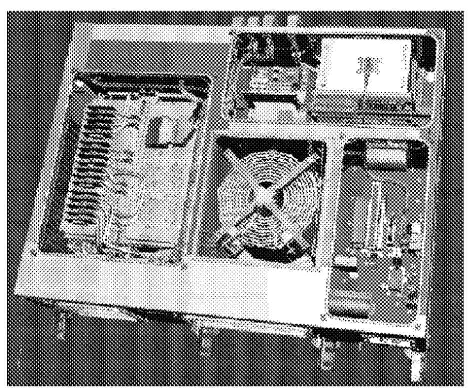


Figure 10: Traction Box

2.6.4.3 Battery Box

The application of the battery is to provide back-up electrical power for safety and auxiliary circuits.
The battery is fitted to the roof of the vehicle. It delivers a nominal voltage of 24V x 2 at 20°C.
In case of emergency, the battery provides the power needed for braking, lighting, signalling, etc.
The battery is also connected to a battery charger.
The battery consists of an enclosure containing an electrical compartment on a power plate and a set of heaters & covers under it.

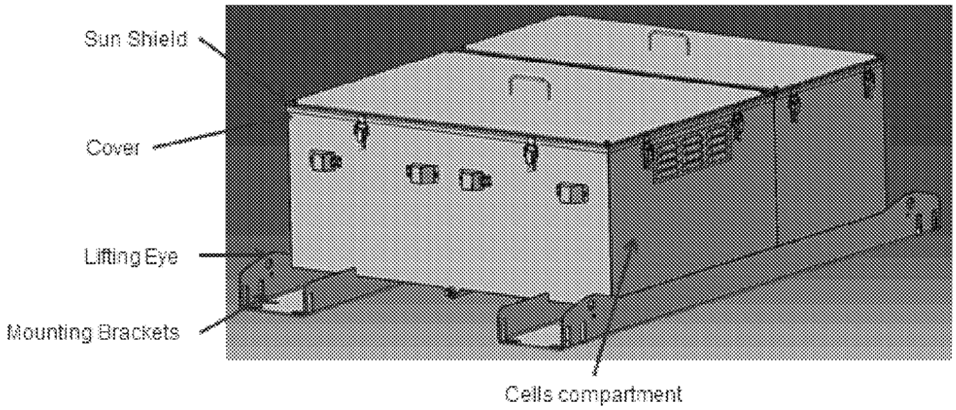


Figure 11: Battery Box

2.6.4.4 APS/CVS Box

The Auxiliary Converter provides electrical energy to the auxiliary equipment.
Main functions are:

- DC supply that supplies batteries and equipment connected to train low voltage from 17V to 34V,
- Three-phases AC (360V to 480V) that supplies air conditioning system (HVAC),
- AC output 120V for internal plug socket and heating floor.

This equipment is mounted on the train of the roof. Mains parts are:

- Electrical devices
- Control command boards and sensor
- Power modules
- Cooling system

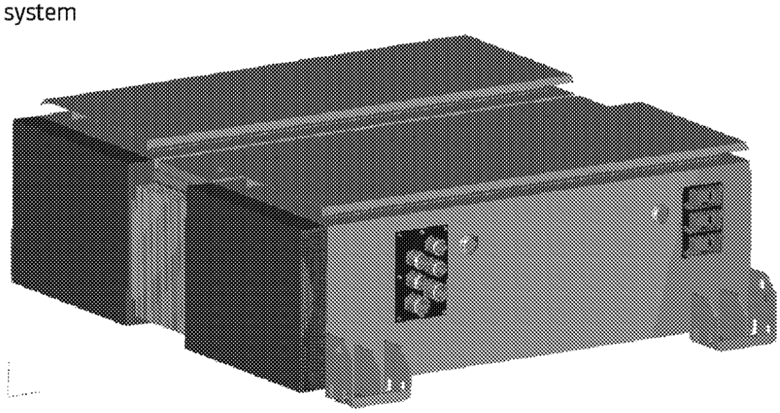


Figure 12: APS/CVS Box

2.6.4.5 Rheostat Box

Rheostats are used to keep DC voltage under control, thus dissipate electric power during the vehicle braking phase when the catenary is not receptive.

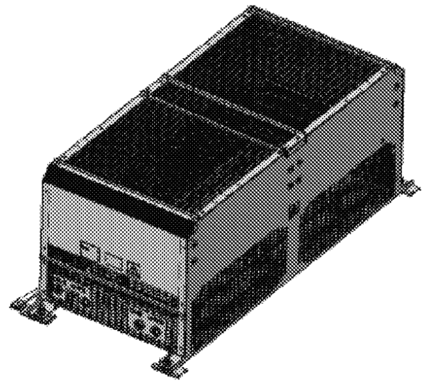


Figure 13: Rheostat Box

2.6.4.6 HVAC

The LRC Heating Ventilation and Air Conditioning (HVAC) unit manufactured by Thermo King is a roof-mount unit designed for the Light Rail Vehicles. The unit provides the cooling, dehumidifying and heating of the air for the passengers and drivers cab to keep the temperature conditions comfortable.

The LRC unit consists of hermetically sealed refrigerant circuit, air system with filters, heating system, electrical circuit, control system, unit frame and covers and auxiliary elements.
The main LRC unit is designed for mounting on rooftop level.

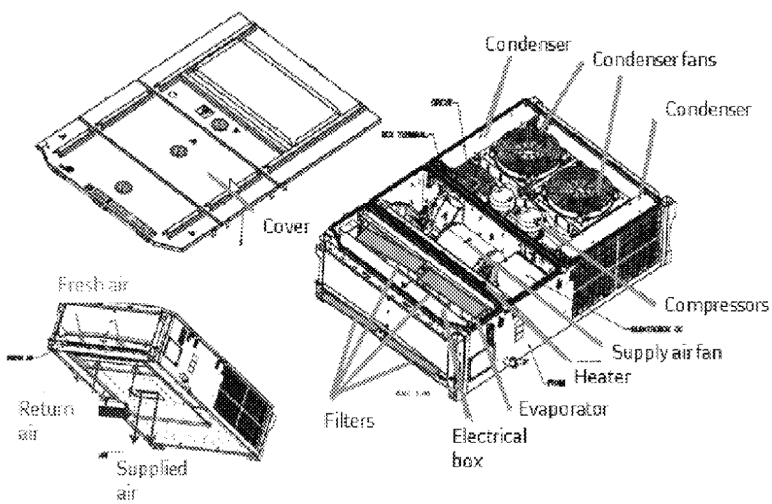


Figure 14: HVAC

2.6.4.7 End Box

It is a box allowing many functions:

- Allows the Low Voltage distribution
- Management of the voltage drops (Distribution apparatus nearest to energy source)
- Allows the intercar power connections without using power connectors (costs)

Generally, this box allows all the electrical links between cars.

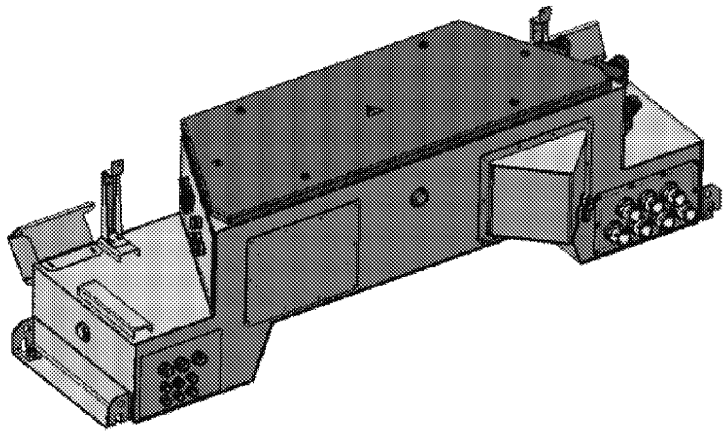


Figure 15: End Box

2.6.4.8 Primary Power Components

On the LCC car there are several components of the traction system which are used in overall protection and distribution of primary power these are:

- Surge arrester
- Primary Power Switch (PPS)
- HSCB Box

They are described in the traction subsystem description which follows

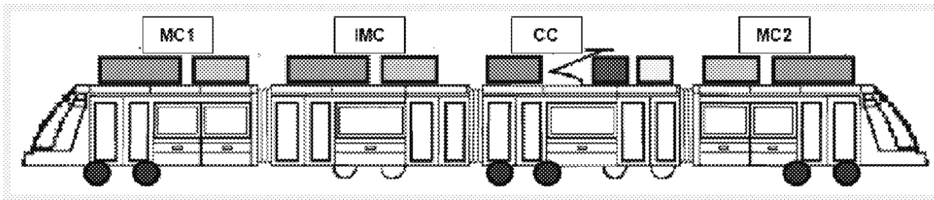
2.6.5 Traction subsystem description

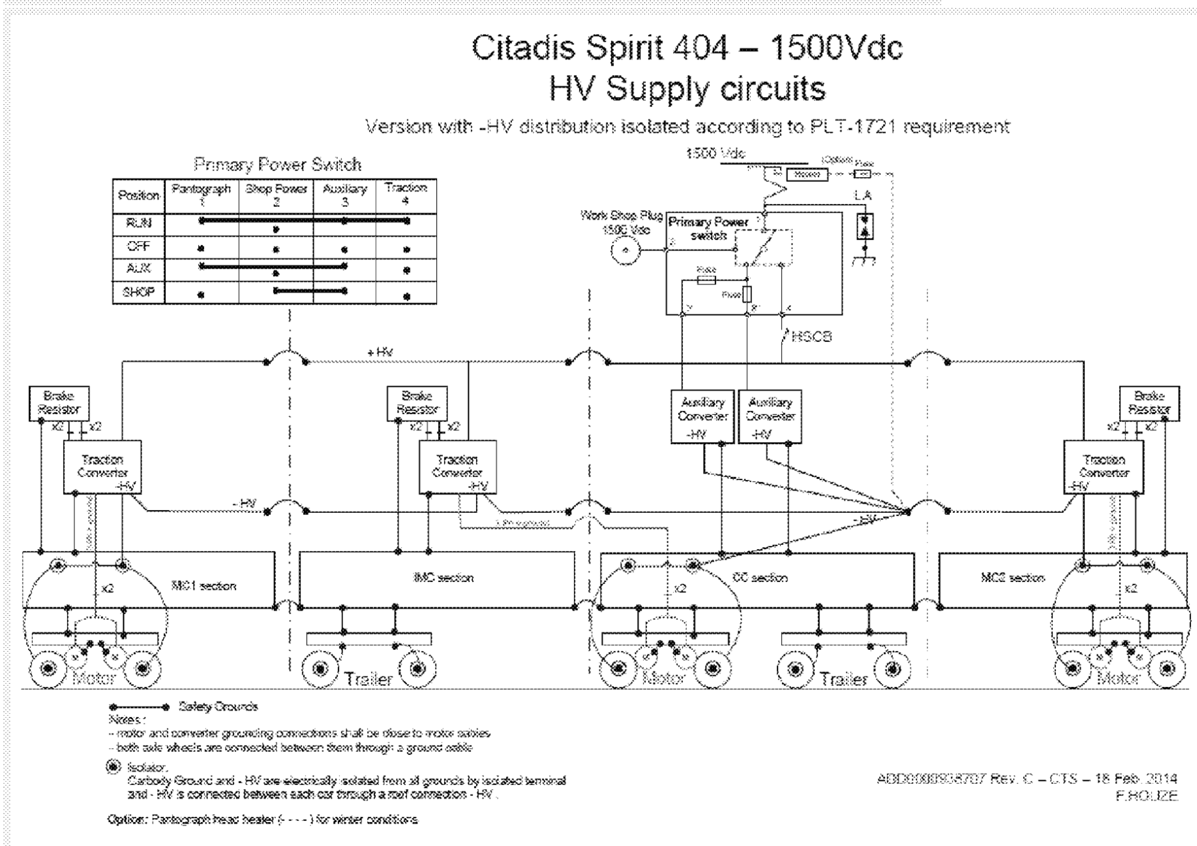
The role of the Traction System is to control and monitor motorized truck, and the related devices. Traction subsystem is composed by: Primary Power Switch (PPS); High Speed Circuit Breaker (HSCB); Surge Arrester (SA); Traction Converters (Traction Braking Control Unit - TBCU); Rheostats Packs; Asynchronous Motors (two per truck).

Hereafter a table and picture with the main equipment number per Train:

Surge Arrester	1
Primary Power Switch	1
HSCB Box	1
Traction Converter	3
Rheostat Packs	3
Traction Motor	6

The following picture shows the main equipment allocation on the Train for 404 Configuration (Single Unit):





2.6.5.1 *High Voltage Architecture*

The high voltage circuit of the complete traction chain is composed by the following main devices:

- The pantograph (not in traction subsystem for RAMS analysis)
- The Primary Power Switch
- The lightning arrester, that protects the high voltage equipment against over-voltages
- The high speed circuit-breaker box
- The traction / braking boxes (one per motor truck with inverter per motor)
- The asynchronous traction motors
- The natural convection-cooled brake rheostats that are installed on an independent frame and equipped with appropriate mechanical protection systems. Each rheostat frame consists of two resistors one supplied by independent connections to each traction inverter.
- Speed sensors (dual channel speed sensor), one for each motor

In particular each TRACTION CONVERTER BOX contains the following equipment:

- The main Line contactor
- A Pre-charge circuit, managed by the electronic control system for limiting the inrush current in the filter capacitors when the contactor closes
- An LC filtering unit used to limit the effects of line transients on the inverter reduces emission of high frequency harmonic currents on the line and limits under most cases the di/dt for fault conditions. Filters are designed to be compliant with European and American regulations on electromagnetic compatibility.
- DC voltage and DC current sensors to protect and control the converter equipment
- An ONIX 2 level voltage, 3 phase IGBT Power Module
- An AGATE electronic control system for inverter control and monitoring of the whole traction converter. Each Traction Unit manages the mechanical brake system of the related truck as well

The power module consists of:

- Two IGBT inverters, each one supplies one traction motor
- Two IGBT braking choppers. Each braking chopper is associated to an inverter and is used to dissipate the braking energy when the catenary line is not receptive, as to protect the traction equipment against over-voltages
- Two filter capacitors connected in parallel

The primary power switch is composed by following equipment:

- A multi contact switch to provide the run/aux/off/shop function
- Fuses to protect auxiliary power converters

- The circuit-breaker box contains the following equipment:
- The ultra-fast circuit-breaker, to protect and isolate the HV distribution to traction converters
- A voltage relay
- A control and command circuit

2.6.5.2 Traction subsystem component

2.6.5.2.1 Surge Arrester

The surge arrester is used to protect all the traction subsystem and auxiliary converter equipment from overvoltage or lighting.

2.6.5.2.2 Primary Power Switch

The Primary Power Switch (following called PPS) is a component electromechanically interlocked that operates manually and it is used with the operating voltage equal to 1500V in nominal condition.

The PPS is composed by 2 poles with 4 available positions, it is employed to:

- Position RUN: connect the Traction and Auxiliary converters to the pantograph;
- Position OFF: switch OFF the Traction and Auxiliary converters;
- Position AUX: connect only Auxiliary converters to the pantograph;
- Position WSS: connect the Auxiliary converter to the Work Shop Socket;

Two fuses and their holder are inside the PPS box to protect the auxiliary converters.
For every position are several auxiliaries contacts, 1 normally closed and 1 normally open.
An electromechanical interlock is implemented with a multiple auxiliary contacts that indicates the position of the interlock.

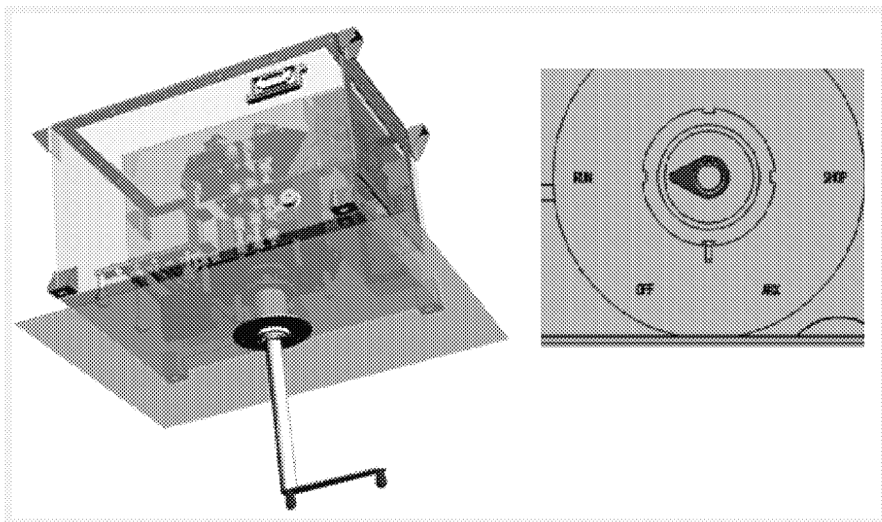


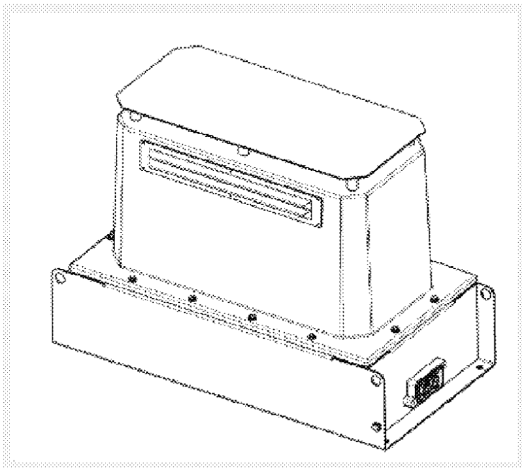
Figure 16: Primary Power Switch

2.6.5.2.3 HSCB Box

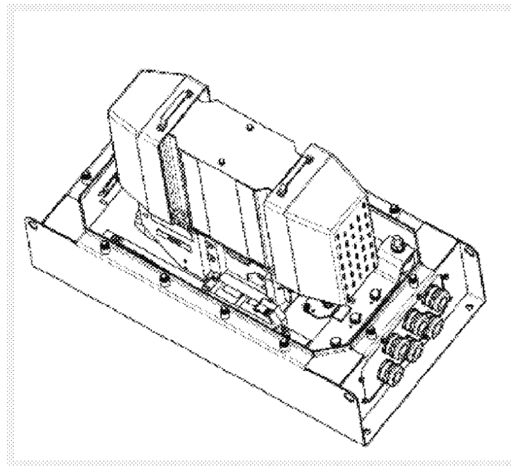
The HSCB (High Speed Circuit Breaker) is used to connect and disconnect from the PPS all traction converters; it is used to protect the power equipment directly connected to the catenary against short-circuit currents.

HSCB closes when HV system is powered by the catenary and the available HV voltage is in the expected range; after that, it is commanded open only for protection purposes following a Traction or TCMS opening request and has an internal instantaneous overcurrent trip mechanism for rapidly rising currents that result from short circuits to carbody or traction negative.

HSCB Box



HSCB



2.6.5.2.4 Traction/Brake Control Unit

Role of the traction converter is to drive the vehicle electrical motors, converting the catenary DC voltage into 3 phase variable voltage variable frequency, AC voltage to feed the motors as to realize the required torque.
One traction converter box (containing 2 inverters) is used to supply two motors mounted on the same motor truck; on the LRV there are as many traction converter boxes as the number of motorized trucks.
Each motor is supplied by one dedicated IGBT inverter with a shared input filter. Traction Control Unit is designed to realize the effort requested by TCMS via trainlines and MVB network interface. Traction software provides spin and slide control, motion direction control, electrical braking blended with friction brake, fault diagnostics and fault protection.

The traction converter is part of the whole traction drive and includes the input LC filter, the ONIX power module (with filter capacitors inside), the cooling system, the AGATE electronic control unit, HV contactors, LV command and control circuit.
Internal layout of the equipment follows easy-maintenance logic, respecting the thermal limit of the components and the EMC standards compliance.

Internal traction converter layout and positions of main components are shown in the following figure.

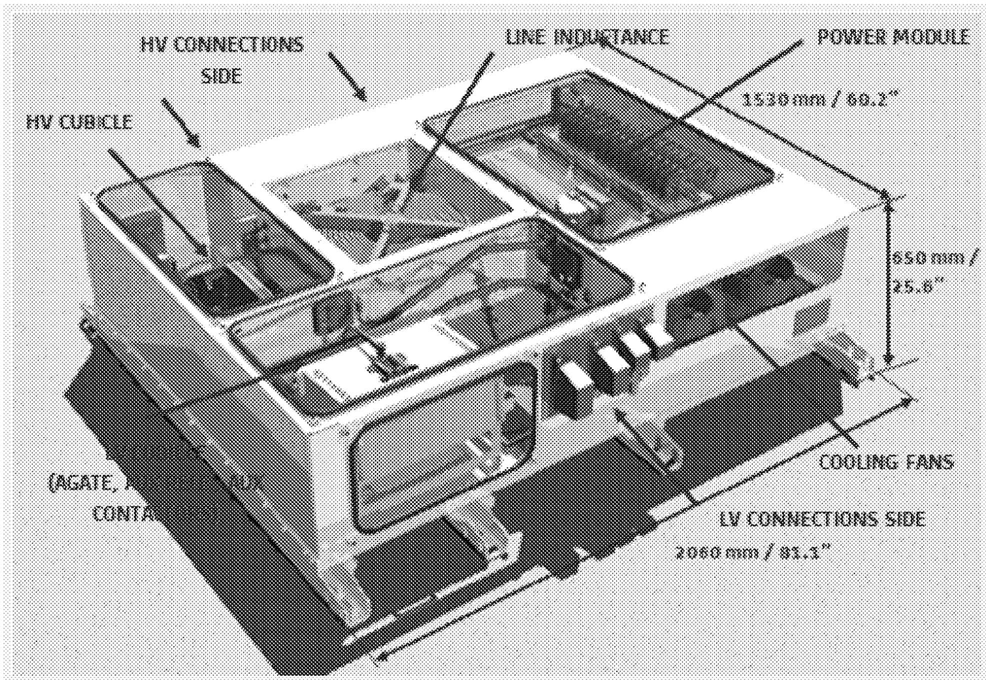


Figure 17: Traction Brake Control Unit

2.6.5.1 Traction Motors - Asynchronous Motor – MAS

The traction motor for Citadis Spirit is a totally enclosed self-ventilated three phase asynchronous motor.

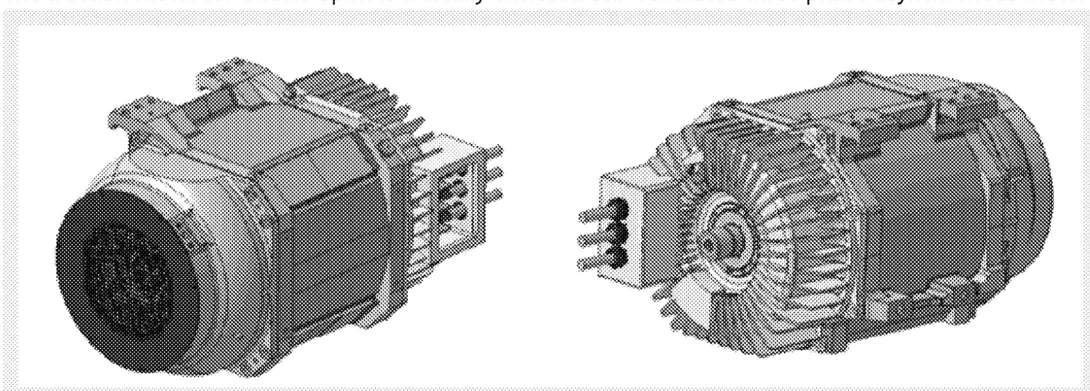


Figure 18: Traction Motors

2.6.5.2 Speed Sensor

A Dual channel Hall Effect speed sensor is installed on the motor case to monitor the rotor speed and direction by observing the teeth of the fan mounted toothed wheel, providing two analogue outputs (square wave signals). The two outputs have the same defined high/low level (i.e. both output channels always either low on a tooth or high on a valley). The two channels are physically displaced within the sensor housing, resulting in a fixed phase relationship as a function of rotational direction of the motor.

2.6.5.3 *Braking Rheostat*

The braking rheostat packs are composed of two braking resistors, one for each truck braking chopper.

The braking resistor is a natural cooling device; the active materials are assembled by a fin technology mounted on ceramic insulators. The physical sizing of the resistor is based upon no vehicle movement. The beneficial effects of cooling as a result of vehicle motion are NOT considered.

A predictive Software thermal model is used to protect the device against over-temperature conditions.

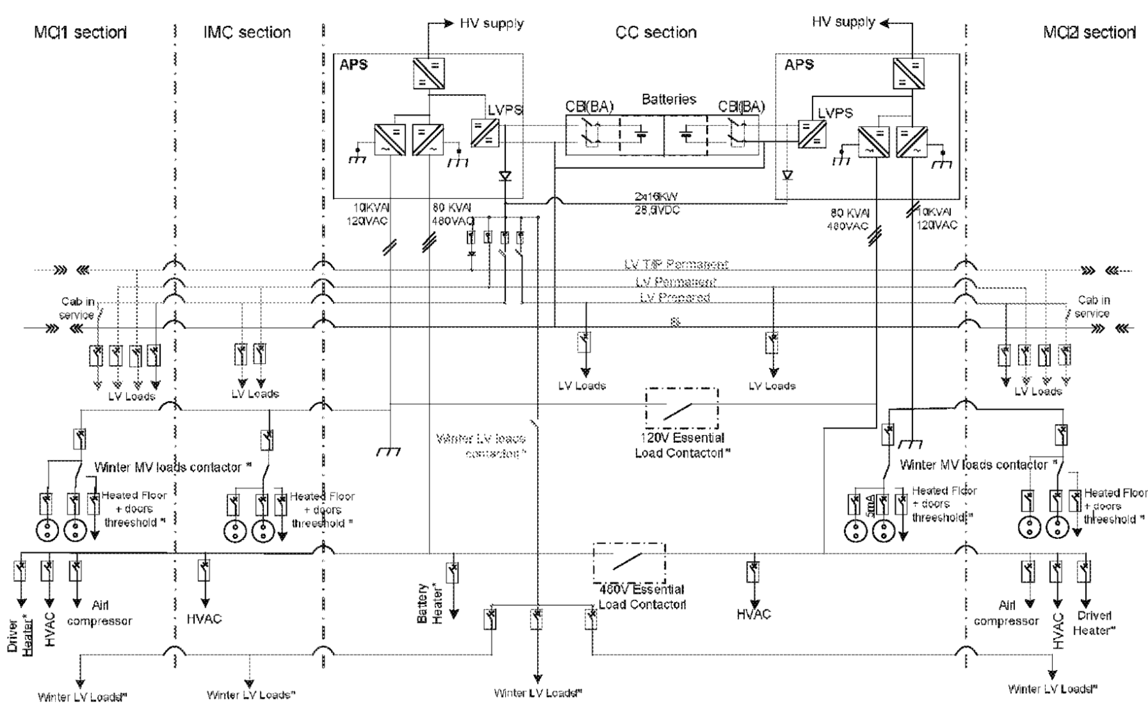
The braking resistor is designed to dissipate all the regenerated vehicle energy in the event that the OCS system does not accept regenerated energy.

2.6.6 Auxiliary Power Supply

2.6.6.1 *APS Description*

APS is powered from the 1500 VDC from the Pantograph or the Workshop Outlet Socket through the Primary Power Supply.

- Two APS and two batteries are located in LCC car.
- Each APS charges one battery charger. The batteries are connected in parallel to the low voltage distribution through diodes.
- The distribution of low and medium voltage is as shown below:



This synoptic is a principle / Sizing and number of circuit breakers for auxiliary loads to be determined later
* Winter options / winter LV Loads = propulsion and sanding heater in motor car, coupler, air compressor and driver seat in MC car

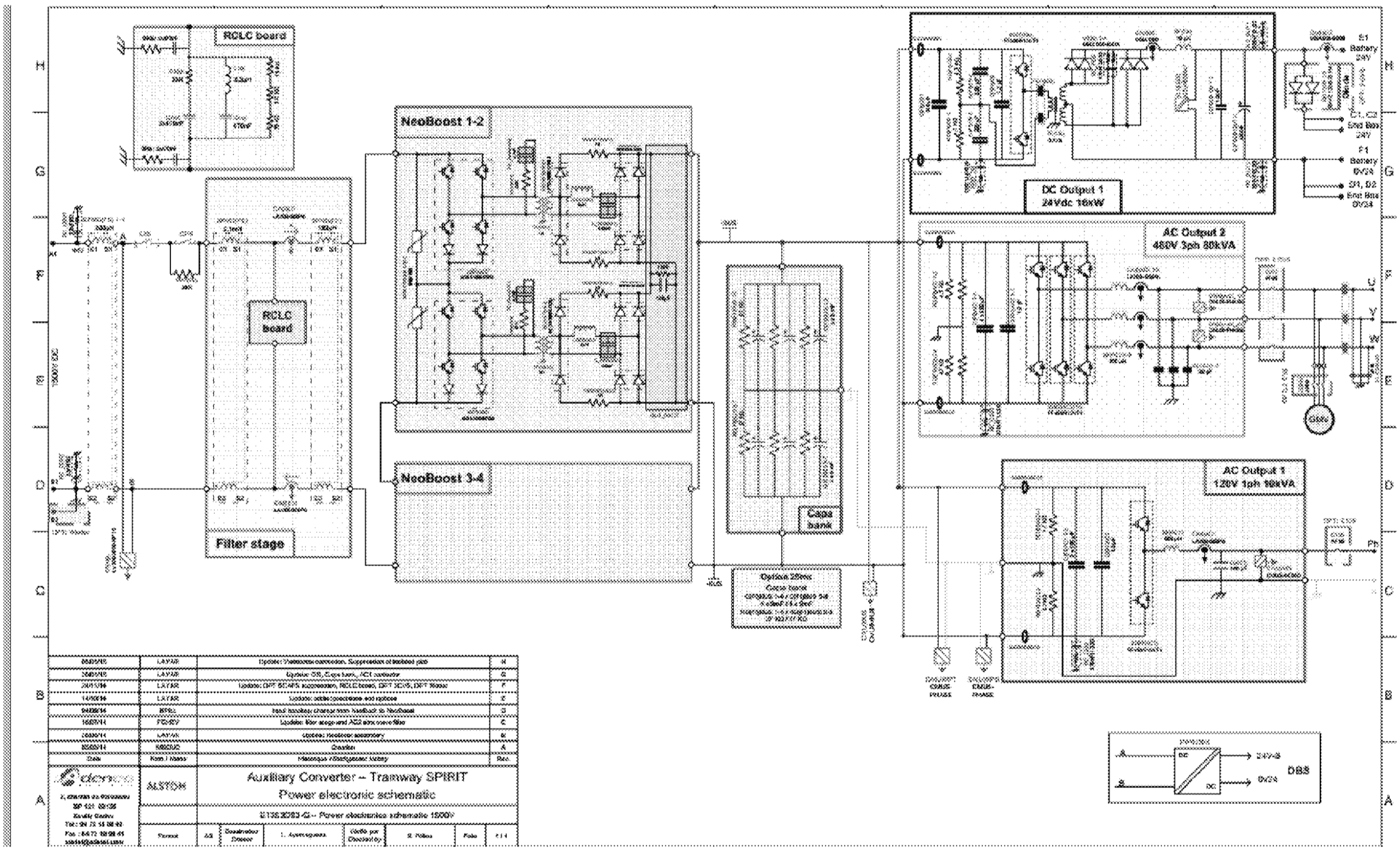
APS supply 3 different electrical networks:

- The 480VAC network is used in variable frequency (360Vtri/45Hz, 400Vtri/50Hz, 440Vtri/55Hz, 480Vtri/60Hz) to supply:
    - HVAC
    - ASU (Air Supply Unit)
    - Driver Heater
    - Battery Heater

- The 120VAC network is used to supply:
    - Floor heaters
    - Doors thresholds
    - Maintenance 120V-sockets in the train
    - All 120V circuits are protected by differential current circuit breakers

- The 24VDC network is used to supply:
    - The batteries through a battery isolation contactor (one per battery).
    - The permanent voltage.
    - Once the train is waking up, it supplies the prepared voltage and LV equipment as:
        - Booster
        - Driver Heating fan
        - Track brake
        - HPU
        - Etc...

2.6.6.2 APS architecture



APS input is composed of:

- An input L-C filter
- An isolation contactor (CIS)
- 4 insulated boost modules (NEOBOOST) (2 NEOBOOST in series per modules) in series in 1500V which:
- Ensure a galvanic insulation between catenary voltage and output
- Create a 680V regulated intermediate voltage

Three independent output converters are:

- Inverter (AC1) converter which:
  - Supply 120V-60Hz loads on the train with a 10kVA output power for one half of the LRV in normal operation
  - is able to disconnect from the auxiliary devices with a contactor
- Inverter (AC2) converter which:
  - Supply with a variable frequency three phases (360/480V)-(45Hz/60Hz) for auxiliary devices on the train with an 80kVA output power for one half of the LRV in normal operation
  - Supply internal fan(s) of the auxiliary converter
  - is able to disconnect from the auxiliary devices with a contactor
- Battery charger (LVPS) converter which:
  - Charge battery with a limited current
  - Supply 24V loads and battery on the train with a 16kW output power
  - Supply 24V loads from the battery through a reverse current diode

Others parts of APS are mainly:

- Control-command electronic board
- Voltage, current and temperature sensors
- Power converters for low voltage electronic
- Forced convection cooling system
- Output isolation contactors on the 120V and 3 Phase outputs, which are opened under fault conditions, and coordinated with the essential service contactors so that the necessary loads across the entire LRV can be powered in the event of failure of one of the AC converters

2.6.7 Battery

2.6.7.1 BATTERY DESCRIPTION

The Vehicle is supplied with a NiCad battery system. The battery system is composed of two independent batteries in a box. Each battery contains 19 SMRX230-F3 cells with their electric interconnections, the terminal covers to protect the cell terminals, a water filling system with two hydraulic circuits, a heating system to maintain the cells over -25°C, contactors to remotely isolate the batteries and magnetics circuit breakers as electrical protection. Both batteries have a monitoring system with temperature sensors and a fire detection cable. All items are located in a complete battery box and are maintained in position by bolts & nuts.

