






**BEML LIMITED**  
**BENGALURU**  
**R & D CENTER**

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Page No.	1/34

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**MRS1 Project**  
**Technical Specification**  
**for HVAC Vehicle Level Test**  
**in Climatic Chamber**

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	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	3/34

## Table of Contents

<b>1. Introduction.....</b>	<b>5</b>
1.1. General .....	5
1.2. Train Composition.....	5
1.3. Climatic & Environmental Conditions .....	5
1.4. Vehicle Performance Requirements .....	6
1.5. Track structure Parameters .....	7
1.6. Current Collection System .....	8
1.7. Signaling System .....	9
1.8. Principal Notional Vehicle Dimensions/ Leading Particulars .....	9
1.9. Car Weights .....	10
1.10. Passenger Capacity (ERTS Clause 3.21.4).....	10
1.11. Power supply details .....	10
1.12. Test schedule .....	10
<b>2. Definitions and Abbreviations.....</b>	<b>11</b>
2.1. Definitions .....	11
2.2. Abbreviations .....	11
<b>3. Qualification criteria .....</b>	<b>12</b>
<b>4. Standards .....</b>	<b>12</b>
<b>5. Technical specifications .....</b>	<b>12</b>
5.1. HVAC Technical specifications .....	12
5.2. Estimated heat load .....	16
5.3. Mounting and airflow arrangement.....	16
<b>6. Test Details .....</b>	<b>18</b>
<b>7. Air flow measurement .....</b>	<b>18</b>
7.1. Return air flow measurement.....	18
7.2. Fresh Air flow measurement .....	19
7.3. Test procedure - airflow measurement .....	20
<b>8. Cooling performance test .....</b>	<b>22</b>
8.1. Test conditions.....	22

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	4/34

8.2. Test details .....	22
8.3. Equipment's .....	22
8.4. Test procedure.....	22
<b>9. Specific Energy Consumption test .....</b>	<b>25</b>
<b>10.Scope of work .....</b>	<b>27</b>
10.1.General .....	27
10.2.Testing .....	28
<b>11. Annexure .....</b>	<b>33</b>
<b>12. Submittals with Technical Offer .....</b>	<b>33</b>

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	5/34

## 1. Introduction

### 1.1. General

This Technical specification document specifies the requirements of climatic chamber tests to be conducted on Metro car fitted with Heating Ventilation and Air Conditioning (HVAC) units to measure Specific Energy Consumption of HVAC system, for the MRS1 Project of Mumbai Metro Line- 2 & 7.

BEML will carry out all required works and activities as Contractor to the Employer for MRS1project, while the subcontractor shall be responsible for all works specified in this PTS document with regard to climatic chamber tests and shall be responsible for supporting the BEML activities as contractor for MRS1project.

One M-car will be subjected to the climatic chamber tests. The scope of work includes all activities required to perform the car level type tests of HVAC system specified in the document meeting the best international practices even if not specifically mentioned in this PTS.

### 1.2. Train Composition

The rake formation shall generally be as follows:

3 Car unit formation : DM – T – M –

6 Car Train formation: DM –T–M – M – T – DM

In case of 8-car formation (if required):

2 Car train formation : – T – M –

8 Car Train formation: DM – T – M – T – M – M – T – DM

where,

DM: Driving Motor Car


T : Trailer Car with pantograph

M : Non -Driving Motor Car

### 1.3. Climatic & Environmental Conditions

The climatic and environmental conditions of Mumbai are as per below table.

Description	Limiting Values
Maximum ambient temperature (See note below)	36 °C
Minimum temperature	14.3 °C
Humidity	≥ 95% RH

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	6/34

Rainfall	The annual precipitation is 2,078 mm with 34%(709mm) falling in the month of July.
Atmosphere during hot season	Extremely dusty including bird feathers
Maximum wind speed	150 km/h
Vibration and Shocks	The sub-systems & their mounting arrangements shall be designed to withstand satisfactorily the vibration and shocks encountered in service as specified in IEC 61373 and IEC 60571.
SO <sub>2</sub> level in atmosphere	80 – 120 mg/m <sup>3</sup>
Suspended particulate matter in atmosphere (TSPM)	360 – 540mg/m <sup>3</sup>
Flood Proofing	The traction sub-systems mounted on the under-frame will be designed to permit propulsion of the train at 10 kmph through water up to a depth of 50mm above rail level. Traction sub-systems shall be made splash proof in accordance with International Standards
Life	The Metro car is designed for min. 35 years of life. Accordingly, the subject items shall also not deteriorate in their performance for 35 years

**Note:**

- 1) The temperature of the metal surfaces of the vehicles when exposed directly to the sun, for long periods of time, may be assumed to rise to 70°C.
- 2) Any moisture condensation shall not lead to any malfunction or failure.
- 3) Adequate margin shall specially be built into the design particularly to take care of the higher ambient temperatures, high humidity, dusty and corrosive conditions, etc. prevailing in Mumbai area.

#### 1.4. Vehicle Performance Requirements

The vehicle performance requirements with fully loaded train and tangent track are as per the following table.


Item		All Corridors
Safe speed	With inflated secondary suspension	90 kmph
	With deflated secondary suspension	80 kmph
Maximum operational speed	With inflated secondary suspension	80 kmph
	With deflated secondary suspension	70 kmph
Minimum Design Average Acceleration rate for fully loaded (AW3) train on level tangent track shall be as under:		
0 kmph to 40 kmph		1.0 m/s <sup>2</sup>
0 kmph to 60 kmph		0.75 m/s <sup>2</sup>
0 kmph to 80 kmph		0.40 m/s <sup>2</sup>

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	7/34

Minimum Operational Average Acceleration rate for AW2 loaded train on level tangent track shall be as under: 0 kmph to 35 kmph 0 kmph to 60 kmph 0 kmph to 80 kmph	1.20 m/s <sup>2</sup> 0.80 m/s <sup>2</sup> 0.45 m/s <sup>2</sup>
Average Service braking rate from 80 kmph to standstill for fully loaded(AW3) train on level tangent track.	1.0 m/s <sup>2</sup>
Average Service braking rate from 80 kmph to standstill for AW2 train on level tangent track.	1.1 m/s <sup>2</sup>
Average Emergency braking rate from 80 kmph to 0 kmph for fully loaded trains on level tangent track	1.3 m/s <sup>2</sup>
Jerk rate (Maximum)	0.75 m/s <sup>3</sup>
Annual running distance of one train (for design purpose)	150,000 km
Note : The specified average minimum acceleration shall be the finally achieved values inclusive of the specified jerk rate.	