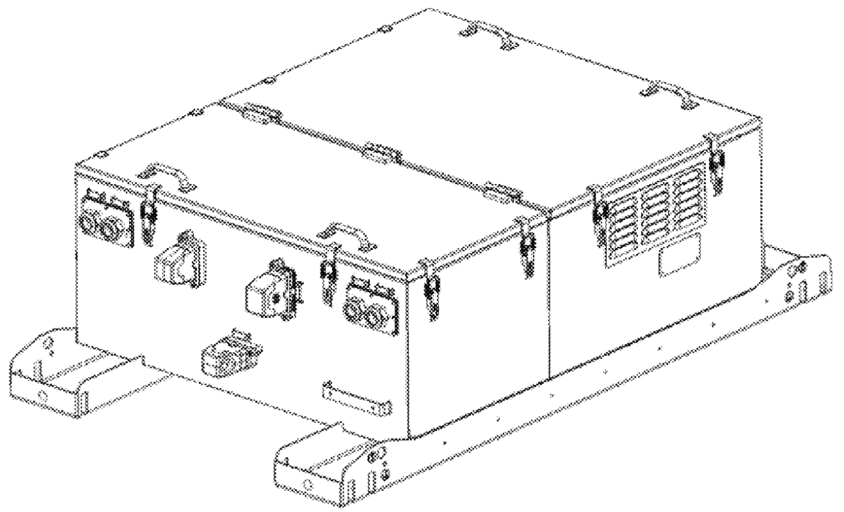


Figure 1 Battery Box

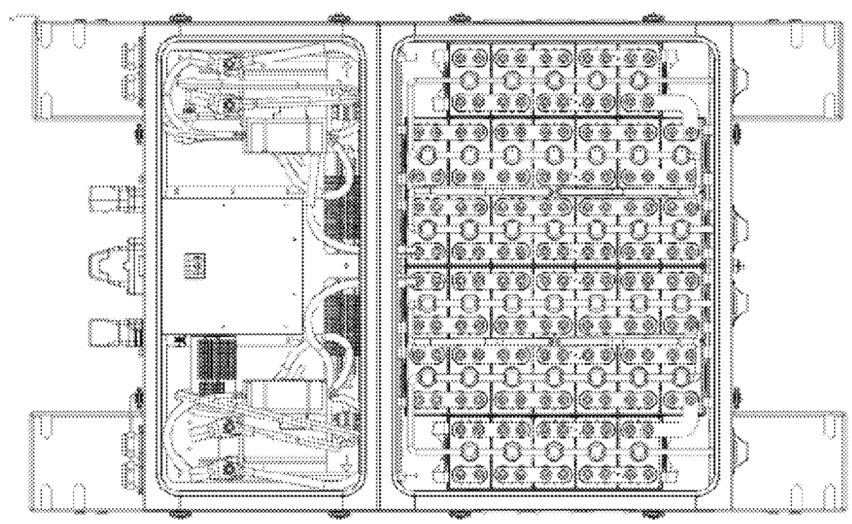


Figure 2 Battery cell Compartments 2 x 19

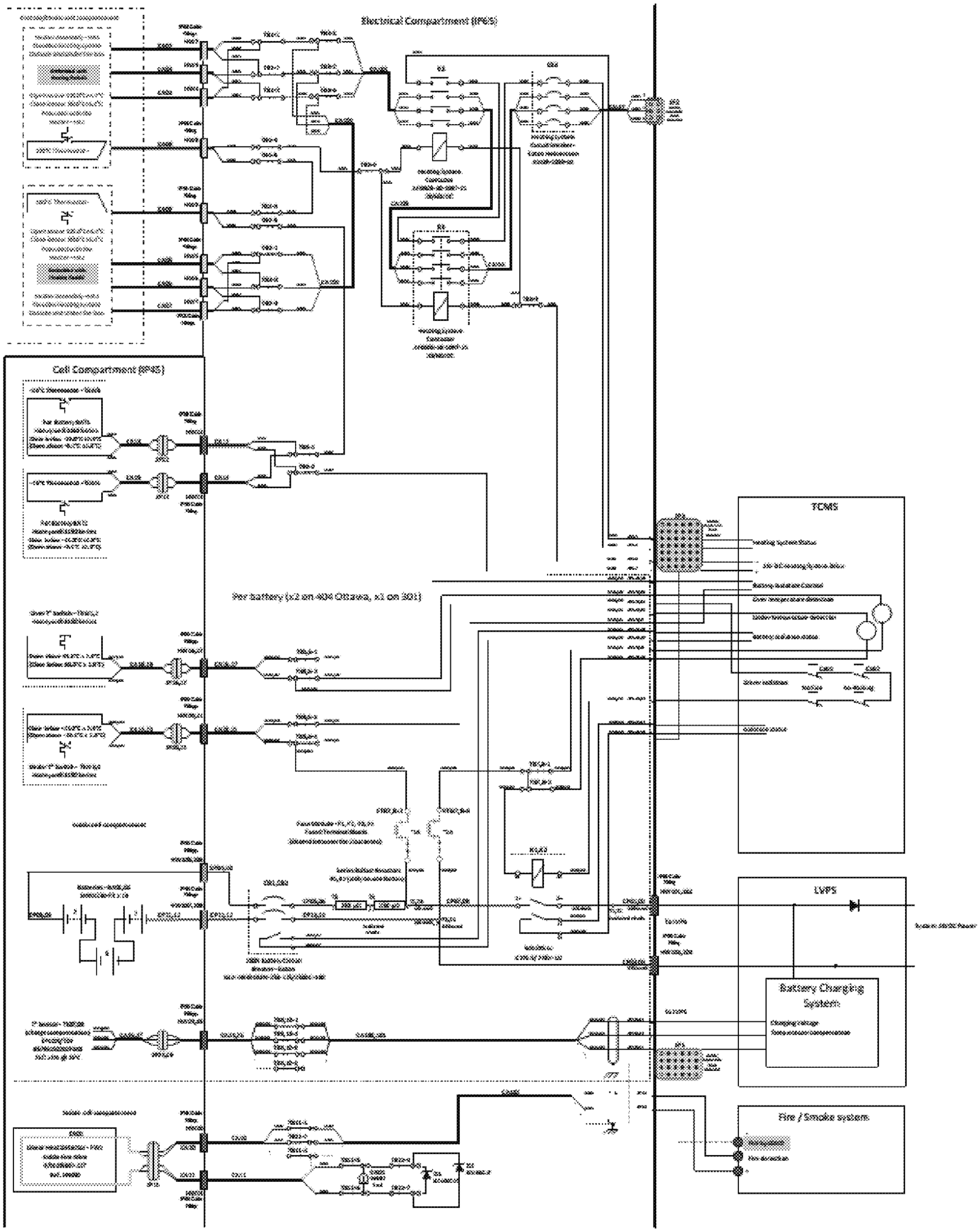
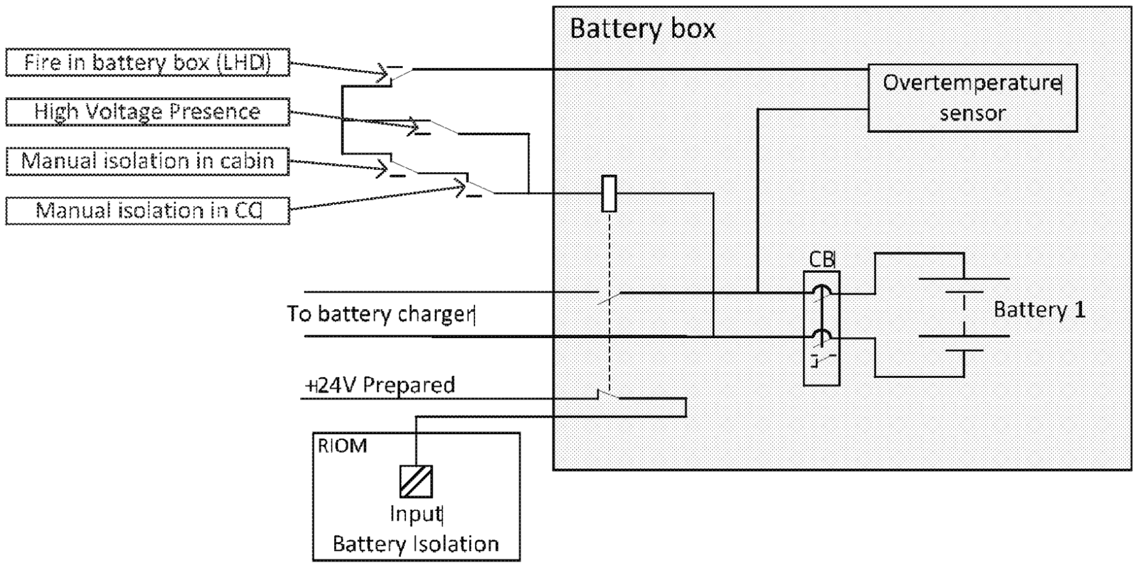


Figure 3 Wiring diagram of the battery

The battery provides the power supply of the low voltage equipment when the Auxiliary Power Supply is not available/out of order. Battery power is permanently available to ensure the power supply back up.

2.6.7.2 *Battery isolation*



The battery can be isolated automatically and manually.

The different causes of manual isolation which take part of the isolation loop:

- By the maintenance staff with a bi-stable switch located on the LCC-car roof. The switch is composed of the "isolated" and "normal" positions.
- By the driver with a mono-stable switch located in each cabin car. When the driver activates this switch, a circuit breaker trip and opens the isolation loop of both batteries. This switch will be activated only in case of fire detection.

The manual isolation is forbidden when the high voltage is present on the train to avoid the creation of an electrical arc of the battery isolation contactor.

The switches are protected against an unintentional manual activation by a padlock.

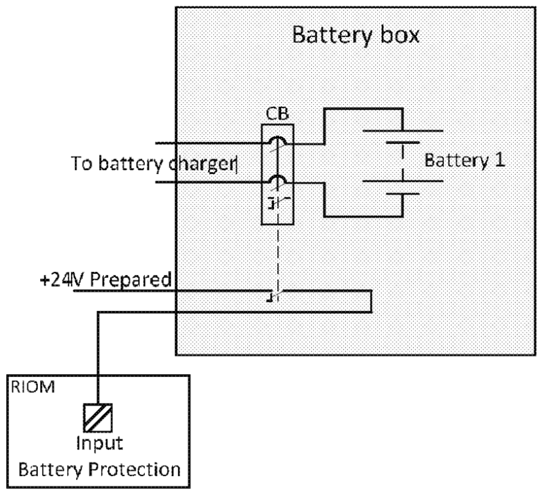
The battery could be automatically isolated if:
- A fire is detected inside the battery box by the LHD wire. An IOS is raised by the FSD function.
- An over-temperature is detected in the battery box (>65°C). An IOS is raised.

These statuses are monitored by the TCMS through a RIOM input and an IOS will be raised to indicate battery isolation (manual or automatic).

2.6.7.3 *Battery under-temperature protection*

One circuit breaker by battery, behind the driver, tripped when the battery temperature is under -25°C. The driver is also informed that the train is not in safety condition to start and the battery should be heated. This CB is monitored and an IOS "train start forbidden" will be raised.

2.6.7.4 *Battery Protection*



The battery protection is an internal circuit breaker installed directly in battery output. The status of this circuit breaker is read by a RIOM.

2.6.7.5 *Battery heater*

Battery heater is supplied in MV by default by APS1.
Heater is controlled by battery box through "Low Temperature switch" (-15°C) which command the heater by a contactor. TCMS monitors Heater status. If temperature is under -20°C and heating system is not operational or if temperature is over -10°C and heating system is stayed operational then a fault and an IOS "heating battery system failed" will be raised.

2.6.8 Ventilation subsystem description

The SALOON system for passenger compartment consists of four HVAC units.

Each HVAC unit is controlled by a microprocessor control panel (controller) located in an enclosure mounted in the unit. The panel controls the unit to maintain the set interior conditions.

HVAC units communicates between each other and the train control system (TCMS, VCU) via CAN interface. Serial communication is used for service purposes such as software upload, test and unit maintenance.

2.6.8.1 General Description of HVAC Unit

The LRC Heating Ventilation and Air Conditioning (HVAC) unit manufactured by Thermo King is a roof - mount unit designed for the Light Rail Vehicles. The unit provides the cooling, dehumidifying and heating of the air for the passengers and drivers cab to keep the temperature conditions comfortable.

Cooling and/or heating is accomplished by drawing air (return air) from the cab interior to the entrance chamber where is mixed with fresh air. This mixed air is filtered and then passes through the evaporator coil, heater and then enters the blower.

The blower pressurizes the conditioned air (cooled or heated or dehumidified) and this pressure move the air from bottom of the unit into the vehicle air distribution (duct) system.

2.6.8.2 Main Parts of HVAC Unit

The LRC unit consists of hermetically sealed refrigerant circuit, air system with filters, heating system, electrical circuit, control system, unit frame and covers and auxiliary elements.

The main LRC unit is designed for mounting on rooftop level. Major components of LRC unit are arranged for easy access and service through hinged covers.

The primary assemblies are:

- Compressor assembly
- Evaporator coil assembly including thermostatic expansion valve and solenoid valve
- Evaporator blower assembly
- Condenser coils and fans assembly
- Heater assembly
- Electric switchboard box (the electrobox)
- Controller box with control panel (the controller)
- DC/DC converter
- Temperature sensors
- Refrigeration circuit accessories:
    - Filter-drier
    - Liquid receiver tank
    - Vibration eliminators
    - Unit protections devices
- Fresh air damper and filters
- Snow duct and brackets
- Structural frame and covers

2.6.8.3 Compressor Assembly

The LRC unit is equipped with compressor assembly consists of two fully hermetic scroll compressors, frame and accessories. The compressors are specially designed for use in cooling systems and provide low consumption, low vibrations and high reliability. The compressors include an internal electrical motor feed from switchboard, an electrical junction box, built-in protection and elastic mounting for elimination of vibrations.

The compressor assembly is located in the centre of the unit at compressor/condenser area.

2.6.8.4 *Evaporator Coil Assembly and Solenoid Valve*

The evaporator coil is an aluminium, wavy fin, copper tube type. Liquid refrigerant flows from the receiver tank to the evaporator coil through the thermostatic expansion valve.

The expansion valve restricts and controls the flow of liquid refrigerant to the evaporator. The pressure and temperature condition inside of the evaporator (refrigerant side) and outside of evaporator (air side) results in heat transfer from the refrigerated air to the evaporator.

The drain pan underneath the evaporator coil is intended to capture any water condensation from the coil surface. Drain lines allow the water to flow away from the unit.

The solenoid valve closes the refrigeration circuit in the moment when the system is in stand-by.

2.6.8.5 *Evaporator Blower Assembly*

The blower is drawing the air from vehicle area and after conditioning (cooling or heating or dehumidification) discharge conditioned air back into the vehicle air distribution system.

The blower is located in the centre of unit, in the lowest part, accessible through middle cover (behind the evaporator and the heater in air flow direction). The blower is fixed in auxiliary frame.

2.6.8.6 *Condenser Coils and Fans*

The LRC unit contains three aluminium, wavy fin, copper tube condenser coil assemblies and one condenser fan assembly.

Pressurized refrigerant gas is discharged by the compressors into the condenser coil for the condensing phase of the refrigeration cycle. Air is drawn through the coils by one propeller type fans. Refrigerant gas condenses in the condenser coil, returning the refrigerant to the liquid state.

The fans are designed for pulling of fresh air from internal area LRC unit and this function effect the air flow through the condenser coil.

The fan assemblies consists of fan including electrical motors, rotors with blades, permanently sealed ball bearings (all in one-piece part), protective grille and fixing parts.

2.6.8.7 *Heater Assembly*

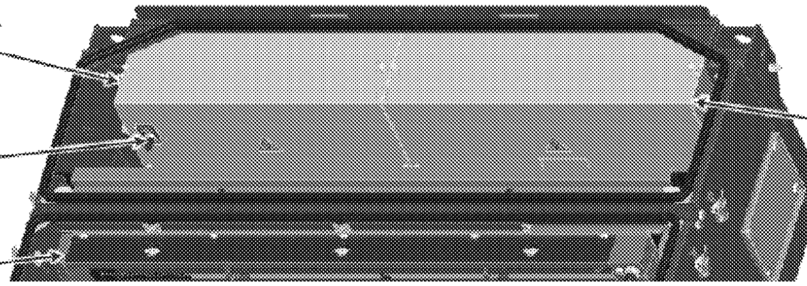
The heater assembly consists of heater frame, heating elements, two temperature limit switches (one for each stage) and overheating protection switch (common). The heating elements are joined in two groups – power stages.

The heater is located between evaporator coil and above evaporator blower.

2.6.8.8 *Electric Switchboard Box (Electrobox)*

The switchboard box is mounted inside of the LRC unit and contains all electrical components for feeding, controlling and protection of electrical circuiting. The switchboard box contains both high voltage and low voltage components.

On the front of switchboard box is "AUTO/O/TEST" mode control system switch and red and green signal lamp.



The switchboard is located in separate box (cabinet, electrobox) mounted on internal side of front part of unit frame. The switchboard is accessible through front cover.

2.6.8.9 Controller box with controller

Controller box is located in evaporator area with access from outside of vehicle.

Thermo King micro-processor-based temperature controller provides system control, fault monitoring, and diagnostics. This controller is a transport industry temperature controller for self-contained refrigeration or HVAC systems.

The controller regulates the temperature in the train through multiple operating (cooling/heating) modes. Several temperature sensors (e.g. return air, fresh air) are used, the controller continually monitors pressure switches in cooling circuit and a few electrical (low voltage) signals used to control.

These operating modes are determined by the system configuration, analogue input values, digital input states, and the system set point. Set point per UIC 553 or per customer request is a function of ambient temperature.

2.6.8.10 DC/DC converter

DC/DC converter is located in the control box. Access is outside the vehicle.

It is especially designed for railway applications. It is maintenance free; vacuum potted, and fulfils the low voltage requirements of the HVAC control. The converter needs no ground load and is continuously short-circuit protected by primary and secondary power limitation. The converter can be switched into an energy-saving stand-by operation mode by a remote control input.

Cooling is achieved by free convection. The converters without heat sink have to be mounted on a heat-dissipating surface.

2.6.8.11 Temperature sensors

The LRC unit contains 3 temperature sensors:

- Fresh Air Temperature Sensor (FAT) – integrated to fresh air eliminator
- Return Air Temperature Sensor (RAT)

- Duct (Supply) Air Temperature Sensor (DAT) – inside blower assembly, reading supply air temperature

The temperature sensors are grade labelled (see for example 2L, 2, 2H on the body).

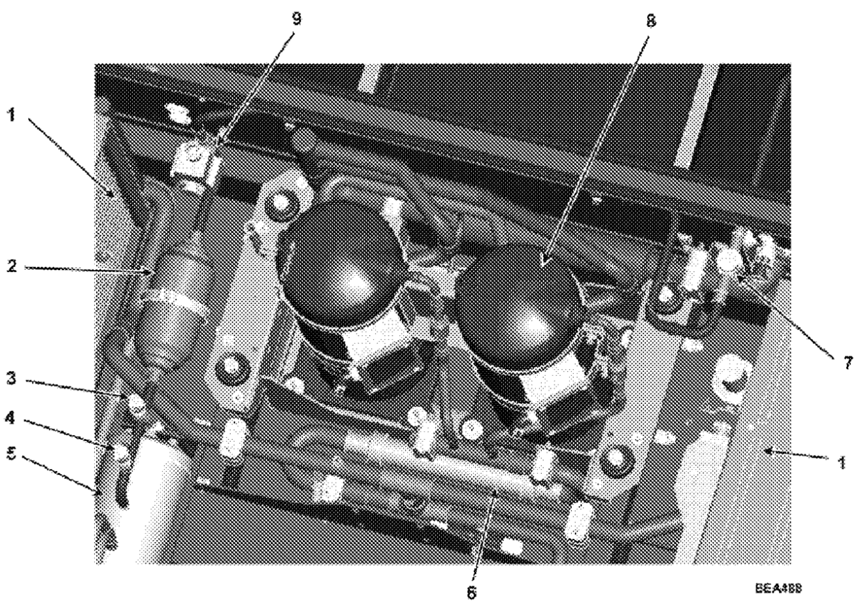
2.6.8.12 Refrigeration circuit accessories

Filter-Drier

The filter-drier (dehydrator) is a cartridge soldered type unit intended for protection the refrigerant against:

- Moisture – by absorbing and retaining it deep within the desiccant
- Foreign matter – the filter-drier will filter out scale, solder particles, carbon, sludge, dirt or any other foreign matter with negligible pressure drop. Fine particles that would go through an ordinary strainer are removed down to a minimum size in one pass filtration.
- Acid – the hydrochloric, hydrofluoric, and various organic acids are adsorbed and held by the desiccant in a manner similar to the adsorption of moisture
- Oil sludge and varnish – all refrigeration oils break down to produce varnish, sludge and organic acids and here are removed

The filter-drier is located on the side of compressor/condenser compartment near right condenser coil.



1	Condenser coil	6	Discharge Vibration Eliminator (DVE)
2	Filter-drier	7	Sight glass
3	High pressure switch HPCO	8	Compressor
4	Modulation pressure switch MPCO	9	Solenoid valve
5	Tank receiver		

Liquid Receiver Tank

A liquid receiver tank holds reserve liquid refrigerant that is needed to support variable system demands. The receiver tank is located in condenser compartment and is connected between the condenser coil outlet line and the filter-drier.

Vibration Eliminators

The suction line and discharge line contain in-line vibration eliminators (situated before and after compressor assembly).

Constructed of stainless steel reinforced flexible hose, the vibration eliminators remove the vibration and noise that are normally produced by the major mechanical devices and transmitted along refrigerant lines to more sensitive components.

Sight Glass

The sight glass is simple system equipment that permits visual inspection of oil and/or refrigerant level and condition.

In the centre of the sight glass is an indicator which changes colour from green when a system is dry, to yellow when a system is wet and indicates the need for a new drier or repair.

The sight glass is located in liquid line.

Unit Protection Devices

High Pressure Cut-out Switch (HPCO)

The high pressure switch is located on the output (high pressure, discharge) line from compressor. The relay-type contact of this switch is a part of low voltage (control) circuit, under normal operation is the contact closed.

If the discharge pressure rises above limit value, the switch/contact will open and the compressor will stop immediately. At the same time the control system will receive the information about this situation.

Low Pressure Cut-out Switch (LPCO)

The low pressure switch is located on input line (low pressure, suction line) before the compressor. The relay-type contact of this switch is a part of low voltage (control) circuit, under normal operation is the contact closed.

If the suction pressure drops below limit value, the switch/contact will open and the compressor will stop immediately. At the same time the control system will receive the information about this situation.

Safety Relief Valve (SRV)

A safety (high pressure) relief valve is installed on the compressor output line to avoid excessive pressure build-up within the refrigeration system from extraordinary and unforeseen circumstances.

The valve is a spring-loaded piston type that opens when refrigerant pressure exceeds limit value.

Compressor overload protection

Compressor overload protection is a built-in part of compressor.

Heat Limiters

The heater is protected by the heat limiters against overheating in two steps:

- When the temperature on the top of the heater assembly is higher than 90 °C (194 °F), the switch stops the heater. This switch is automatically reset if the temperature decreases to approximately 50 °C. Each heater stage has its own switch.
- When the temperature is higher than 140 °C (284 °F), the switch stops heater power supply (for both stages). This protection requires manual reset.

2.6.8.13 Air Filters and Fresh Air Damper

The LRC unit is equipped with two types of air filters:

- Fresh air filter (class G3) protects the unit against the pollution from outside air. This filter removes most of all solid particles that can be included in air. Fresh air filter is located on the side of unit behind ribbed fresh air grille, before air dampers.
- Mixed air filter (class G3) removes impurities from the return air (this air is mixed with fresh air already) entering the LRC unit. This filter is located in front of evaporator coil.

The filter elements are enclosed in filter boxes and can be accessible through unit front cover.

2.6.8.14 Snow duct and brackets

The purpose of the snow duct is not to separate snow. That is done by water eliminator louvers that are part of every air intake. The snow duct merely lifts the intake location to a higher level so when there is a snow layer on the roof, the intake is not blocked.

There is a maintenance door on both sides of the duct in order to clean it. It is opened by removing 4 bolts. Vacuum cleaner is needed to remove large particles such as leaves (small particles are separated by the fresh air filter which is changed separately).

2.6.8.15 Structural Frame and Cover

The LRC structural frame including the covers is manufactured from aluminium.

The main top covers provide access into the unit, to all components except controller; the controller box has its own cover. The front part cover and rear condenser/compressor compartment cover are hinged and in open position can be fixed with support/beam (each cover has two supports). In closed position is the cover secured with latches – locking elements.

Dead-man switch

For safety reasons the unit some covers are protected with mechanical dead-man switches. These switches are relay-type equipment located under cover. If the cover is opened when the unit is running in normal operation, the relay of dead-man switch opens and the unit immediately turns OFF (the controller is switched OFF).

Unit Decals

Serial number, refrigerant type and warning decals/nameplates are situated on different places on the unit. These decals provide information that may be necessary for service or repair of the unit. Service technicians should especially read and follow the instructions on all warning decals.

<u>Serial Number Locations</u>

- Electric motors: nameplate attached to the motor housing.
- Compressor: nameplate attached to the compressor housing.
- Unit: nameplate on the side of the unit.

2.6.9 Coupler subsystem description

The automatic couplers are fitted to the outer ends of the train set. These automatic couplers are designed to enable rail vehicles to couple automatically (mechanically and electrically).

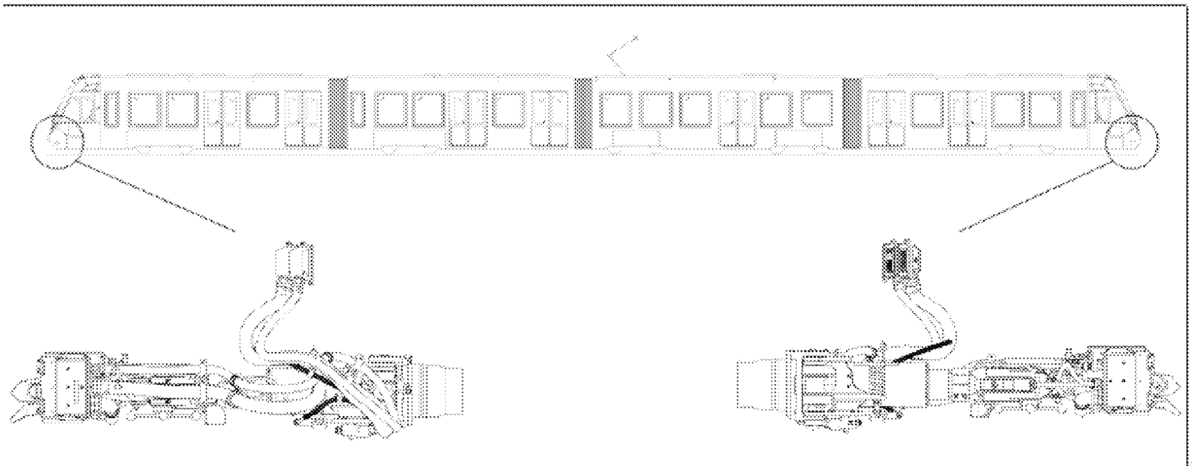


Figure 1 Automatic Coupler Type COMPACT®

2.6.9.1 Overview of Subassemblies

The automatic coupler COMPACT consists of following assembly-groups:

- Mechanical Coupler Head COMPACT (1)
- Electric Coupler (2)
- Pneumatic actuating device for electrical coupler (3)
- Pneumatic control unit (4)
- Folding joint (5)
- Draft gear (6)
- Articulation (7) with deformation tube
- Support (vertical supporting device and device) (8)
- Two muff couplings (9)
- Cover plate for protection the automatic coupler against atmospheric influences (10).
- Hand lever (enclosed loose) for operating the manual uncoupling devices of the mechanical coupler head and of the electrical head (11).

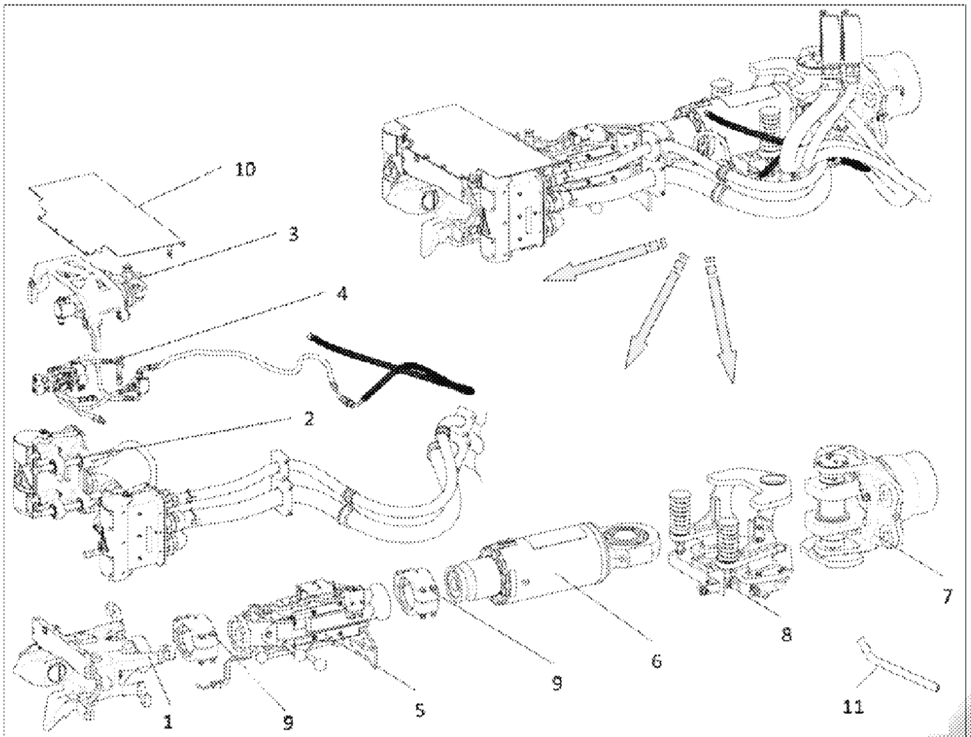


Figure 2 Overview of Subassemblies of Automatic Coupler Type COMPACT®

2.6.9.2 Mechanical Coupler Head COMPACT

The coupler head type COMPACT of the automatic coupler is shown in Figure 3. The cross section through the coupler head body in Figure 4 shows the arrangement of the individual components. The coupler head body (1) is made of high tensile cast steel. The construction design of the body with its guide surfaces permits the alignment of the couplers during the coupling process with different loads in the two vehicles that are to be coupled with each other and in a curve.

The coupler head and the folding joint are connected by a muff coupling which is fixed on the flange (cf. Figure 3, (2)) of the coupler head body.

The built in locking system provides for automatic mechanical connection of the couplers. The coupler pin (cf. Figure 3, (3)) made of high-strength steel is held in its normal position by two springs. During the coupling process the coupler pins of both couplers mutually push each other back until they engage with their noses one after the other through the force of the springs. For uncoupling the coupler pin of one coupler is pulled back until the coupler pin of the opposing coupler is freed.

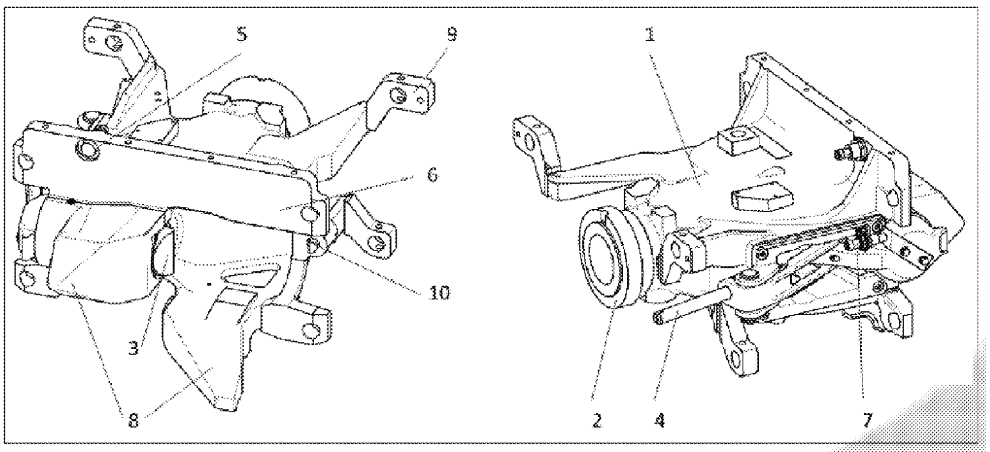
A locking device (10) is adapted to the coupler head in order to save the uncoupling operation. For uncoupling procedure the uncoupling lever will be operated up to the open position of the coupler pin, see Figure 5. In this position the uncoupling lever locks into the locking device and the coupler pin remains in open position during the uncoupling process. Once the cars are separated the uncoupling lever and the coupler pin are freed.

A built in pneumatic cylinder (cf. Figure 4, (2)) in the coupler head housing provides for remote uncoupling, actuated by a magnetic valve of the pneumatic control device.

A manual uncoupling lever is also provided for manual uncoupling. A connecting piece (cf. Figure 3, (4)) is arranged at the rear side of the manual uncoupling lever for inserting a hand lever (FT part no. D252995-200). For manual uncoupling, the uncoupling lever on either coupler head has to be pulled to move the coupling mechanism to the uncoupled position.

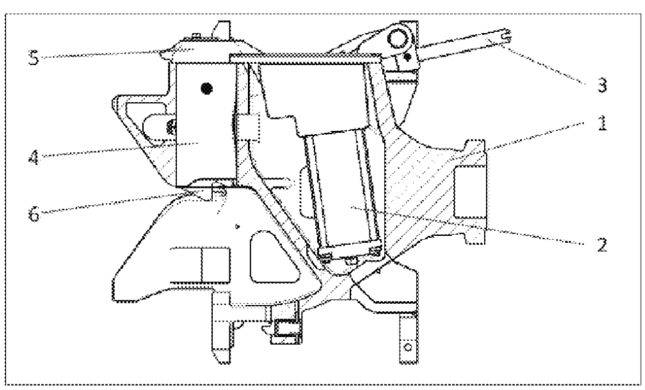
One inductive proximity switch (5) is arranged at the coupler buffing face (6) which senses the correct position of both coupled coupler heads. The other inductive proximity switch (7) is built-in at the manual uncoupling lever (cf. Figure 4, (5)) and senses the locked position of the coupler pin. The signal of both proximity switches initiates the automatic actuation for coupling of the electric heads.

The protruded gathering horns (cf. Figure 3, (8)) of the coupler head implies the coupler sufficient gathering range to couple automatically even with certain mismatch between the coupler centres.



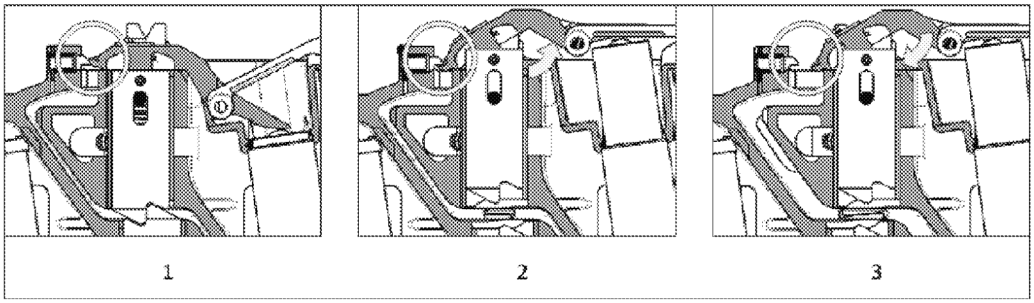
1	Coupler Head Body	6	Coupler Buffing Face
2	Flange for Muff Coupling	7	Inductive Proximity Switch
3	Coupler Pin	8	Gathering Horn
4	Connection for Manual Uncoupling Lever	9	Bracket
5	Inductive Proximity Switch	10	Locking Device

Figure 3 Mechanical Coupler Head Type COMPACT®



1	Coupler Head Body	4	Clamping Bushing with Built-in Springs
2	Uncoupling Cylinder	5	Uncoupling Lever
3	Connection for Manual Uncoupling Lever	6	Coupler Pin

Figure 4 Cross Section through Mechanical Coupler Head Type COMPACT®



1 Coupled
2 Uncoupled (Open Position is Locked)
3 Separation of Cars

Figure 5 Locking Device

2.6.9.3 Electric Coupler

The automatic coupler type COMPACT is equipped with two side mounted electric cable couplers as shown in Figure 6. Upon coupling of the mechanical heads, the electric heads (1, 2) couple together to establish the electric connections between the vehicles. The electric heads are mounted on both sides of the mechanical head. Each head contains an insulating phenolic block carrying a mixture of contacts. Each of the electric couplers is guided on two guiding bars (3). The support, mounted above the coupler heads and pneumatic actuating device, is linked with side walls of the cable boxes (4), left and right. The support is actuated by the drive mechanism of the pneumatic actuating device and in case of coupling or uncoupling of the electric coupler the support moves the electric heads forward and backward.

Upon coupling of the mechanical heads, the electric heads are driven forward automatically by means of a pneumatic drive mechanism to couple together and to establish the electric connections between the vehicles. When mechanical coupling has been completed, the electro pneumatic control unit gets impulses from the two proximity switches of the coupler head and air pressure from the pneumatic vehicle connection is built up. The cylinders of both couplers will be extended and the electric heads are moved into operable position being ready for work. A guide pin (5) and receptacle (6) in the front face of the electric head ensure accurate location and gather with the opposing electric head.

The electric couplers will be retracted automatically when the mechanical coupler heads switch to uncoupled position.

In case of electrical defect at the vehicle the uncoupling of the heads becomes necessary, for this the air supply to pneumatic control unit is separated by a stop-cock, and the heads can be moved manually with a special tool.

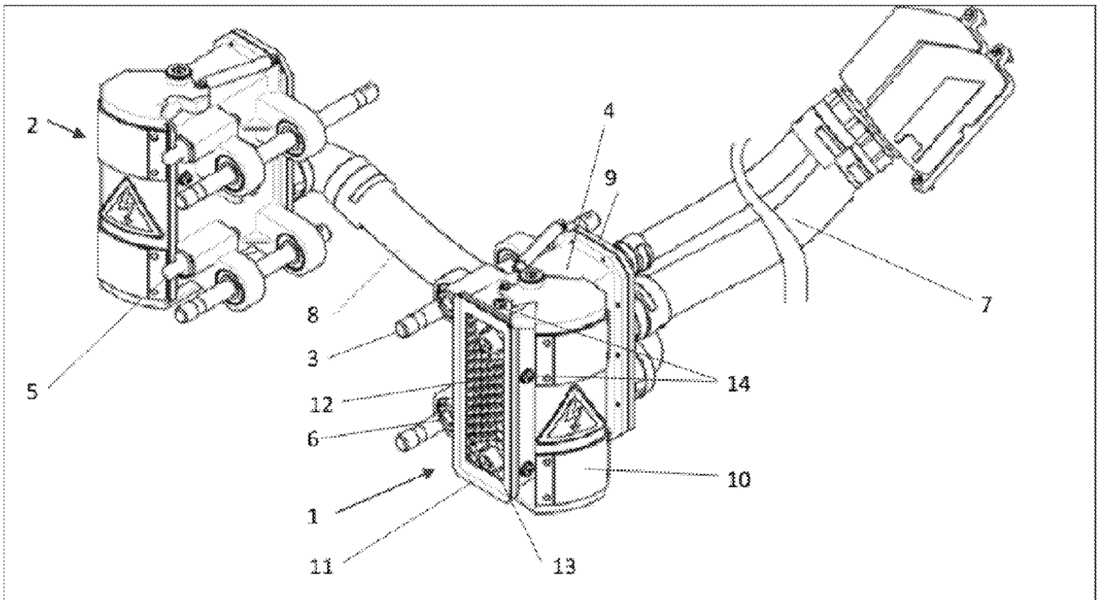
Each electric head is provided with a heating mat in order to protect the electric heads against humidity and formation of ice and to care for a perfect winter operation.

Coupler cables (7) between vehicle and electric coupler are arranged on the electric coupler left. The two electric couplers are connected with a bridge cable (8). Cable gland and sealing are fitted to rear cover (9) of cable box of electric coupler. The boxes are protected by a front cover (10) and sealing rubber profile. Upon coupling the front covers roll open automatically and close automatically in the neutral position. The front rubber gasket (11) which is fitted around the contact block (12) protects the contacts against moisture and dust in coupled and uncoupled condition.

The contact blocks are made by dielectric material and arranged within the cable box. The left contact block is equipped with 53 pin contacts and 2 Ethernet pin contacts, as well as the right contact block with 53 socket contacts and with 2 Ethernet socket contacts. Fittings of wires are held anti-swivelling by square section in contact block.

The contact front parts are replaceable from the front with commercial tools without opening of cable box.

After repairs or new installation of cable couplers the parallel alignment of the cable couplers and their position to the coupler head are to be checked, in order to prevent damage to the contacts and to ensure flawless transmission. The contact block is positioned to the coupler head with the help of a gauge by adjusting of the adjusting screws (14).



1	Electric Head, Left (with Front Cover in Opened Position)	8	Bridge Cable
2	Electric Head, Right (with Front Cover in Closed Position)	9	Rear Cover
3	Guiding Bar	10	Front Cover
4	Cable Box	11	Front Rubber Gasket
5	Guide Pin	12	Contact Block with Pin Contacts (the Right Contact Block is Equipped with Socket Contacts)
6	Guide Receptacle	13	Ethernet Contact
7	Coupler Cable with Plug Connector	14	Adjusting Screw

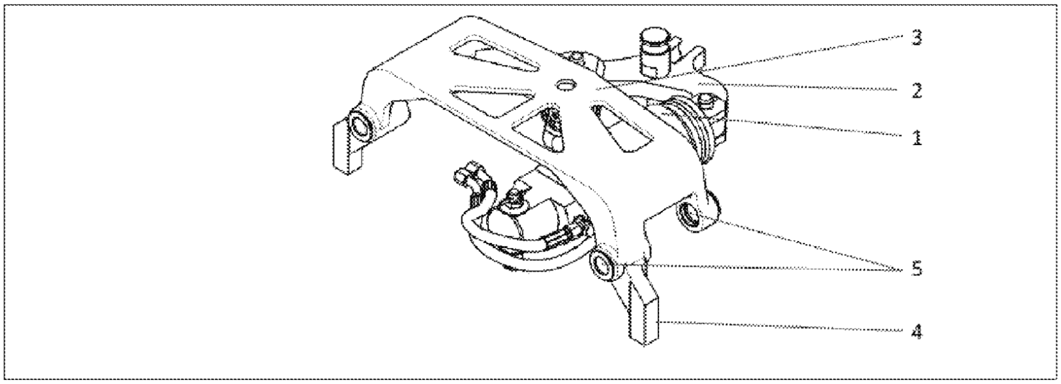
Figure 6 Electric Coupler

2.6.9.4 Pneumatic Actuating Device

To couple the electric trainlines automatically, the couplers are fitted with pneumatic actuating device for driving the electric heads forward and backward as shown in Figure 7. This device consists of a double acting pneumatic cylinder (1) and a lever mechanism (2), the device is located at the top of the mechanical coupler head. The lever mechanism actuates the support (3) which connects the electric heads by the cantilever (4).

During coupling of the mechanical coupler heads, the inductive proximity switches on both coupler heads indicate that mechanical coupling has been established. This action releases air to the respective control valve and then to the operating actuators to drive the electric heads forward and couple together.

In case of electrical defect at the vehicle a manual uncoupling of the heads becomes necessary, for this the air supply to the pneumatic control unit is separated by the stop-cock, and the heads can be moved by manually operating of the pneumatic actuating device with the aid of a special tool.



1 Pneumatic Cylinder
2 Lever Mechanism
3 Support
4 Cantilever
5 Guidance for Guiding Bars

Figure 7 Pneumatic Actuating Device

2.6.9.5 Pneumatic Control Unit

To control and monitor the movement and the position of the electric head a pneumatic control circuit is integrated on the top of the coupler head. Additionally the uncoupling cylinder of the mechanical coupler head will be controlled by the pneumatic control unit. Basically the control unit consists of hoses, two magnetic valves and one stop-cock.

Before electrical coupling ensure that the mechanical connection of both couplers is completed. The magnetic valve gets air from the car side supply, then reverses and then releases air for the operating cylinder. The cylinder will be extended and the electric coupler is moved into operable position being ready for work.

A manual uncoupling of the electric coupler becomes necessary, if the vehicles must be separated electrically in case of electrical defect at the vehicle. The air supply to pneumatic control is separated by stop-cock for this. The electric coupler can be moved manually. Locking of the stop-cock before coupling prevents a removing of the electric coupler after automatic coupling. It is necessary in case of coupling with a foreign coupler.

2.6.9.6 Electro Pneumatic Control Circuit

To control and monitor the movement and the position of the locking device and electric heads an electro pneumatic control circuit is integrated in the coupler head.

2.6.9.7 Folding Joint

The automatic coupler is equipped with a folding joint, which allows the coupler to be folded and stowed away when not in use. The folding joint is manually operated.

In folded position the automatic coupler is locked in its movements by a bolt, mounted on top of the mechanical coupler head which is held by a lock device.

The folding joint consists of two pieces, the fork (1) and the drawbar (2), which are connected together by a bolt connection (3) as shown in Figure 11.

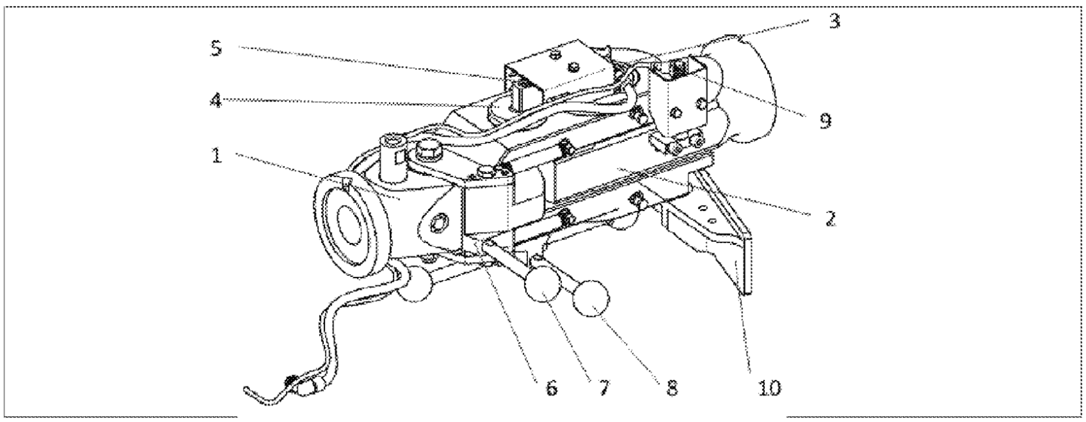
A locking bolt (4) locks the folding joint in folded and in straight position. The locked position of the locking bolt (2) is monitored by an inductive proximity switch (5).

In straight position the loads are transmitted from the fork (1) to the rear drawbar (2), via the bolt (4).

In folding / unfolding process the folding device will be unlocked by releasing the locking bolt (4). When the catch (6) is released via the handle (7) the locking bolt (4) can be turned in released position via the handle (8). The catch (6) locks the locking bolt (4) in released position.

The inductive proximity switch (9) is installed to the drawbar (2) for monitoring the straight position of the folding joint.

Both ends of the folding joint form a muff flange for connecting the muff couplings.



1	Fork	6	Catch
2	Drawbar	7	Handle (Catch)
3	Bolt	8	Handle (Locking Bolt)
4	Locking Bolt	9	Inductive Proximity Switch (Straight)
5	Inductive Proximity Switch (Locking Bolt Locked)	10	Deflector Plate

Figure 11 Folding Joint Assembly

2.6.9.8 Draft Gear and Articulation with Energy Absorbing Device

The loads are transmitted to the vehicle from the coupler mechanical head connection through the folding joint, the draft gear (1) and the articulation (2) as shown in Figure 12. Inside the articulation is the pivot point. The articulation is bolted onto the vehicle underframe. In case of collisions, at a defined force level, the coupler slides into the deformation tube (3). Due to deformation of the tube, a high energy will be absorbed.

The draft gear, as shown in Figure 12, is on the one hand connected by the spherolastic rubber ball bearing (1) to the main pivot and on the other hand connected over flange and muff coupling (2).

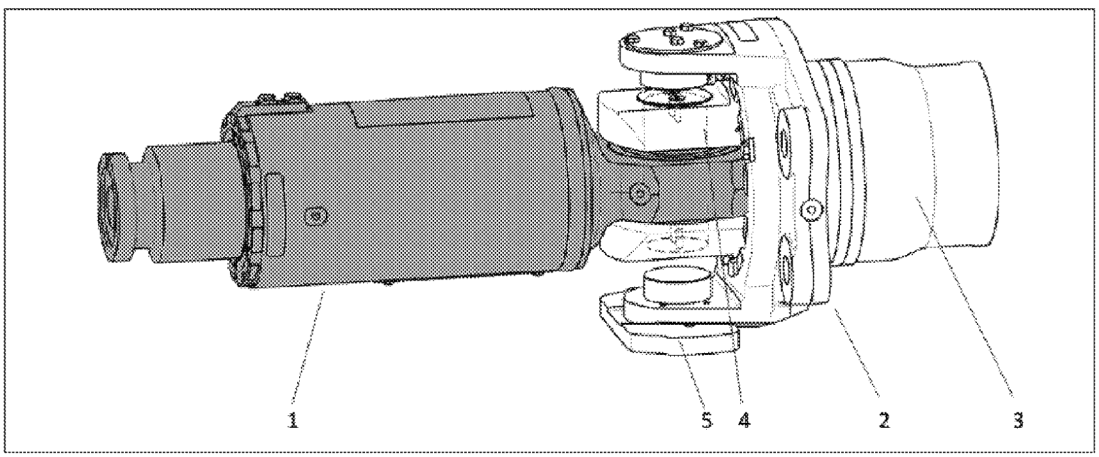
The draft gear consists of a mechanical recoverable shock absorption device (gas hydraulic capsule, (3)) to absorb coupling energies. A Ringfeder-spring (4) is arranged in housing for energy absorption in draw direction and a gas hydraulic capsule is arranged in housing (5) for energy absorption in compressive direction. A very high energy absorption capacity is reached by the gas hydraulic capsule.

The horizontal movement of the coupler is realized by the movement of the pivot pin (Figure 12, (4)), the vertical movement and the tilting movement is given by the elasticity of the spherolastic bearing within the bearing bracket which also allows for a tilting angle of ±2,8° (in exceptions up to two times a week ±6,8 °). The advantages of this design are high energy absorption, long life, maintenance free, slack and noise free, regeneration after buff, no parts to change, improved passenger comfort.

Small to medium impacts that occur in normal operation at the time of coupling and braking are compensated by recoverable energy absorbing system (gas hydraulic capsule works in compressive direction and Ringfeder spring in tensile direction). There is a replaceable permanently deformable energy absorbing system that absorbs the energies which caused by over-speed coupling and more severe impacts. In this process the coupler moves into the deformation tube and becomes free after the deformation of the whole length of the deformation tube. In addition the deformation tube in this case works as a guide and support for the coupler, preventing it from falling down.

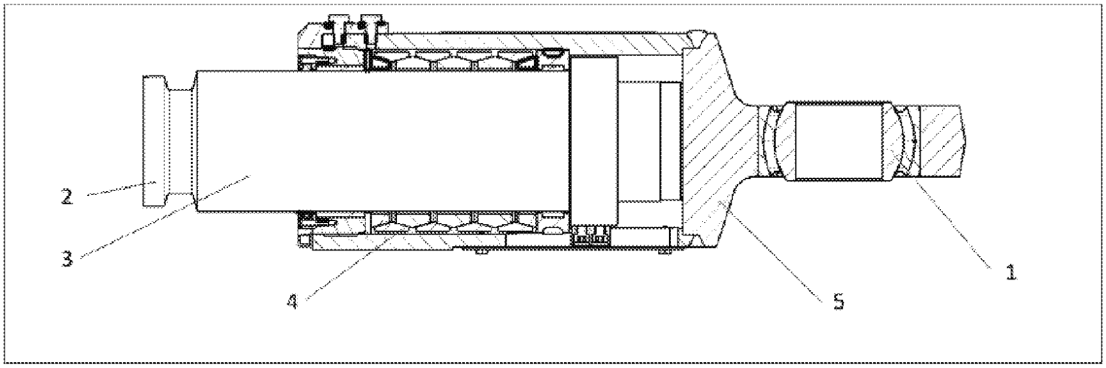
After complete deformation of the deformation tube the stroke of the coupler is only limited by the width of the parts mounted to the folding device. Therefore the coupler does not influence the vehicle crash elements.

A red painted indicator spring pin, attached at the energy absorbing device is released in the case of deformation of the tube. A missing spring pin is an indication that the energy absorbing device has responded and an inspection of the automatic coupler should be conducted along with replacement of the energy absorbing device.



1 Draft Gear
2 Articulation (with integrated deformation tube)
3 Deformation Tube
4 Pivot Pin (Shown in Dashed Lines)
5 Cam

Figure 12 Draft Gear and Articulation



1 Spherical Rubber Ball Bearing
2 Muff Coupling Flange
3 Gashydraulic Capsule
4 Ringfeder®-Spring
5 Housing

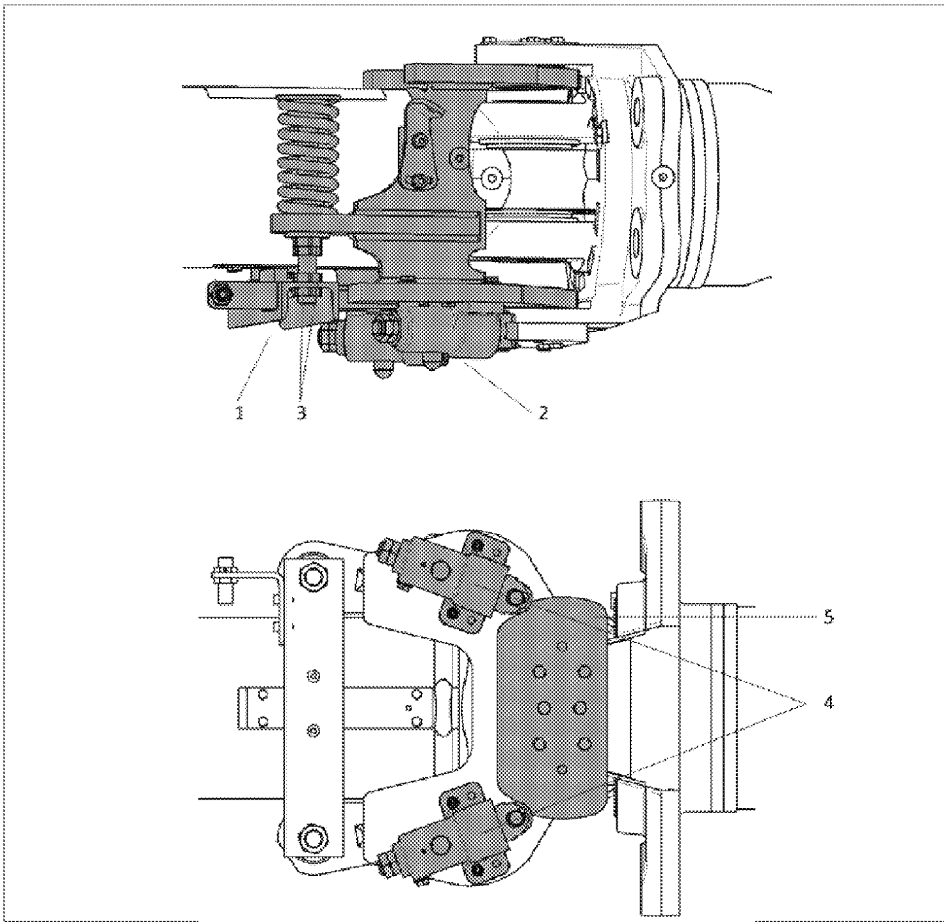
Figure 13 Cross Section through Draft Gear

2.6.9.9 Support (Vertical Supporting Device and Re-centring Device)

At the articulation a support is mounted, as shown in Figure 15. The support consists of a vertical supporting device (1) and a centring device (2).

A spring supported holder which is mounted to the articulation functions as vertical supporting device and supports the automatic coupler in the range of the draft gear. The two springs are provided initial tension by bolts on the spring guides so they do not compress from the weight of the coupler. The height of the coupler above top of rail can be easily set or changed via nuts (3) on the bolts of the supporting device.

Additionally a centering device is integrated. Two spring loaded plungers (4) work against a cam (5) to hold the coupler in centre position while uncoupled. The recentring effect is available in the range of ±9, after that the device can be overruled manually by a single person by swinging the coupler horizontally out of its centered position. This is also needed to couple the coupler in extreme small curve radius where the coupler needs manual alignment. The plungers can be adjusted for proper horizontal alignment of the coupler.



1 Vertical Supporting Device
2 Recentring Device
3 Height Adjustment Nuts
4 Recentring Device Plungers
5 Cam (Part of Articulation)

Figure 15 Support

2.6.9.10 Muff Coupling

The muff couplings connect the coupler head with the folding joint and the folding joint with the draft gear. They form a rigid connection for transferring tensile and compressive forces along the coupler longitudinal axis. The two halves of the muff coupling are clamped by four screw connections with a defined torque.

2.6.9.11 Coupler heaters

The coupler equipment is fitted out with four heating elements with 50W power consumption each. Those heating elements are powered by the "Winter Prepared" low voltage power supply line.

2.6.10 Doors subsystem description

2.6.10.1 Doors Architecture

The door equipment on the Ottawa Project is a double-leaf sliding-plug type. In order to allow passengers in and out, the door panels protrude and part from each other by parallel movement along the car exterior. The electromechanical drive unit will be located inside a covered space in the header area of the door opening. There, it will not be accessible by the passengers, but will allow easy access by the maintenance team.

The Ottawa Citadis Spirit vehicles are equipped with 14 passenger doors (7 per side, directly across from one another). Each door is equipped with an internal emergency door release (EDR) handle which, in case of need, causes the door to be unlocked and enables it to be manually opened when the vehicle is stopped. Each door is also equipped with an external Emergency Access Device (EAD), accessible only by the vehicle staff, which, when operated, causes the door to be unlocked and enables it to be manually opened.

The four doors at the extreme ends of the LRV (two on each vehicle side) are provided with a Crew Switch Device, which allows the vehicle staff to command the opening/closing of the related door. The Crew Switch Device is accessible from inside and outside the vehicle.

The following picture shows the distribution of the doors in the train.

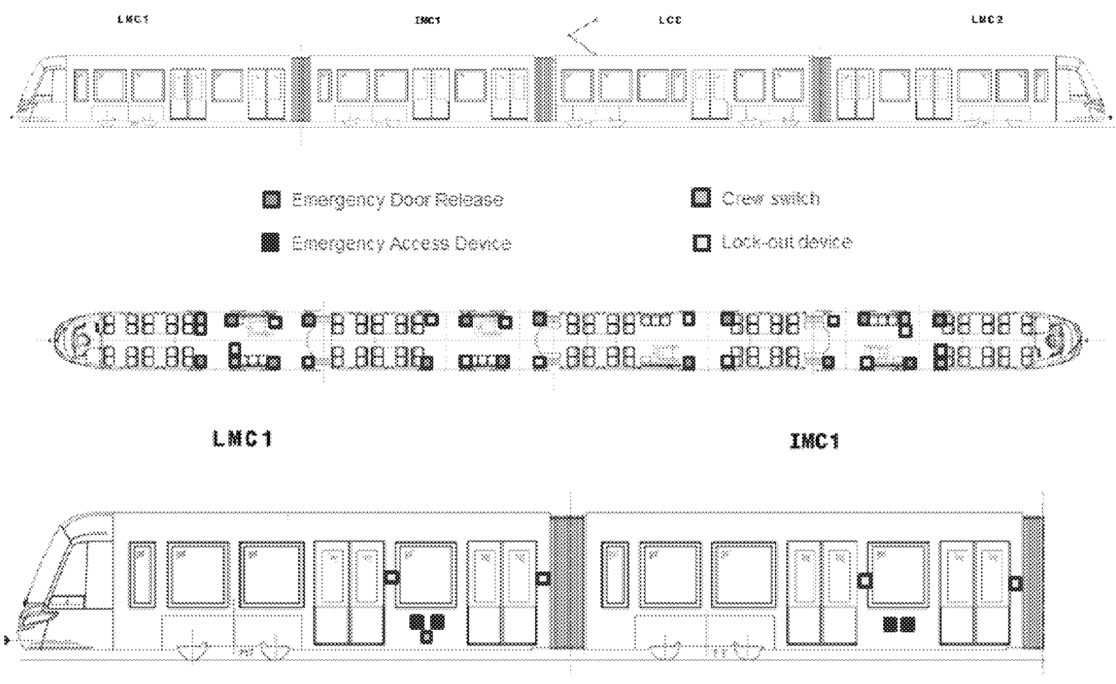


Figure 19: Distribution of the doors on the train

The door is composed of the following main components:

- Door Operator (1);
- Door Panels (RH and LH) (2);
- Vertical Shafts (RH and LH) (3);
- Lower Rails (RH and LH) (4);
- Additional Retention Devices (5);

- Emergency Door Release (EDR) (6);
- Lock Out Device (7);
- Emergency Access Device (EAD) (8);
- Crew Switch (9)

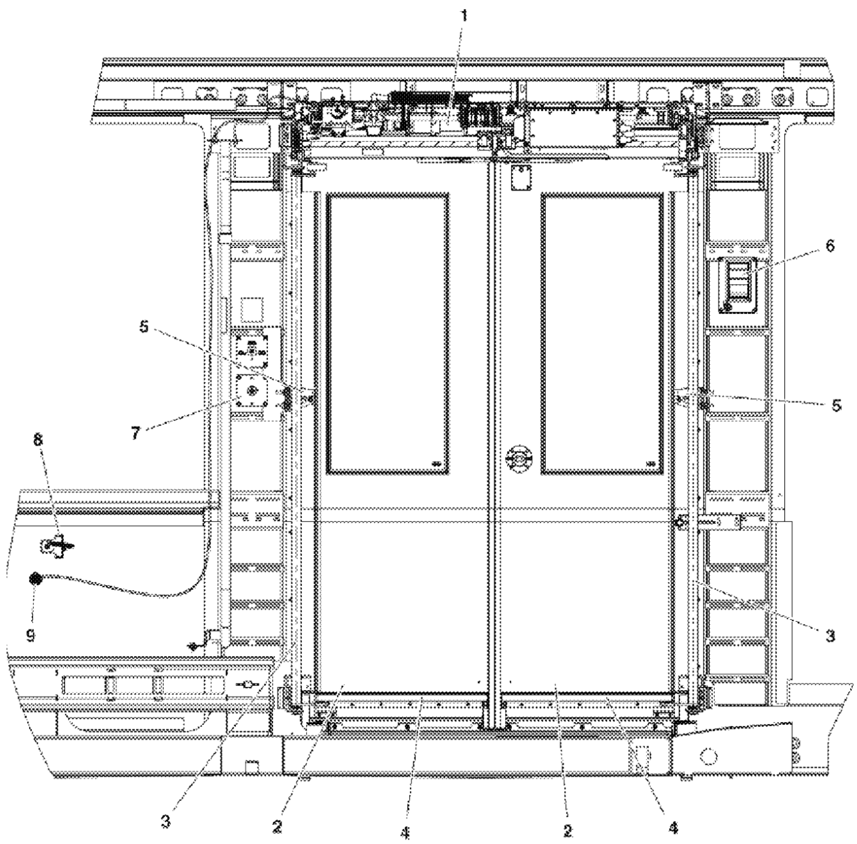


Figure 20: Doors main components

2.6.10.2 Door Operator

The Door Operator comprising the equipment that makes the door move is composed of the following main parts:

- Drive Unit (1);
- Door Control Unit (DCU) (2);
- Fixed System (Header Assembly) (3);
- Mobile System (Carriage Assembly) (4);
- Upper Rail (5);
- Door Operator Wiring.

The Door Operator main parts are the Header Assembly and the Carriage Assembly.
During the in/out door panels movement all the Carriage Assembly moves since it is stiffly connected with the panels, through the pulling arms and the panel hanging support.

The movement is realized by means of an electric motor (belonging to the Header Assembly) which by means of a planetary gear transmits the movement to the over centre shaft and to a system composed of two lead screws. These screws are on a single shaft.
The over centre shaft rotation movement is transformed in an unplugging/plugging movement of the door panel by means of a couple of connecting rods.
The two lead screws transmit the longitudinal movement to the two pulling arms stiffly connected to the door panels.
During the opening phase, the movement is first divided between the two systems (over centre shaft and lead screws) according to the geometry of the upper sliding guide. Once the unplugging phase is completed the over centre shaft rotation is completed and the panel movement becomes purely longitudinal (along the carbody side, parallel to it) and it is managed by the system screw-nut screw. All of this is possible for the planetary gear which carries out the differential function.
The closing movement follows the same steps in reverse order.

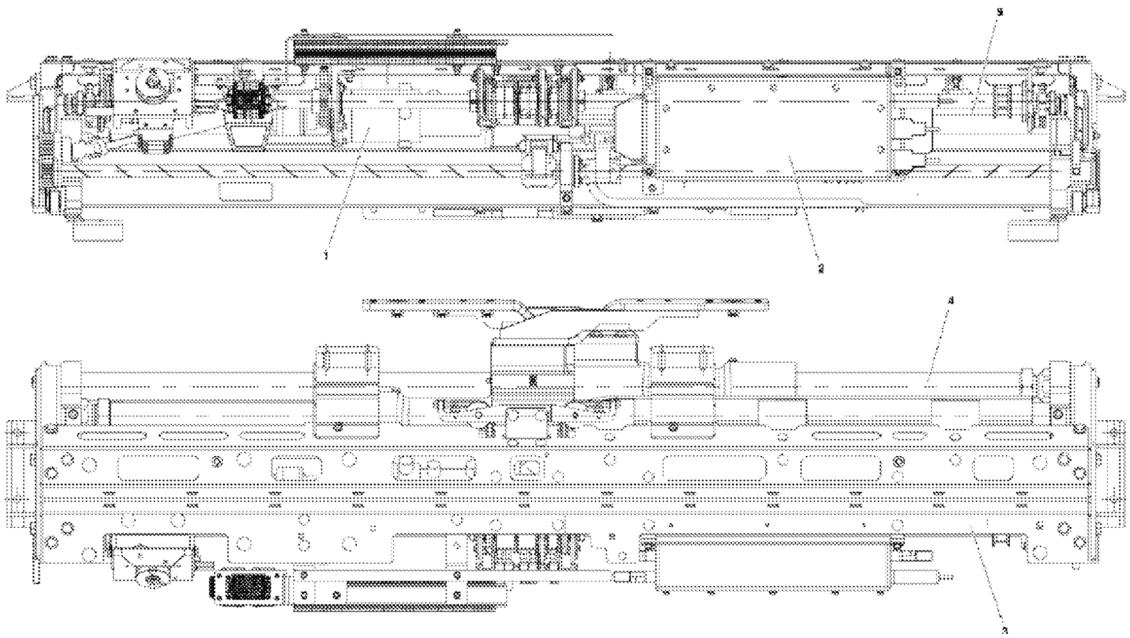


Figure 21: Door Operator

2.6.10.3 *Door Control Unit*

Each door system is equipped with a microprocessor based Door Control Unit (DCU) mounted on the door operator.
This DCU controls the electric motor that moves the door panels. A position encoder mounted on the electric motor transmits the door panel position to the control unit, thus allowing control of acceleration, deceleration and position stops for the door.

Integrated into the door motor control circuit is monitoring of the door motor current for detection of obsticles that block the door from either opening or closing.

In addition to controlling the door motion, the DCU is responsible for the door system diagnostics and communications. The diagnostic information is stored in the DCU for retrieval by maintenance personnel. The communication capabilities of the DCU include communication with:

- [redacted]

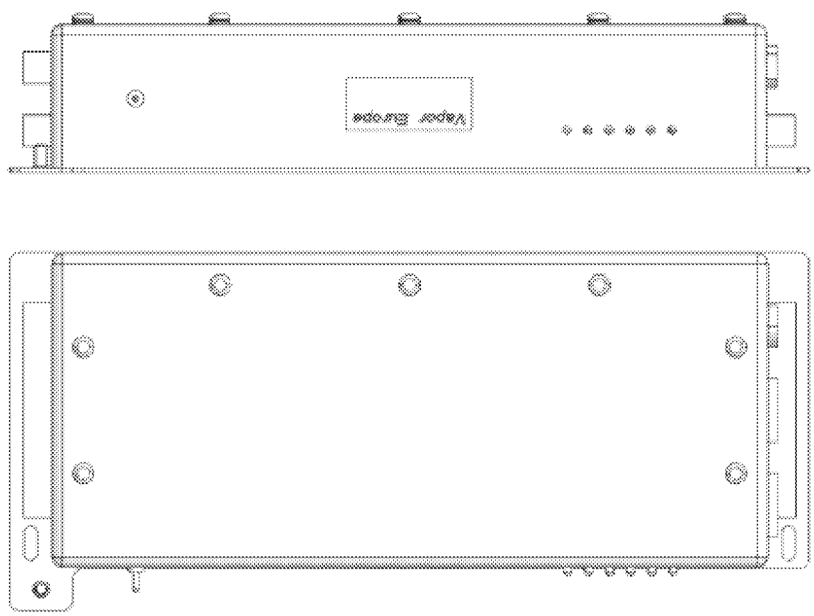


Figure 22: Door Control Unit

2.6.10.4 *Carriage Assembly*

On the Carriage Assembly the two support shafts (1) that sustain the door panels are mounted. On each shaft slides, by means of sliding bushes (2), a metallic support (3), each support sustains one door panel.
The expulsion movement of the carriage assembly is carried out by four roller pins (6) mounted on the header assembly lateral brackets, on which the two lateral guides ("C" shaped) (4) are laced.
The two "C" shaped guides are mounted on the carriage assembly lateral brackets.
The expulsion movement command is carried out by the two following systems:
Upper rail fastened to the header assembly on which a roller (5), stiffly connected to one of the two panels support, slides. This is the device that defines the panel expulsion stroke.

The connecting rod – crank mechanism (7) that takes the motion from the over centre shaft (1) mounted on the header assembly. This is the device that guarantees the carriage assembly locking, once retracted.

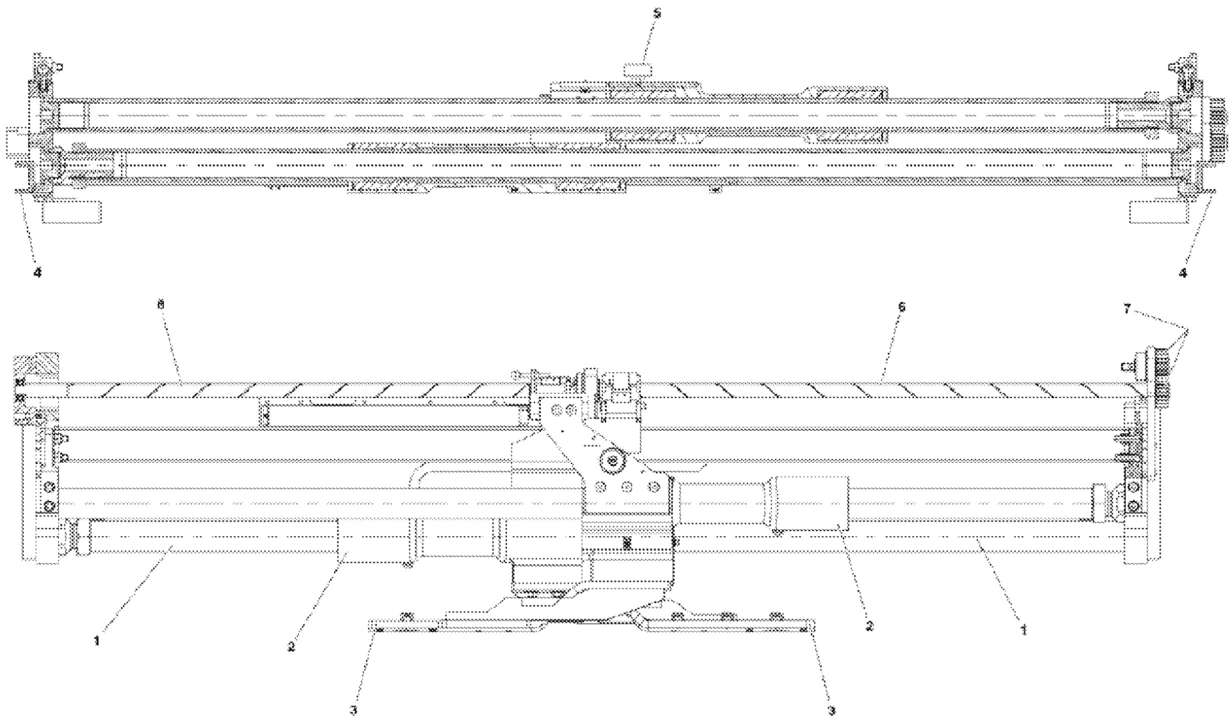


Figure 23: Carriage Assembly

2.6.10.5 *Door Panels (RH and LH)*

Each door is equipped with one left-hand (LH) and one right-hand (RH) door panel. A door panel is assembled from a door bare panel, a bonded window (1), a leading edge seal (2), an upper-trailing seal (3), a lower seal (4), a double sided pushbutton (5) mounted on the window and a bottom guide (6).

The door panels are designed to be installed on the door operator.
From the interior side, a pushbutton, on the right hand door window, is accessible to give an opening command to the door system. From the exterior side, on the same window, a pushbutton is also accessible for the same purpose. The pushbutton is a double sided window mounted type.
The electrical connections of the pushbutton are located inside the top portion of the door. They are accessible through a small access panel.

Integrated into the right door panel leading edge seal is a sensitive edge detector used to detect small obstructions between the two door panels upon closure.

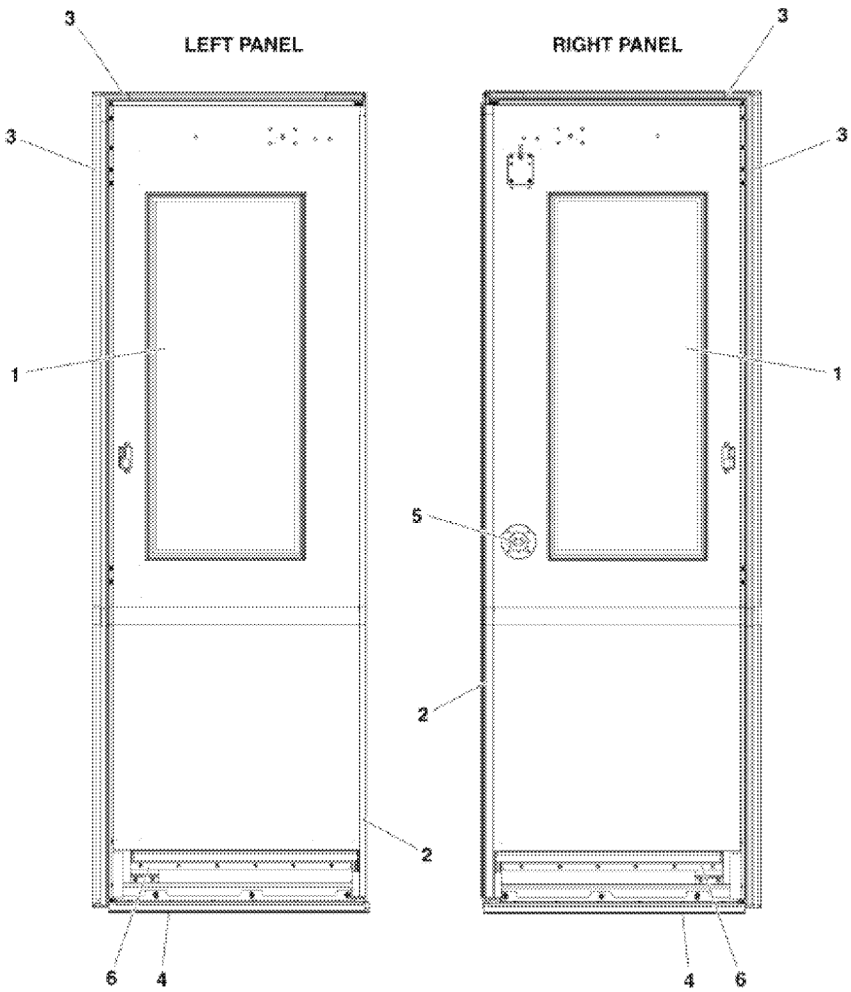


Figure 24: Door Panels

2.6.10.6 Vertical Shafts (RH and LH)

Two vertical shafts (one per side) are fitted parallel to the door jambs, with the aim of providing guidance and retention of the door panels in the lower area.
Each shaft ends with a horizontal arm carrying a roller. The roller engages in a horizontal channel (guide track) within the door panel.
Via short connecting rods, the mechanism imparts rotation to the vertical shaft during opening and closing of the door, in particular during the plugging and unplugging movements.
The vertical shaft and arm arrangement contributes to guiding the door panel in its motion. Additionally, it enhances the plugging effect in the door closed position, adding to the overall stability and tightness of the system.

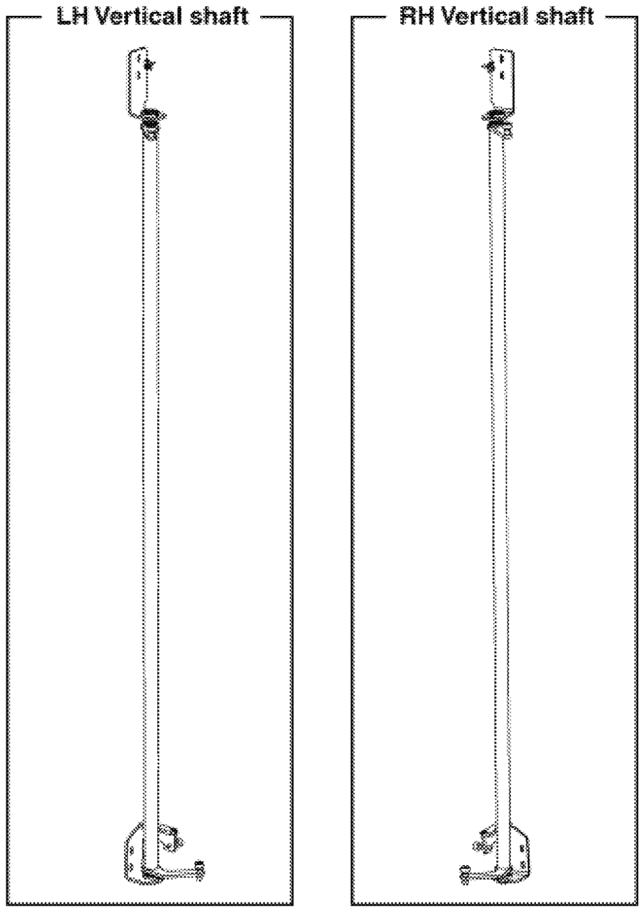


Figure 25: Vertical Shafts

2.6.10.7 Emergency Door Release (EDR)

The Emergency Door Release is located inside the vehicle next to each door opening under a frangible cover. Emergency opening is accomplished by removing the cover, and acting on the emergency release handle..