### 1.5. Track structure Parameters

The MRS1 cars will operate with the track parameters as specified in the following table: Description	Elevated and At-grade Corridor		Underground Corridor
	Ballasted	Ballast less (DFF)	Ballast less (DFF)
Track Laying Gauge	1435 mm		
Rail Type (Main Line & Depot)	60 EI (UIC 60) 880/HH	60 EI (UIC 60) 1080/HH	60 EI (UIC 60) 1080/HH
Rail Profile	UIC 861-3		
Inclination Of Rail	1 in 20		
Sleeper Spacing (Main line)	600 mm ± 10mm	600 mm ± 10mm	700 mm ± 10mm
Sleeper Spacing (Depot)	650 mm ± 10mm	Not applicable	
Ballast Cushion Depth(Main line)	300mm	Not applicable	
Ballast Cushion Depth (Depot)	250mm	Not applicable	
Standard Rail Length	13m and 18m	18m	
Rail Panel Lengths	Longer than 200m		
Minimum Radius of Curvature	200m-Underground, 110m-Elevated 100m-Depot		
Minimum Turn out Radius.- (Main line)	1 in 9 - 300m radius, 1 in 7- 190m radius		


	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	8/34

Minimum Turn Out Radius Depot	1 in 7 - 190m radius		
Maximum Cant Permissible	110 mm		
Maximum Cant Desirable	110 mm		
Maximum Cant Deficiency Permissible	85mm		
Maximum Cant Deficiency Desirable	85 mm		
Maximum Permissible Cant Gradient	1 in 440		
Maximum Desirable Cant Gradient	1 in 720		
Turn-out Speed: Turnout (1 in 9) R-300	45 km/h	45 km/h	40 km/h
Turn-out Speed: Scissors (1 in 9) R-300	45 km/h	45 km/h	40 km/h
Turn-out Speed: In Depots (1 in 7)R-190	35 km/h	35 km/h	25 km/h
Turn-out Speed: Turnout (1 in 7) R-190	35 km/h	35 km/h	25 km/h
Turn-out Speed: Turnout(1 in 12) R-410	50 km/h	50 km/h	50 km/h
Turn-out Speed: Turnout(1 in 12) R-410	50 km/h	50 km/h	50 km/h
Turn-out Speed: Turnout (1 in 8.5)R-218	30 km/h	30 km/h	30 km/h
Turn-out Speed : Turnout(1 in 8.5)R-218	30 km/h	30 km/h	30 km/h
Maximum Gradient Main Line	4%		
Maximum Gradient Depot Connection	4%		
Minimum vertical curve radius of curvature	1500m		

### 1.6. Current Collection System

System Particulars	For all sections and depot
Supply Voltage System	25kV AC single phase 50Hz
Current Collection	Through Pantograph



	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	9/34

### 1.7. Signaling System

Item	Description
Train Control System	CBTC based On board Continuous Automatic Train Control system (CATC) consisting of <ul style="list-style-type: none"> <li>i) Automatic Train Protection</li> <li>ii) Automatic Train Operation (ATO)</li> <li>iii) Automatic Train Super-vision (ATS)</li> <li>iv) Attended/Unattended train operation (GoA2/GoA3/GoA4)</li> </ul>
Train Control mode	<ul style="list-style-type: none"> <li>i) Automatic mode</li> <li>ii) Coded Manual modes</li> <li>iii) Restricted Manual mode</li> <li>iv) Run on Sight mode</li> <li>v) Cut-out mode</li> <li>vi) UTO</li> <li>vii) Standby</li> </ul>

### 1.8. Principal Notional Vehicle Dimensions/ Leading Particulars

Description		Dimension
Gauge		1,435 mm
Maximum Length over body(including end-fairings)	DM car	22,010 mm
	T and M cars	22,010 mm
Maximum Length over couplers for all cars		23,000 mm
Maximum Width over Body		3,200 mm
Minimum Passenger Saloon Headroom		2,050 mm
Locked down pantograph height for 25kV AC cars from rail level at Car Centre Line		4,048 mm
Maximum Floor height above rail level of any unloaded vehicle		1,130 mm
Minimum Floor height above rail level of fully loaded vehicle		1,100 mm
Maximum height of coupler above rail level for unloaded vehicle		815 mm
Minimum height of coupler above rail level for fully loaded vehicle		740 mm
Bogie Wheel Base	Maximum	2400 mm
	Minimum	2200 mm
Distance between bogie centres	Maximum	15,100 mm
	Minimum	14,400 mm
Wheel diameters	New	860 mm

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	10/34

	Fully worn	780 mm
Maximum axle load		17 Tonne (including all tolerances as per IEC 1133-1992)

### 1.9. Car Weights

	DM-Car	T-Car	M-Car
Tare weight (AW0)	Less than 42,000 kg	Less than 42,000 kg	Less than 42,000 kg
Crush Loading (AW2)	Less than 61.500 kg	Less than 61.500 kg	Less than 61.500 kg
Fully loaded(AW3)	Less than 68,000 kg	Less than 68,000 kg	Less than 68,000 kg
Axle load	17,000 kg	17,000 kg	17,000 kg

### 1.10. Passenger Capacity (ERTS Clause 3.21.4)

	Seating	Standing		Total (Seating +Standing)	
		Fully Loaded/Dense Crush loaded (AW3)	Crush Loading (AW2)	Fully Loaded/Dense Crush loaded (AW3)	Crush Loading (AW2)
'DM' Car	46(each 'DM' car)	334	254	380	300
'T' Car	56 (each 'T' car)	324	244	380	300
'M' Car	56 (each 'M' car)	324	244	380	300
<b>Total</b>	<b>316</b>	<b>1964</b>	<b>1484</b>	<b>2280</b>	<b>1800</b>

### 1.11. Power supply details

Power supply	Limiting Value
AC Input power supply	3-phase, AC 415 V $\pm$ 5 %, 50 Hz
DC Control Power supply	110V DC, -30%, +25%

### 1.12. Test schedule

It is preferred to conduct tests during Feb/Mar - 2026. Subcontractor shall submit the available testing slot in the technical proposal. Exact test date and schedule may be

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	11/34

mutually discussed and finalized.

## 2. Definitions and Abbreviations

### 2.1. Definitions

The following definitions are applicable to this PTS.

- **“Employer”** means Delhi Metro Rail Corporation Limited (DMRC), its legal successors and assignees.
- **“Contractor”** means BEML Ltd., the firm appointed by the Employer to undertake the execution of MRS1 project.
- **“Sub-contractor”** means the firm appointed by contractor to take up the HVAC Vehicle Level Test in Climatic Chamber for MRS1 project.
- **“Contract”** means the contract between Subcontractor and BEML in relation to the HVAC Vehicle Level Test in Climatic Chamber for MRS1 project.
- **“Engineer”** means any person nominated or appointed from time to time by the Employer to act as the Engineer for the purposes of the Contract and notified as such in writing to the Contractor.
- **“Engineer's Representative”** means any Assistant of the Employer appointed from time to time by the Employer.

### 2.2. Abbreviations

- HVAC : Heating Ventilation and Air Conditioning
- GOA : Grade of Automation
- UTO : Unattended Train Operation
- ISO : International Standards Organization
- EN : European Standard
- MRTS : Mass Rapid Transit System
- TCMS : Train Control Management System
- SEC : Specific Energy Consumption

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	12/34

- RH : Relative Humidity
- DSSP : Declared Scheduled Speed

### 3. Qualification criteria

- Subcontractor shall have in-house climatic chamber to accommodate 25m long metro car with all facilities required for performing specific energy consumption (SEC) measurement test.
- Subcontractor shall have adequate experience in performing vehicle level type test for HVAC system at ambient air speed of 40 kmph (Air flow in the direction of travel). The testing firm should have carried out the car level HVAC validation tests (thermal comfort and SEC tests) of Metro rolling stock on at least three mass rapid transit systems (MRTS).
- The subcontractor shall submit all the documents in support of meeting above requirements along with technical offer.


### 4. Standards

The testing of the vehicle level HVAC test shall conform to the latest editions of EN14750-1 and EN14750-2

### 5. Technical specifications

#### 5.1. HVAC Technical specifications

Item	Unit Specifications	
Cooling capacity	60 kW	
Heating capacity	8 kW - For dehumidification	
Supply air	≥6000 m <sup>3</sup> /h	
	<b>External conditions</b>	<b>Internal conditions</b>
Summer conditions	36°C, 65% RH	25°C, 60% RH
Monsoon conditions	32°C, 85% RH	25°C, 60% RH
Passenger Capacity (M-Car)	AW3 - 380 AW2 - 300	
Refrigerant	R-407C	
Maximum operating temperature	Full load operation up to 50 °C. Unloaded operation between 50 °C and 58 °C.	