The emergency release red handle causes the over-centre shaft to move out of the over-centre locking position and the door panels to open approximately 30 mm. A mechanical latch within the handle holds the handle in the active position until reset with a key.

The emergency release device:

- Latches mechanically requiring a deliberate reset action to be taken.
- Remains operable and effective also in case of a power supply failure and can be operated even when the vehicle is running;
    - Note that when the vehicle is in motion, although the door is unlocked, it is held closed by motor power, until the vehicle reaches zero speed.
- When the door is isolated locally (out-of-service status),it will not be possible to override the isolation lock and to open the door using this device;

- Status is signalled to the vehicle logic by a microswitch.

The resetting of the Emergency Release system is effected by a special key in local position.
Once that the device has been reset, the door will start automatically a closing process at reduced speed, provided that a power supply is present and no serious system fault has occurred.

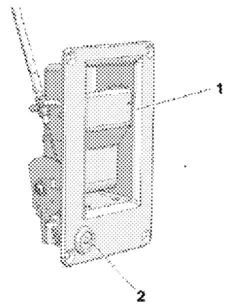


Figure 26: Emergency Door Release

2.6.10.8 Emergency Access Device (EAD)

Each door is provided with an external Emergency Access Device.

The device consists of an external access and a cable that unlocks the door. This device is linked to the internal emergency release handle mechanism and then to the door operator, and is operable only by the train staff using a special key.
When the external device is actuated the door will unlock and the door panels will unplug and open approximately 30 mm, allowing the door to be further opened manually if the train is at a standstill.
When the door is isolated (lock-out status), it will not be possible to override the isolation lock and to open the door panels using this device.

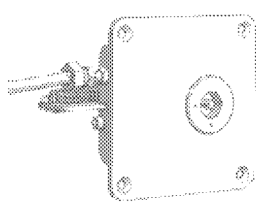


Figure 27: Emergency Access Device

2.6.10.9 Lock-Out Device

An internal and external door lock-out device is operable via a special key.
The device is located on the doorway jamb, in a position accessible from inside and outside the vehicle.
The door lock-out status (isolation status) is signalled to the vehicle logic by a microswitch. When the door is out of service, switches are used to bypass the safety loop circuit in order to allow the vehicle to move.

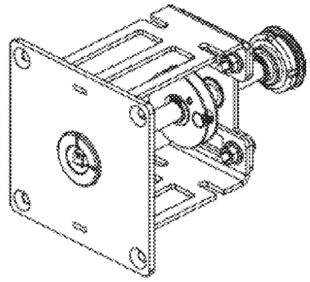


Figure 28: Lock-Out Device

2.6.10.10 Crew Switch

Four doors per train, (extremity doors) are equipped with Crew Switch.
Each extremity door has two Crew Switches, one inside the vehicle and one outside.

The device has three positions: OPEN, NEUTRAL and CLOSE.

A spring shall return the device to the NEUTRAL position.
When the Crew Switch is rotated to the OPEN position, the adjacent door shall open within the specified time.
When the Crew Switch is rotated to the CLOSE position, the adjacent door shall close within the specified time.
The Crew Switch will work only if the door system is powered and the activation process is finished successfully.

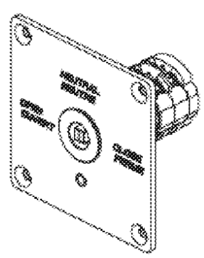


Figure 29: Crew Switch

2.6.11 Brake subsystem description

Brake systems are independent at truck level. The following descriptions are for one truck's equipment.

The braking system was subject to multiple design reviews, beginning with the First Prefinal Design Review Brake System Details [R42], the Second Prefinal Design Review Brake System Details [R43] and the final design review meeting, which was a close out of all previous design reviews, and review of brake system installation drawings.

2.6.11.1 Brake System Components

2.6.11.1.1 Hydraulic Power Unit (HPU)

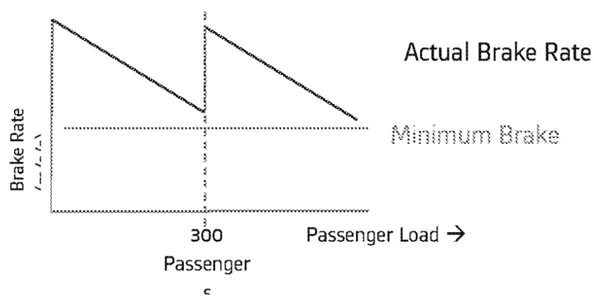
The HPU is a self-contained unit which is used to supply hydraulic pressure to the accumulator and the callipers. It consists of a reservoir, pump, motor and a hydraulic valve manifold. The motor drives the pump which builds pressure in the accumulator. The pressurized fluid is routed through the valves in the manifold and delivered to the callipers in order to regulate the forces necessary to stop the vehicle. The HPU is a compact unit designed to mount under the car body or on the truck frame.

The emergency brake level is fixed on the motor trucks, and variable as a function of load weigh, on the trailer trucks.

2.6.11.1.1.1 Project Evolution - HPU

Due to the change in callipers, described in 2.6.11.2.1 below, there were changes required to the HPU, and specifically the brake release pressure switch, so that the correct threshold for brake released was detected.

In addition a change was made to the hydraulic schematic on the trailer trucks, replacing the single, emergency valve which had variable load compensation control, to a two valve emergency control scheme, where one valve is set to meet the brake rate at ~3.3 passengers per square meter, and a second valve applies pressure consistent with the demand at AW3, the transition between the two settings happens when the brake system senses approximately 300 passengers on the train. The sketch below shows the resulting train performance;



2.6.11.1.2 Brake Calliper

The system has a spring-applied calliper; during service braking the hydraulic pressure is used to regulate the brakes through the service brake hydraulic pressure port. During parking the pressure to the calliper is completely removed, causing the spring applied brake to be fully applied. In the event the parking brake needs to be disengaged manually, the calliper has a mechanical cut-out mechanism. To manually disengage the calliper, pull on the ring to turn the release “toggle” 90 degrees. This fully releases the brakes and the slack adjuster. To reset the calliper return the toggle to its normal opposition, the calliper will automatically reset after having the brakes cycled 5 times from apply to full release.

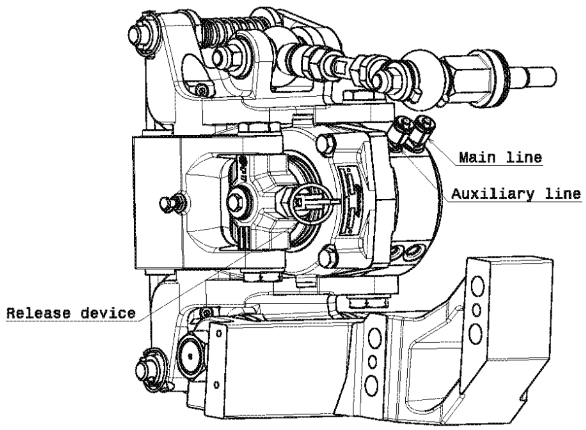


Figure 30: Brake Calliper

The Wabtec Faiveley braking system is distinguished by several key design features. These features are outlined below and provide an extra level of service proven reliability and durability in Wabtec Faiveley braking equipment.

The calliper has a second cylinder, which is used to release the brake hydraulically from inside the car using a hand pump.

2.6.11.1.2.1 Project Evolution - Calliper

It is important to note the design evolution through the project, and the change from a Tec-Tran (Wabtec) to a Faiveley calliper. This took place following the purchase of Faiveley by Wabtec, and issues with the original design being able to meet the fatigue and endurance testing requirements of the qualification program. The Faiveley calliper which uses the same cylinder assembly as those found on Bombardier's streetcars for Toronto transit, with modified mounting to suit Alstom's bogie.

2.6.11.1.3 Disc

The disc is 1-piece design with a solid friction ring. The material is special alloy cast iron providing an efficient combination of strength, thermal conductivity, thermal storage, and braking performance. The ventilated design allows for quicker heat dissipation through a series of radial fins between the two friction surfaces, providing air flow efficiency and cooling capacity.

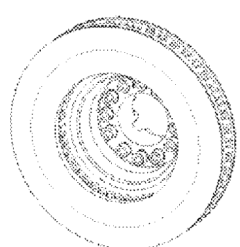
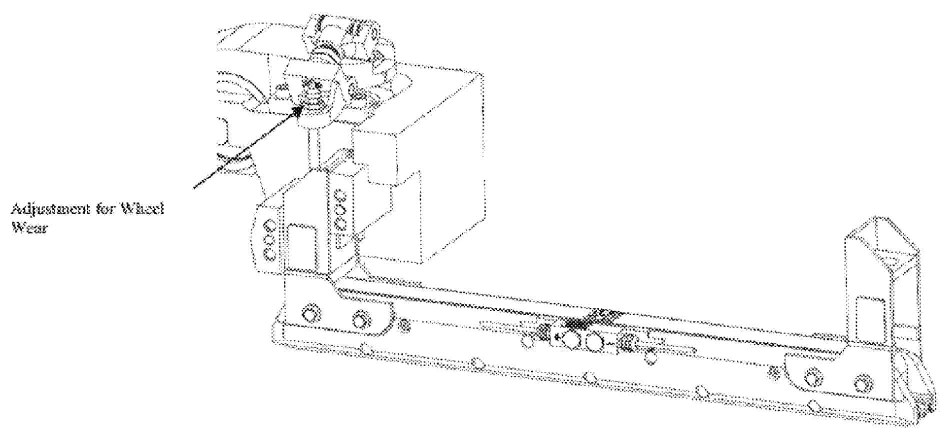


Figure 31: Segmented Brake Disc

2.6.11.1.4 Track Brake

The Track Brake is a solid design as shown in Figure 32. The suspension interfaces with the truck utilizing two articulating joints which follow the deflection of the secondary suspension spring. This design allows the track brake to maintain an 8-10mm distance from the rail as the suspension deflects. The track brakes are easily adjustable to compensate for wheel wear and pole shoe wear, as shown below. Suspension and coil design is based on service proven equipment over many years of operation. Control of the track brakes is redundant, and each bogie's application is independent from the other bogies on the train. Eliminating single point failures from disabling more than one track brake pair. Monitoring is provided to ensure that both track brakes in a pair are deployed when commanded otherwise a fault is declared.

Figure 32: Track Brake



2.6.11.1.5 Friction Brake Pads

The material is formulated for consistent performance and low noise emissions. This material is highly metallic and is rated to a peak temperature of 650 °C. It is provided by a proven pad supplier and is service proven.

2.6.11.1.6 Electronic Brake Control

The Friction Brake Control will be done differently between the trucks. The Trailer Truck will utilize a fully functioning Electronic Brake Control Unit (EBCU). The EBCU will be capable of reading train line and MVB signals in order to provide blending braking as well as doing spin/slide control, system level self-tests, and fault monitoring and logging. The Motor Truck Electronic Brake Control Card (EBCC) will have a simplified functionality and the spin/slide control will be handled by the Traction Brake Control Unit (TBCU).

2.6.11.1.6.1 Trailer Truck: Electronic Brake Control Unit (EBCU)

The TBCU monitors the vehicle control, propulsion feedback, tachometers (speed sensors), and load weigh information to provide braking effort requests to the EBCU. Each EBCU will be capable of providing friction brake pressure control, system level self-tests, slip-slide control, fault monitoring and data logging, and fault analysis via a portable test unit (PTU). [redacted]

2.6.11.1.6.2 *Motor Truck: Electronic Brake Control Card (EBCC)*

The TBCU monitors the vehicle control, propulsion feedback, tachometers (speed sensors), and load weigh information to provide braking effort requests to the EBCC. Each EBCC will be capable of providing friction brake pressure control, brakes released and applied signals, and fault annunciation. Spin-Slide control will be handled by the TBCU.

2.6.11.2 *Brake System Functionality*

There are three basic operating modes for the brake system on the train:

- Service brakes
- Maximum Service Brake
- Emergency Brake

The operation of each mode is outlined in the following sections

2.6.11.2.1 *Service brakes*

Service brakes are the normal braking mode of the vehicle, and are a variable rate command up to a maximum of 1.34 m/s/s on tangent track. Service brakes are commanded by the master controller, (or the ATC system in ATO mode) and are comprised of a blended braking between electro-dynamic brake through the traction system, and friction brake. The blending of friction and dynamic brake is managed by the TCMS MPU, which prioritizes electrodynamic brake, up to the maximum available before adding friction brake. Service braking includes wheel slide protection and control

At low speed,(approximately 5 KPH) there is a transition to friction brake only as the ability to maintain effort through electrodynamic brakes is diminished.

At very low speed (0.5kph) a holding brake is automatically applied when the vehicle is in braking mode, which applies a pressure to the callipers that ensures for the case where one bogie is cut out for friction brake, there is sufficient force to hold the vehicle on the worst case gradient.

The speed for holding brake application is set to 0.5kph so that the holding brake does not apply prematurely when the ATC is attempting to approach the platform target.

2.6.11.2.2 *Maximum Service brake*

Maximum service brake is a mode consisting of a combination of electrodynamic brake and friction brake, plus the deployment of the electromagnetic track brakes. It achieves a minimum of 2.0 m/s/s under all car weights.

The maximum service brake is commanded by train line signals to the brake and propulsion systems, and includes wheel slide protection.

Maximum service brake can be commanded by the master controller, in which case the application is retrievable once the master controller is moved out of the maximum service brake position, or commanded in the event that train safety loops (such as all doors closed) are broken in which case it is irretrievable to zero speed. Track brake application is released once the vehicle is stopped.

2.6.11.2.3 *Emergency Brake*

Emergency brake is the combination of friction brake (i.e. disk only) combined with electromagnetic track brake and automatic application of sand.

Emergency brake is activated by the red emergency brake push button on the driver's desk, or by the Automatic Train Protection (ATP). It is important to note that at the onset of the project, the emergency brake was split into two distinct functions,

- A disk only brake application to be used by the ATP and
- A disk plus magnetic track brake application activated only by the pushbutton in the operator's cab.

During early interface meetings it was determined that in order to meet the Guaranteed Emergency Brake Rate (see 2.6.11.2.4 below) required by the ATP supplier, it was necessary to make the Push Button emergency brake function available to the ATP system, eliminating the need for the disk only emergency brake. This point was raised in the First Prefinal Design Review – Brake system Details [R42], clarified in the Brake System Clarification [R41], and followed up with a "white Paper" [R44] to discuss the trade offs between disk only and disk plus track brake as it applied to the GEBR, as well as discussions regarding the final dry track performance level of the emergency braking system

Emergency brake is controlled directly by safety loops that ensure no single point failure in the application of the emergency brake, and is irretrievable down to zero speed. Emergency brake must be reset before the train can start to move again.

Application of emergency brake by the individual elements that are operated, is directly controlled by hardware, with the emergency brake trainlines safety loops, and relay logic deploying the track brakes and 0perating the emergency valves on the HPU.

There is software involved in two specific aspects of emergency brake control, specifically:

- Load weigh compensation as discussed in 2.6.11.1.1.1 for the trailer trucks, and
- Release of the track brakes at a pre-determined speed (8 kph) to lessen the jerk at a stop, without seriously impacting the overall stopping distance.

This second point was subject of a significant discussion in the project, in order to ensure that in the event of synchronous slide of all axles, the track brakes would not instantly release compromising the emergency brake rate.

The fundamental means to ensure premature release of the track brakes does not occur is achieved by using both the traction control electronics (designed and programmed by Alstom) and the friction Brake control electronics (designed and programmed by Wabtec) to jointly determine independently the speed of the train, and in both cases, to have maximum limits applied to rate of change of speed.

2.6.11.2.4 *Guaranteed Emergency Brake Rate (GEBR)*

The Guaranteed Emergency Brake Rate or GRBR is the minimum assured brake rate for the train, used in the determination of safe train separation and/or otherwise operation of the train within its movement authority.

As noted in the preceding section on emergency brakes, in order to meet the required 0.92 m/s/s brake rate, the use of electromagnetic track brakes was included in the emergency brake function. In addition to the effort contributed by the track brakes, the track brakes have a beneficial effect of "ccleaning" or "preparing' the rail for improved adhesion of the wheelsets. This was all discussed in the white paper on brakes [R44].

As required by specification, the GEBR is based upon some preset criteria, specifically

- Sanding was not to be considered as available
- Load weight functions, as described in 2.6.11.1.1 on the HPU are to be considered failed in the most permissive state (in this case AW0)
- The credible list of failures of braking equipment is considered, and
- The analysis is done at a mutually agreed level of sliding adhesion, based upon the operational maintenance to be done with respect to the quality of the track, in this case, 0.85%

The "White Paper" on brakes [R44] describes the credible failures and rates achievable at different adhesion levels, and was the basis for the final configuration of the emergency brake, and set the thresholds for credible failures to be studied in SSR brakes for failure to achieve emergency brake.

2.6.12 Truck

Trucks are designed for several purposes:

- Support of the rail vehicle body.
- Stability on both straight and curved track.
- Ensuring ride comfort by absorbing vibration and minimizing the impact of centrifugal forces when the train runs on curves at high speed.
- Minimizing generation of track irregularities and rail abrasion.

The truck frame is a cast steel structure and supports most of sub-truck equipment. Motor truck frame and trailer truck frames are identical but are equipped differently as a function of the specific position and secondary equipment installed.

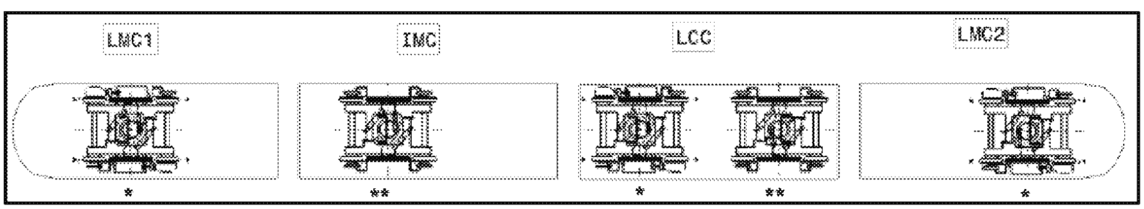


Figure 33: Truck

* Motor truck
** Trailer truck

2.6.12.1 Pivoting Trailer Truck description

There are 2 pivoting trailer trucks on the train

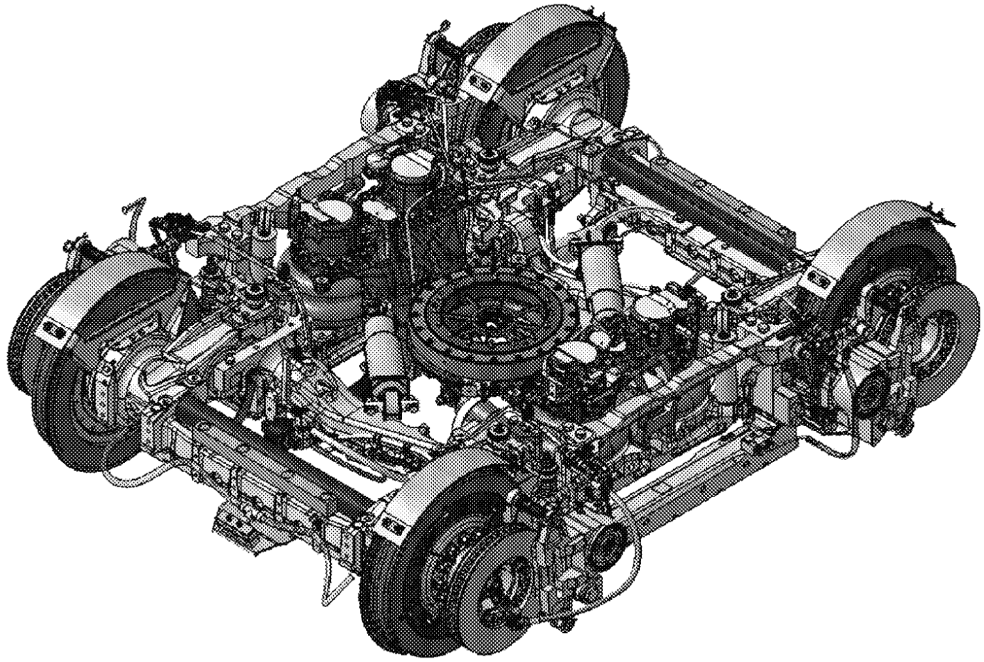


Figure 34: Pivoting Trailer Truck description

2.6.12.2 Pivoting Motor Truck description

There are 3 pivoting motors trucks on the train.

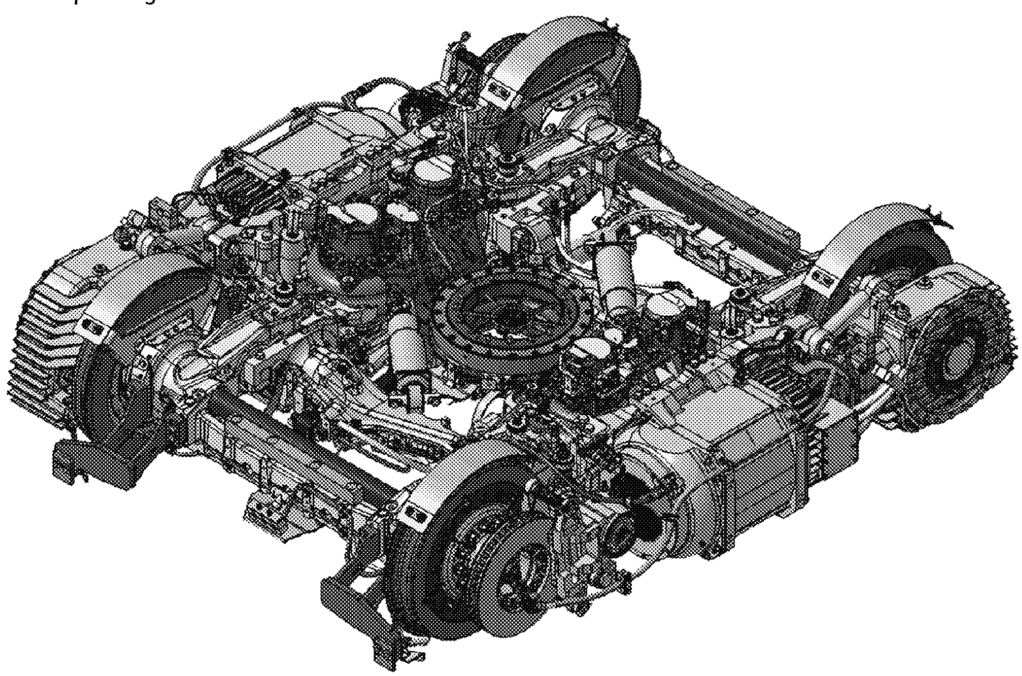


Figure 35: Pivoting Motor Truck description

2.6.13 External Signalling description

2.6.13.1 Description of equipment of external light signalling

The external light signalling system is equipped with:

On each cab				
Lights	**Number**	**Colour**	**Power (W)**	**Dimension (mm)**
Apex	1	White	26	Ø170
Headlights	2	White	26	Ø170
Brake-Stop/Tails Lights	2	Red	3(brake)/1(tail)	Ø96
Red Marker Lights	2	Red	2,5	Ø85
Amber Marker Lights	2	Amber	2,5	Ø85
On each side				
Twin indicators	3	Green, white, blue	2,5	Ø85
Turn Lights	2	Amber	2,5	Ø85

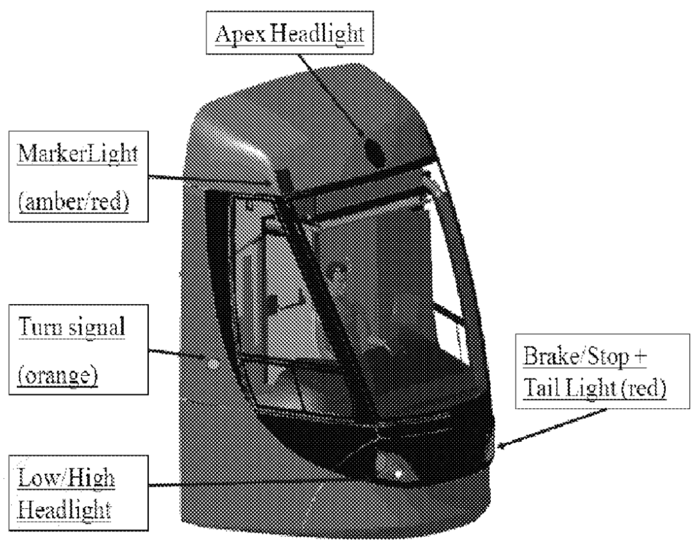


Figure 36: External Signalling description

At each end of the train, the red marker lights and the brake-stop/tail light are cross fed by 2 circuit breakers, (e.g. one breaker supplies the red marker lights of the left side and the brake-stop/tail light of the right side the second circuit breaker supplies the opposite lights) in order to avoid the loss of all red lights of the same side or all lights of one type on an end, if a single circuit breaker tripped.

When the flashing mode is activated, the lights flash at the frequency of 1,5Hz.

<u>On the driver desk:</u>

- Two lights are illuminated on the signalling box to indicate that the turn lights are activated.
- A toggle allows choosing the turn side.
- A bi-stable push-button allows activating the four-way lights (all the turn lights).
- A bi-stable light push-button allows switching between low and high beam for the headlights.

<u>In Multiple units/Towing-Pushing mode:</u>

All of the lights can be illuminated on multiple units and towing-pushing mode, except the lights of the coupled ends,

Headlights/Apex:
The Apex and low/high headlights are illuminated when the forward direction is selected relative to the end with the active cab.

Tail lights and red marker lights:

- The tail lights and red marker lights are illuminated at the end with the non-active cabin when the train is in forward direction or when the train is stopped.
- The tail lights and red marker are illuminated at both ends when no direction is selected.
- The tail lights and red marker flash at the end with the active cabin when the train is in reverse direction. The tail lights and red marker flash at the end with the non-active cabin when at least one door is opened.

Amber marker lights:

- The amber marker lights are illuminated at the end with the active cabin when train is in the forward position.
- The amber marker lights flash at the active cabin end when at least one door is opened.
- The amber marker lights flash at the non-active cabin end when the train is in the reverse position.

Brake-Stop lights:

- The brake-stop lights are illuminated at the non-active cabin end when the train is standstill or in braking phase.
- The brake-stop lights flash at the non-active cabin end when at least one door is opened.
- The brake-stop lights flash at the active cabin end when the train is in reverse direction.

The table below resumes the behaviour of the different lights:

Equipment/Mode	APEX	HeadLight	Tail Light	Red marker	Amber Marker	Brake/Stop Light	Right Turn Light	Left Turn Light
No direction selected			2 in AC 2 in NC	2 in AC 2 in NC				
Forward Mode	1 in AC	2 in AC	2 in NC	2 in NC	2 in AC			
Reverse Mode			2 flash in AC	2 flash in AC	2 flash in NC	2 flash in AC		
Train Stopped			2 in NC	2 in NC		2 in NC		
Braking						2 in NC		
At least one door opened			2 flash in NC	2 flash in NC	2 flash in AC	2 flash in NC		
Left switch selected by driver								Flashs
Right switch selected by driver							Flashs	
Four Way							Flashs	Flashs

2.6.13.2 *Description of the horn*

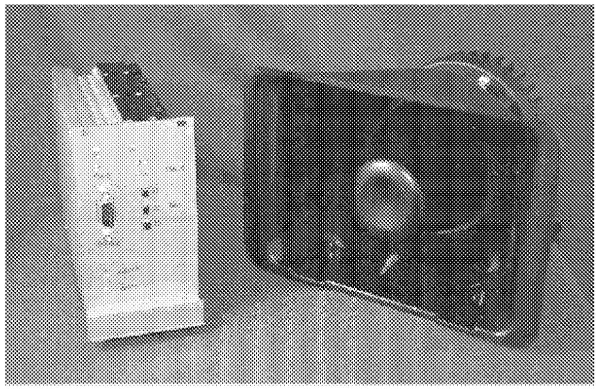


Figure 37: Train Digital Sound Generator

The Train Digital Sound Generator (TDSG) provides automatic exterior and interior digital announcements, sounds and tones for public transportation vehicles. The system consists of a controller/amplifier unit which is mounted inside the vehicle and an exterior/interior speaker system. The exterior system consists of a professional audio driver and horn. To withstand extreme external environmental conditions, the exterior speaker system housing is IP67 waterproof compliant.

The volume of announcement, sounds and tones can be configured for time-of-day segments using an integrated real time clock.

To command the horn, the driver has to use the blue push button BP-HORN identified in the following layout of the driver desk:

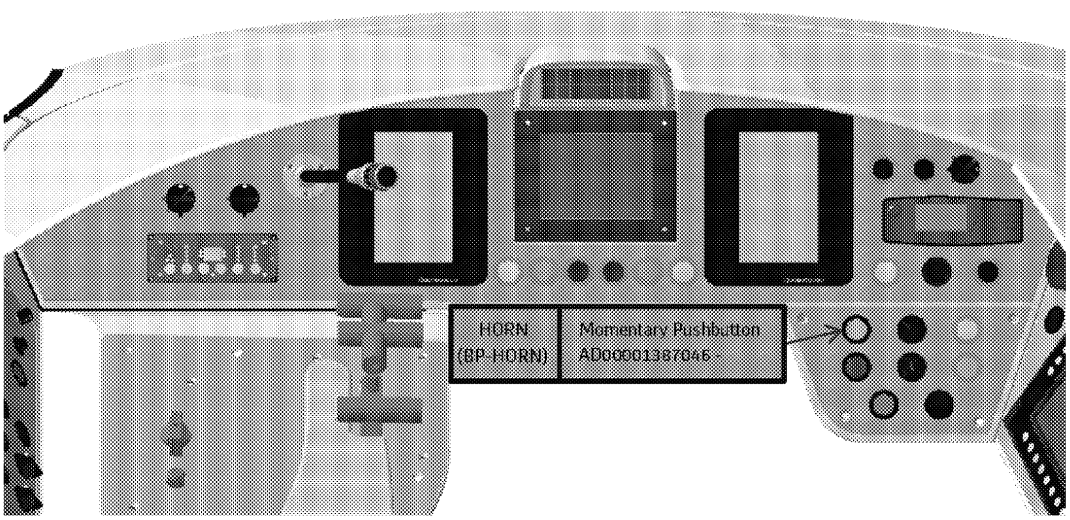


Figure 38: HORN

2.6.14 Internal lighting description

2.6.14.1 Configuration

Each element has its own configuration. Each configuration depends on the length of the element and is composed by many panels.

- There are 5 types of panels:

Panel	Length
1	**1235**
2	**1208**
3	**1334**
4	**1474**
5	**2000**

- Each type of panel is composed by a specific number of PCB.

	PCB Layout									
Type of panel	1		2		3		4		5	
Type of PCB	A	B	A	B	A	B	A	B	A	B
Number of PCB by panel	0	6	3	1	4	0	2	4	3	5

- There are 2 types of PCB. The length of the PCB is different between type A (12") and type B (8"):

PCB	Length (mm)	Length (in)
A	324	12,75
B	203	8

Panels are independent from each other. This independence ensures that loss of one panel doesn't lead to the loss of internal lighting on one side of one element.

2.6.14.1.1 MC1/2 Configuration:

In MC1/2 element, there are 6 panels (types 4-5-4-5-4-3). This configuration is the same at left side and at right side. The total length of the MCx element is 9787.5mm. There are gaps (3.5mm) between each panel.

MC1/2 ELEMENT													
	Position Representing Panel or Gap Size												
Total Int Length	1	2	3	4	5	6	7	8	9	10	11	12	13
9787,5	3,5	1474	3,5	2000	3,5	1474	3,5	2000	3,5	1474	3,5	1334	3,5

2.6.14.1.2 *IMC1 Configuration:*

In IMC1 element, there are 6 panels (types 4-5-4-5-4-2). This configuration is the same at left side and at right side. The total length of the IMC1 element is 9661.5mm. There are gaps (3.5mm) between each panel.

IMC1 ELEMENT													
	Position Representing Panel or Gap Size												
Total Int Length	1	2	3	4	5	6	7	8	9	10	11	12	13
9661,5	3,5	1474	3,5	2000	3,5	1474	3,5	2000	3,5	1474	3,5	1208	3,5

2.6.14.1.3 *CC configuration:*

In CC element, there are 8 panels (types 1-3-1-5-1-3-4-3). This configuration is the same at left side and at right side. The total length of the CC element is 11221.5mm. There are gaps (4mm) between each panel.

CC ELEMENT																	
	Position Representing Panel or Gap Size																
Total Int Length	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
11221,5	4	1235	4	1334	4	1235	4	2000	4	1235	4	1334	4	1474	4	1334	4

2.6.14.2 *Lighting command*

On the driver desk, the following interfaces are provided to the driver:

- A dimmer to control the driver desk lights;
- A dimmer to control the driver cab lights;
- A push button for the passenger lights

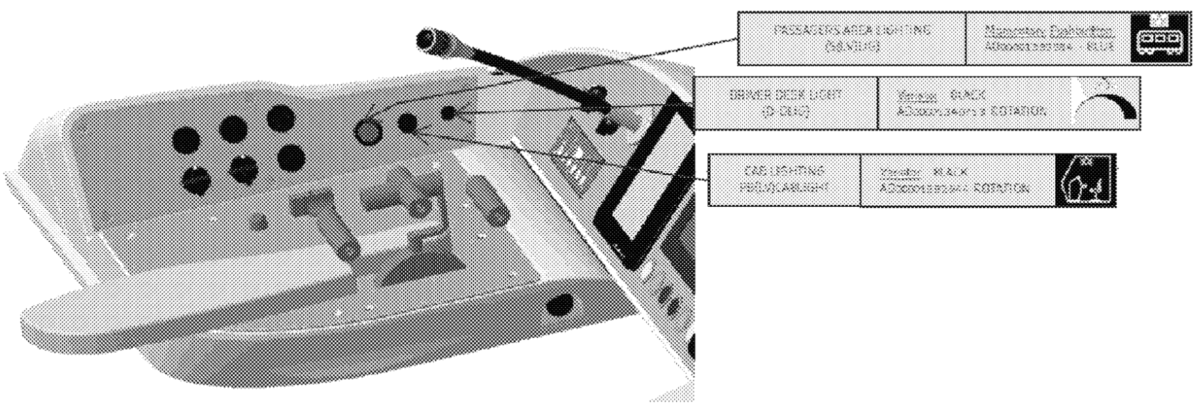


Figure 39: Lighting command

In passengers area, there are two levels of lighting:

- Emergency level if:
  - The train is in layover mode
  - High Voltage is lost

- One battery charger is lost
- The driver commands the emergency lighting through the push-button on the driver desk (S(LV)LIG)).

➢ Normal level when the train is in service retain mode or prepared (operating) mode.

The layover mode is activated when no cabin is taken after a predefined delay.

The train changes its mode from layover mode to normal mode when the operator activating the crew switch to enter the vehicle, or, when any cab is placed in Active mode.

Passenger lighting in each carbody element is separated by two different power supplies by two specific circuit breakers on prepared low voltage (side by side in the breaker panel).

2.6.14.3 Cab Lighting

The cab lighting is configured as a central LED panel and two moveable LED Spots located in the cab ceiling, the lights are controlled by a dash mounted dimmer (see figure 39, paragraph 2.6.14.2 for location). The dimmer allowed for a range of 10% to 100% illumination.

2.6.14.3.1 Design Evolution

During pre-revenue service trials it was observed that at night time, there was an annoying reflection on the windscreen from the cab lights. To eliminate the reflection, a change will be implemented to permit complete shutdown of the cab ceiling lights.

2.6.14.4 Low Level emergency Path Marking (LLEPM)

The LLEPM system is designed to identify the location of primary door exits and the exit path to be used to reach such doors by passengers and rail transit personnel under conditions of darkness when normal and emergency sources of illumination are obscured by smoke or are inoperative.

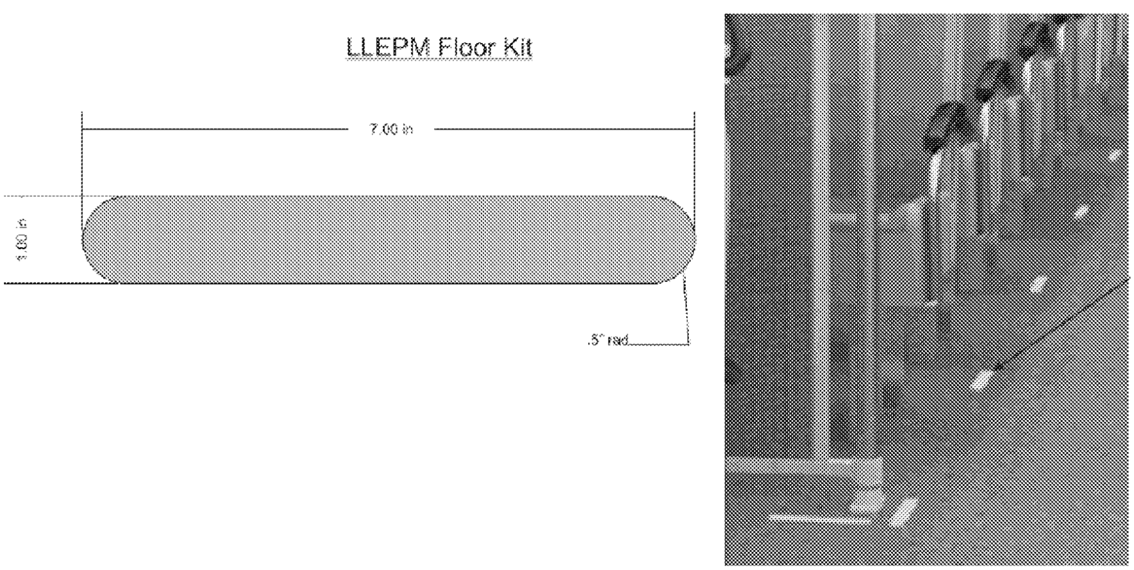


Figure 40: Emergency Path Marking

2.6.15 Driver visibility

2.6.15.1 Windscreen wiper/washer

Windscreen is equipped of windscreen wiper/washer system. This system is commanded by the driver through the windscreen wiper switch S-WSWP for wiping and washing. The switch S-WSWP has 4 positions:

- O: Off position
- I: Intermittent position
- LS: Low Speed position
- HS: High Speed position

The switch S-WSWP has in integrated push-button which permit to wash when it is pushed.

2.6.15.2 Defrosting system

The defrosting system is composed by:

- An embedded $4W/dm^2$ resistive element in the windshield
- A forced air cab heater that can add additional heat into the cab, with vents that put heated air over the windshield and side windows.

2.6.15.2.1 Embedded Defrosting system

A heating system mounted on the windscreen through the resistor Z1(DEFROST).

The command of the heating system is realized by the driver through the Driver Display Unit (DDU). The heating system is automatically stopped if one of the following conditions occurs:

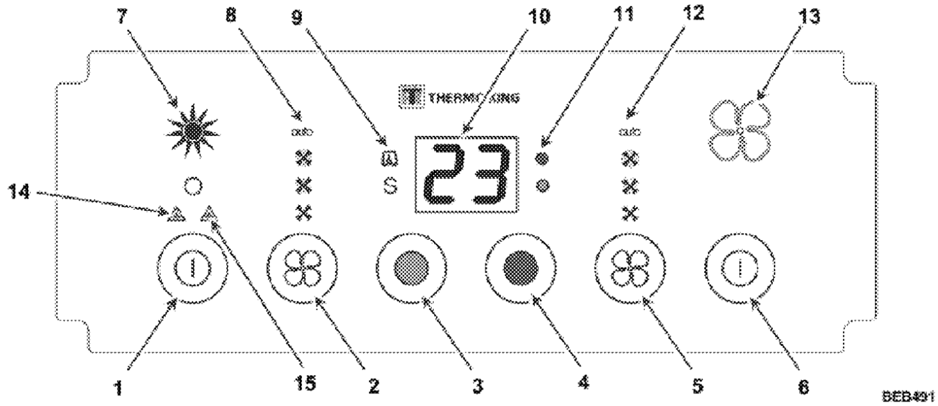
- Driver request on DDU
- Track brakes application
- Loss of High Voltage
- After a specified time of use (currently 20 minutes)

When the driver commands the heating system, Z1(DEFROST) is supplied thanks to the contactor C(DEFROST).

2.6.15.2.2 Cab Heater system

The cab heater is commanded through the Clim Aire Interface Driver (CAID) located on the driver desk:

The heater unit has a 2 KW (nominal power at 480V.60Hz) and a variable speed blower with a maximum air flow rate of 300 m^3/h.



1	Heater – ON/OFF key	9	Temperature setting indicators
2	Heater – Blower speed selection	10	Display
3	Heater – Temperature key DOWN (blue)	11	Heater – Heating Elements ON/OFF indicators
4	Heater – Temperature key UP (red)	12	Booster – Blower speed indicators
5	Booster – Blower speed selection	13	Booster – ON/OFF indicator
6	Booster – ON/OFF key	14	Red alarm indicator
7	Heater – ON/OFF indicator	15	Yellow alarm indicator
8	Heater – Blower speed indicators		

Figure 41: Defrosting system

2.6.15.2.3 Design Evolution

Due to concerns expressed by the customer about possible freezing of the windscreen, several areas with respect to control have been investigated:

- Operating time of the embedded defroster
  - Currently 20 minutes to be made continuous any time the winterization function is active.
- Operation of the cab heater, to be enabled even during layover mode.

The combination of these two measures is intended to ensure the windscreen is always above 0°C

In addition, a review of the thermal performance of the cab heater has been conducted, and two specific points have been identified

- The return air inlet draws unconditioned air from under the driver's desk/behind cab interior lining,
  - As this air is between cab interior temperature and exterior, it causes the return air temperature to read below the actual cab temperature
  - The evacuation of air from this space leads to an increased loss thermally in the cab as this air should remain still for best insulation value
  - The cab heater power is being wasted trying to heat cold air as opposed to starting from cab ambient, reducing the outlet temperature of air being passed over the windscreen

- The cab heater maximum power is only available at the maximum frequency of the Auxiliary inverter, and the frequency control is based upon the passenger compartment HVAC requirements, which may reduce the output to as low as 360V/45Hz, or effectively for the heater half of the maximum power.

2.6.15.3 Sunblind

The windscreen of the driver cab is equipped with a manually operated sunblind. Characteristics of the sunblind are identified in the following drawing:

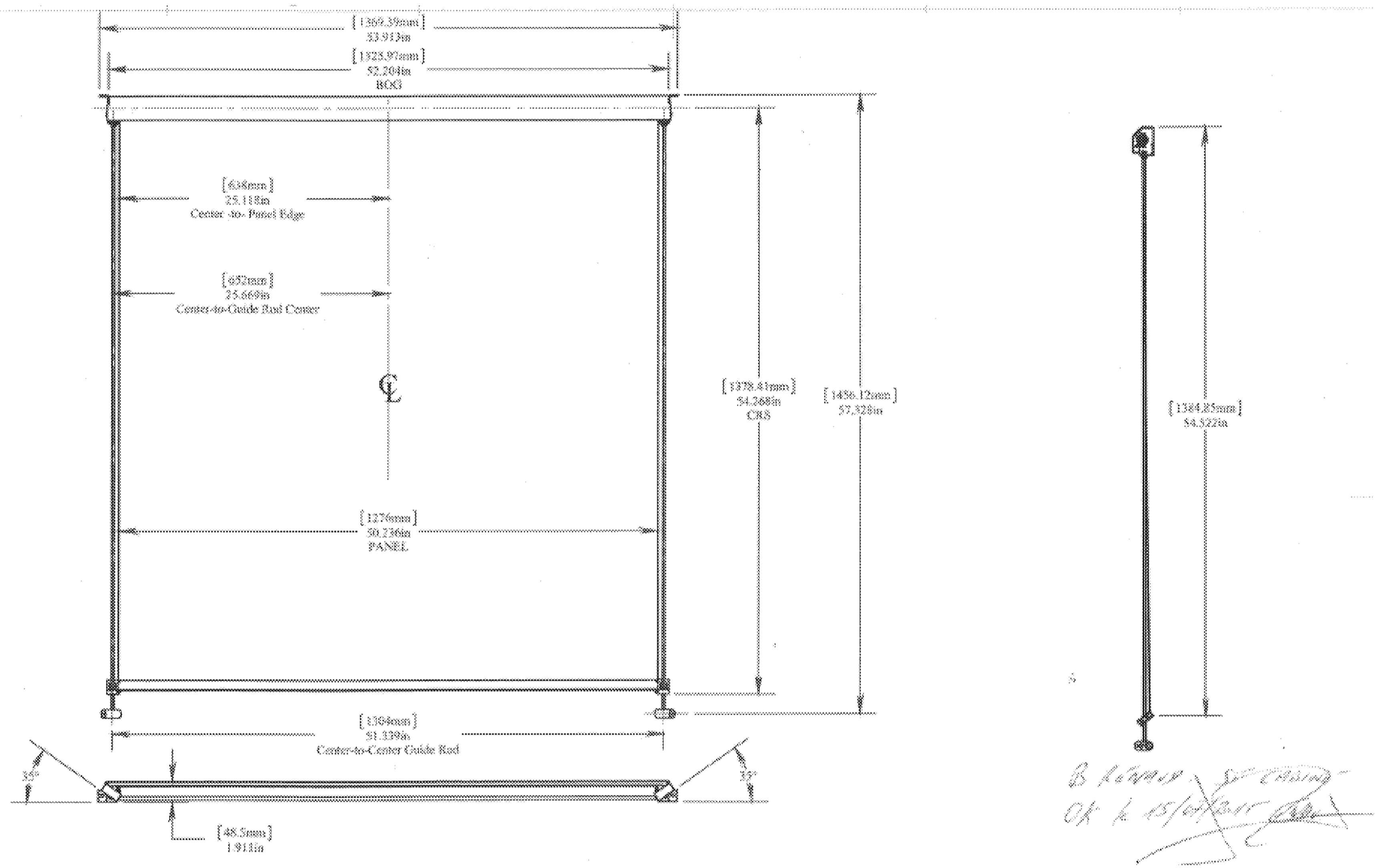


Figure 42: Sunblind

3 SAFETY REQUIREMENTS

3.1 *General description*

All safety analysis are based on a 2 coupled LRV of 4 element-trainset configuration: [Mc1-IMc1-CC-Mc2] - [Mc1-IMc1-CC-Mc2]

Simple unit configuration is considered and constraint will be exported.

Because of the complexity of the industrial organization and the diversity of the technologies, the RAMS Project Management process includes an intermediate integration phase at function level. It is more appropriate to monitor functions, than subsystems because in many cases not all of a function is implemented in one subsystem. Monitoring by subsystem opens the potential for omission at the interface boundaries, which can be avoided by using a functional approach

For this Project, the main functions for level 1 are defined as follows:

Table 6: Rolling Stock functional breakdown

AIR	Provide pneumatic energy
APC	Passengers counting
ATC	Automatic train control
BOG	Track (truck)
BRK	Manage mechanical brake
CDD	Control & Diagnostic Display
CLM	Provide proper climate with HVAC
CPL	Enable flexible configuration or towing
DRS	provide access by external door
DRV	Driving
DSF	Deadman
EAS	External Access Surveillance
EBR	Track brake
ESG	External lights signalling
FSD	Protect against fire
HVS	Provide high voltage energy
JRU	Juridical recorder Unit
LIG	Provide Interior Lighting
MAS	Maintenance Assistance
PAI	Provide public address and info
SAN	Sanding
SFT	Safety train

TBS	Manage propulsion
TGC	Train ground communication
MVS	provide energy for aux and batteries
TCN	Manage train control network
TMR	Tachometer
VSS	Provide surveillance
WFL	Wheels Flange lubrication
WWD	Wipers, washer, defogger

All these functions are not under car-builder's responsibility but they are considered in the FBS.

The list of external equipment which is not considered is:

- On-board Automatic Train Control equipment
- Voice Radio
- Data Radio
- Platform CCTV

It is important to note, however, that the interface circuits to the above equipment is considered as part of the analysis.

This functional breakdown associated to the Product Breakdown Structure (PBS) of the Rolling Stock will be the basis for System assurance throughout the project process. The cross reference between the RS functions and the PBS will be established according to an internal ALSTOM TRANSPORT standard.

The Product Breakdown Structure is a Project Management document [R1].

3.2 *Safety Contractual requirements*

The general policy of Alstom Transport is to apply the set of European Standard and specially the EN 50 126 [A1] or the International Standard IEC 62278 [A5], using (on a qualitative point of view) the GAME principle and (on a quantitative point of view) the allocations targets values.

Throughout the project Documents, the utmost importance is given to Safety considerations that must be taken into account for the OTTAWA project:

Requirements are compliant with the definition of MIL-STD-882 [A7] and the application of the methodology of EN50126 [A1]

3.3 *Hazard Identification and categorization*

The objective of the Hazard identification process is to ensure that hazards are identified as soon as possible, and entered into the risk resolution process after categorisation.

The objective of the Hazard categorisation process is to determine:

- Hazard severity level,
- Hazard frequency.

3.3.1 Hazard Severity Level

Severity levels are identified and defined as follows:

Table 7: Hazard Severity Level

Class		Definition
I	Catastrophic	Could result in death, permanent total disability, loss exceeding $1M, or irreversible severe environmental damage that violates law or regulation.
II	Critical	Could result in permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, loss exceeding $200K but less than $1M, or reversible environmental damage causing a violation of law or • Regulation.
III	Marginal	Operating conditions such that personnel error, environment, design deficiencies, sub-system or component failure or procedural deficiencies will result in: • a single severe injury, or • Several minor injuries, or • Train withdraws from revenue service.
IV	Negligible	Operating conditions such that personnel error, environment, design deficiencies, sub-system or component failure or procedural deficiencies will result in: • A single minor injury, or • A minor disturbance of revenue service (no train withdrawal).

3.3.2 Hazard frequency

Categories of hazard frequency of occurrence per vehicle are defined as follows:

Table 8: Hazard Frequency

Category of occurrence		*Description of the probability*	*Frequency of occurrence of hazardous events*
Frequent	F	Likely to occur frequently. The hazard will be continually experienced	λ > 10-2/h
Probable	E	Will occur several times. The hazard can be expected to occur often	10-3/h < λ ≤ 10-2/h
Occasional	D	Likely to occur several times. The hazard can be expected to occur several times	10-4/h < λ ≤ 10-3/h
Remote	C	Likely to occur sometime in the system life cycle. The hazard can reasonably expected to occur	10-6/h < λ ≤ 10-4/h
Improbable	B	Unlikely to occur but possible. It can be assumed that the hazard may exceptionally occur.	10-8/h < λ ≤ 10-6/h

Incredible	A	Extremely unlikely to occur. It can be assumed that the hazard may not occur.	λ ≤ 10-8/h

3.4 ***Risk assessment***

The objective of the risk assessment is to determine if the risk is acceptable for safety or if further resolution actions are required. To do that, it is necessary to:

- Classify the risk to define the acceptability.

Acceptability risk matrix

Frequency of occurrence of a hazardous event	Severity Levels of Hazard Consequence			
	Insignificant	Marginal	Critical	Catastrophic
Frequent	Undesirable	Intolerable	Intolerable	Intolerable
Probable	Tolerable	Undesirable	Intolerable	Intolerable
Occasional	Tolerable	Undesirable	Undesirable	Intolerable
Remote	Negligible	Tolerable	Undesirable	Undesirable
Improbable	Negligible	Negligible	Tolerable	Tolerable
Incredible	Negligible	Negligible	Negligible	Negligible

- Acceptability Matrix Meaning:

Acceptability Matrix meaning

Risk category acceptability level	Actions to be applied
Intolerable	Shall be eliminated
Undesirable	Shall only be accepted when risk reduction is impracticable and with the agreement of the customer
Tolerable	Acceptable with adequate control and the agreement of the customer
Negligible	Acceptable without any agreement

4 SAFETY MANAGEMENT

4.1 *Rolling Stock Interface coordination*

A RS Safety network is set up and leads by the RS Project RAMS Manager. He is responsible for the Safety activities at the RS level.

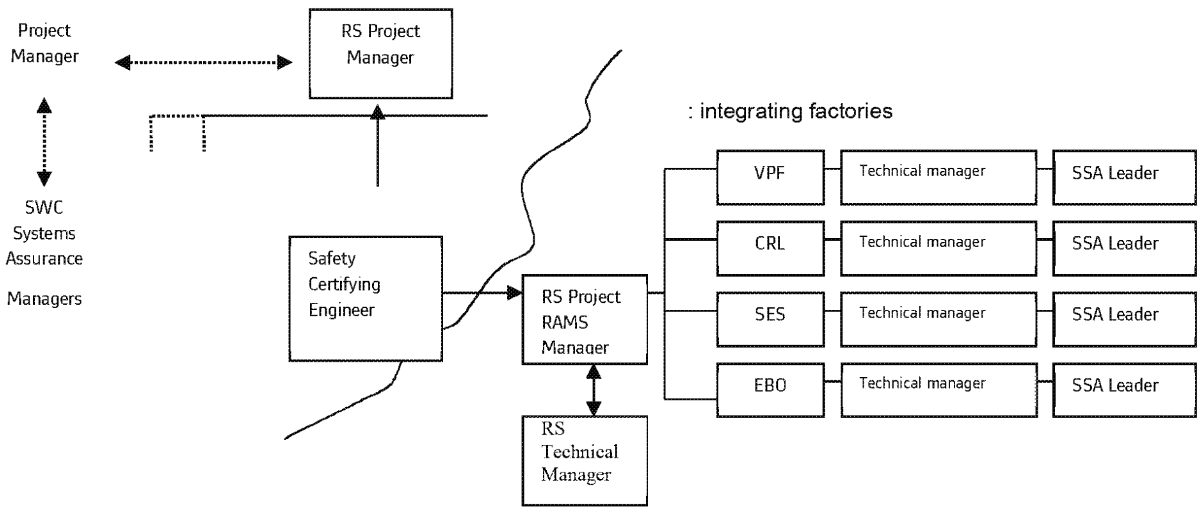


Figure 43: Rolling Stock Safety network

4.2 *Rolling Stock Implementation of safety*

Approach consists in implementing an iterative and progressive process based on hazards evaluation until the safety requirements are met.

This approach described here after will ensure compliance with the safety requirements:

- Identification and tracking of Hazards from identification to resolution.
- Close interaction between design engineers and safety engineers early in the design stage to ensure that appropriate safety concepts are built in.
- Constant follow up of every sub-contractor.
- Close interaction with OTTAWA Safety Engineer and the Safety Certifying Engineer throughout all the phases of the project to validate that the subsystem design integrates with the overall safety requirements.
- Close monitoring and control of the safety assurance program.

This iterative approach takes benefit from past experience and allows an early detection of design weakness and safety related items or interfaces with appropriate safety analyses. There will be continuous interaction and feedback between safety analyses and design.

The approach proposed to implement the safety program is illustrated by figure 44. This figure shows the different tasks that will be carried out to manage safety. In this process, the interaction between safety analyses and design is managed with the help of the following tasks:

- Identification of safety critical items and proposal of risk reduction recommendations,
- Generation of a Hazard Log,
- Safety review of general documents.

These specific tasks are described in section 3.3.

The safety provisions and the corrective actions issued from SRIL, Hazard Log and safety reviews are implemented and managed according to a specific procedure.

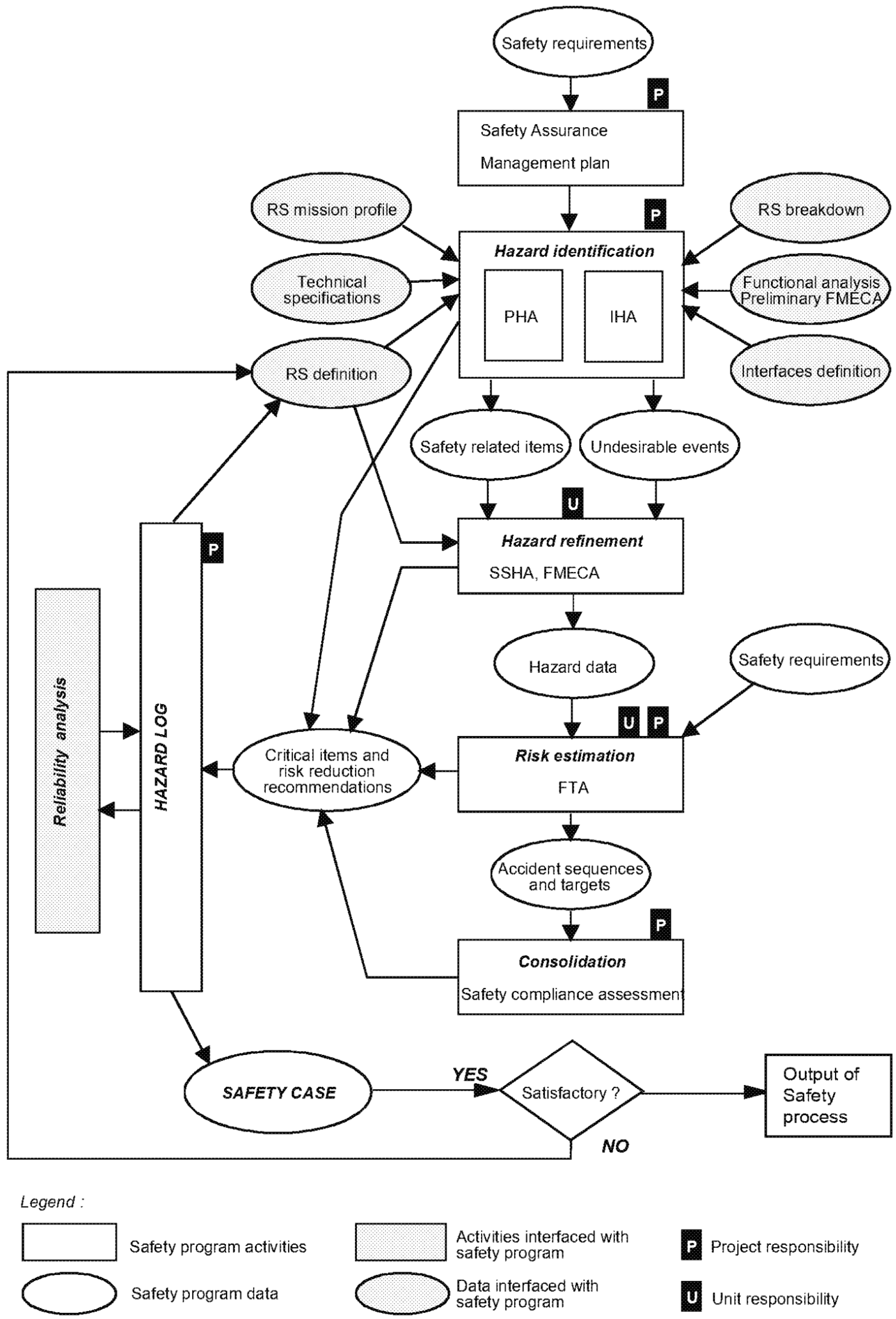


Figure 44: Safety Program

4.3 *Management of the interaction between safety analyses and design*

4.3.1 Build-up of a Safety Related Item List

A Safety Related Item List (SRIL) will be established and kept current by the Rolling Stock Project RAMS Manager, on the basis of information issued from the different safety analyses.

This SRIL will record all the safety related items which can directly impact the safety at catastrophic or critical level (category I and II).

The methodology used to build up the SRIL is detailed in a specific document related Alstom Transport.

Main Inputs of SRIL:

- PHA, FTA, SSHA, IHA, FMECA

Outputs of SRIL:

- Safety Related Item list and relevant safety status

4.3.2 Development of a Hazard Log

One of the inputs of the Hazard Log is the current ALSTOM Return of Experience. This one already defines a RS Preliminary Hazards List (PHL). This will be in addition to the specific hazards required by the Ottawa Specification Schedule 15.2 part 4, paragraph 3.14.b.ii

A Hazard Log will be used as a tool to track safety risks. It will be set up and regularly up-dated by the Rolling Stock Project RAMS Manager.

- Safety risks are issued from the different safety analyses: those conducted by respective participating units of integrating factories (SSHA, FMECA, FTA),
- Those performed at the RS level (PHA, IHA, and FTA).

Prior to be classified as "safety related problem", these issues are first examined through the safety reviews.

When accepted as a valid potential safety concern by the relevant Safety Leader, the problem is then recorded through the Hazard Log at the Rolling Stock level. Someone is then designated by the Rolling Stock Technical Manager as responsible for the tracking of the associated corrective action until its closing out.

The methodology and the detailed principles for the achievement of the hazard log are described in the specific document related to Hazard Log.

The Hazard Log is managed and controlled according to the rules defined in the Procedure for hazard resolution follow-up at Alstom Transport Level RSA-GDL-006.

4.3.3 Tests and validation

The Project RAMS Manager is responsible for ensuring safety assurance and validation. This implies that all products comply with the safety design provisions when delivered.

Validation of safety for a product generally requires testing the associated safety provisions of the items identified in the SRIL. However, some safety provisions might be validated through other appropriate means such as calculation and/or simulations and/or tests.

For specific provisions that have to be verified by test, the Project RAMS Manager might specify tests at different levels (design, installation, testing and commissioning) to complement the overall verification and the validation of the system.

4.3.4 Safety review of general documents

With respect of points designated as valid potential safety concerns, both the Safety Certifying Engineer and the Rolling Stock Project RAMS Manager will:

- Review and approve design changes, design releases, maintenance and operating manuals and test programs (the approval will be issued after the completion of the relevant studies),
- Build up a file for each approval, in order to document it and to demonstrate it is relevant,

Rolling Stock Project RAMS Manager will be assisted by the Safety Leaders of the integrating factories, for the relevant part of the demonstration.

4.4 *Industrial Organization*

System Safety Assurance is one of the activities of the Rolling Stock Project Management as required by ALSTOM TRANSPORT internal policy. A dedicated organization is set up to manage this performance.

This organization includes human resources and a structure made of entities with a clear statement of each other's responsibilities. As shown on figure 45

, it is based on a two layer pyramidal structure which interfaces, when necessary, with the System level management.

The key characteristics of this organization are:

- A clear definition of responsibilities,
- Adequate human resources and close relationship with the engineering,
- System Safety Assurance leaders or managers at each layer of the structure close to the Engineering teams.

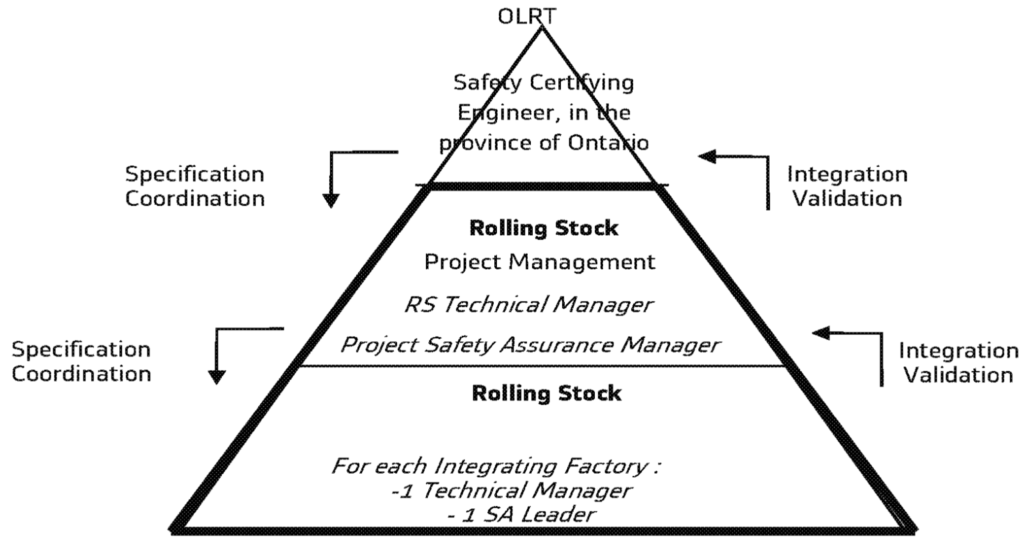


Figure 45: Organization of the Rolling Stock System Safety Assurance activity

4.5 *Safety main activities*

4.5.1 System life-cycle

The life-cycle of the Rolling Stock system is divided into several stages: Contract, Preliminary Design, Pre-final Design, Final Design, Manufacturing and Integration, Testing and Commissioning and Operation.

This cycle is illustrated by the diagram presented on Figure 46.

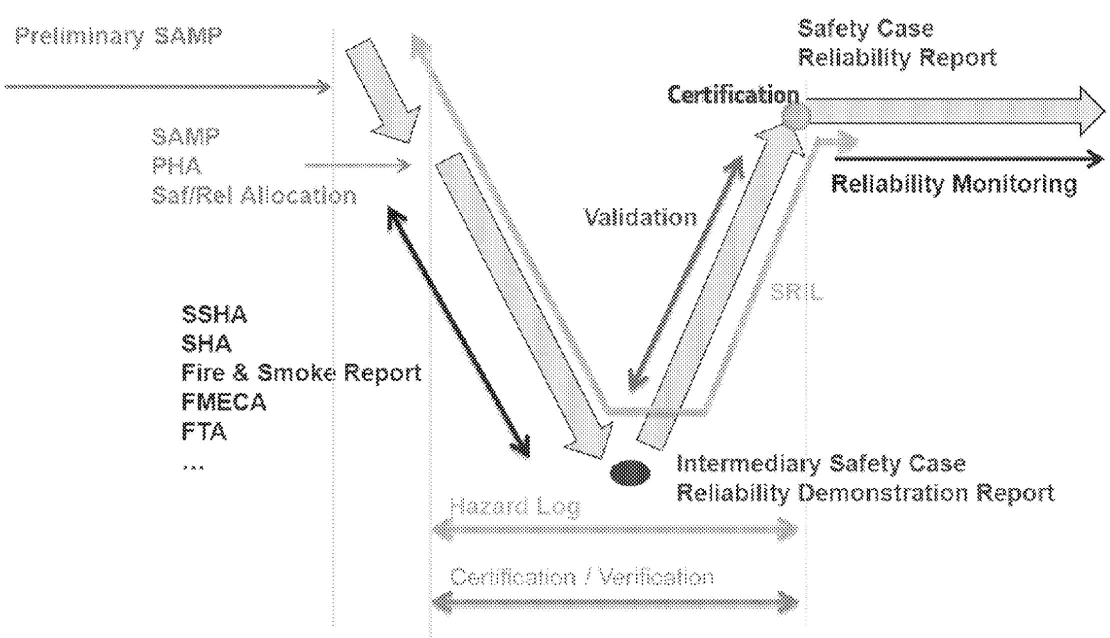


Figure 46: V - Project Life-cycle and deliveries

4.5.2 Safety activities

Each phase of the project development generates specific safety activities:

Preliminary design: this stage aims to define and to validate the preliminary design of the system. Safety activity aims to define a specification and an allocation of the safety requirements to the Integrating Factories. Weaknesses of the system are identified, ranked and corrective actions are defined.

Pre-Final design: this stage aims to define and to validate the pre-final design of the system. Safety activity aims to analyse safety characteristics of the subsystems designed by the Integrating Factories. Weaknesses of the subsystems are identified, ranked and corrective actions are defined.

Final design: this stage aims to define and to validate the final design of the system. Safety activity includes the elaboration of the predicted safety performance by the Integrating Factories, the integration and the validation of these performances by the Project Management. Weaknesses of the main contributory elements are identified and corrective actions are defined.

Testing and Commissioning: this stage of the project aims to test the new components and subsystems and to commission the system. The Safety Related Items List has to be defined for this stage and the implementation status of the various provisions included in this list has to be checked and monitored.

Certification: this stage of the projects aims to have self-certification by Safety Certifying Engineer, in the province of Ontario.

Operation: this stage of a project aims to operate the system. Safety activity consists in verifying that safety provisions are integrated into the appropriate manuals.

4.6 *Management of interaction between safety and DFQ cycle*

As part of the Alstom Transport quality and project management policy, a set of internal review meetings called "Gate Reviews" are planned at each major milestones of the project life-cycle. The following figure identifies all the gate reviews applicable to a rolling stock project. As a general principle, the purpose of each gate review is to verify, using pre-defined check lists, that the activities necessary to start the next phase have been adequately performed. The results of each review are formalized in an internal report.

- TGR : Tender Gate Review
- LGR : Launch Gate Review
- SGR : Specification Gate Review
- PGR : Preliminary Gate Review
- CGR : Critical Gate Review
- GFV : Go For Validation
- IQR : Internal Qualification Review
- GSR : Go Serial Review
- VGR : Validation Gate Review
- FQA : Final Quality Acceptance

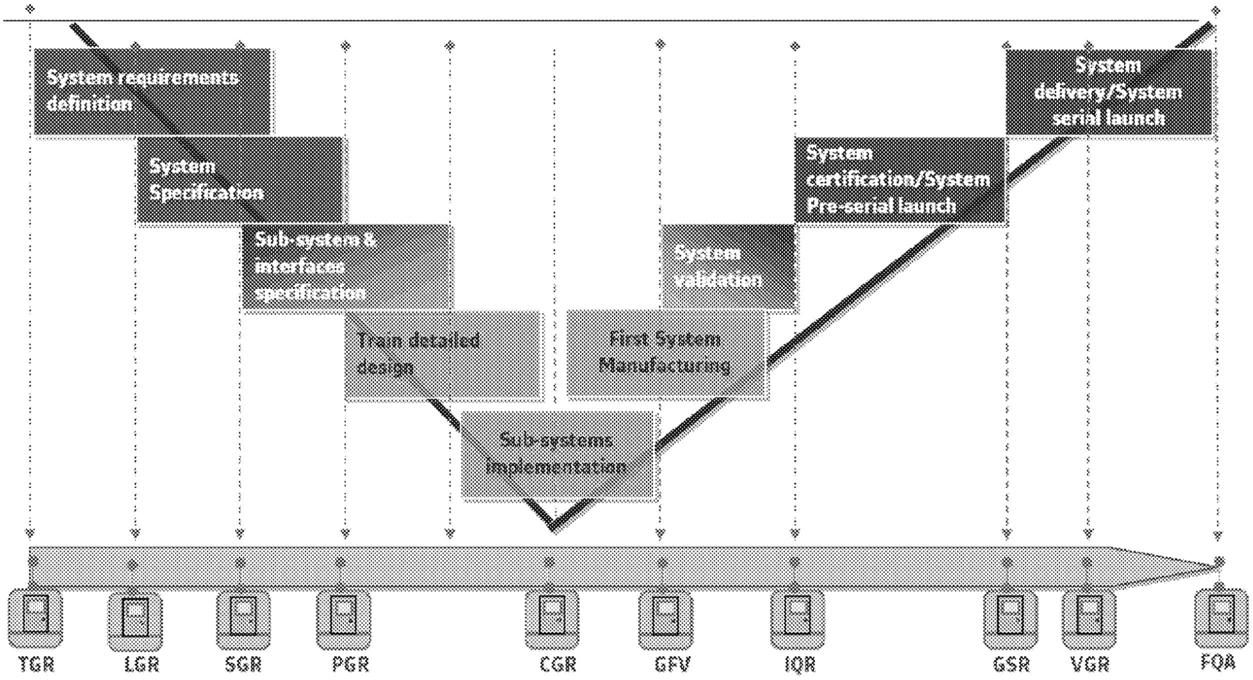


Figure 47: DFQ Cycle

The detailed definition of each gate review is in the Project Quality Assurance Plan.

The safety is implemented using the internal safety design reviews. Before each project gate review, a **Safety Design Review** is performed to measure the safety maturity at each project phase.

4.7 *Organization and responsibility*

Safety activities are in the scope of RAMS Department in ALSTOM TRANSPORT.

The RAMS team for integration is composed of:

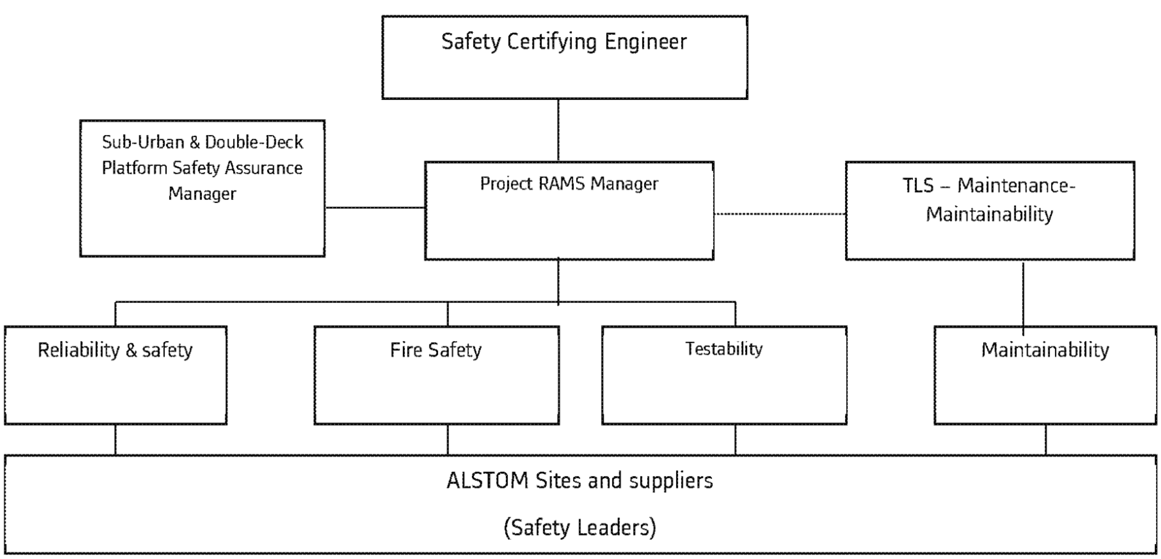


Figure 48: Organization and responsibility chart

Table 9: Responsibility

Site	Job	Name
ALSTOM Hornell	Safety Certifying Engineer, in the province of Ontario	Lowell GOUDGE
ALSTOM VPF (Train System Design lead, integration)	Sub-Urban & Double-Deck Platform Safety Assurance Manager	Christophe DEHONDT
ALSTOM VPF (Train System Design lead, integration)	Project RAMS Manager.	Christophe DEHONDT
ALSTOM VPF	Train Life Service TLS	Emilie GUILLOT
ALSTOM Villeurbannes (Train Information Solution, PA/PIS)	RAMS Manager truck equipment.	Denis GRIMAULT
ALSTOM Sesto (traction)	RAMS Manager TCMS equipment.	Sandrine CALIXTE
ALSTOM Charleroi (Auxiliary Inverter)	RAMS Manager Traction equipment.	Michelangelo BAORTO

A Safety Assurance network will be set up according to the general principles explained in section 3.4. As illustrated, the Safety network will be constituted of:

- A Safety Manager integrated in the project team, normally the Safety manager is designed Project RAMS Manager in charge of all dependability (Reliability, Availability, Safety, Testability...) activities, as shown in the organization chart above.
- Safety Leaders integrated in the project team of each integrating factories.
- Safety Certifying Engineer (licensed by P.E.O.): This function will be carried out by the Project Train System Engineer, who will be responsible to review and approve / sign all project specifications, as well as the safety certification documents to the customer.

4.7.1 The Project RAMS Manager

The Project RAMS Manager carries out the safety assurance activities for sub-system interfaces and at train level under the control of Project Management, according to the rules defined in the Procedure for hazard resolution follow-up.