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	13/34

Fresh air flow	<p>Adjustable with motor operated dampers</p> <ul style="list-style-type: none"> <li>○ Closed (smoke in ambient air)</li> <li>○ AW0, AW1, AW2, AW3 flow (normal operation) as a function of the passenger load <ul style="list-style-type: none"> <li>○ AW3: 1520 m<sup>3</sup>/h per AC</li> <li>○ AW2: 1200 m<sup>3</sup>/h per AC</li> <li>○ AW1: 760 m<sup>3</sup>/h per AC</li> <li>○ AW0: 760 m<sup>3</sup>/h per AC</li> </ul> </li> <li>○ Emergency ventilation via emergency inverter installed in the saloon = 1900 m<sup>3</sup>/h with closed return air damper</li> </ul>
Return air damper (installed in the return air duct)	<p>Motor-operated</p> <p>The damper has two positions:</p> <ul style="list-style-type: none"> <li>○ Open (normal operation)</li> <li>○ Closed (emergency ventilation, precooling)</li> </ul>
Electrical Power	415V AC / 3Phase / 50Hz (Main power supply-Normal operation) and 110VDC (Control power supply and Emergency Ventilation)
Weight	1100 Kg approx
Max Dimension	4100 L x 2100 W x 460 H Approx.
Communication interfaces	<ul style="list-style-type: none"> <li>○ Service interface: RS-232 port on the control panel</li> <li>○ TCMS: 'Hardwire' controls and Ethernet digital communication interface</li> </ul>

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	14/34

Modes of operation	<p>Normal operation</p> <ul style="list-style-type: none"> <li>○ Fresh air ventilation (fresh air flow varies as per passenger load)</li> <li>○ 50 % cooling</li> <li>○ 100 % cooling</li> <li>○ Dehumidification (1 cooling circuit operates together with the heater)</li> </ul> <p>Pre-cooling</p> <ul style="list-style-type: none"> <li>○ Full load cooling with AW0 passengers and closed fresh air dampers to bring down the indoor temperature to the specified target</li> </ul> <p>Emergency ventilation</p> <ul style="list-style-type: none"> <li>○ Supply fan motor is supplied through the emergency inverter</li> </ul> <p>Ambient air smoke</p> <ul style="list-style-type: none"> <li>○ Fresh air dampers close. Saloon air is recirculated and cooled / dehumidified as required to maintain the specified target temperatures</li> </ul> <p>Indoor smoke</p> <ul style="list-style-type: none"> <li>○ HVAC shutdown</li> </ul>
Temperature controls	<ul style="list-style-type: none"> <li>○ Return air temperature sensor - To control the cooling power and saloon temperature</li> <li>○ 1 fresh air temperature sensor - To control pre-cooling operation and high temperature unloading of the refrigerant circuits</li> <li>○ 1 supply air temperature sensor - To monitor air flow through the cooling coil</li> </ul>
Humidity control	<p>1 solid-stated relative humidity sensor - 1 solid-stated relative humidity sensor</p>

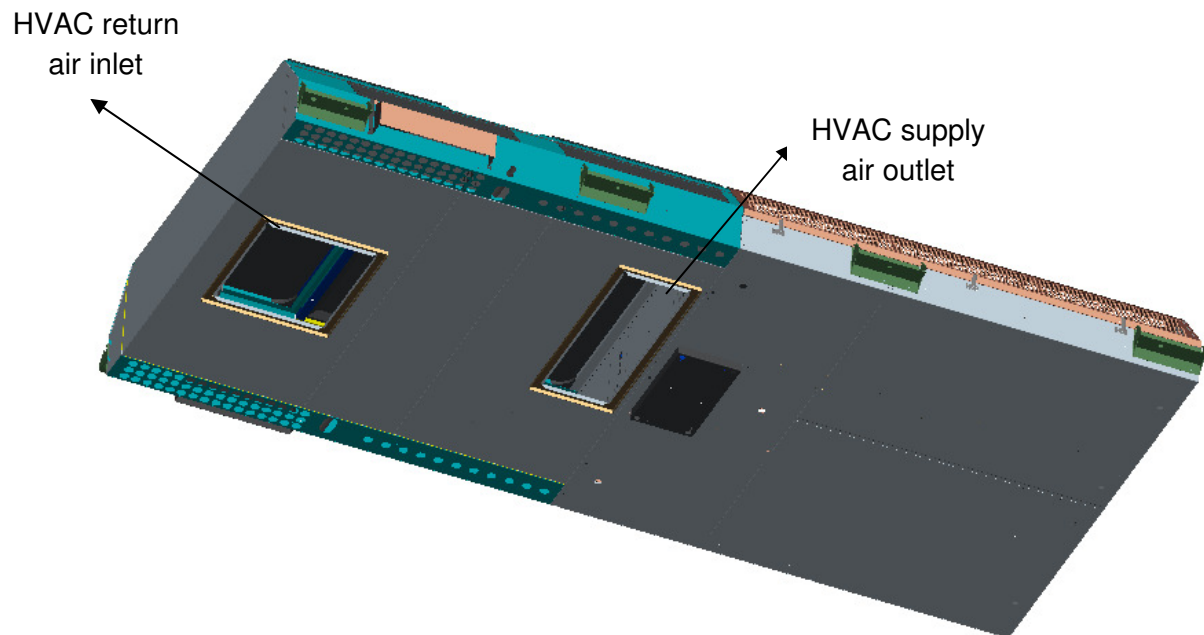
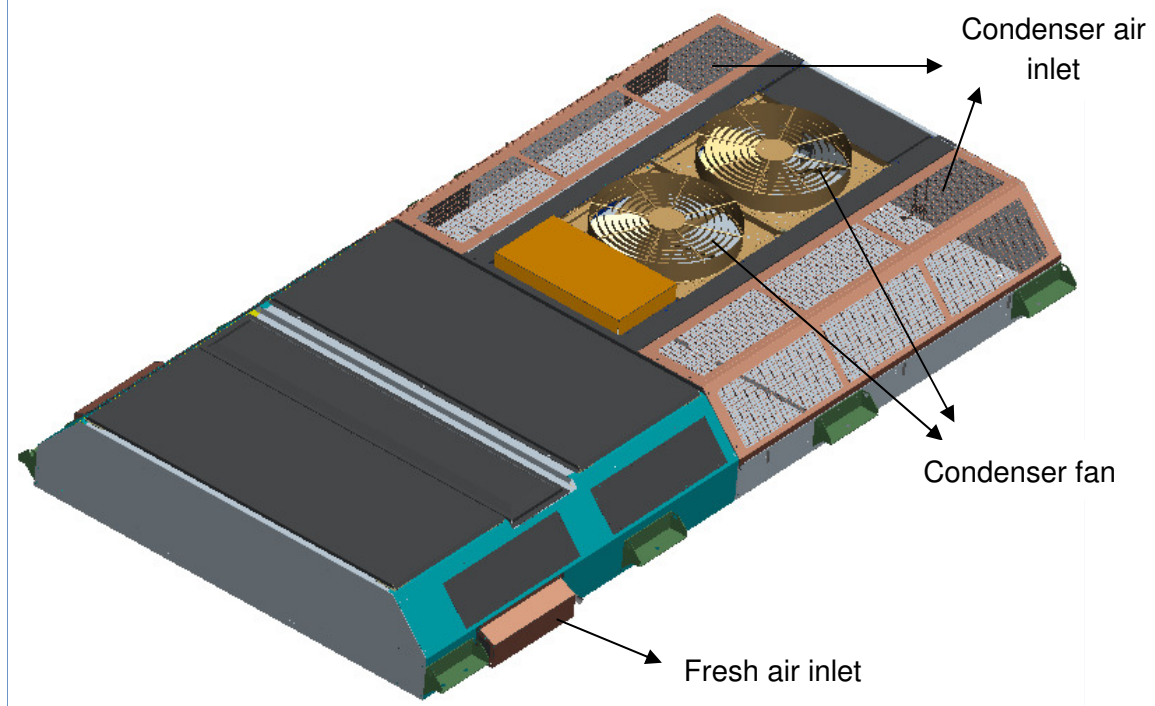



Figure 1: HVAC unit interfaces

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	16/34

## 5.2. Estimated heat load

The estimated heat load under various passenger load conditions for summer climatic conditions for M-car are tabulated below

Ambient condition		Summer	
Passenger load condition		AW3	AW2
Number of passengers		380	300
Solar Gain (kW)		7.9	7.9
Transmission gain (kW)		5.3	5.3
Internal electrical load (kW)		1.4	1.4
Passenger load (kW)	Sensible heat	28.5	22.5
	Latent heat	16	12.6
Ventilation gain (kW)	Sensible heat	10.5	8.3
	Latent heat	31.3	24.7
Total heat load (kW)		100.9	82.7
Heat due to ingress of air during door opening		7.2	7.3
Total heat load per car		108.1	90

Note: Heat loads specified in the table above are based on estimation and actual values may change marginally during testing

## 5.3. Mounting and airflow arrangement

This HVAC system suffice the requirement of only Ventilation & air-conditioning and heaters are provided for dehumidification purpose only. Two identical HVAC units are suitably mounted on roof to achieve the required saloon interior conditions. General arrangement of M-car is attached at Annexure-A

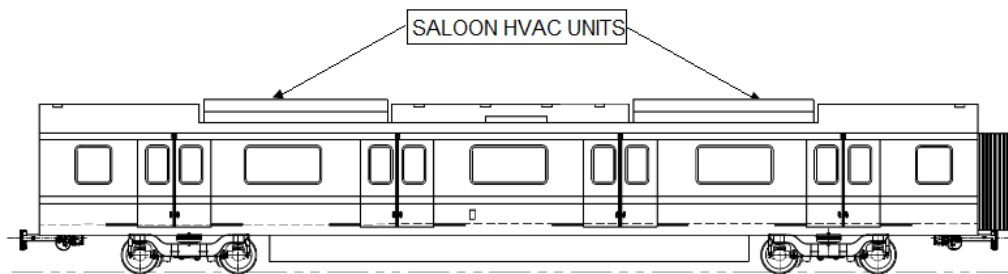



Figure 2: HVAC unit Arrangement on M-car

Conditioned air from each unit is directly introduced into a duct running full length of the car and further uniformly distributed in the saloon through diffusers. The supply air duct is diagonally split for each HVAC unit to feeds one side of the car, so that even in case of failure of one HVAC, the other working HVAC will be able to cool the saloon passenger area uniformly. The duct is fully lagged with non-combustible insulation material to



	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	17/34

prevent the formation of condensation. Two rows of air diffusers are mounted on each side of ceiling panel, for supply of conditioned air to saloon. Exhaust air path is provided through openings below the seats, allowing the interior air to pass through the gap between the inner and outer layers of side walls and discharging to atmosphere from outlets provided on the roof at centre and as well as at the ends.

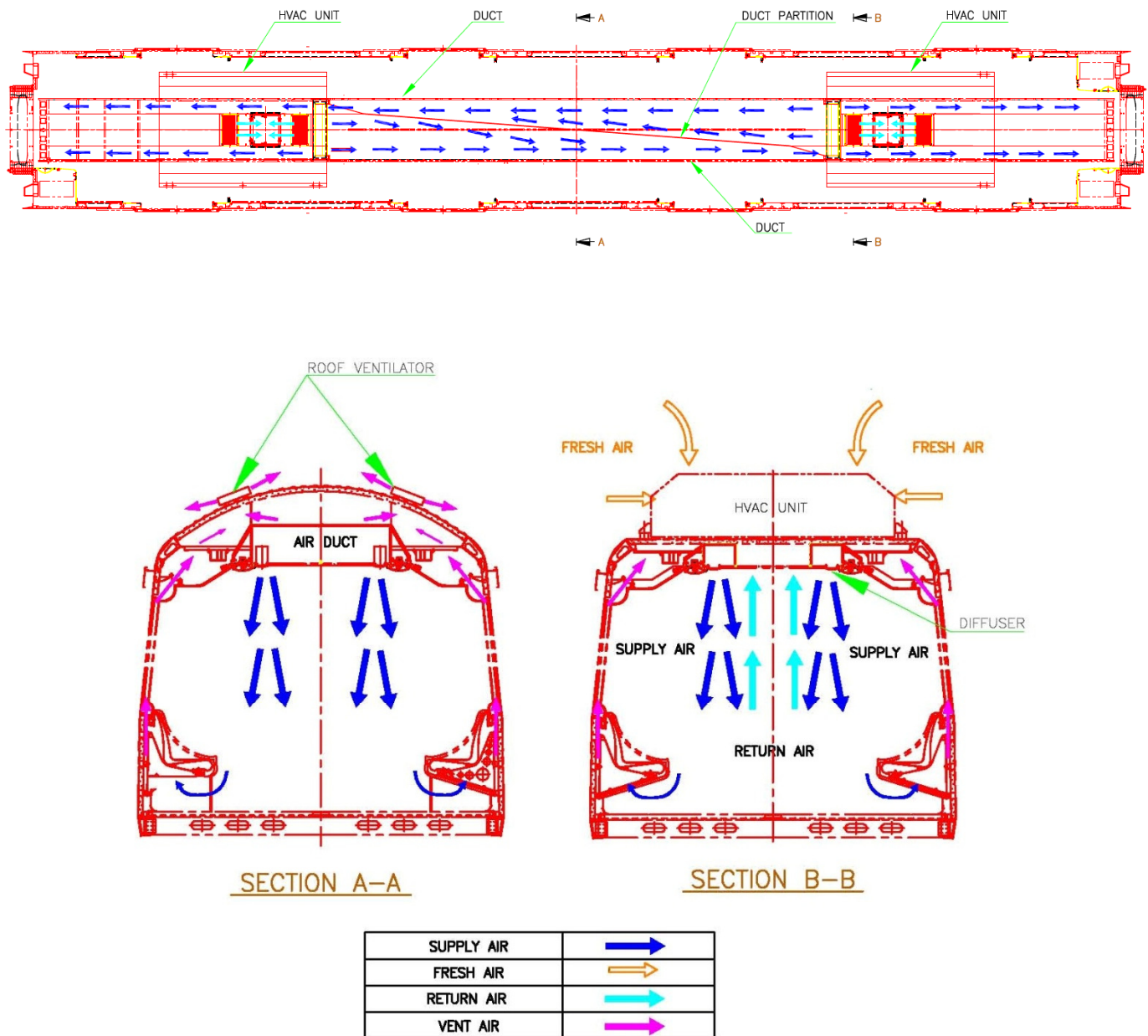


Figure 3: Air flow path

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	18/34

## 6. Test Details

One M-car equipped with all interior finish and all under-frame mounted equipment, shall be tested to demonstrate the effectiveness of the equipment in meeting the specified temperature and humidity conditions inside the car. Car will be subjected to following tests

1. Air flow measurement
2. Cooling performance test
3. Specific Energy Consumption test

Sanity check shall be performed on the test car before taking up the car for air flow/climatic chamber tests. Air flow measurements shall be made in preparation chamber while specific energy consumption tests shall be conducted in a climatic chamber.