The Rolling Stock Project RAMS Manager reports to the Platform RAMS Manager, assuring the independence from Project Team. He is responsible for the implementation of the Safety policy and the production of deliveries required by the Contract. This includes the following tasks:

- Achievement of safety analyses at RS project level, according to the approach described in section 3.2,
- Specification and allocation of Safety requirements to the Integrating Factories and external suppliers,
- Scheduling and co-ordination of the Safety work performed by the Integrating Factories through the Safety network,
- Integration and validation of the Integrating Factories deliveries and production of the deliveries which are to be submitted to Project RAMS Manager

- Identification of weakness and definition of corrective actions and follow-up,
- Manage the Safety Engineers team involved at project level.
- Reporting to the Sub-Urban & Double-Deck Platform Safety Assurance Manager
- Liaise with the Safety Certifying Engineer

4.7.2 The Platform RAMS Manager

In this case the platform designed is Sub-Urban & Double-Deck. He is responsible to ensure that the Rolling Stock Safety process is respected and well conducted during all phases of project. He supports the Project RAMS Manager during all life cycle of project, assuring the understanding of contractual and regulation requirements.

4.7.3 Participating Unit RAMS

Other ALSTOM sites are involved in OTTAWA project. Those sites (except from Valenciennes) are : Le Creusot (France), Villeurbannes (France), SESTO (Italy) and Charleroi (Belgium).

In each Integrating Factory, Truck/TCMS/Traction/APS/ICT, there are RAMS departments in charge of Safety activities (Safety Leaders).

Each factory has a Site RAMS Manager, he is responsible for the implementation of the Safety policy and the production of deliveries asked by the Project Management.

This includes the following tasks :

- Achievement of safety analyses for the products and services which it's factory is responsible for, according to the approach described in section 3.2 and, in order to meet the requirements issued from the RS project level,
- Specification of Safety requirements to subcontractors and suppliers,
- Integration and validation of subcontractors and suppliers documents,
- Integration and validation of their analyses to produce their deliveries,
- Scheduling and co-ordination of their Safety analyses,
- Identification of weakness and definition of corrective actions and follow-up,

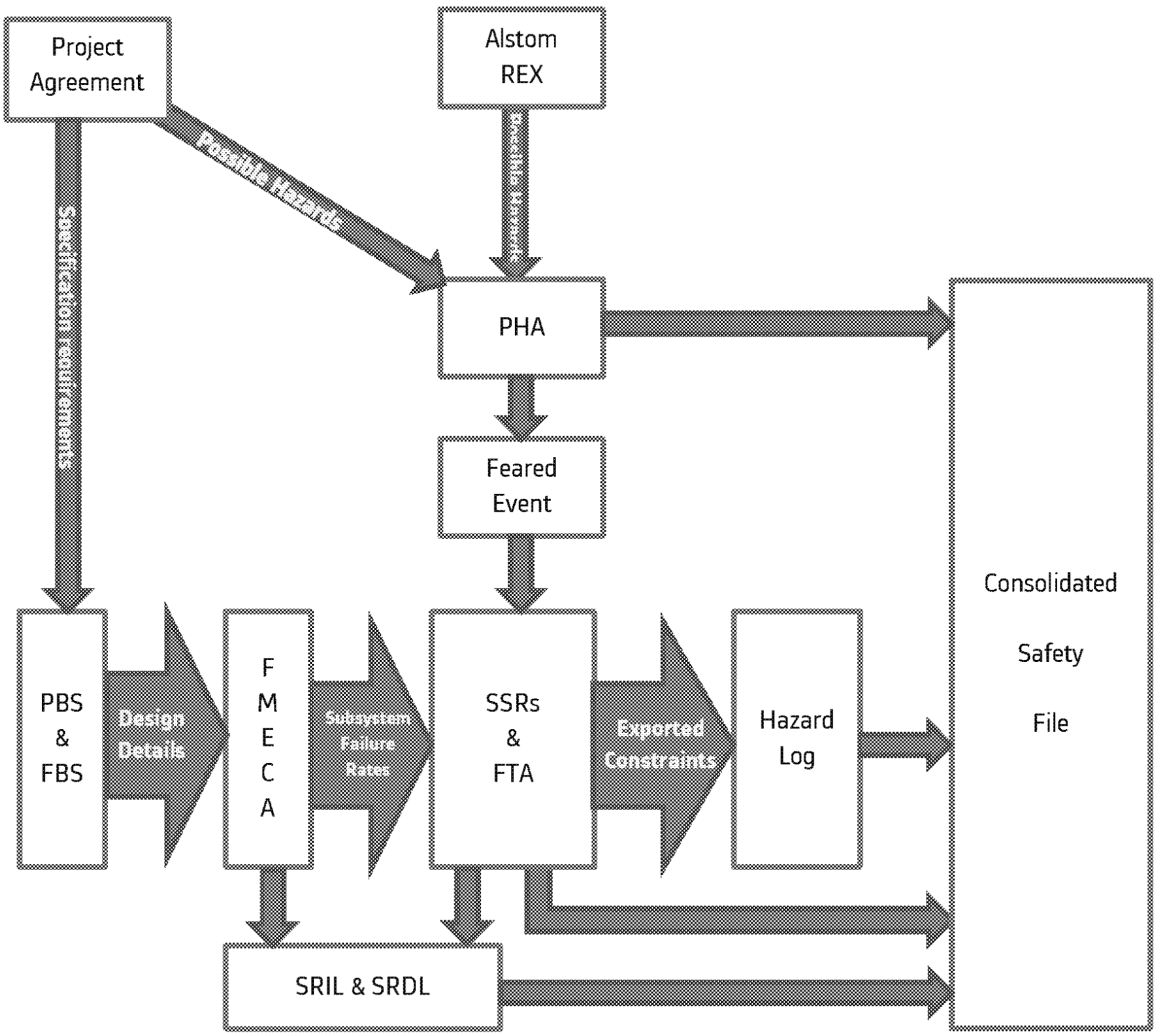
4.7.4 Safety Certifying Engineer

In this case, the Train System Engineer and train integrator is a licensed engineer in the province of Ontario, who will also be responsible to certify the design of the vehicle with respect to safety. His duties as train system engineer include:

- Approval of all design documentation
    - This will also include by default all reviews and approvals pertaining to system safety
- Participation in all internal design reviews
- Participation in all customer design reviews

5 SAFETY DOCUMENTATION AND RELATIONSHIP BETWEEN DOCUMENTS

The following flow chart depicts the overall flow of Safety requirements and the relationship between documents from the project specification to the final Consolidated Safety Report.



6 SAFETY STUDIES

6.1 *Critical Events*

The purpose of this Consolidated Safety File is to demonstrate the level of safety of the OTTAWA project through the sub-systems.

6.1.1 Preliminary Hazard Analysis (PHA)

The Preliminary Hazard Analysis was conducted using the events described in Schedule 15-2 part 4 Article 3.14.b of the project agreement supplemented by additional hazards based upon Alstom REX and other technical requirements distributed throughout Schedule 15-2 Part 4 Article 3.

To ease the "navigation' through the PHA, the following table was developed to identify the relationship between Alstom's nomenclature for the hazard analysis and the applicable specification paragraphs.

Feared Event	Severity	Project Agreement Paragraph
Doors remaining closed while emergency evacuation is needed	Catastrophic	None
Electromagnetic interference	Catastrophic	3.15(b)
Fall of equipment	Catastrophic	None
Indication of not coupled when coupled	Catastrophic	3.14(b)(ii)K
Lack of appropriate reaction	Catastrophic	None
Locked axle	Catastrophic	None
Loss of structural integrity	Catastrophic	None
Start of fire	Catastrophic	3.14(b)(ii)J
Unavailability of effective emergency brake	Catastrophic	3.14(b)(ii)A 3.14(b)(ii)D
Unbraked section after integrity loss	Catastrophic	3.14(b)(ii)A 3.14(b)(ii)N
Undetected traction in the wrong direction	Catastrophic	3.14(b)(ii)L
Undetected unavailability of effective holding brake	Catastrophic	None
Unsanctioned train overspeed	Catastrophic	3.14(b)(ii)A 3.14(b)(ii)B 3.14(b)(ii)M 3.14(b)(ii)B
Violation of clearance envelope	Catastrophic	3.7(a)
Battery explosion	Catastrophic	3.23(g)(iii)

Feared Event	Severity	Project Agreement Paragraph
Electrocution of people	Catastrophic	3.33(s)(v)A
Fall and/or harm of people	Critical	3.17(d)(v) 3.33(c)(i)A
Lack of communication between passengers and the train driver	Critical	3.19(d)(i)L 3.27(a)(iii)
Lack of communication between driver and OCC	Critical	3.27(a)(iv)
Loss of external lights	Catastrophic	3.28(b)(v)D(iv) 3.19(g)(v) 3.22(b)(v)
Loss of horn	Catastrophic	None
Loss of internal lighting	Critical	3.22(c) 3.22(b)(iv)
Loss of train driver visibility	Catastrophic	None
Loss of ventilation	Catastrophic	None
Mechanical explosion	Catastrophic	None
No braking on train driver incapacity	Catastrophic	None
No braking while the train is in motion and a door is open	Catastrophic	3.14(b)(ii)B 3.14(b)(ii)M
Passengers caught in doors	Catastrophic	3.14(b)(ii)H
Undetected door remaining open	Catastrophic	3.14(b)(ii)I
Unsanctioned rollback while the train starts on uphill grade	Catastrophic	3.14(b)(ii)L 3.14(b)(ii)M 3.14(b)(ii)B
Untimely opening of a door	Catastrophic	3.14(b)(ii)E 3.14(b)(ii)F 3.14(b)(ii)G
Untimely traction	Catastrophic	3.14(b)(ii)C
Violation of ATC networks	Critical	None
Incorrect Incident/Accident Analysis	Marginal	None
Untimely high voltage regeneration	Catastrophic	3.14(b)(ii)O.
Service brake fails to apply when requested by the master controller	Critical	None
Passengers caught between gangway and the platform	Catastrophic	3.17(d)(iii)

6.1.2 Critical Events identified at the onset of the project

The preliminary top events pertaining to the vehicle and vehicle design, coming from the Boundary Hazard identified in the PHA were:

Sub-system / SSR	Critical Events/Dangerous Occurrence	Mode	Gravity	Targets (f/h)
Doors	Doors remaining closed while emergency evacuation is needed	ALL	I	10^{-8}
Doors	Untimely opening of a door	ALL	I	10^{-8}
Doors	Undetected door remaining open	ALL	I	10^{-8}
Doors	No braking while the train is in motion and door is open	ALL	I	10^{-8}
Doors	Passenger caught in door	ALL	I	10^{-8}
Brakes	Unavailability of effective emergency brake	ALL	I	10^{-8}
Brakes	Unbraked section after integrity loss	ALL	I	10^{-8}
Brakes	Undetected unavailability of effective holding brake	ALL	I	10^{-8}
Brakes	No braking on train driver incapacity	ALL	I	10^{-8}
Brakes	No braking while the train is in motion and door is open	ALL	I	10^{-8}
Brakes	Service brake fails to apply when requested by the master controller	ALL	II	10^{-6}
Gauge	Violation of clearance envelope	ALL	I	10^{-8}
Gauge	Fall of equipment	ALL	I	10^{-8}
Gauge	Loss of structural integrity	ALL	I	10^{-8}
External Signalling	Loss of external lights	ALL	I	10^{-8}
External Signalling	Loss of horn	ALL	I	10^{-8}
Traction	Undetected traction in the wrong direction	ALL	I	10^{-8}
Traction	Untimely traction	ALL	I	10^{-8}
Traction	Unsanctioned rollback while the train starts or stops on uphill grade	ALL	I	10^{-8}
Driver visibility	Loss of train driver visibility	ALL	I	10^{-8}
Interior lighting	Loss of internal lighting	ALL	II	10^{-6}
Gravity II feared events	Lack of communication between passengers and the train driver	ALL	II	10^{-6}
Gravity II feared events	Lack of communication between train driver and OCC	ALL	II	10^{-6}
Gravity II feared events	Fall and/or harm of people	ALL	II	10^{-6}
Gravity II feared	False accident analysis	ALL	III	10^{-4}

events				
Gravity I feared events	Electromagnetic interference	ALL	I	10^{-8}
Gravity I feared events	Indication of uncoupled when not uncoupled	ALL	I	10^{-8}
Gravity I feared events	Locked axle	ALL	I	10^{-8}
Gravity I feared events	Start of fire	ALL	I	10^{-8}
Gravity I feared events	Battery explosion	ALL	I	10^{-8}
Gravity I feared events	Electrocution of people	ALL	I	10^{-8}
Gravity I feared events	Loss of ventilation	ALL	I	10^{-8}
Gravity I feared events	Mechanical explosion	ALL	I	10^{-8}

Table 10: Boundary Hazard

Safety Studies Reports (SSR) were conducted by function/subsystem to address the critical events.

6.1.3 Critical Events identified during the project

The following critical events were identified during the project through customer analysis of external threats or events:

Sub-system / SSR	Critical Events/Dangerous Occurrence	Mode	Gravity	Targets (f/h)
Gangway	Passengers caught between gangway and the platform	ALL	I	
Gangway **Coupler**	Passenger Riding on the exterior of the train	ALL	I	

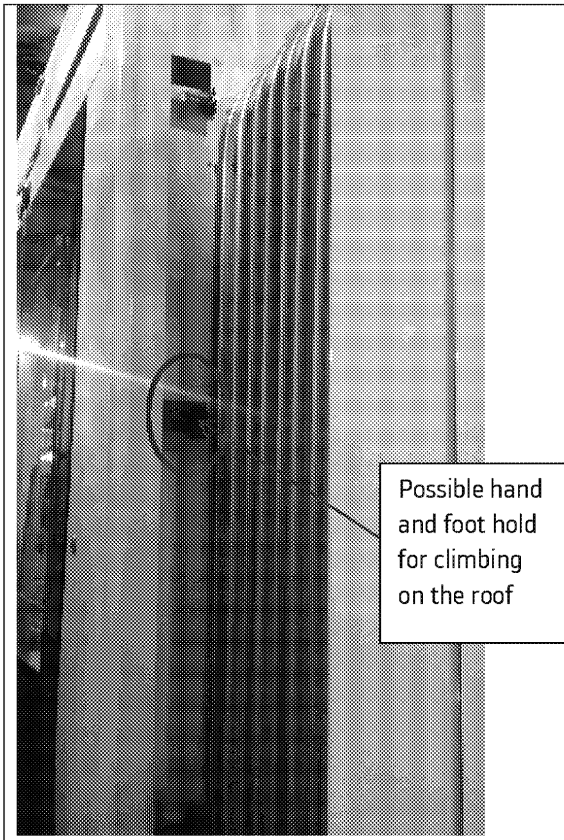
These events have been analysed qualitatively and addressed with design changes;

6.1.3.1 Gangway

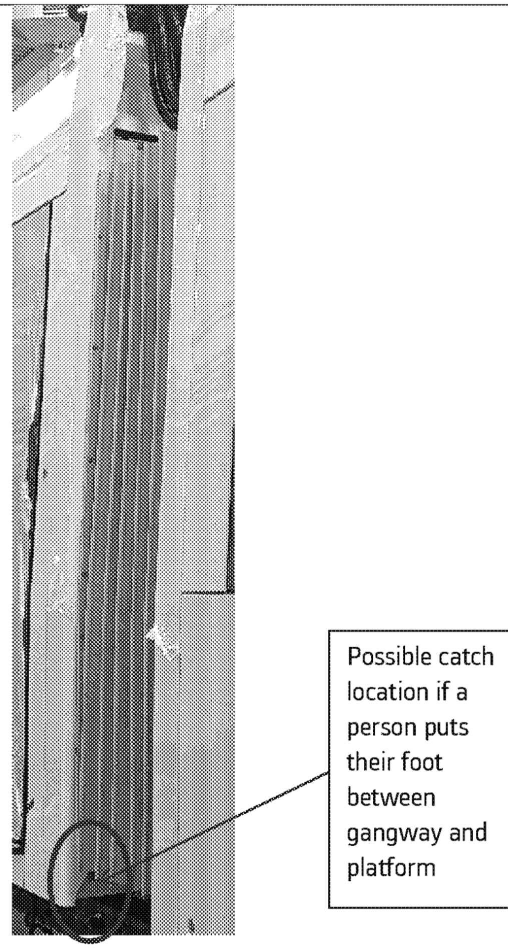
6.1.3.1.1 Passenger trapped between platform and train

Passenger trapped between platform and train was analysed qualitatively by OLRTC and Alstom, based upon a dimensional analysis and a case prepared for OC Transpo, using these arguments. OLRTC developed a safety Certificate (Safety Certificate 9207) that presented the dimensional analysis and ability to view the side of the car with the platform cameras. While Alstom and OLRTC considered the hazard mitigated, OC Transpo insisted upon a design change to add a third layer to the bellows to reduce the gap to the minimum practical.

The photos below show the change in the depth of the recess at the bellows.



View of un modified gangway



View of prototype gangway with 3rd layer of bellows

While the nearly flush gangway mitigates most of the risk of a passenger being trapped or falling between the platform edge and the side of the car, an entrapment hazard was identified with the straight bottom of the bellows. It is conceivable that a person could put their foot between the platform edge and the gangway, and the straight bottom of the gangway would then prevent withdrawing the foot. The final design will have a curved bottom, so the foot cannot be caught on the bottom of the bellows (See photo of prototype)

6.1.3.1.2 Passenger Riding on train exterior

As shown in the photos of the gangway in 6.1.3.1.1, the bracket for the body extensions (mud flaps) in some locations provided suitable steps that were considered as a hazard for the external threat of passengers riding on the exterior of the train (subway surfing). The addition of the third bellows eliminates this threat

6.1.3.2 Passenger Riding on the coupler

Subway surfing was also considered a threat with respect to passengers riding on the bellows. This was to be managed at the system level by OLRTC with the Guideway Intrusion Detection (GIDS), however there has been a suggestion to use the forward and rear facing cameras mounted in the cab to monitor the space between trains by the driver prior to departure from the station. This is not yet finalized.

6.1.4 Management of Critical Events

The risk analysis and management on the CITADIS Spirit functions is done with the three following methodologies:

- Failure Mode, Effect and Criticality Analysis (FMECA)
- Fault Tree Analysis (FTA)
- Qualitative Justification of the Design (Analysis done when FTA is not applicable)

and is supported by the following methodologies at suppliers' level:

- Sub-System Hazard Analysis (SSHA)
- Failure Mode, Effect and Criticality Analysis (FMECA)
- Fault Tree Analysis (FTA)

6.2 *Hazard description*

6.2.1 Doors Hazard description

The correspondence log and closure status of SSR Doors is found in Appendix 2 – Approval Status of Safety Related Documents

6.2.1.1 Doors Remaining Closed while Emergency Evacuation is needed

The event is the possibility that passengers could not release the door in front of them or a door on the same side, within the car section by using the interior Emergency Door Release (EDR) mechanism.

It can be caused by a mechanical locking of the release mechanism of the door, or by failure to remove the closing effort of the door, or if a door is locked out.

It could result in a longer delay for passengers to evacuate an unsafe train in the event of an emergency. The high number of passenger doors per side, reduces the number of people in an emergency situation in the event of a single failure.

Its severity is **catastrophic**, so the THR is set to 10^{-8}/h.

This scenario is considered as catastrophic when two doors are failed in the same unit/same side. This is set by the criteria to remain in service with door failures (see appendix 1 – Degraded Modes).

6.2.1.2 Untimely Opening of a Door

The event is that a door became open while the train is in motion or without command.

This undesired event includes the following:

- Door opens spontaneously when not commanded;
- Door opens on wrong side of vehicle.

It could result in a passenger fall.

The mishap is **catastrophic**, so the THR is set to 10^{-8}/h.

The conclusion of the studies is that neither the Vapor door system, or the Alstom TCMS contain a single point failure that can lead to an untimely door opening.

6.2.1.3 Undetected Door Remaining Open

The event is the fact that a door remains open after a closing sequence and that all doors are detected closed.

This undesired event includes the following ones:

- Door interlocks erroneously, indicating door is closed and locked.

It could result in the train starting with a passenger caught.

The mishap is **catastrophic**, so the THR is set to 10^{-8}/h.

6.2.1.4 *Passenger Caught in Door*

This event is a passenger trapped during the closing or opening phase of a door.
It could result in the death of a trapped passenger.

The mishap is **catastrophic**, so the THR is set to 10^{-8}/h.

6.2.2 Brake Hazard description

The correspondence log and closure status of SSR Brakes is found in Appendix 2 – Approval Status of Safety Related Documents

6.2.2.1 *Unavailability of effective emergency brake*

The event is the fact that the train driver or ATC system could not trigger an emergency brake (PBEB) or the braking effort induced is not able to efficiently reduce the train speed and stop it in the expected distance and delay.

This undesired event includes the following ones:

- Emergency brakes (PBEB) fail to apply when requested;
- Insufficient brake rate achieved when EB applied;
- Propulsion fails to cease when emergency brake is requested.

It could result in a collision with another vehicle (rail vehicle or car).

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.2.2 *Unbraked section after integrity loss*

The event is the fact that a vehicle is split in two parts and both parts do not apply a sufficient braking effort to keep parts at standstill.

Operational uncoupling is processed with a train at standstill (holding brake applied).

The event is related to an untimely uncoupling and a lack of emergency braking effort.

It could result in a drifting part of the train and thus a collision with another train or personnel on the track, or in the maintenance facilities (only if the ATC system fails to detect train separation, or when running without ATC).

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.2.3 *Undetected unavailability of effective holding brake*

The event is the fact that the train driver should not be advised that the holding brake he triggered should not provide a braking effort able to avoid train (in AW3) to drift. The feared event occurs if the train driver has no reaction whereas the train is drifting.

It can be caused by a failure to trigger/apply holding brake combined with a failure which untimely detects holding brake application.

It could result in a drifting train and thus a collision with another vehicle (rail vehicle or car). It would be detected by ATC.

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.2.4 Service brake fails to apply when requested by the master controller

The event is the failure of the Maximum Service Brake whereas the master controller commands a MSB.

This undesired event includes the following ones:

- Maximum Service Brake fails to apply when requested by the master controller;

- Insufficient braking effort when MSB commanded by the master controller

It could result in an increase of the braking distance and a driver disturb. The driver must use the PBEB to stop the train in case of failure of Maximum Service Brake through the master controller (Ottawa_SSR Brake_010).

The mishap is critical, so the THR is set to 10-6/h.

6.2.2.5 No braking on train driver incapacity

The event is the absence of Maximum Service Brake in the event of the incapacity of the train driver.

It can be caused by:

- The conjunction of a loss of the operator capacity to drive the train and an untimely detection of a train driver action (ATC detection) – in ATO mode, an alert system provided by Thales is responsible to move the train, with reduce speed, to the next station on loss of driver capacity;
- A failure to activate the deadman device or to trigger or realize an effective Maximum Service Brake (in ATP-M or RM).

It could result in a derailment or a collision with another vehicle. The fault tree analysis will include provision for the occurrence of incapacity of the train driver in ATP-M, ATP bypass mode and Restricted Manual mode only, as Thales is responsible in ATO mode for the limits of train movement authority.

The mishap is critical, so the THR is set to 10^{-8}/h.

6.2.2.6 No braking while the train is in motion and door is open

The event is the fact that the train should be in motion while a door is not closed and that no braking effort reduces the train speed and stop it.

This undesired event includes the following ones:

- Door interlocks erroneously indicates door is closed;
- Service brakes fail to apply when requested;

It could result in a passenger to fall outside.

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.3 Gauge Hazard Description

The correspondence log and closure status of SSR Gauge is found in Appendix 2 – Approval Status of Safety Related Documents

6.2.3.1 Violation of Clearance Envelope

The event "Violation of Clearance Envelope" may lead to collision with infrastructure or passing vehicle and eventually to derailment. It could be cause by mechanical failure or a door panel collision with obstacle outside vehicle clearance.
Its severity is catastrophic, so the THR is set to 10^{-8}/h.

6.2.3.2 Fall of Equipment

The event "Fall of Equipment" may lead to various mishaps depending on the place where the equipment falls, including derailment of the LRV or another one, collision of another vehicle, or injury of people inside or outside the LRV.
Its severity is catastrophic, so the THR is set to 10^{-8}/h.

6.2.3.3 Loss of Structural Integrity

The event "Loss of Structural Integrity" may lead to various mishaps, including fall and crushing of passengers, collision of a part of the LRV with another vehicle or derailment.
Its severity is catastrophic, so the THR is set to 10^{-8}/h.

6.2.4 External signalling hazard description

The correspondence log and closure status of SSR ESG is found in Appendix 2 – Approval Status of Safety Related Documents

6.2.4.1 Loss of external lights

The event is the loss of external lights on the train.

It can be caused by a failure of head lights and tail lights or a loss of their electrical supply.

It could result in a potential collision between a revenue vehicle and a maintenance vehicle. For Ottawa project the train travels on a dedicated train line. Furthermore, ATC system manages this function. That's why, the hazard is not possible in revenue service; it can only appear in maintenance yard because of dedicated track.

The mishap is catastrophic so the THR is set to 10^{-8}/h.

6.2.4.2 *Loss of horn*

The event "Loss of horn" may lead to a collision with a pedestrian or another vehicle. For Ottawa Project, the train travels on a dedicated track. Therefore, the hazard can only appear in maintenance phase. The hazard is catastrophic, so the THR is set to 10^{-8}/h.

6.2.5 Traction hazards description

The correspondence log and closure status of SSR Traction is found in Appendix 2 – Approval Status of Safety Related Documents

6.2.5.1 *Undetected traction in the wrong direction*

The event is a tractive effort in the direction opposite to the one selected by the train driver or by the ATC.

It can be caused by the conjunction of an erroneous traction effort (50% or more) in the wrong direction and an erroneous detection of the travel direction control.

It could result a collision with personnel on the track, vehicles (reduced safe distance with approaching trains) or in the maintenance facilities.

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.5.2 *Untimely traction*

The event is a tractive effort while the train is commanded to brake. The case of tractive effort while a door is open has its own fault tree analysis.

It can be caused by an erroneous tractive effort or an erroneous traction authorization combined with a loss of detection.

It could result in a collision with another train or personnel on the track, or in the maintenance facilities. The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.5.3 *Unsanctioned rollback while the train starts or stops on uphill grade*

The event is an unsanctioned rollback of the train while it starts or stops on an uphill grade.

It can be caused by the conjunction of an insufficient tractive effort when taking power or insufficient friction braking effort and a failure to detect the rollback or to trigger or realize an effective Maximum Service Brake.

It could result in a collision with the next vehicle behind the train impacted, due to reduction in the separation of trains, ultimately to the point that safe stopping distance is infringed upon.

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.6 Driver visibility hazard description

The correspondence log and closure status of SSR Driver Visibiility is found in Appendix 2 – Approval Status of Safety Related Documents

6.2.6.1 Loss of train driver visibility

The event "Loss of train driver visibility" may lead to collision with unauthorized personnel on the track, or in the maintenance facilities.

Its severity is catastrophic, so the THR is set to 10^{-8}/h.

6.2.7 Interior lighting hazard description

The correspondence log and closure status of SSR LIG is found in Appendix 2 – Approval Status of Safety Related Documents

6.2.7.1 Loss of internal lighting

The event is the complete loss of internal lighting in one car.

It can be caused by the failure of the internal normal lights in a section of the vehicle, their command or a loss of their electrical supply combined with the failure of emergency lights in the same section or a loss of their electrical supply.

We assume that the visibility of internal normal lights of the other body section through the gangway and the low level emergency path marking prevent harmful consequences.

It could result in passenger's disorientation.

The mishap is critical, so the THR is set to 10^{-6}/h.

6.2.8 Gravity II feared events hazard description

The correspondence log and closure status of SSR Gravity II feared events is found in Appendix 2 – Approval Status of Safety Related Documents

6.2.8.1 Lack of communication between passengers and the train driver

The event "Lack of communication between passengers and the train driver" may lead to ineffectiveness of emergency reaction increasing other mishap.

Its severity is critical, so the THR is set to 10^{-6}/h.

6.2.8.2 Lack of communication between train driver and OCC

The event "Lack of communication between train driver and OCC" may lead to ineffectiveness of emergency reaction increasing other mishap.

Its severity is critical, so the THR is set to 10^{-6}/h.

6.2.8.3 Fall and/or harm of people

The event "fall and/or harm of people" may lead to injury of passengers outside the train.

Its severity is critical, so the THR is set to 10^{-6}/h.

6.2.8.4 False accident analysis

The event "False accident analysis" may lead to false responsibility assessment after other accident and to undue financial damages.

Its severity is marginal, so the THR is set to 10^{-4}/h.

6.2.9 Gravity I feared events hazard description

The correspondence log and closure status of SSR Gravity I feared events is found in Appendix 2 – Approval Status of Safety Related Documents

6.2.9.1 Electromagnetic interference

The event "Electromagnetic interference" may lead to various mishaps depending on the electrical equipment affected in the LRV. The worst scenarios identified lead to catastrophic mishaps, so the THR is set to 10^{-8}/h.

6.2.9.2 Indication of uncoupled when not uncoupled

The event is an erroneous indication of not coupled when the train is actually coupled.

It can be caused by the failure of the coupling monitoring.

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.9.3 Locked axle

The event "Locked Axle" may lead to starting of a fire, due to sparks emitting from the wheel rail interface, which will be addressed under event "**Error! Reference source not found.**" or large flats and development of an excessive flange in the area of the flat which can lead to a derailment of the train when transiting switches.

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.9.4 *Start of fire*

The event is excessive current or overheated equipment that causes fire hazard.

It can be caused by:

- Battery explosion ;
- Brake disc remains applied without detection. This cause is the fact that a friction brake should not release itself. It can be caused by the conjunction of failure to release a friction brake unit and failure to detect it.

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.9.5 *Battery explosion*

The event "Battery explosion" may lead to injured people or disability of people with mechanical or chemical projections or chemical emissions, mainly during maintenance operations due to the location of the battery.

Its severity is catastrophic, so the THR is set to 10^{-8}/h.

6.2.9.6 *Electrocution of people*

The event is a lack of high voltage presence indication after nominal processing of high voltage circuit breaking and discharging and procedural delay before accessing to high voltage circuit.

It can be caused by the conjunction of discharging and loss of high voltage presence indication.

It could result in maintainer electrocution.

The mishap is catastrophic, so the THR is set to 10^{-8}/h.

6.2.9.7 *Loss of ventilation*

The event "Loss of ventilation or air conditioning" may lead to discomfort of passenger or train driver and eventually death of the weakest ones. It could appear when the train cannot move i.e. when high voltage supply is loss.

Its severity is catastrophic, so the THR is set to 10^{-8}/h.

6.2.9.8 *Mechanical explosion*

The event is the explosion of a compressed air tank or pipeline.

It can be caused by the conjunction of failures of air pressure regulation and overpressure protection.

It could result in an explosion that will throw debris and it can lead to high pressure air exposure causing air embolisms if there is unprotected skin exposed to the flow. Due to the tanks location on the vehicle, the mishap could affect a reduce number of people, mainly during maintenance operations.

Its severity is catastrophic, so the THR is set to 10^{-8}/h.

6.3 *Results Synthesis*

6.3.1 Critical events synthesis

This document part aimed to demonstrate the compliance of the rolling stock with safety targets of the train system. The following table identifies results versus targets for all feared events.

The following results are valid only if recommendations listed in the "Hazard Log" and summarized in chapters 8;9; 10 are fulfilled.

REFERENCE DOCUMENT	*SUBSYSTEM*	*CRITICAL EVENTS*	*GRAVITY*	*TARGET (F/H)*	*RESULT (F/H)*	*COMPLIANCE*	*REMARK*
ADD0000939630	Doors	Doors remaining closed while emergency evacuation is needed	I	10^{-8}	$3.17.10^{-9}$	OK	
ADD0000939630	Doors	Untimely opening of a door	I	10^{-8}	$8.28.10^{-9}$	OK	
ADD0000939630	Doors	Undetected door remaining open	I	10^{-8}	$9.56.10^{-13}$	OK	
ADD0000939630	Doors	Passenger caught in door	I	10^{-8}	$1,077.10^{-9}$	OK	
ADD0000939631	Brake	No braking while the train is in motion and door is open	I	10^{-8}	$5,81.10^{-10}$	OK	
ADD0000939631	Brakes	Unavailability of effective emergency brake	I	10^{-8}	$5,24.10^{-10}$	OK	
ADD0000939631	Brakes	Unbraked section after integrity loss	I	10^{-8}	$4,11.10^{-14}$	OK	
ADD0000939631	Brakes	Undetected unavailability of effective holding brake	I	10^{-8}	$2,24.10^{-11}$	OK	
ADD0000939631	Brakes	No braking on train driver incapacity	I	10^{-8}	$2,63.10^{-13}$	OK	
ADD0000939631	Brakes	Service brake fails to apply when requested by the master controller	II	10^{-6}	$7,72.10^{-8}$	OK	
ADD0000939262	Gauge	Violation of clearance envelope	I	10^{-8}	Qualitative way	OK	
ADD0000939262	Gauge	Fall of equipment	I	10^{-8}	Qualitative way	OK	

ADD0000939262	Gauge	Loss of structural integrity	I	10^{-8}	Qualitative way	OK	
ADD0000939641	External Signalling	Loss of external lights	I	10^{-8}	$1,15.10^{-10}$	OK	
ADD0000939641	External Signalling	Loss of horn	I	10^{-8}	$3,38.10^{-9}$	OK	
ADD0000939632	Traction	Undetected traction in the wrong direction	I	10^{-8}	$4,.83.10^{-9}$	OK	
ADD0000939632	Traction	Untimely traction	I	10^{-8}	$8,65.10^{-12}$	OK	
ADD0000939632	Traction	Unsanctioned rollback while the train starts or stops on uphill grade	I	10^{-8}	$6,17.10^{-11}$	OK	
ADD0000939277	Driver visibility	Loss of train driver visibility	I	10^{-8}	Qualitative way	OK	
ADD0000939640	Interior lighting	Loss of internal lighting	II	10^{-6}	$5.38.10^{-13}$	OK	
ADD0000939278	Gravity II feared events	Lack of communication between passengers and the train driver	II	10^{-6}	$2.1*10^{-7}$	OK	
ADD0000939278	Gravity II feared events	Lack of communication between train driver and OCC	II	10^{-6}	$5.48*10^{-7}$	OK	
ADD0000939278	Gravity II feared events	Fall and/or harm of people	II	10^{-6}	Qualitative way	OK	
ADD0000939278	Gravity II feared events	False accident analysis	III	10^{-4}	Qualitative way	OK	
ADD0000939279	Gravity I feared events	Electromagnetic interference	I	10^{-8}	Qualitative way	OK	
ADD0000939279	Gravity I feared events	Indication of uncoupled when not uncoupled	I	10^{-8}	Qualitative way	OK	

ADD0000939279	Gravity I feared events	Locked axle	I	10^{-8}	Qualitative way	OK	
ADD0000939279	Gravity I feared events	Start of fire	I	10^{-8}	Qualitative way except for: - Battery: 1.77E-11/h - APS: 1.52E-9/h - HVAC: 2.8E-12/h	OK	
ADD0000939279	Gravity I feared events	Battery explosion	I	10^{-8}	Battery failure: 4.17E-20/h CVS failure: 6.16E-11/h	OK	
ADD0000939279	Gravity I feared events	Electrocution of people	I	10^{-8}	Qualitative way	OK	
ADD0000939279	Gravity I feared events	Loss of ventilation	I	10^{-8}	3.78*10-27/h	OK	
[redacted]							

6.3.2 Software Safety Integrity Level (SIL)

As defined in paragraph 8.8.5 of the SAMP where functions necessary for the safety of a function are implemented in software they are assessed based upon the tolerable hazard threshold and assigned SIL levels that ensure the overall safety of the function. These are identified in the individual Safety Studies Reports (SSRs).

The compiled synthesis of these requirements and the verification of the SIL levels is given in the sections below. The SIL allocations from the safety studies is an input into the Software Management Plan

6.3.2.1 Software Safety Integrity Level (SIL) synthesis

Note that the table below was extracted from the findings of the Software management plan, and the requirements assumed at the start of the project and the comparison between the contracted levels and the requirements identified in the safety studies

Document	Title	SIL allocation in SSR	Comments
ADD0000939630	SSR Doors	SIL 2	
ADD0000939631	SSR Brakes	None	Note SwIL2 (to IEEE 1024) was contracted but is not mentioned in the SSR
ADD0000939632	SSR Traction	none	Note that there is no SIL hypothesis in the SSR but software was contracted to SIL 2

6.3.2.2 Verification of SIL levels

SIL levels have been verified by external assessors, the reports are contained in appendix 6

6.3.2.2.1 Door Certification

The door certification is in appendix 6.1

6.3.2.2.2 Traction Certification.

The traction certification is in appendix 6.2

6.3.2.2.3 Brake Certification

The brake certification is in appendix 6.3

The certification of the brake system software was changed from SwIL2 to SwIL1 following a review of the redesign of the HPU for the trailer trucks, which upon review of the hazards and credible failures no longer required SwIL2 software maturity level.

6.4 *Interface Hazard analysis*

The interface hazard analysis is dealt with in two specific manners, the vehicle interface hazard analysis, from Alstom's side, and through the importation of External Constraints from OLRTC where through integration studies with other systems, generate requirements to be addressed or verified at the vehicle level.

6.4.1 Vehicle Interface Hazard analysis

There is no formal vehicle interface hazard analysis document. The premise is that by managing the topics that impact interfaces between the train and the surrounding environment, the risks are mitigated.

For OTTAWA project, the followings documents and plans are used by the rolling stock designers to ensure safe interfaces with the surrounding infrastructure are managed:

- Railway dynamic Management Plan [R34]
- EMC Management Plan [R35]
- Environment Management Plan [R36]
- Noise Management Plan [R37]
- Eco-design Management Plan [R38]
- Vibro-acoustic Management Plan [R39]
- Occupational Health and Safety Management Plan [R40]

With the exception of the Occupational Health and safety Plan, which is specific for each building site, each of the above plans generated different documents used to transfer and validate the requirements.