## 7. Air flow measurement

Following airflow measurements shall be made in preparation room at climatic chamber test facility before conducting the climatic chamber tests, to confirm the airflow rates meets the contract requirement.

1. Return air flow
2. Fresh Air flow
3. Condenser air flow

Brief test procedure for above tests is described below. Sub-contractor shall prepare the detailed test procedure and submit to BEML for approval before conducting the tests. Sub-contractor may propose better methods of flow measurements. Acceptance of same will be subjected to approval from BEML.

### 7.1. Return air flow measurement

Return air shall be measured using measuring duct. Measuring duct shall be mounted at the return air grill. Details of return air measuring duct and measuring points is shown in the figure below.

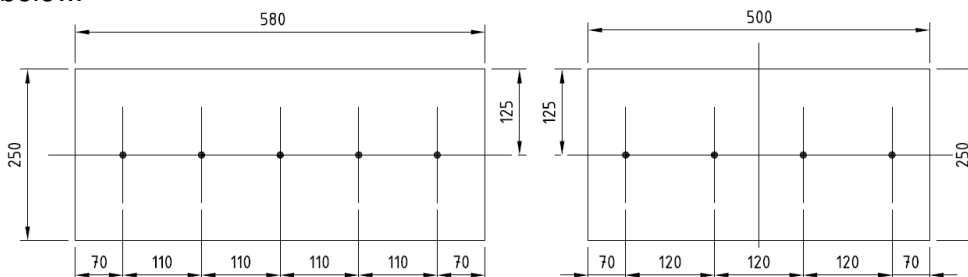



Figure 4: Return air measurement duct

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	19/34

Velocity will be recorded at all measurement points shown in the picture above. Average velocity shall be multiplied with the measuring duct inlet area to obtain the return air flow rate. This procedure shall be repeated at all four return air openings shown in the figure below.

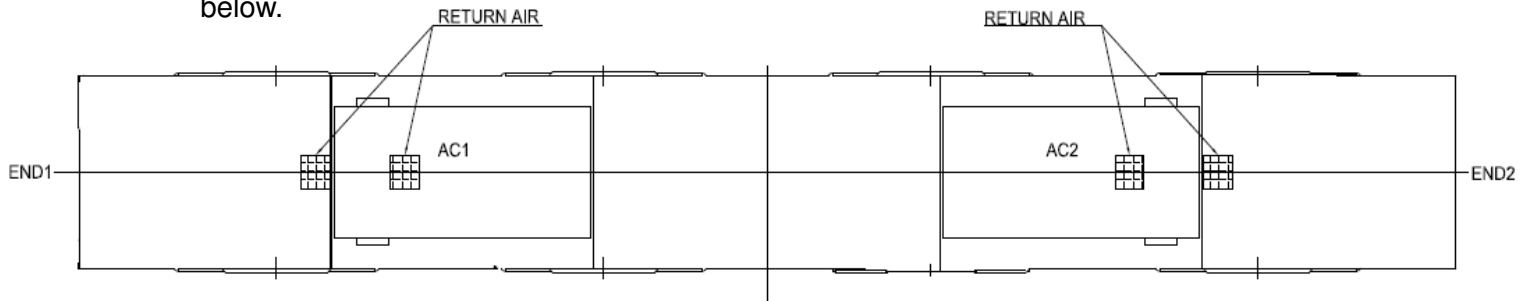
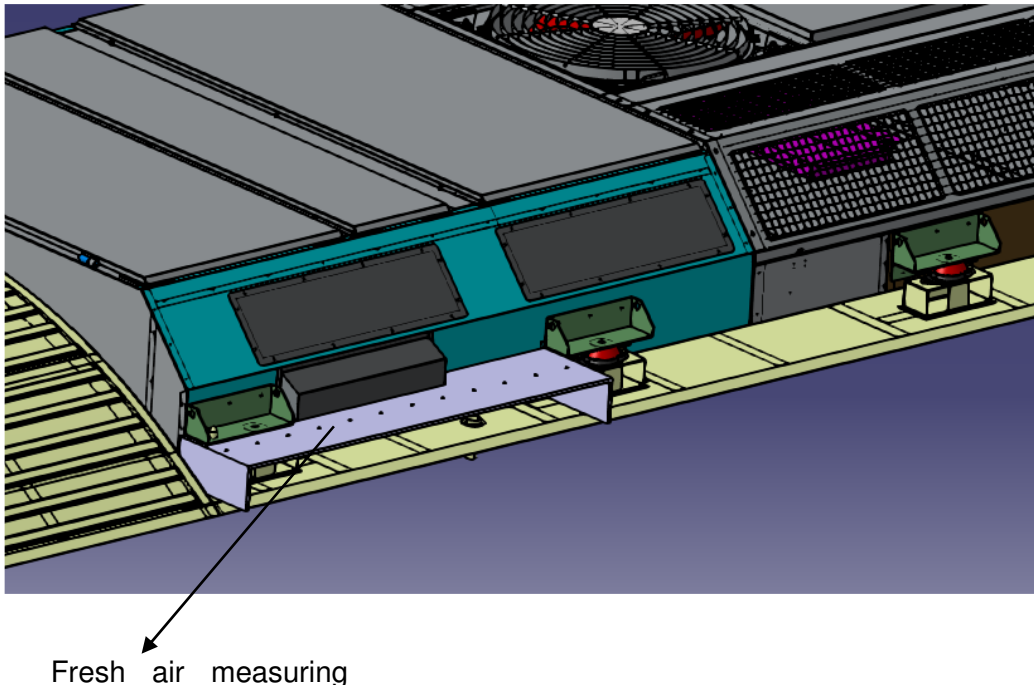


Figure 5: Return air inlet locations on car

## 7.2. Fresh Air flow measurement

Measurement of fresh air on either side of each HVAC units shall be done using measuring ducts. Fresh air inlet is from side opening and through holes on the bottom plate. Fresh air flow openings are shown in the Figure 8.

For measurement of fresh air, duct shall be mounted on the side as shown in the picture below. Other sides on the bottom of HVAC unit shall be closed using suitable material to block the air flow from that side. With the blockage of other sides, air flow will be only from side



	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	20/34

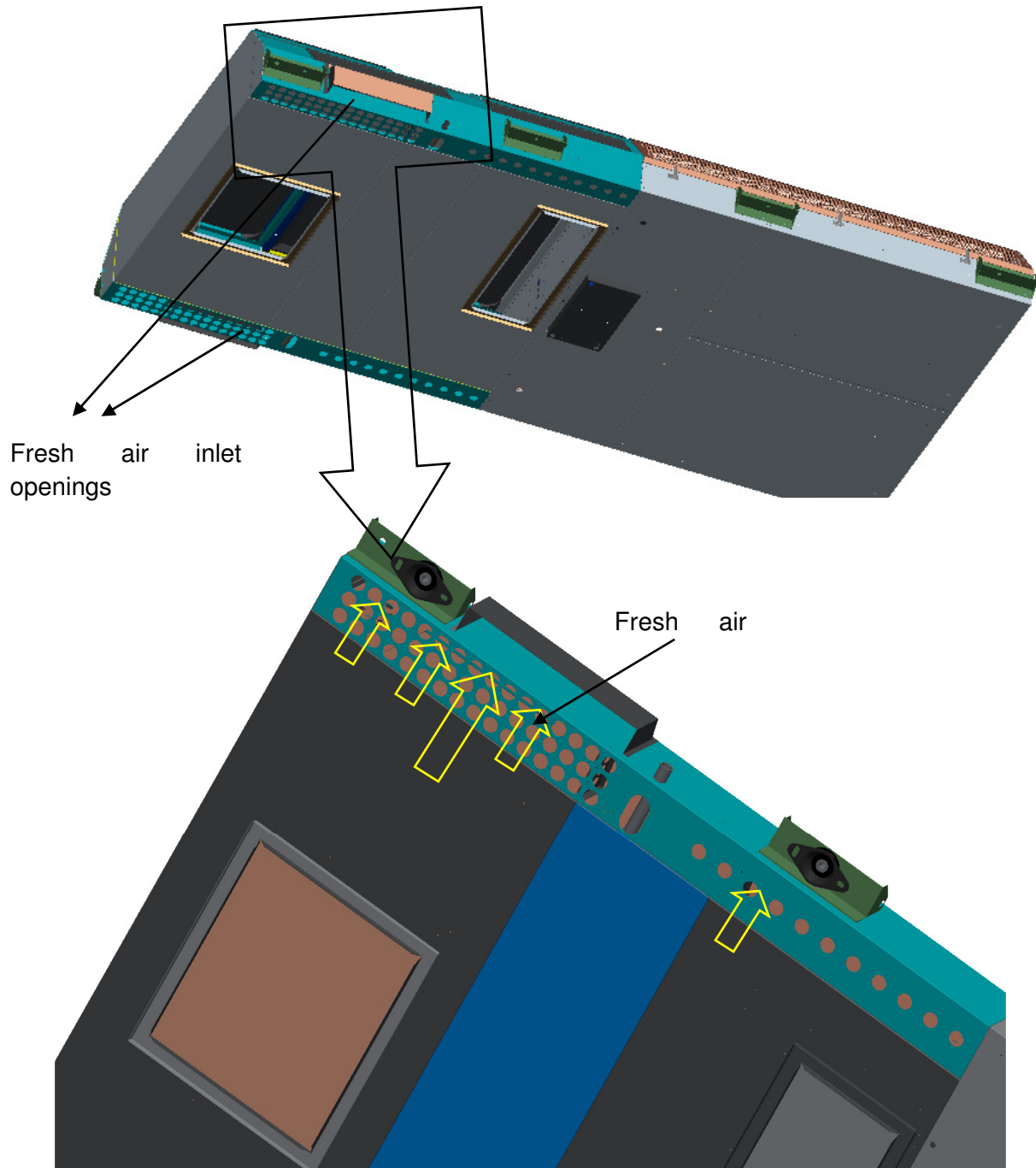



Figure 6: Fresh air inlet locations on car

### 7.3. Test procedure - airflow measurement

Brief test procedure for air flow measurement tests is described below. Sub-contractor shall prepare the detailed test procedure along with data record sheet and submit to BEML for approval before conducting the tests. Airflow rates shall be measure with clean filters under normal ventilation mode

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	21/34

### 7.3.1. Fresh airflow measurement

Test conditions:

1. Only blower fans “on”
2. Keep all saloon doors closed and Gangway openings shall be closed
3. Fresh air dampers opening – AW2 and AW3 conditions
4. Return air dampers open
5. Air filters clean

Test procedure:

Fresh air flow shall be recorded at Fresh air dampers opening at AW2 and AW3 conditions

### 7.3.2. Return airflow measurement

Test conditions:

1. Only blower fans “on” (all other equipment “off”)
2. Keep all saloon doors closed
3. Gangway openings shall be closed
4. Fresh air dampers opening – at AW2 and AW3 conditions
5. Return air dampers open
6. Air filters clean

Test procedure


Return air flow shall be recorded at Fresh air dampers opening at AW2 and AW3 conditions

Flow rate is equal to the product of average flow velocity and cross-sectional area of measurement duct. Flow velocity shall be measured by suitable flow velocity apparatus. Length and width of measurement duct shall be measured by measuring tape.

### 7.3.3. Measurement instruments

Minimum following equipment's shall be required for conducting above tests

1. Hot wire anemometer / Flow hood

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	22/34

## 8. Cooling performance test

Purpose of these tests is to ensure that HVAC performance is as per contract / EN 14750-1 & 2 requirements.

### 8.1. Test conditions

Test Conditions	External Conditions	Internal conditions
Summer	Dry Bulb Temp 36°C 65% RH	Dry Bulb Temp 25°C 60% RH

### 8.2. Test details

These tests shall be conducted inside a Climate Chamber for judging the cooling performances of the HVAC system. Heating and humidifying equipment and all measurement equipment's shall be provided in the car for test purposes. Following tests shall be carried out

- a) Cooling Tests in Summer (36°C & 65%RH ambient condition)
  - 1) Pre-cooling in AW0, with FAD closed, as per EN 14750-2
  - 2) Regulation for AW3, for 1 hour or 3 cycles, as per EN 14750-2
  - 3) Doors open for 30 sec close for 2 min, for 10 cycles, as per EN 14750-2
  - 4) Measurement of Cooling Capacity in Summer, as per ERTS 15.22.2(iii)(b)

### 8.3. Equipment's

Minimum following equipment's shall be required for conducting above tests

- 1. Data acquisition system
- 2. Sensible and latent heat load simulators
- 3. Measurement instruments for Voltage, current, temperature, humidity, etc

### 8.4. Test procedure

Brief test procedure for cooling performance tests is described below. Sub-contractor shall prepare the detailed test procedure and submit to BEML for approval before conducting the tests.

#### 8.4.1. Pre-cooling

Pre-cooling test is performed to determine the time taken by HVACs to bring car interior temperature to set-temperature. Test shall be conducted for summer conditions

- a) Test conditions

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	23/34

1. Before conducting pre-cooling tests, the test car shall be soaked in the specified ambient temperature and RH of the climate chamber with HVACs switched off.
2. Before the start of the pre-cooling test, the interior air and surface temperatures shall be stabilised within  $\pm 1$  K of the exterior air temperature.
3. Feed the set temperature in HVAC system
4. Doors closed
5. Air filters clean
6. Solar load 100%, passenger load AW0 and fresh air dampers shall fully closed
7. Outside air velocity 40 kmph
  - b) Test procedure
    1. Start HVACs.
    2. Record the interior conditions
    3. Record the time required to bring car interior temperature to set-temperature
  - c) Acceptance criteria
    1. Mean interior temp. (Tim)  $\leq 25 \pm 2^\circ \text{C}$  within 30 min
    2. RH  $\leq 60\%$
    3. HVACs should not tri

#### 8.4.2. Regulation test

Regulation test is performed to check stability of temperature achieved in the comfort zone. Test shall be conducted for summer conditions

- a) Test conditions
  1. Feed the set temperature to HVAC
  2. Doors closed
  3. Air filters clean
  4. Solar load 100% & passenger load AW3
  5. Outside air velocity 40 kmph
- b) Test procedure
  1. Keep the HVACs running for 1h or 3 cycles
  2. Record the temperatures, humidity and total energy consumption
- c) Acceptance criteria
  1. Temperature at 1.1m within  $8^\circ \text{C}$  range



	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	24/34

2. Temperature at any vertical to be within 8°C range
3. Tim  $\leq 25 \pm 2$  °C and RH  $\leq 60\%$
4. HVACs should not trip

#### 8.4.3. Doors open close test

Door open-close test is performed to check stability of temperature achieved in the comfort zone with AW3 passenger load. Test shall be conducted for summer conditions