Document	TRS	Test specification	Test procedures	Test Report
Railway dynamic Management Plan [ADD0000938682]	TRS – Railway Dynamics [DTD0000067477]	Bogie stability test specification [ADD0000938912]	type test procedure – safety of running [ADD0000939009]	type test report – safety of running [ADD0000939010]
		Ride comfort test specification [ADD0000938913]	type test procedure – ride comfort [ADD0000939011]	type test report – ride comfort [ADD0000939012]
EMC Management Plan [ADD0000938681]	TRS EMC [DTD0000067465]	Type Test Specification – EMC – Radiated Emissions [ADD0000938970]	Citadis Spirit Type test procedure EMC-Radiated Emissions [ADD0000938969]	type test report - EMC Radiated emissions [ADD0000938971]
Environment Management Plan [ADD0000938684]	TRS ENVIRONMENTAL PROTECTION AND RECYCLING [DTD0000074225]			
Noise Management Plan [AD0000938679]	TRS ACOUSTICS – NOISE [DTD0000067467]	type test specification - Noise [ADD0000939602]	type test procedure - Noise [ADD0000939603]	type test report – Noise [ADD0000939604]
Eco-design Management Plan [DTD0000208565]				

Vibro-acoustic Management Plan [DTD0000212472]	TRS SHOCK AND VIBRATION [DTD000067485]	Type test specification – Vibrations [ADD0000939049]	Type test procedure – Vibrations [ADD0000939050]	Type test report – Vibrations [ADD0000939051]
		Static comfort test specification [ADD0000938948]	Spirit type test procedure – noise [ADD0000939003]	Spirit type test report – noise [ADD0000939004]

6.4.2 Imported Constraints from others

It is important to note that at the onset of the project there were no imported constraints, or requirements from other systems or stakeholders.

This remained unchanged until virtually all vehicles had been built and provisionally accepted. At which time a list of constraints was sent from OLRTC and their systems hazard analysis. The list as responded by Alstom is found in Appendix 7

Alstom response was to identify, where possible the design documentation where proof of mitigation was offered,

Alstom had been asked in the past, to review the MSF and Mainline Hazard Analysis prepared by OLRTC, for reference, these are also included in appendix 7, Alstom offered comments on the complete document in both cases as part of establishing an understanding of intended use.

Alstom received no feedback from either commented document,

6.5 ***Hazard Log***

The Hazard Log is used as exchange tool with project stakeholders regarding safety open points taken from Safety Studies Report (SSR). It will be used as a traceability tool too.
The Hazard Log open points consist of safety requirements to take into account by the project stakeholders.

Safety points are taken from all Safety Studies Report (SSR) and uploaded in the Hazard Log in order to allow a properly monitoring of these points for contributing to the Safety performance of Railway Systems.

When a safety point is identified in a Safety Studies Report (SSR), this point will be open in the Hazard Log. Its follow-up will be treated in this Log.

The closure of safety open points is done in the Hazard Log without necessarily updating the Safety Studies Report (SSR) where the open point is coming from. The closure of safety open point is efficient as soon as all evidences are present and under the status “closed”.

The Train Safety Assurance Manager (TSAM) makes sure that safety open points are taking into account by the relevant project stakeholders (Engineering, ILS, Validation ...) to ensure the good follow-up of Hazard Log.

A change to the hazard log was done following a request from the auditors in the Intrusive audit, to show all of the mitigated by design hazards that were completely contained in the design process. This added more than 500 lines to the hazard log.

6.5.1 Exported constraints linked to safety analysis

6.5.1.1 Maintenance task summary links to the safety

Reference of critical point	Critical point description	Recommendation	Constraints type
Ottawa_SSR Traction_003	Loss of braking performances	A daily test (24 hours) has to be realized on brake function to check that no brake is ineffective (emergency push button and track brake test).	Maintenance
Ottawa_SSR Traction_004	Loss of rollback detection	The rollback protection must be tested every year for each PCE.	Maintenance
Ottawa_SSR Traction_006	Degraded braking effort	Calipers have to be checked every 30,000km. The aim is to identify the good application of the caliper.	Maintenance
Ottawa_SSR Brake_003	Degraded braking effort	A daily test (24 hours) has to be realized on brake function to check that no brake is ineffective (emergency push button and track brake test).	Maintenance
Ottawa_SSR Brake_004	Failure of deadman function	The deadman function has to be tested every year	Maintenance
Ottawa_SSR Brake_005	A door is seen unduly closed	Perform a daily test (every 24h) of complete opening and closing door cycle and visual check of each door of the real opening/closing status.Check the status of opening/closing state on the DDU.	Maintenance
Ottawa_SSR Brake_007	Degraded braking effort	Calipers have to be checked every 30000 miles. The aim is to identify the good application of the caliper.	Maintenance
Ottawa_SSR Brake_009	Failure of track brake command	The redundancy of the relays Q(LV)EBR in MC1 and MC2 must be checked every two years.	Maintenance
Ottawa_SSR Doors_001	Untimely opening of a door	Perform a functional test of the door opening movement in accordance with the preventive maintenance instructions every year.	Maintenance
Ottawa_SSR Doors_002	Untimely opening of a door	Perform a tightening check of hanger assembly in accordance with preventive maintenance instructions every two years.	Maintenance
Ottawa_SSR Doors_003	Untimely opening of a door	Respect preventive maintenance defined by supplier : tightening anti-unscrew check of overcentre shaft every two years	Maintenance
Ottawa_SSR Doors_005	Door remaining closed while emergency evacuation is needed	Perform a functional test of the emergency handle in accordance with the preventive maintenance instructions every two years	Maintenance
Ottawa_SSR Doors_006	Door remaining closed while emergency evacuation is needed	Respect preventive maintenance defined by supplier : lubrication/adjustment of internal/external Bowden cables every 5 years	Maintenance
Ottawa_SSR Doors_009	Fall of passengers outside	Respect preventive maintenance defined by supplier : a visual check of the glass every year	Maintenance

Ottawa_SSR Doors_010	Passengers caught in door	Perform a functional test of the proper obstacle detection operation in accordance with the preventive maintenance instructions every year	Maintenance
Ottawa_SSR Doors_011	Undetected door remaining open	Perform a functional test of the door closing movement in accordance with the preventive maintenance instructions every year.	Maintenance
Ottawa_SSR Doors_013	Undetected door remaining open	Respect preventive maintenance defined by supplier : state of contacts check every 2 years and replacement after 15 years for Closed and Locked microswitches	Maintenance
Ottawa_SSR Doors_014	Undetected door remaining open	Respect preventive maintenance defined by supplier : state of contacts check every 5 years for Lock-out microswitches	Maintenance
Ottawa_SSR Doors_015	Door remaining closed while emergency evacuation is needed	Perform a daily test (every 24h) of complete opening and closing door cycle and visual check of each door of the real opening/closing status. Check the status of opening/closing state on the DDU and on push button (PBL(Closed))	Maintenance
Ottawa_SSR Doors_018	Door remaining closed while emergency evacuation is needed	Perform a test every 6 months of every EDR, opening and closing the door manually. and visual check of each door of the real opening/closing status. Check that each EDR allows to open the door.	Maintenance
Ottawa_SSR_External signalling_003	Loss of external lights	Tail lights, head lights and APEX light have to be check every 24 hours. For this test, the forward direction must be selected in order to check the command of the lights.	Maintenance
Ottawa_SSR_External signalling_004	Loss of external lights in UTO mode	Maintenance procedures must be respected in UTO mode.	Maintenance
Ottawa_SSR_External signalling_005	Impossible signalling with horn	The horn has to be tested each day.	Maintenance
Ottawa_SSR_Gauge_047	Fall of equipment	Regular preventive maintenance according to manuals	Maintenance
Ottawa_SSR_Gauge_048	Fall of equipment	Regular preventive maintenance according to manuals	Maintenance
Ottawa_SSR_Gauge_049	Fall of equipment	Regular preventive maintenance according to manuals	Maintenance
Ottawa_SSR_Gauge_050	Fall of equipment	Regular preventive maintenance according to manuals	Maintenance
Ottawa_SSR_Gauge_051	Fall of equipment	Regular preventive maintenance according to manuals	Maintenance
Ottawa_SSR_Gauge_053	Fall of equipment / Violation of clearance envelope	Battery box inspection (for loose items) shall be done in accordance with Battery subsystem.	Maintenance
Ottawa_SSR_Gauge_056	Loss of structural integrity / Fall of equipment	Periodical inspection maintenance	Maintenance
Ottawa_SSR_Gauge_058	Fall of equipment	Visual inspection during maintenance	Maintenance
Ottawa_SSR_Gauge_059	Fall of equipment	Visual inspection during maintenance	Maintenance

Ottawa_SSR_Gauge_060	Fall of equipment	Visual inspection during maintenance	Maintenance
Ottawa_SSR_Gauge_061	Fall of equipment	Additive or visual detection by maintenance personnel	Maintenance
Ottawa_SSR_Gauge_062	Fall of equipment / Violation of clearance envelope	Replaced at Overhaul -inspection/ preventive maintenance / maintenance instruction / changing of damaged parts	Maintenance
Ottawa_SSR_Gauge_063	Fall of equipment / Violation of clearance envelope	Inspected at Overhaul (replace worn or damaged parts)l -inspection/ preventive maintenance / maintenance instruction / changing of damaged parts	Maintenance
Ottawa_SSR_Gauge_067	Fall of equipment	Traction motor (MAS) : procedures for maintenance shall avoid incorrect assembling or greasing of motor bearings, to avoid the risk of motor jamming	Maintenance
Ottawa_SSR_Gauge_068	Fall of equipment	Visual inspection of the HSCB mechanical frame (dirtying, deformation, heating) shall be performed every one year, to avoid the risk of mechanical failures	Maintenance
Ottawa_SSR_Gauge_069	Fall of equipment	TBCU mechanical frame: visual inspection of mechanical support and HV/LV connections shall be performed every 5 years, to avoid the risk of mechanical failures	Maintenance
Ottawa_SSR_Gauge_070	Fall of equipment	Visual inspection of the mechanical fixings of the motors (MAS) shall be performed periodically, to avoid the risk of cracks and breaks according to maintenance plan	Maintenance
Ottawa_SSR_Gauge_075	Failure of bogie elastic wheel	Monthly visual inspection wheel integrity	Maintenance
Ottawa_SSR_Gauge_076	Failure of bogie elastic wheel	Visual inspection every 25 000km . Tread wear . Flange wear . Tyre wear . Wheel-centre / Tyre relative position . Tyre, wheel-centre and wheel-ring integrity . M16 screws fastening by "loosening-check" mark	Maintenance

Ottawa_SSR_Gauge_077	Failure of bogie elastic wheel	Wheel tyre re-profiling (tyre profile) expected to be performed every 30 000km Instrumental inspection during re-profiling . Tyre flange dimensions . Tyre width . Tyre tread roll over . Tread defects . Rolling diameter . Tyre geometrical tolerances . M16 screws fastening by "loosening-check" mark . Wheel fastening axle beam hub by "loosening-check" mark . Tyre, wheel-centre and wheel-ring coating	Maintenance
Ottawa_SSR_Gauge_078	Failure of bogie elastic wheel	Replace the studs fixing wheel centre on axle beam hub every 3*tyre replacements	Maintenance
Ottawa_SSR_Gauge_079	Failure of bogie axle beam	Monthly visual inspection mechanical integrity of the wheel	Maintenance
Ottawa_SSR_Gauge_080	Failure of bogie axle beam	Visual inspection every 25 000 km mechanical integrity of the axle beam no grease leakage at the dynamic seals location no grease leakage at the "by pass" location presence of the lubricator nipple	Maintenance
Ottawa_SSR_Gauge_081	Failure of bogie axle beam	Wheel tyre re-profiling(tyre profile) expected to be performed every 30 000km wheel fastening on axle beam hub by "loosening-check" mark	Maintenance
Ottawa_SSR_Gauge_082	Failure of bogie axle beam	Visual inspection every 50 000 km fixings(by "loosening-check" mark)	Maintenance
Ottawa_SSR_Gauge_083	Failure of bogie axle beam	Every wheel tyre replacement visual inspection of the stud bolts and nuts for wheel fixings (replacement if necessary) every 3 times of wheel tyre replacement replacement of the stud bolts and nuts for wheel fixings on the axle beam hub	Maintenance
Ottawa_SSR_Gauge_084	Failure of bogie axle beam	Visual inspection every 150 000 km grease supply	Maintenance

Ottawa_SSR_Gauge_085	Failure of bogie frame	Visual inspection every 25 000 km mechanical integrity of the two half bogie frames mechanical integrity of the motor upper supports (on motor bogie) mechanical integrity of the actuator rods supports (on trailer bogie)	Maintenance
Ottawa_SSR_Gauge_086	Failure of bogie frame	Visual inspection every 150 000 km - mechanical structure and fixings (by "loosening-check" mark) - half frames and their fixings - motor supports and their fixings (on motor bogie) - brake actuator rods supports and their fixings (on trailer bogie) - primary suspension vertical stop fixings - anti-roll bar support and their fixings - anti-pitch damper support and their fixings - presence of shims underneath the half frame articulation shaft - bogie frame bush	Maintenance
Ottawa_SSR_Gauge_087	Failure of bogie frame	Non destructive test of highly stressed areas on half frame (10 years or 1 000 000 km) only 5% of the bogie frame	Maintenance
Ottawa_SSR_Gauge_088	Failure of traction motor	Visual inspection every 30 000 km . Motor safety noze integrity . Fixins (continuity of marking)	Maintenance
Ottawa_SSR_Gauge_089	Failure of transmission assembly	Visual inspection every 25 000 km . Structure integrity of gearbox case, inferior safety nose (anti-rotation bracket for the gearbox) & reaction rod . Oil leakage (mainly at the input seal) . Drain magnetic plug , Oil level plug & Drain plug integrity	Maintenance
Ottawa_SSR_Gauge_090	Failure of transmission assembly	Visual inspection every 50 000 km of Fixins (continuity of marking) . Cartridges, Covers & Plugs . Inferior safety nose (anti-rotation bracket for the gearbox) . Reaction rod	Maintenance
Ottawa_SSR_Gauge_091	Failure of transmission assembly	Oil level check & (make up oil if needed) every 100 000km	Maintenance
Ottawa_SSR_Gauge_092	Failure of transmission assembly	Oil change every 150 000km	Maintenance

Ottawa_SSR_Gauge_093	Failure of transmission assembly	Visual inspection every wheel tyre replacement . Gearbox hub and its fixings on axle beam hub (continuity of marking) . Pinion gear teeth and wheel gear teeth (twice times in the rolling stock life time) . Input & Output felt covers replacement	Maintenance
Ottawa_SSR_Gauge_094	Failure of transmission assembly	Every 10 years or 1 Mkm (which term is reached the first) . Gear reducer overhaul . NDT check of the gearbox hub structure	Maintenance
Ottawa_SSR_Gauge_095	Failure of transmission assembly	Visual inspection every 25 000 km . Reaction rod & anti-rotation integrity	Maintenance
Ottawa_SSR_Gauge_096	Failure of transmission assembly	Visual inspection every 50 000 km . Fixing (continuity of marking)	Maintenance
Ottawa_SSR_Gauge_097	Failure of transmission assembly	Visual inspection every 25 000km Mechanical integrity of the coupling Mechanical aspect: wear, presence of particle, sand or foreign matter in the open area Thermal aspect: discoloring of the painting Leakage	Maintenance
Ottawa_SSR_Gauge_098	Failure of transmission assembly	Visual inspection every 50 000km: Mechanical connection Fixing (continuity of marking)	Maintenance
Ottawa_SSR_Gauge_099	Failure of transmission assembly	Overhaul every two wheel tyres replacement: Overhaul - change of grease	Maintenance
Ottawa_SSR_Gauge_100	Failure of primary suspension	Every 100 000km . visual inspection of lower seat fastenings and their fastening (continuity of marking) . visual inspection of suspension bush axle and their fastenings (continuity of marking) . visual inspection of suspension bush clamp and their fastenings (continuity of marking) . visual inspection of lower bump stop and their fastenings (continuity of marking)	Maintenance
Ottawa_SSR_Gauge_101	Failure of primary suspension	Every 150 000km . Clean spring location (sand or dust) . Visual inspection of springs	Maintenance

Ottawa_SSR_Gauge_102	Failure of primary suspension	Every 10 years or 1 Mkm (which term is reached the first) . Pickling of paint on steel spring . Check on behavior of steel spring	Maintenance
Ottawa_SSR_Gauge_103	Failure of primary suspension	Every 100 000km . visual inspection of primary suspension low stops and their fixing	Maintenance
Ottawa_SSR_Gauge_104	Failure of primary suspension	Every 100 000km Visual inspection of the anti-pitch damper support, anti-pitch damper and their fastenings (continuity of marking) Check the absence of oil seepage	Maintenance
Ottawa_SSR_Gauge_105	Failure of primary suspension	After the first 5 years or 500 000km (which term is reached the first) anti-pitch damper - expertize on 2 consists - once.	Maintenance
Ottawa_SSR_Gauge_106	Failure of primary suspension	Overhaul every 10 years or 1 Mkm (which term is reached the first)	Maintenance
Ottawa_SSR_Gauge_107	Failure of Secondary suspension	Every 100 000km Visual inspection of the dampers support, dampers and their fastenings (continuity of marking) Check the absence of oil seepage	Maintenance
Ottawa_SSR_Gauge_108	Failure of Secondary suspension	After the first 5 years or 500 000km (which term is reached the first) expertises of dampers on 1 or 2 rames - once	Maintenance
Ottawa_SSR_Gauge_109	Failure of Secondary suspension	Overhaul of dampers every 10 years or 1 Mkm (which term is reached the first)	Maintenance
Ottawa_SSR_Gauge_110	Failure of Secondary suspension	Every 100 000km visual inspection of the pneumatic lining of secondary suspension	Maintenance
Ottawa_SSR_Gauge_111	Failure of Secondary suspension	After the first 5 years or 500 000km (which term is reached the first) check by the supplier of suspension on 3 bogies	Maintenance
Ottawa_SSR_Gauge_112	Failure of Secondary suspension	Every 10 years or 1 Mkm (which term is reached the first) Replace the pneumatic membrane of secondary suspension	Maintenance
Ottawa_SSR_Gauge_113	Failure of Secondary suspension	Overhaul of helicoidal spring every 10 years or 1 Mkm (which term is reached the first) - Magnetic Particule Inspection - Stiffness characteristics check - Remove the paint/Paint	Maintenance
Ottawa_SSR_Gauge_114	Failure of Secondary suspension	Every 10 years or 1 Mkm (which term is reached the first) replace rubber pad of secondary suspension	Maintenance

Ottawa_SSR_Gauge_115	Failure of Secondary suspension	Every 100 000km visual inspection of vertical low stop and the fixation (marking continuity)	Maintenance
Ottawa_SSR_Gauge_116	Failure of Secondary suspension	Every 10 years or 1 Mkm (which term is reached the first) replacement of vertical low stop of secondary suspension	Maintenance
Ottawa_SSR_Gauge_117	Failure of Secondary suspension	Every 100 000km visual inspection of lateral stop of secondary suspension + fixation (marquing continuity)	Maintenance
Ottawa_SSR_Gauge_118	Failure of Secondary suspension	Every 10 years or 1 Mkm (which term is reached the first) replacement of lateral stop of secondary suspension	Maintenance
Ottawa_SSR_Gauge_119	Failure of Secondary suspension	Visual inspection every 100 000km - anti-roll bar structure - anti-roll bar bearing support & anti-roll bar rod support structure and fixings (by "loosening-check" mark) - anti-roll bar rod structure, bellow, joints & fixings (by "loosening-check" mark)	Maintenance
Ottawa_SSR_Gauge_120	Failure of Secondary suspension	After the first 5 years or 500 000km (which term is reached the first) - anti-roll bar bearings replacement	Maintenance
Ottawa_SSR_Gauge_121	Failure of Secondary suspension	Every 10 years or 1 Mkm (which term is reached the first) - anti-roll bar rods replacement - non destructive test on the anti-roll bars of one trainset - anti-roll bar - remove paint/apply paint	Maintenance
Ottawa_SSR_Gauge_122	Failure of Driving Assembly	Every 150 000km . grease make-up in the slewing ring	Maintenance
Ottawa_SSR_Gauge_123	Failure of Driving Assembly	Every bogie removing from the carbody . visual inspection of the slewing ring structure and its fixing on the carbody (by "loosening-check" mark) . visual inspection of the slewing ring sealing joint	Maintenance
Ottawa_SSR_Gauge_124	Failure of Driving Assembly	Visual inspection every 25 000 km . mechanical integrity of the rods	Maintenance

Ottawa__SSR__Gauge__125	Failure of Driving Assembly	Every 100 000km . visual inspection of the driving rod, bush axles structure and its fixing (by "loosening-check" mark) . visual inspection of the bushes	Maintenance
Ottawa__SSR__Gauge__126	Failure of Driving Assembly	Every bogie removing from the carbody . visual inspection of the rotation stop and its fixing (by "loosening-check" mark)	Maintenance
Ottawa__SSR__Gauge__127	Failure of BRAKING ASSEMBLY	Every 5 000/7 500km . Remove all metallic objects and parts located on the Magnetic track brake shoe	Maintenance
Ottawa__SSR__Gauge__128	Failure of BRAKING ASSEMBLY	Visual inspection every 25 000 km . mechanical integrity of the brake disc and its fixings . mechanical integrity of the brake disc actuator and its fixings . mechanical integrity of the brake pad . mechanical integrity of the magnetic track brake	Maintenance
Ottawa__SSR__Gauge__129	Failure of BRAKING ASSEMBLY	Visual inspection every 50 000 km . component fixings of the brake disc actuator & brake disc actuator own fixings on bogie frame (by "loosening-check" mark) . brake disc own fixings on axle beam (by "loosening-check" mark) . component fixings of the magnetic track brake & magnetic track brake own fixings on bogie frame (by "loosening-check" mark)	Maintenance
Ottawa__SSR__Gauge__130	Failure of LIFEGUARD SANDING	Visual inspection every 25 000 km . Lifeguard and Sanding support on axle beam mechanical integrity and fastenings (continuity of marking)	Maintenance
Ottawa__SSR__Gauge__131	Failure of LIFEGUARD SANDING	Visual inspection every 50 000 km . Lifeguard and Sanding mechanical integrity and fastenings (continuity of marking) . State of heating nozzles cabling	Maintenance
Ottawa__SSR__Gauge__132	Failure of WHEEL FLANGE LUBRICATOR	Preventive Maintenance: Visual inspection of the equipments brackets state (25 000 km)	Maintenance
Ottawa__SSR__G2__001	Fall and/or Harm of people	Check use by date of the fire extinguisher. Change it if needed.	Maintenance
Ottawa__SSR__G2__002	Fall and/or Harm of people	Maintenance staff must wear personal protection equipment before any intervention on the train	Maintenance
Ottawa__SSR__G2__003	Fall and/or Harm of people	Maintenance staff must be trained to manipulate safety products such as oil, lubrication, glue…	Maintenance

Ottawa_SSR_G2_004	Fall and/or Harm of people	The maintainer intervening on the refrigeration system of refrigerated ventilation group must be formed on the gestures and behavior to adopt in case of direct contact with the liquid	Maintenance
Ottawa_SSR_G2_005	Loss of communication (driver/passenger + driver OCC)	Perform a maintenance task every 2 years on all PAPIS equipments (during the emergency handle test) : check the PEI PushButton check the PEI loudspeaker check the PEI microphone check the cab microphone check the cab handset check the communication between the PEI and the cab check all internal loudspeakers in the train	Maintenance
Ottawa_SSR_G2_011	Fall of passengers inside the train	Visual check of the bogie box step (stairs nosing and yellow safety walk strip). Replace safety walk strip if needed	Maintenance
Ottawa_SSR_G2_012	Fall of passengers inside the train	Test every floor heater panel once a year (before winter). Replace if necessary.	Maintenance
Ottawa_SSR Interior lighting_003	Fall and/or Harm of people	Interior lighting has to be checked every week (max 168h). If a panel is failed, it has to be changed.	Maintenance
Ottawa_SSR Driver visibility_005	Ineffective wiping/washing function	The level of glass cleaner must be checked every day. The washer tank must be filled.	Maintenance
Ottawa_SSR Driver visibility_006	Ineffective sunblind	The sunblind must be checked every year	Maintenance
Ottawa_SSR Driver visibility_007	Ineffective wiper/washer	The wiper/washer must be checked every year	Maintenance
Ottawa_SSR Driver visibility_010	Bad transmittance / reflectance of the side cab windows	Check if ventilation flows on windscreen and cab side windows every year	Maintenance
Ottawa_SSR_G1_001	Insulation Fault	Test every 100 000 kms the "good" behavior of the circuit breaker	Maintenance
Ottawa_SSR_G1_002	Insulation Fault	Test every 500 000 kms the resistor (120 Ω +/- 5%)	Maintenance
Ottawa_SSR_G1_003	Ground mounting	Verify by the maintenance operator the closure and locking of all cabinets and roof arches at the end of each intervention.	Maintenance
Ottawa_SSR_G1_004	Battery electrocution	Maintenance manual specifies that batteries be manually isolated and locked out from power using circuit breaker before proceeding with battery maintenance	Maintenance

Ottawa_SSR_G1_006	Battery electrocution	Identify polarity markings in maintenance procedures.	Maintenance
Ottawa_SSR_G1_007	Battery electrocution	Follow battery layout and connections in accordance with installation procedures in maintenance manual.	Maintenance
Ottawa_SSR_G1_008	Ground braids HVAC	Visual inspection. Check if harnesses are fixed mounted. Check if they are not close to a sharp edge. Repair if necessary.	Maintenance
Ottawa_SSR_G1_010	APS electrocution	To do electric safety test compulsory before maintenance on APS	Maintenance
Ottawa_SSR_G1_011	Passengers Access Doors electrocution	Visual inspection of grounding braids fixations	Maintenance
Ottawa_SSR_G1_012	Heat Floor electrocution	Check the grounding of the COMFLOOR in the overhaul maintenance	Maintenance
Ottawa_SSR_G1_013	Loss of ventilation	Every 112 days - Visually inspect dampers for free motion (rotate vanes). Repair if necessary. Visually inspect fresh air intakes. Clean if necessary.	Maintenance
Ottawa_SSR_G1_014	Loss of ventilation	Every year, check each detector for correct operation in accordance to manufacturer's recommendation. Visually check all cables and fittings are undamaged.	Maintenance
Ottawa_SSR_G1_015	Loss of overheating protection	HSCB ARC 812/1512 (main breaker): visual inspection of arc chute, power and auxiliary contacts and wear-out conditions shall be performed every 12 months, to avoid the risk of contactor blocked in closed position	Maintenance
Ottawa_SSR_G1_016	Loss of overheating protection	HSCB control panel: visual inspection of relay, power and auxiliary contacts and wear-out conditions shall be performed every 12 months, to avoid the risk of relay blocked in closed position	Maintenance
Ottawa_SSR_G1_017	No opening of line contactor when required	Line contactor: visual inspection of arc chute, power and auxiliary contacts and wear-out conditions shall be performed every 1 year, to avoid the risk of contactor blocked in closed position	Maintenance
Ottawa_SSR_G1_018	Preload contactor blocked in closed position	Preload contactor: visual inspection of arc chute, power and auxiliary contacts and wear-out conditions shall be performed every 1 year, to avoid the risk of contactor blocked in closed position	Maintenance
Ottawa_SSR_G1_019	Motor contactor blocked in closed position	Motor contactor: visual inspection of arc chute, power and auxiliary contacts and wear-out conditions shall be performed every 6 months, to avoid the risk of contactor blocked in closed position	Maintenance
Ottawa_SSR_G1_020	Filter inductor in short-circuit, open circuit, or in loss of insulation to the ground	Filter inductor: visual inspection of cooling channels, connection cables and frame shall be performed every 1 year, to avoid the risk of short circuit between connections, open circuit, loss of insulation to the ground, mechanical failure of the frame	Maintenance

Ottawa_SSR_G1_021	Filter inductor in short-circuit or in loss of insulation to the ground	Filter inductor: inductor cleaning shall be performed every 1 year, to avoid the risk of short circuit between connections and loss of insulation to the ground	Maintenance
Ottawa_SSR_G1_022	Degradation of heat dispersion of the power module / Ground connection fault of the power module	Power module finned heatsink: visual inspection and periodical cleaning shall be performed every 2 years to avoid the risk of degradation of heat dispersion or ground connection fault	Maintenance
Ottawa_SSR_G1_023	Drift resistance value of the braking rheostat	Braking rheostat: visual inspection for dust and dirt shall be performed every 1 year, to avoid the risk of drift of resistance value	Maintenance
Ottawa_SSR_G1_024	Drift resistance value of the braking rheostat	Braking rheostat: dielectric test and verification of insulation shall be performed every 4 years to avoid the risk of drift of resistance value	Maintenance
Ottawa_SSR_G1_025	Traction motor damaged	A periodic inspection shall be performed on the traction motor to verify the absence of foreign bodies which may damage the equipment	Maintenance
Ottawa_SSR_G1_026	Traction motor blocked	Traction motor: minor failures of motor bearings shall be detected before they cause serious damage, jamming and blocking of the rotor. They can be detected during maintenance due to noise. Inspection is recommended at every maintenance session.	Maintenance
Ottawa_SSR_G1_027	Traction motor blocked	Traction motor: preventive actions according to the maintenance plan: bearing greasing, inspection + replacement of bearings and gaskets and always in case of fault, to avoid the risk of motor jamming	Maintenance
Ottawa_SSR_G1_028	Traction motor blocked	Traction motor : procedures for maintenance shall avoid incorrect assembling or greasing of motor bearings, to avoid the risk of motor jamming	Maintenance
Ottawa_SSR_G1_029	Untimely heating from preheating system	Preheating system : the overall integrity of thermostats TTCU1, TTCU2, TTCU3 have to be checked once a year in October (e.g., a -30°C gas has to be sprayed upon thermostats and force a change of status)	Maintenance
Ottawa_SSR_G1_030	Loss of overheating protection	Primary Power Switch: Every 6 months a visual inspection of the main contacts	Maintenance
Ottawa_SSR_G1_031	Loss of overheating protection	Primary Power Switch: Every 25.000 operations replacement of the copper contacts	Maintenance
Ottawa_SSR_G1_041	Traction motor blocked	Traction motor: minor failures of motor bearings shall be detected before they cause serious damage, jamming and blocking of the rotor. They can be detected during maintenance due to noise. Inspection is recommended at every maintenance session.	Maintenance
Ottawa_SSR_G1_042	Traction motor blocked	Traction motor: preventive actions according to the maintenance plan: bearing greasing, inspection + replacement of bearings and gaskets and always in case of fault, to avoid the risk of motor jamming	Maintenance

Ottawa_SSR_G1_043	Traction motor blocked	Traction motor: procedures for maintenance shall avoid incorrect assembling or greasing of motor bearings, to avoid the risk of motor jamming	Maintenance
Ottawa_SSR_G1_044	Motor contactor blocked in closed position	Motor contactor: visual inspection of arc chute, power and auxiliary contacts and wear-out conditions shall be performed every 6 months, to avoid the risk of contactor blocked in closed position	Maintenance
Ottawa_SSR_G1_051	Incorrect battery temperature sent to the APS	The temperature sensor must be check every 2 years	Maintenance
Ottawa_SSR_G1_053	HSCB / Electrocution of people	HSCB ARC 812/1512 (main breaker): visual inspection of arc chute, power and auxiliary contacts and wear-out conditions shall be performed every 12 months, to avoid the risk of contactor blocked in closed position	Maintenance
Ottawa_SSR_G1_054	HSCB control panel / Electrocution of people	HSCB control panel: visual inspection of relay, power and auxiliary contacts and wear-out conditions shall be performed every 12 months, to avoid the risk of relay blocked in closed position	Maintenance
Ottawa_SSR_G1_055	Traction / Filter inductor / Electrocution of people	Filter inductor: visual inspection of cooling channels, connection cables and frame shall be performed every 1 year, to avoid the risk of short circuit between connections, open circuit, loss of insulation to the ground, mechanical failure of the frame	Maintenance
Ottawa_SSR_G1_056	Traction / Filter inductor / Electrocution of people	Filter inductor: inductor cleaning shall be performed every 1 year, to avoid the risk of short circuit between connections and loss of insulation to the ground	Maintenance
Ottawa_SSR_G1_057	Traction / Electrocution of people	Maintenance procedures for safe access to Traction converter and Power module shall be followed by maintenance operators, to avoid the risk of electrocution or wounding	Maintenance
Ottawa_SSR_G1_058	Traction / Resistance / Electrocution of people	During corrective maintenance of the Power module, the resistance value of discharge resistors must be checked following maintenance procedures	Maintenance
Ottawa_SSR_G1_059	Traction / Electrocution of people	It shall be ensured that maintenance actions are performed in safe conditions.	Maintenance
Ottawa_SSR_G1_066	Ineffective heater thermostat	HVAC - Heater thermostats / Heat limiters: Warm up thermostats by heat gun, test thermostat function every 360 days	Maintenance
Ottawa_SSR_G1_067	Ineffective insulation resistance of HVAC power circuit	HVAC - Power Circuit : Insulation resistance - recording the voltage drop across the terminals every 720 days	Maintenance
Ottawa_SSR_G1_068	Pantograph / Electrocution of people	Maintenance Training program will be provided as specified. Manuals will be prepared that include appropriate procedures, cautions and warnings.	Maintenance

Ottawa_SSR_G1_070	Maintenance action on Hydraulic Friction Brake Equipment / Electrocution of people	Low voltage (24 volts) battery system. HPU removal to be performed while train is powered down. Train is grounded.	Maintenance
Ottawa_SSR_G1_076	Ineffective major fault light	The major fault light must be tested every day to ensure that it is not failed.	Maintenance
Ottawa_SSR_G1_077	Explosion on HSCB opening	HSCB ARC 812/1512 (main breaker): visual inspection of arc chute, power and auxiliary contacts and wear-out conditions shall be performed every 12 months, to avoid the risk of contactor blocked in closed position	Maintenance
Ottawa_SSR_G1_078	Overheating of power module	Power module finned heatsink: visual inspection and periodical cleaning shall be performed every 2 years to avoid the risk of degradation of heat dispersion or ground connection fault	Maintenance
Ottawa_SSR_G1_086	Failure of the command of the major fault / immediate stop light	The command of the major fault / immediate stop light must be tested every year in each cabin.	Maintenance
Ottawa_SSR_G1_087	Drying of battery cells	Cells topping up in accordance with equipment maintenance manual (SAFT) - every 2 years	Maintenance
Ottawa_SSR_G1_088	Drying of battery cells	Water filling function verified as specified in the equipment maintenance manual (SAFT)	Maintenance
Ottawa_SSR_G1_089	Drying of battery cells	Pressure test of water filling system as specified in the equipment maintenance manual (SAFT)	Maintenance
Ottawa_SSR_G1_090	Chafing / damage on cables in battery box	Visual inspection of battery box cables during scheduled maintenance activity	Maintenance
Ottawa_SSR_G1_092	Arcing or heat buildup due to incorrect battery torque	Battery cell terminals shall be torqued as specified in the EMM	Maintenance
Ottawa_SSR_G1_094	Undetected overpressure	Safety valves SV1 and SV2 (Air supply) must be tested or replaced every 12090 hours.	Maintenance
Ottawa_SSR_G1_095	Overheating of the battery	Heater including thermostat must be replaced every 15 years	Maintenance
Ottawa_SSR_G1_096	Ineffective battery	Battery cells replacement in accordance with the maintenance plan (15 years)	Maintenance
Ottawa_SSR_G1_099	Locked axle (bearing of axle beam)	Check the beam housing tightness - no grease leakage at the dynamic seals location. Every 25 000km	Maintenance
Ottawa_SSR_G1_101	Locked axle (bearing of reducer)	Gear box - Oil level check & (make up oil if needed) every 100 000km	Maintenance
Ottawa_SSR_G1_102	Locked axle (bearing of reducer)	Gear box - Oil change every 150 000km	Maintenance
Ottawa_SSR_G1_105	Electrocution of people	When PPS in position "OFF" and the S(IS)PPS in close position (padlock switch) please check that the L(ISOL)PPS is switch on	Maintenance

Ottawa_SSR_G1_106	Failure of CURRENT RETURN	Visual inspection every 25 000 km - mechanical integrity and component fixings of the following return current components (by "loosening-check" mark) . contact disc on housing . connection arm on contact disc . cable on connection arm	Maintenance
Ottawa_SSR_G1_107	Failure of CURRENT RETURN	Visual inspection every 25 000 km Visual inspection of earth and return cable and/or braid, connectors and fastenings (continuity of marking)	Maintenance
Ottawa_SSR_G1_108	Failure of CURRENT RETURN	Wheel tyre re-profiling (tyre profile) expected to be performed every 30 000km . visual inspection: mechanical integrity of the shunt and their fixings (by "loosening-check" mark)	Maintenance
Ottawa_SSR_G1_109	Failure of CURRENT RETURN	Visual inspection every 100 000 km . component fixings of the return current cable on the return current assembly (by "loosening-check" mark)	Maintenance
Ottawa_SSR_G1_110	Failure of CURRENT RETURN	Visual inspection every 100 000 km -Dust extraction -Check of the contact disc state and its good rotation -Check the good sliding of the brushes, the state of the brushes contact surface and their wear	Maintenance
Ottawa_SSR_G1_113	Undetected Overpressure	Safety valves SV1 and SV2 (Air supply) must be tested or replaced every 8760 hours. (KB)	Maintenance
Ottawa_SSR_G1_114	Failure of CURRENT RETURN	Check at least once a year the tightening torque mark on ground braids screws located on the gangways	Maintenance
Ottawa_Availability_001	Ineffective master controller	The snap action switch must exchange every 5 Mio. Switching cycles	Maintenance
Ottawa_Availability_002	Ineffective master controller	Cleaning the Master Controller after 5 Mio. Switching cycles	Maintenance
Ottawa_Availability_003	Ineffective master controller	Maintain the cylinder lock of the master controller every 6 months	Maintenance
Ottawa_Availability_004	Ineffective battery	Caution statement regarding spraying of battery box is not recommended because battery boxes have vents and water ingresses in the box	Maintenance