##### a) Test conditions

1. Feed the set temperature to HVAC
2. Air filters clean
3. Doors open/close
4. Solar load 100% & passenger load AW3
5. Outside air velocity 40 kmph

##### b) Test procedure

1. Keep the HVACs running
2. Door open 30 sec – close 2 min on one side of the vehicle, 10 operational cycles
3. Record interior temperatures, humidity

##### c) Acceptance criteria

1. Tim  $\leq 25 \pm 2$  °C and RH  $\leq 60\%$  at the end of each cycle
2. HVACs should not trip


#### 8.4.4. Cooling Capacity

Cooling capacity test is performed to check cooling capacity of HVAC unit. Test shall be conducted for both summer conditions

##### a) Test conditions

1. All HVAC run at full cooling capacity during the full test period
2. Air filters clean
3. Fresh air damper closed
4. Return air damper open
5. Doors closed



	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	25/34


6. Variable heat load
7. Outside air velocity 40 kmph
  - b) Test procedure
    1. Keep the interior condition  $25^{\circ}\text{C}\pm 2^{\circ}\text{C}$ ,  $60\%\pm 5\%\text{RH}$  by adjusting the number of heaters and steam generators.
    2. Monitor supply and return air temp and RH.
    3. After stabilization of parameters, HVACs shall keep running for 2 hours and 9 readings of all relevant temperature, humidity and power consumption values shall be taken at 15-minute intervals
  - c) Acceptance criteria
    1. HVACs should not trip
    2. Cooling capacity  $\geq 120\text{kW}$

## 9. Specific Energy Consumption test

### a. Test details

SEC test shall be conducted under following conditions:

1. Specific Energy Consumption of HVAC system shall be determined by conducting test on one M-car in climatic chamber
2. Round Trip time and run time between stations shall be corresponding to scheduled speed from Dahisar East station to Mandala as per Annexure-C
3. Dwell time for each intermediate station shall be 30 seconds including doors opening and closing. At terminal station, door opening and closing shall be considered twice, one on arrival and second before leaving the terminal. Total Turnaround time at both Dahisar East and Mandala stations including Dwell time at both the stations shall be 6 minutes (i.e. 3 minutes at each terminal station).
4. Test shall be conducted with AW2 loading for starting station to end station and at AW0 loading condition for Turnaround time at both Dahisar East and Mandala stations including Dwell time at both the stations shall be 6 minutes (i.e. 3 minutes at each terminal station).
5. Inside car temperature to be maintained at  $25^{\circ}\text{C}\pm 2^{\circ}\text{C}$  as per standard EN 14750-1, clause No 9.1.1. The car inside temperature before opening of the saloon doors at each station shall be within  $25^{\circ}\text{C}$ .
6. Ambient summer conditions shall be maintained outside the car. Ambient temperature, humidity and air speed of outside car shall be monitored as per EN 14750-2. Energy Consumption test shall be conducted at an air speed of 40 kmph.

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	26/34

7. Door opening and closing as per schedule to and fro run on the route

The energy measured on one car (M Car) in the climatic chamber will be multiplied by six (6) to determine the energy consumption by HVACs of a 6-car train in climatic chamber ( $SEC_{H-CC}$ ). BEML will provide Cable losses between Auxiliary Converter-Inverter and HVAC, Efficiency curve of Auxiliary Converter-Inverter, Cable loss between Auxiliary Converter-Inverter and main transformer and Efficiency curves of Main Transformer during run, turnaround and during dwell time. Energy loss on account of these items shall then be added to the measured value above ( $SEC_{H-CC}$ ) to determine the value of  $SEC_H$ .

The objective of this test is to check if the HVAC system meets the requirements of declared Specific Energy Consumption (SEC) for the HVAC system for to-and-fro run-on scheduled speed from Dahisar East station to Mandala with AW2 passenger load. Brief test procedure for Specific Energy Consumption tests is described below. Sub-contractor shall prepare the detailed test procedure and submit to BEML for approval before conducting the tests.


**b. Test conditions**

1. Climate chamber temperature to be 36 °C and humidity 65%
2. Feed the set temperature to HVAC
3. Air filters clean
4. All lights “on” and equipment load maximum
5. Solar load 100% and passenger load AW2
6. Fresh air damper position AW2
7. Outside car air velocity 40 km/h
8. One side doors to be opened and closed as per route running timings (for to-and-fro run on scheduled speed from Dahisar East station to Mandala)

**c. Test procedure**

1. M car to be soaked in summer ambient condition.
2. All doors to be closed and vestibule opening to be temporarily blocked and sealed.
3. Feed the set temperature to HVAC.
4. HVACs and Data recording to be started.
5. Pre-cooling to be done without any solar, passenger or equipment heat loads. After reaching stabilised conditions, let the HVACs keep running for 1 hour with doors closed.

Note: “Stabilised condition” means that the average interior temperature at 1.1 m (Tim)

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	27/34

remains almost constant within the tolerance limit of  $\pm 2^{\circ}\text{C}$  with respect to the interior temperature setting while the HVACs function under the nominal performance.

6. Add heats of solar load, AW2 passenger load and equipment load. Also switch “on” all the lights. Doors will remain closed.
7. Let the air conditioning system be operated until conditions interior temperatures stabilise. Then the HVACs should be kept running under stabilised condition for another 1 hour.
8. After 1 hour of stabilised operation, the testing for SEC will start. Starting time of the test will be marked and recorded.
9. The doors open/close operations to be sequenced as per the run time schedule specified for round trip of the earmarked section.
10. 6 minutes of turn back operation at last station will be simulated without passenger load.
11. Time of completion of doors open/close cycles for simulated round trip of Dahisar East station to Mandala station and back will be marked (recorded).

#### **d. Data recording**

- a. Energy consumption (kWh) by energy meter (at 100 samples/second rate)
- b. Data recording by data logger


#### **e. Acceptance criteria**

1.  $T_{im} \leq 25 \pm 2^{\circ}\text{C}$  and  $RH \leq 60\%$  under stabilised conditions and before every door opening in the doors open/close cycles for the simulated round-trip run
2. Temperatures at 1.1m from floor to be within  $8^{\circ}\text{C}$  range during the entire test.
3. Temperatures at all three vertical planes to be within  $8^{\circ}\text{C}$  range during the test.
4. HVACs should not trip during the entire test.

## **10. Scope of work**

### **10.1. General**

1. One M-car will be subjected to the climatic chamber tests. BEML will transport one M-car car from BEML unit to the test facility. BEML team along with HVAC supplier representatives will participate in the tests. All tests will be witnessed by customer technical team.
2. All the facilities required for in-house (within sub-contractor premises) movement of car, all material / consumables required for tests, electrical power supply, sensors and measuring instruments, data loggers, heating elements, humidifiers and any material / facility required for testing shall be in sub contractor's scope

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	28/34

3. Manpower required for all activities listed in scope of work shall be in sub contractor's scope.
4. Sub-contractor shall be responsible for conducting all the tests specified in clause no. 7, 8 and 9 of this document.
5. Air flow measurement tests specified at Clause No. 7 shall be carried out before starting climatic chamber tests.
6. Cooling performance tests (pre-cooling, regulation, cooling capacity tests and specific Energy measurement tests) under summer conditions specified at clause no 8 and 9 shall be checked and verified by BEML before calling the customer for witnessing the tests.
7. All tests specified at clause no 7,8 and 9 shall be conducted in presence of customer