Ottawa_Availability_005	Ineffective battery	Caution statement regarding use of high pressure spray on battery cells is prohibited	Maintenance
Ottawa_Availability_006	Ineffective battery	Cleaning procedure from SAFT is required annually	Maintenance
Ottawa_Other Constraint_001	Minor injury to maintenance personnel	Maintenance personnel has to wear Protection Personal Equipment	Maintenance
Ottawa_Other Constraint_002	Minor injury to maintenance personnel	Maintenance operations shall be performed according to Equipment Maintenance Manual from SAFT	Maintenance
Ottawa_Other Constraint_003	Minor injury of passenger/maintainer	High Pressure Switch, Modulation Pressure Switch: Turn unit on, restrict condenser airflow rate, test switch function (360 days)	Maintenance
Ottawa_Other Constraint_004	Minor injury of passenger/maintainer	Low Pressure Switch: Turn unit on, close solenoid valve, test switch function (360 days)	Maintenance
Ottawa_Availability_008	No detection of smoke in one car	Smoke detector: Record status of LED, test function by smoke (90 days)	Maintenance
Ottawa_Availability_009	APS off	Maintenance of the cooling turbine bearing every 40000 hours (over 5 years)	Maintenance
Ottawa_Availability_010	APS off	Super capacitor maintenance every 160000 hours (every 20 years)	Maintenance
Ottawa_Other Constraint_005	Possible unsafe situations	When performing forcing of variables during maintenance or commissioning, the operator shall verify that it does not lead to unsafe situations for the operators.	Maintenance
Ottawa_Other Constraint_006	Possible unsafe situations	After software uploading, the operator shall ask for software and verify that it corresponds to the right uploaded version	Maintenance
Ottawa_Other Constraint_008	Loss of traction / braking performances	A hardware self-test of AC3mini shall be performed at each power-up or reboot and at least every 20 hours in case of continuous service, otherwise every 24 hours	Maintenance
Ottawa_Other Constraint_009	Unavailability of effective emergency brake	An Emergency Brake test / Maximum Service Brake must be performed at least once every 1 year. The braking performances must be assessed during this test.	Maintenance

6.5.1.2 *Operation constraints link to the safety*

Reference of critical point	Critical point description	Recommendation	Constraints type
Ottawa_SSR Brake_001	Ineffective APS	In case of loss of one APS, the train shall be withdrawn at the end of the tour.	Operation
Ottawa_SSR Brake_002	Ineffective battery	In case of loss of one battery, the train shall be withdrawn at the end of the tour.	Operation
Ottawa_SSR Brake_008	Degraded braking effort	The train driver must advise the OCC when a track brake pair is isolated.	Operation
Ottawa_SSR Brake_010	Ineffective/degraded service brake from the master controller	In case of failure of service brake from the master controller, the driver must use the PBEB to stop the train.	Operation
Ottawa_SSR Doors_016	Passengers caught in door	Driver must use the rear view system to check if people are not caught in doors and use the cameras on platform edge	Operation
Ottawa_SSR Doors_017	Door remaining closed while emergency evacuation is needed	In case of LCC car door failure which needs to be locked out, the driver must check if a disable people (in wheel chair) is present in that car (LCC car) and if so, ask him to move to another car (by passing on the platform).	Operation
Ottawa_SSR_External signalling_001	Ineffective APS	In case of loss of one APS, the train shall be withdrawn at the end of the tour.	Operation
Ottawa_SSR_External signalling_002	Ineffective battery	In case of loss of one battery, the train shall be withdrawn at the end of the tour.	Operation
Ottawa_SSR_G2_006	Loss of communication between driver and OCC	The RADIO P25 must have a failure rate greater than 1.10^(-4) f/h	Operation
Ottawa_SSR_G2_007	Loss of communication between driver and OCC	The walki talki must have a failure rate greater than 1.10^(-4) f/h	Operation
Ottawa_SSR Interior lighting_001	Ineffective APS	In case of loss of one APS, the train shall be withdrawn at the end of the tour.	Operation
Ottawa_SSR Interior lighting_002	Ineffective battery	In case of loss of one battery, the train shall be withdrawn at the end of the tour.	Operation
Ottawa_SSR Driver visibility_001	Ineffective wiper/washer	In case of deterioration of the wiping function (degradation of the cleanliness of the windscreen), the driver must inform the OCC in order to provide a repair. OCC will advise maintenance team.	Operation
Ottawa_SSR Driver visibility_002	Ineffective sunblind	In case of deterioration of the sunblind (blocking / difficulty of use), the driver must inform the OCC in order to provide a repair. OCC will advise maintenance team.	Operation

Ottawa_SSR Driver visibility_003	Ineffective defroster	In case of degradation of defrosting function (part of the windscreen no defrosted), the driver must inform the OCC in order to provide a repair. OCC will advise maintenance team.	Operation
Ottawa_SSR Driver visibility_004	Unsuitable speed in case of degraded driver visibility	The driver must adjust/reduce the train speed in case of degraded visibility	Operation
Ottawa_SSR_G1_075	Traction with brake applied	In case of lighting of the major fault light on the driver desk, the driver must immediately stop the train and isolate the brake failed.	Operation
Ottawa_SSR_G1_104	Insufficient fresh air renewal	In case of loss of at least 3 HVACs or 3 fresh air dampers closed in a single unit, the train be withdrawn at the end of tour	Operation
Ottawa_Availability_007	Ineffective battery	Vehicle pre-departure test to ensure battery is charged to at least 90% of full capacity	Operation
Ottawa_Other Constraint_007	Train running in unsafe conditions	In case a TBCU sends a fault message during self-tests at reboot, the train must not begin service and it must be sent to maintenance.	Operation
Ottawa_SSR_RearView_001	Rear View System Out of service	The train driver shall inform the OCC when he cannot have access to the platform camera feeds before departure	Operation
Ottawa_SSR_RearView_002	Rear View System Out of service	An operational procedure should be activated by the OCC to guide the train deriver until the end of the line and take the train oout of service	Operation
Ottawa_SSR_RearView_003	Rear View System Out of service	The OCC shall send an adequate number of operators on the platform to help the drivers with the door closure and tell them when the train is good for departure	Operation

6.5.1.3 Validation constraints link to the safety

Reference of critical point	Critical point description	Recommendation	Constraints type
Ottawa__SSR Traction__005	Wheel spin on one motor	Validation must perform an operational test for the wheel spin detection function	Validation
Ottawa__SSR Doors__004	Untimely opening of a door	Perform a test for door opening movement in accordance with Type Test and Routine Test instructions	Validation
Ottawa__SSR Doors__007	Door remaining closed while emergency evacuation is needed	Perform a test for internal/external emergency device in accordance with Type Test and Routine Test instructions	Validation
Ottawa__SSR Doors__008	Fall of passengers outside	Perform a test to check the mechanical strength of the leaf and the glass	Validation
Ottawa__SSR Doors__012	Undetected door remaining open	Perform a test for door closing movement in accordance with Type Test and Routine Test instructions	Validation
Ottawa__SSR__Gauge__054	Fall of equipment / Violation of clearance envelope	Heater fasteners Verified by shock and vibration tests	Validation
Ottawa__SSR__Gauge__055	Fall of equipment / Violation of clearance envelope	Shock and Vibration Qualification Tests confirm heating system design meet fixation requirements	Validation
Ottawa__SSR__Gauge__057	Loss of structural integrity / Fall of equipment	Tread Plate Load Test Procedure	Validation
Ottawa__SSR__Gauge__071	Fall of equipment	Shock and vibrations test must be performed for HSCB	Validation
Ottawa__SSR__Gauge__072	Fall of equipment	Shock and vibrations test must be performed by external supplier for braking rheostat	Validation
Ottawa__SSR__Gauge__073	Fall of equipment	Shock and vibrations test must be performed for Traction converter	Validation
Ottawa__SSR__Gauge__074	Fall of equipment	Shock and vibrations test must be performed for Primary Power Switch	Validation
Ottawa__SSR__G2__008	Untimely traction	Validation must perform an Operational Test for Motoring and braking control (ID7.3)	Validation

Ottawa_SSR_G2_009	Fall of passengers inside the train	Validation must perform a Combined Test for Basic motoring and braking tests (CT306)	Validation
Ottawa_SSR_G2_010	Fall of passengers inside the train	Traction Software must be fully validated (module and integration tests, functional validation)	Validation
Ottawa_SSR Driver visibility_008	Ineffective defroster	A type test of the heating system of the windscreen must be done to validate the equipment.	Validation
Ottawa_SSR Driver visibility_009	Bad transmittance / reflectance of the windscreen	A solar energy transmittance and reflectance test shall be done to validate the windscreen	Validation
Ottawa_SSR_G1_034	No protection of inverters	Validation must perform a Combined Test for Inverters electrical protection (CT203, TT-5)	Validation
Ottawa_SSR_G1_035	Fire due to incorrect thermal models	Combined Test for Thermal models validation (CT312)	Validation
Ottawa_SSR_G1_036	Fire due to overload of the motor	Combined Test for Thermal overload test (CT403)	Validation
Ottawa_SSR_G1_037	Fire due to incorrect fault handling	Validation must perform a Combined Test for Fault Handling test (CT405)	Validation
Ottawa_SSR_G1_038	No air flow in the traction converter	Operational Test to Check correct rotating direction of fans and traction auxiliaries aeroulic/hydraulic flow (ID4.3)	Validation
Ottawa_SSR_G1_039	Degraded air flow in the power module	An air flow rate test must be performed for the Power Module fan (TT-3)	Validation
Ottawa_SSR_G1_040	Fire due to traction software failure	Traction Software must be fully validated (module and integration tests, functional validation)	Validation
Ottawa_SSR_G1_045	No protection of inverters	Validation must perform a Combined Test for Inverters electrical protection (CT203, TT-5)	Validation
Ottawa_SSR_G1_046	Locked axle due to incorrect thermal models	Combined Test for Thermal models validation (CT312)	Validation
Ottawa_SSR_G1_047	Locked axle due to overload of the motor	Combined Test for Thermal overload test (CT403)	Validation
Ottawa_SSR_G1_048	Locked due to incorrect fault handling	Validation must perform a Combined Test for Fault Handling test (CT405)	Validation

Ottawa_SSR_G1_049	Locked axle due to traction software failure	Traction Software must be fully validated (module and integration tests, functional validation)	Validation
Ottawa_SSR_G1_060	Traction / Inverter / Electrocution of people	Validation must perform a Combined Test for Inverters electrical protection (CT203, TT-5)	Validation
Ottawa_SSR_G1_061	Traction / Filter / Electrocution of people	Validation must perform a Combined Test for Filter charging and discharge (CT301, TT-14)	Validation
Ottawa_SSR_G1_062	Traction / Electrocution of people	Operational Test for Check of high voltage circuit (ID5.1)	Validation
Ottawa_SSR_G1_063	Traction SW / Electrocution of people	Traction Software must be fully validated (module and integration tests, functional validation)	Validation
Ottawa_SSR_G1_065	Electromagnetic interference	Perform a EMC type test	Validation
Ottawa_SSR_G1_071	Electrocution of people	Realized an earthing/grounding type test procedure/report	Validation
Ottawa_SSR_G1_072	Electromagnetic interference	Perform EMC type Test on auxiliary converter	Validation
Ottawa_SSR_G1_073	Electromagnetic interference	Perform EMC type Test on auxiliary converter	Validation
Ottawa_SSR_G1_074	Electromagnetic interference	Perform EMC type Test on traction	Validation
Ottawa_SSR_G1_080	No protection of inverters	Validation must perform a Combined Test for Inverters electrical protection (CT203, TT-5)	Validation
Ottawa_SSR_G1_081	Explosion due to incorrect thermal models	Combined Test for Thermal models validation (CT312)	Validation
Ottawa_SSR_G1_082	Explosion due to overload of the motor	Combined Test for Thermal overload test (CT403)	Validation
Ottawa_SSR_G1_083	No air flow in the traction converter	Operational Test to Check correct rotating direction of fans and traction auxiliaries aeroulic/hydraulic flow (ID4.3)	Validation
Ottawa_SSR_G1_084	Degraded air flow in the power module	An air flow rate test must be performed for the Power Module fan (TT-3)	Validation
Ottawa_SSR_G1_085	Explosion due to traction software failure	Traction Software must be fully validated (module and integration tests, functional validation)	Validation

6.5.1.4 *DESIGN task summary links to the safety*

Reference of critical point	Critical point description	Recommendation	Constraints type
Ottawa_SSR Brake_006	Failure of deadman function in ATO mode	In case of ATO mode, deadman function must be fully managed by Thales. If driver incapacity is detected, the train must go to the next station at reduce speed under ATP control.	Design
Ottawa_SSR Brake_011	Degraded braking performances during a Maximum Service Brake	TCMS has to monitor the life signal of the TBCU in order to guarantee the daily latency time at train level.	Design
Ottawa_SSR_Gauge_052	Fall of equipment	Calculation note + vibration and shock tests to prevent the risk	Design
Ottawa_SSR_Gauge_064	Loss of structural integrity	Calculation note + vibration and shock tests to prevent the risk	Design
Ottawa_SSR_Gauge_065	Loss of structural integrity	Calculation note + vibration and shock tests to prevent the risk	Design
Ottawa_SSR_Gauge_066	Fall of equipment	Compliance of mechanical fixings of Traction equipment on the roof and under frame to appropriate shock and vibrations standards must be demonstrated	Design
Ottawa_SSR_G1_005	Battery electrocution	Use of identification labels for each car connection.	Design
Ottawa_SSR_G1_009	Warning safety label electrocution	Put the safety label electroction on : HVAC, Cab Heater, AGTU, Booster, MV Box, LV Box, Auxiliary compressor (pneumatic), Auxiliary compressor (hydraulic), APS, Battery, Brake module, Pantograph, Track brake, Current return, Braking resistor , Traction box, Traction motor, End Box, DJC box, Electrical cabinets, Medium voltage electric cabinets , Low voltage electric cabinets MC1, Low voltage electric cabinets MC2, Cabinet (cab), Flange lubrication main components, Motors cooling system, Transformer cooling system, High voltage equipment, HSCB, Primary power switch, Workshop plug, Surge arrestor, Passenger access door (DCU), UMC/VMC/CC, DRCS, Backbone, MPU AL2, MPU AL3, RIOM, ATP on-board equipment, ATO on-board equipment, EVR	Design
Ottawa_SSR_G1_032	Degraded supply and protections of the heating resistors	Heating resistors shall be supplied by a specific low voltage line, equipped with adequate electric protections.	Design

Ottawa_SSR_G1_033	Wrong dimensioning of the bearing / excessive flexure of the shaft	- The calculations of dynamic load ratings and life ratings for motor bearings shall be carried out following ISO 281 standard '- Bearings clearance after assembly shall be calculated '- Calculations on the deformation of the shaft have been carried out, to avoid excessive flexion '- Functional analysis to verify that bearing backlash is sufficient in all conditions	Design
Ottawa_SSR_G1_050	Wrong dimensioning of the bearing / excessive flexure of the shaft	- The calculations of dynamic load ratings and life ratingsfor motor bearings shall be carried out following ISO 281 standard '- Bearings clearance after assembly shall be calculated '- Calculations on the deformation of the shaft have been carried out, to avoid excessive flexion '- Functional analysis to verify that bearing backlash is sufficient in all conditions	Design
Ottawa_SSR_G1_052	Traction / Electrocution of people	Failure of the tram electrical ground connection through the bogies shall be minimized in order to avoid electrocution of passengers.	Design
Ottawa_SSR_G1_064	Eletromagnetic interference	Respect the following standards : IEEE C95.1-2005: IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 3 to 300 GHz IEEE C95.6-2002: IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0 to 3 kHz	Design
Ottawa_SSR_G1_069	Pantograph / Electrocution of people	Design adequate isolation and grounding into equipment.	Design
Ottawa_SSR_G1_079	No de-ionization of the air around the HSCB	When the circuit breaker opens under short circuit current, the circuit must be able to close and break again this short circuit current few seconds after the first opening. A third and last operation of closing and opening is possible about 60S after this second opening, to allow the de-ionization of the air. Timing of open and close sequences to be respected: O 20 CO 60 CO	Design
Ottawa_SSR_G1_091	Overcharge of the battery	Battery charger shall have limitation against over-current leading to battery over-charge	Design
Ottawa_SSR_G1_093	Traction with brake applied	A traction effort with a brake applied should be detected in order to cut off the traction.	Design
Ottawa_SSR_G1_097	Fire ignition due to locke axle	Realized an Fire Safety Design Plan	Design
Ottawa_SSR_G1_098	Fire ignition due to locke axle	Realized an Fire Safety Design Report	Design
Ottawa_SSR_G1_100	Locked axle (bearing of axle beam)	Perform a bearing life time calculation note - bearing beam housing	Design

Ottawa_SSR_G1_103	Locked axle (bearing of reducer)	Perform a bearing life time calculation note - reducer gear box	Design
Ottawa_SSR_G1_111	Not coupled when coupled	Thales must managed the train lenght regarding loss of integrity hazard	Design

6.6 *Failure modes, effects, and criticality analysis (fmeca)*

Individual FMECAs were provided from suppliers and initially attached as appendices to the hazard analysis, and Safety Study Reports in addition to individual FMECAs that were conducted function by function on the Principle Schematic.

These were used as part of the individual hazards mitigation and validation, as were subsystem FMECAs. In review of the submittals it was highlighted that there was no "Roll-up" consolidating all the individual FMECA's into a single consolidated vehicle level FMECA.

Additionally, the failures of the TCMS electronics components (RIOMs and MPUs etc...) were not included initially in the FMECAs for the principle schematic.

These two items were addressed by an update of the individual schematic FMECAs as well as the generation of an overall Vehicle FMECA [R23],

The overall vehicle FMECA also allowed for a numerical reliability calculation at the vehicle level that could be compared against the reliability prediction.

6.7 *Safety Related Items List*

The Safety Related Items List (SRIL)[R22] is a list of items identified as safety related at train and component level, which must be managed properly for contributing to the Safety performance of Railway Systems.

It also helps to inform all people involved from conception to implementation, that a part and / or assembly are safety related.

A part or assembly is declared « safety related » when a failure of the item is likely to hurt directly, seriously and collectively those in contact with rolling stock (passenger, driving crew, maintenance or operating).

The safety related items list do not take into account fire & smoke aspect. This aspect is studied in Fire & Smoke classification plan.

The failure modes may have originated from the design of the part and its assembly, but also its maintenance or other parameters such as storage or operation.

The Safety Related Items List is the input data that allows all relevant services (Design, Quality, Maintenance ...) identify safety related elements and safety characteristics.

This list is not restrictive regarding quality controls on other equipment. In other way, it defines the tests to be performed on safety related parts but does not remove any controls on unsafe parts and assemblies.

This list evolves according to safety studies that will be conducted throughout the RAMS process and we use our experience to complete this list.

6.8 *Safety Related Documents List*

The Safety Related Documents list [R24] is a compilation of all documents that are linked to safety Studies.

All such documents carry the safety logo, ▽ and are checked and approved by both the project RAMS engineer and the safety certifying engineer.

These documents generally are linked to either the mitigation of a hazard by calculation, study or test, or to highlight safety critical information with respect to assembly and maintenance (such as torque values etc. on critical assemblies)

7 FIRE SAFETY

Fire safety consists of 2 parts,

- the study of the hazard start of fire identified in the list of critical events, in paragraph 5.1 and studied in the SSR Gravity 1 Feared Events, (see paragraph 5.2.9.4) [R31}
- compliance to the prescriptive design requirements of the project agreement
  - Schedule 15-2 part 4 Article 3.33(m) – Materials requirements
  - Schedule 15-2 part 4 Article 3.16 Fire Safety

  And the compliance to NFPA 130 required by both these sections

To answer the second bullet point above, the Fire Safety Design Plan - Ottawa [R32] defined the complete program, tests and analysis to be conducted on the project to ensure the design limits the spread of fire, generation of smoke, and that the structure is secure from external fire. There are several outputs from the fire safety Design Plan, specifically

- Fire Safety Design Report [R33]
- 404 CITADIS SPIRIT - TYPE TEST PROCEDURE FLOOR AND ROOF FIRE RESISTANCE – [R28]
- 404 CITADIS SPIRIT - TYPE TEST REPORT ROOF AND FLOOR FIRE RESISTANCE - [R29]

  The fire safety design report provided the full matrix of combustable materials, heat release rates, total heat release rate and smoke and toxic gas prodiction.

7.1 *Fire Safety Design Report[R33]*

The fire safety design report provided the full matrix of combustable materials, heat release rates, total heat release rate and smoke and toxic gas production. It demonstrated that Alstom met its commitment to OLRTC to have a total heat content less than 161 GJ emergy. In addition, there were non compliant materials that had to be incorporated into the design for functional requirements. In total roughly 220 kilos out of 11 metric tons of combustible material. These non compliant materials generated a number of specification change requests, specifically: SCR-069, SCR-077, SCR-078 ,SCR-079, SCR-080, SCR-081, SCR-082, SCR-083, SCR-084, and SCR-085, for which relief was granted.

7.2 *TYPE TEST PROCEDURE FLOOR AND ROOF FIRE RESISTANCE – [R28]*

There were several points of discussion on the procedure and the mock-up sections selected

For the roof,

- the principal issue was that the roof would be tested unloaded, because the chamber used for the test required the roof section to be tested upside down, and part of the design simulations showed that the equipment attachment points could soften and lose integrity if put in tension while under fire loading, as the boxed would normally be expected to sit on the roof once the attachment points softened

For the Floor:

- the discussion focused on how much of the low floor section would be tested, and the possibility that the low floor area might collapse under fire test.
- Alstom's position was that
    - The section selected was based upon Alstom's internal design simulations and reviews which indicated the bogie box area of the vehicle was the most probable to fail for thermal temperature rise issues
    - Floor collapse is not a credible failure mode for a low floor car because, the maximum potential deflection before the structure was sitting on the running rails would be in the order of 150mm maximum (with secondary suspension deflated)

7.3 *TYPE TEST REPORT FLOOR AND ROOF FIRE RESISTANCE – [R29]*

In total, 5 fire tests were conducted , 2 on the roof section and 3 on the floor section. The results are summarized below

7.3.1 Roof fire resistance

The initial roof fire test failed prematurely, and the cause of failure was determined to be the result of loss of the seal between the lab and the mock-up, caused by buckling distortion of the mock-up. Review of the mock-up upon disassembly indicated that the mock-up was over constrained for lateral thermal expansion, and this led to the buckling of the roof and loss of the seal at the cut end

A retest was conducted with 2 modifications,

- the cut end of the extrusion was sealed with an aluminium plate, simulating the end ring attachment that would normally be at the extremities of the carshell. This provided a continuous surface to seal to the lab as opposed to the 3mm thickness of the extrusion
- the mock-up was allowed to "float" laterally to allow for an expected 25mm lateral expansion under the temperature of the test.

The retest, was successful, however the full 30 minutes was not achieved due to failure of a cable penetration that was exposed to the full furnace temperature, because the "End Box" of the roof which normally would cover the penetration could not be mounted as it interfered with the installation of the mock-up into the chamber.

Given the chamber installation made the actual test more onerous, the 27 minutes achieved under fire test was considered as acceptable.

7.3.2 Floor Fire resistance

In total, the floor section was tested 3 times. It should be noted that under normal conditions, there was never an issue with the internal temperature rise, or structural failure. With respect to internal fire the following areas of weakness were discovered:

- Penetrations and heat distortion were found at the sand box openings that led to a direct failure.
    - A design change was made and this issue corrected by reinforcing the interface between the bogie box and the sanding unit, eliminating the distortion and closing the penetrations that were present as part of the manufacturing process

- Flash over of the paint and some interior insulation on the bogie box due to the direct contact of the thin, (2mm) of the bogie box in the lateral seat areas which is directly exposed to the exterior.
    - Intumescent paint was used to limit the sheet steel temperature rise, and while the retest using intumescent paint still demonstrated flashover a few minutes before the end of test, it was found to be only 0.5-1.0mm thick, when the design called for 2 mm. It is considered based upon sample testing of the material, that if the correct thickness is applied the ability to pass the test without flashover is assured.
    - The production vehicles had paint applied as a retrofit due to the time of implementation of the paint, into the manufacturing process. As a result there are some areas where the paint is not applied due to other equipment mounted in place. For small items such as brackets and piping, this is not a concern as the remaining area is protected and will act as a heat sink. For larger parts such as the HPU and Accumulator, these parts will act as a shield, protecting the unpainted area. Revenue service will begin without the areas under larger equipment being painted.

- Flashover of paint and other materials in the underfloor area, combined with the lack of sealing of the underfloor to the side wall, led to fire inside the sidewall lining and ultimately the interior of the car. This this was corrected on the mock-up with intumescent bricks in the cavity where the sidewall connection bolts were accessible, and demonstrated to meet the requirements:
    - On production cars the long side wall area of the low floor section will be similarly sealed with a combination of plates and intumescent product.
    - Revenue service will begin without the sidewall protection installed, under a waiver from the city.

7.3.3 Fire Test Conclusion

Ultimately it was concluded that the vehicle design, while not demonstrated, could with all the modifications and process corrections outlined in paragraphs 7.3.1 and 7.3.2 above, would meet the design requirements, and Alstom certified this, with a separate certification by a Professional Engineer (see appendix 8)

8 COMPLIANCE DEMONSTRATION

Compliance demonstration consists of two parts,

- the first being compliance to the SAMP, and completion of the safety studies as required by the SAMP and described in section 6 of this document.
- The second being the demonstration of compliance to the Project Agreement, on design areas pertaining to safety of the vehicle, through design and test documentation. This is monitored through the Compliance Matrix [R45], which
    - provides a clause by clause to the vehicle specification [A8],

- Identifies clause by clause the means of proof to be provided, (i.e. design documents and / or test specifications procedures and results).
- Identifies noncompliance and the status of any requested Specification Change Request (SCR)
- Identifies the approval status and correspondence trail of all submitted documents.
- Identifies documents that are submitted as part of proof of compliance that are on the safety related documents list.

9 AUDITS AND REVIEWS

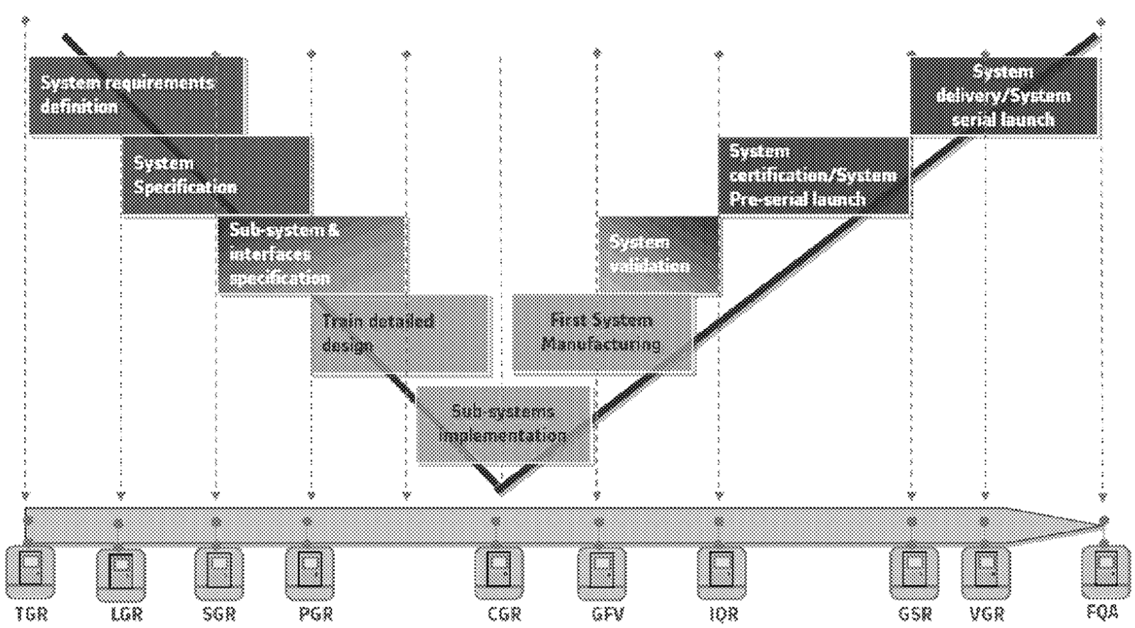
Throughout the project, there have been both internal and external reviews. Internal reviews follow Alstom's process for status at critical points in the project.

Two external reviews/audits of the project, were conducted to evaluate the design maturity and status of the project with respect to safety.

9.1 *Internal Gate Reviews*

Throughout the project the maturity of the reliability and safety documentation and process is reviewed and recorded. There are the specific points throughout the V cycle where the status is captured. These are:

- Go For Validation (GFV)
- Go for Serial Production Internal Quality Review (IQR)
- Go for Revenue Service - Validation Gate Review (VGR)



The review checklists are attached in appendix 3 for both RAMs and Safety

9.2 *External Reviews and Audits*

9.2.1 Customer Design Reviews

There were three specific RAMS design reviews prepared for this project:

- The First Prefinal Design Review RAMS [R25] & ILS [R26]
- The second Prefinal Design Review – RAMS [R27]
- The final Design review – RAMS

The first 2 design reviews were presentation based, with the first design review introducing the overall structure of the rams program, and the second showing a snapshot of the status through the project work scope.

The final design review was a working session with review of all of the submitted RAMS associated documents, and the first pass through of all the comments on these documents. The documents involved specifically were:

- the FTA, hazard analysis,
- all the safety studies reports SSR's, and
- the reliability monitoring plan.

In addition, during the final design review, 2 safety related train design topics were presented and reviewed

- the proposed test procedure for the floor and roof fire withstand tests to be conducted as required by NFPA 130 and ASTM E119. [R28]
- The presentation of the crash withstand simulation for ASME RT1,[R30] and the justification for simulation only, using the comparison of the simulation and actual test for the TTNG (CITADIS DUALIS) project.

9.2.2 AAPP Audit

Alstom was notified in September 2017 of a City sponsored audit, using the German TUV standards. The audit was a document check, where Alstom was required to provide the document references called out in the work breakdown structure.

Alstom provided all the document references, and also indicated whether these were deliverables or internal documents only. The completed survey is attached in Appendix 3

Alstom was never provided with any conclusions from the audit, or any auditors report.

9.2.3 Intrusive Audit and Integration Reviews

Alstom was notified in April 2018 that OLRTC was conducting an intrusive audit to be held in May 2018, with 2 follow on system Integration Reviews,

9.2.3.1 Intrusive Audit

The audit addressed the project as a whole, beginning with the Project Management Plan, Quality Management Plan, and Safety Assurance Management Plan, and drilled down through, the design process, Focusing largely on requirement management , Verification and Validation, and Safety Management,

A copy of the audit report and Alstom's response is in Appendix 4.

As is evident from Alstom's responses to this audit, it was apparent the auditors did not understand the nature of the contract and the responsibilities of the different stake holders within the overall project. This was evidenced by the auditor's observations in the following areas:

- Questions relative to the separation between the initial design concept and planning phase that takes place before any request for proposal, proposal phase of a project, the supply contract phase, and commercial service phase. Alstom was audited on all 4 phases of the development of the entire project, while the actual contract for Alstom is only the design to specification phase of the vehicle.
- Observations that the project transitioned directly from requirements to solution with no study, which was a direct consequence of the City's requirement to provide service proven technology.

The audit did highlight one area of "potential improvement" specifically related to the management of requirements and more specifically incorporation of internally generated requirements. This led to an update of the Project requirements management plan to document how internally generated requirements were flowed down.

10 SUMMARY AND CONCLUSION

10.1 *Waivers and Restrictions*

The following list comprises the total list of known design and quality issues with resolution or containment still to be implemented on the vehicle, pertaining to closure of safety studies, related safety activities, or ultimately vehicle safety. These waivers have been considered as acceptable to start revenue service, providing that they are implemented in a timely manner during the warranty period.

Tracking and closure of these issues will be done by the quality department, through the "Minor Deficiencies list".

Waiver Minor / deficiencies list No.	Subject	Reference chapter (in this document)	Issue	Mitigating Measure to start service	Ultimate Resolution
LRV66	Drivers cab door lock	2.2 Table 4	The cab key is a commercially available item, and although selected and agreed by the city, threat assessments have raised cab/driver access by unauthorized persons as a safety issue,	Review of the issue suggests that the only threats would need to be premeditated, (specifically purchase a key in advance), and not a random attempt to interfere with the driver, or otherwise enter the cab.	Change the lock to one with a non-commercially available item (available only to Alstom – OCTranspo)
LRV26	Drivers cab lighting	2.6.14.3.1	Dimmer does not permit complete shut off of cab light, causing reflection in the windshield at night and driver distraction.	Switch off the circuit breaker to remove power from the cab ceiling lights	The dimmer will be modified to permit complete shutdown of the cab ceiling lights.
No waiver raised, LRV27	Non flush gangway	2.6.2.1.1 & 6.1.3.1	Non flush gangway bellows allows a place for people to be trapped between gangway and the platform	Mitigation is achieved by using the rear view camera system to ensure the side of the car is clear of passengers prior to departure. The full risk assessment was done by OLRTC, under safety Certificate 2907	Add a 3rd layer to bring the bellows almost flush with the side of the train.
LRV32	Carbody fire resistance	7.3.2	The low floor section of the underfloor area is not sealed to the side of the car, permitting a flashover under the floor to propagate up the vehicle sidewall	None, risk considered acceptable as the guideway is completely closed and external fire sources that could lead to a fire under the low floor area of the vehicle are restricted.	Add blocking plates and intumescent seals to prevent underfloor fire from entering the interior.

Waiver Minor / deficiencies list No.	Subject	Reference chapter (in this document)	Issue	Mitigating Measure to start service	Ultimate Resolution
LRV9	Carbody fire resistance	7.3.2	Some areas of the thin steel of the bogie box are not painted due to the presence of other equipment	None, implementation in the short term is acceptable as mounted equipment offers thermal shielding	Paint these areas when the bogie is removed and better accessibility to apply paint is possible
LRV10	Door Sensitive Edge	2.6.10.5	Quality issue with door sensitive edge, not fully inserted to within 1 inch (25mm) of the bottom of the door as required by APTA standard	None, the risk is mitigated with the door overcurrent detection and use of the rear view system,	Realign / reinstall install sensitive edge to correct placement
LRV301	Cab Door material	N/A	The cab door is currently made from laminated safety glass as required by the PA but is prone to breakage,	a temporary solution has been found to replace the glass with acrylic, however this material is not presently accounted for in the fire safety design report, the impact is to increase marginally the total heat load but not exceed the maximum required heat load	Ultimate resolution will be a completely redesigned door, to ensure that the glass panel does not break.
LRV302	Rear View Camera System	N/A	The rear view camera system screen is appearing blank too frequently to be considered reliable on its own for monitoring the platform prior to departure of the train	Mitigation is achieved by the use of Platform Spotters at each station to offer assistance for departure of the trains as identified in the Hazard Log items. Ottawa_SSR_RearView_001 Ottawa_SSR_RearView_002 Ottawa_SSR_RearView_003	Modification of the PAPIS and HSDR software to resolve the functional reliability. A field Notification has been raised to outline the responsibilities of a platform spotter and the driver to mitigate the issue, operation with the platform spotters will continue until the system has been demonstrated to operate with no failures for a minimum of 2 weeks

10.2 *Summary*

The whole RAMS studies have been realized as required by the Rolling Stock RAM Plan [R21] and the Safety Assurance Management Plan [R20]. The hazards are evaluated and the necessary actions to eliminated or control them are set up.

The studies bring the proofs that the safety targets are respected as specified and the hazards link to dysfunction are controlled.

The hazard management gets through the respected constraints set up in the different analysis.

Tests realized on the rolling stock before its exploitation phases have demonstrated the performance and functionality of the train functions and subsystems.

The maintenance constraints have been sent through the train preventive maintenance plan.

The exploitation constraints have to be respected according to the different situations where the train can be in exploitation phases.

10.3 *Conclusion*

As evidenced within this report and subject to the above noted waivers, the Rolling Stock is safe and suitable for its intended use in revenue service as defined sections 2.3 through 2.5 inclusive.

11 APPENDICES

11.1 *Appendix 1 - Degraded Modes – Impact on service*

ADD0000938741 _Appendix1_Degraded Modes – Impact on Service_

11.2 *Appendix 2 - Approval status of Safety related documents*

11.3 *Appendix 3 - Alstom internal reviews*

- Go For Validation (GFV)
- Go for Serial Production Internal Quality Review (IQR)
- Go for Revenue Service - Validation Gate Review (VGR)

11.4 *Appendix 4 - AAPP audit*

AAPP audit worksheet

OLRT Authority Approval Process Plan (AAPP) of System Assurance Evidence

Work Breakdown Structure (WBS) Level 2 (L2) to Level 9 (L9) - Deliverables, Activities and Milestones

11.5 *Appendix 5 - Intrusive Audit*

Intrusive Audit Report and Alstom response.

11.6 *Appendix 6 – Independent Software Assessments*

11.6.1 Appendix 6.1 – Door System SIL 2 Certification

11.6.2 Appendix 6.2 – Propulsion System SIL 2 Certification

11.6.3 Appendix 6.3 – Brake System SIL 2 Certification

11.7 *Appendix 7 – Imported Constraints from OLRTC*

11.7.1 Appendix 7-1 – Imported Constraints from OLRTC

Incoming Letter	Outgoing letter	Document
OLR-ALS-1804		IHL to Alstom.xlsx (as responded by Alstom)
OLR-ALS-2043	ALS-OLRT-02791	Alstom Tier2 Derrived Safety Reqs.xlsx

11.7.2 Appendix 7-2 – Review of Mainline and MSF PHA

11.8 *Appendix 8 – Fire Safety Certification*