## 10.2. Testing


Brief test procedure for each test is described above. The sub-contractor shall prepare the detailed test procedure for all the tests and submit to BEML for approval. Test procedure shall be mutually discussed and agreed upon. Test procedure shall include following as minimum

1. Details of test facility to be used
2. Test schedule
3. All the data required from car builder and HVAC supplier
4. Standards to be followed
5. Test equipment's and sensors specifications
6. Sensor calibration certificates
7. Test methodology
8. Sensor mounting arrangement at all specified locations
9. Heat load simulation details
10. Humidity simulation details
11. Energy consumption calculations
12. Any other details and equipment required

### 10.2.1. Air flow measurement

Air flow measurement test shall include but not limited to following activities

1. Preparation of test plan

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	29/34

2. Air flow measurement ducts shall be prepared by sub-contractor and mounted to specified location.
3. Preparation of car for the test - closing the gangway openings to make it airtight, electrical power connection to HVAC and control system, preparation of test setup
4. Perform all the air flow measurement tests specified in clause no 7 of this document.
5. If the measured values are not meeting the contract requirement, BEML / HVAC supplier will take up the required modification on HVAC unit and air distributing ducts to adjust the air flow parameters. Sub-contractor shall repeat the air flow measurement test after modification

#### **10.2.2. Cooling performance test**


Cooling performance test include but not limited to following activities

1. Preparation of test plan
2. Preparation of car for the test - closing the gangway openings to make it airtight, electrical power connection to HVAC and control system, preparation of test setup, installation of sensors, installation of data logging system, preparation of heat loads & humidifiers and all other aspect related to testing
3. Perform all the cooling performance tests specified in clause no 8 of this document. All tests shall be as per EN 14750.
4. If the measured values are not meeting the contract requirement, BEML / HVAC supplier will take up the required modification on HVAC unit and air distributing ducts to adjust the cooling parameters. Sub-contractor shall repeat the Cooling performance test after modification

#### **10.2.3. Specific Energy Consumption test**

Specific Energy Consumption test shall include but not limited to following activities

1. Preparation of car for the test - preparation of test plan to simulate round trip run, preparation of test setup, installation of sensors& energy measurement instruments, installation of data logging system, preparation of heat loads & humidifiers and all other aspect related to testing
2. Pre cooling the car till stabilized conditions achieved inside saloon
3. Perform the Specific Energy Consumption test specified in clause no 9 of this document. All tests shall be as per EN 14750. The doors open/close operations and climatic chamber air speed to be sequenced as per the run time schedule specified for round trip

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	30/34

#### 10.2.4. Test report


All test reports shall be prepared by the subcontractor and submitted to BEML/DMRC. Reports shall be in English language. The Test reports shall include, but not be limited to, the followings:

1. The reference to the corresponding Test Procedure
2. The date of the test was executed
3. Details of the climatic chamber including size of climatic chamber and available test facilities
4. Details of heaters and humidifiers used (Make, Model, technical specifications sheet from manufacturer, pictures of instrument) along with calibration certificate
5. Details of solar loads, air velocity in climatic chamber
6. Details of test instruments used (Make, Model, technical specifications sheet from manufacturer, pictures of instrument) along with calibration certificate.
7. Details of test conditions, test procedure, heat load calculations, humidity load calculations,
8. Location of heaters, humidifiers, temperature sensors, humidity sensors, sensors in climatic chambers, energy measuring points
9. The test results for each test including a Passed / Failed indication. A sample test data record sheet is given below.

SN	PARAMETER	CRITERIA	ACHIEVED	PASS/FAIL
1.	<b>Basic information</b>			
1.1	Test No.			
1.2	Test conditions			
(i)	Ambient condition			
(ii)	Set-temperature (Tic)			
(iii)	Filters (clean/clogged)			
(iv)	Passenger load (AW2/AW0)			
(v)	F/A dampers (open/close)			
1.3	Date & time of test			
(i)	Date			
(ii)	Start time			

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	31/34

(iii)	End time			
(iv)	Duration (minutes)			
(v)	Did HVACs trip? (Yes/No)			
1.4	Plotted graphs reference			
<b>2.</b>	<b>Heat loads</b>			
2.1	Avg. water boilers & film heaters for passenger (W)			
2.2	Avg. electrical heaters (W)			
2.3	Avg. film heaters for cabinet (W)			
<b>3.</b>	<b>Criteria temp. and humidity</b>			
3.1	Exterior			
(i)	Min. avg. fresh air temp.			
(ii)	Min. avg. fresh air humidity			
(iii)	Min. avg. ext. side wall temp.			
3.2	Interior			
(i)	Max. Tim			
(ii)	Max. humidity			
(iii)	Max. Tim -Tic			
(iv)	Max. vertical temp. gradient			
(v)	Max. horizontal temp. gradient			
(vi)	Min. supply air temp.			
3.3	Max. cubicle temp.			
3.4	Max. cubicle surface temp.			
<b>4.</b>	<b>HVAC performance</b>			
4.1	For AC1-			
(i)	Avg. fresh air temp. (°C)			
(ii)	Avg. fresh air humidity (%)			
(iii)	Avg. return air temp. (°C)			
(iv)	Avg. return air humidity (%)			

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	32/34

(v)	Avg. supply air temp. (°C)			
(vi)	Avg. supply air humidity (%)			
4.2	For AC2-			
(i)	Avg. fresh air temp. (°C)			
(ii)	Avg. fresh air humidity (%)			
(iii)	Avg. return air temp. (°C)			
(iv)	Avg. return air humidity (%)			
(v)	Avg. supply air temp. (°C)			
(vi)	Avg. supply air humidity (%)			
4.3	Energy meter readings			
(i)	Avg. power consumed (kW)			
(ii)	Total energy consumed (kW-h)			

Sub-contractor shall prepare the data record sheet as applicable for individual tests

#### 10. Graphical representation of all test results

- Temperatures and humidity data inside saloon, temperature at fresh air inlet, return air, supply air condenser air inlet & outlet,
- Temperature and humidity data in climatic chamber,
- Power consumption by AC units, blower fans, condenser fans, heaters, humidifiers
- Any other data required by customer

11. Test reports of all tests performed shall be submitted within 2 weeks of test performance to BEML/DMRC for acceptance.

12. BEML will review the test report and offer comments. Sub-contractor shall modify the test report as per BEML comments as required.

#### 10.2.5. Test schedule

Tentative test schedule is tabulated below. Sub-contractor shall prepare the detailed test schedule and submit along with technical proposal. In case the results of any test is not meeting the acceptance criteria, BEML / HVAC supplier will take up the required modification on HVAC unit and test shall be repeated. Hence sub-contractor shall keep few reserve days for repeated tests. Sub-contractor shall indicate the cost per extra days



	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	33/34

in the offer incase the test get extended beyond the schedule submitted by them in the offer.

SN	Test description	Duration	Remarks
1	Car preparation	1 day	Internal tests
2	Air flow	1 day	
3	Car sanitization & Heat load arrangement	Test Agency to confirm	
4	Pre cooling test	1 day	
5	Regulation test		
6	Door open close test	1 day	
7	Measurement of cooling capacity test		
8	Specific energy consumption test	1 day	
9	Additional day	1 day	
10	Air flow	1 day	External tests
11	Pre cooling test	1 day	
12	Regulation test		
13	Door open close test	1 day	
14	Measurement of cooling capacity test		
15	Specific energy consumption test	1 day	
16	Additional day	1 day	

## 11. Annexure

1. Annexure - A: General Arrangement Drawing of M-Car
2. Annexure - B: Declared schedule speed
3. Annexure - C: Submittals Check Sheet

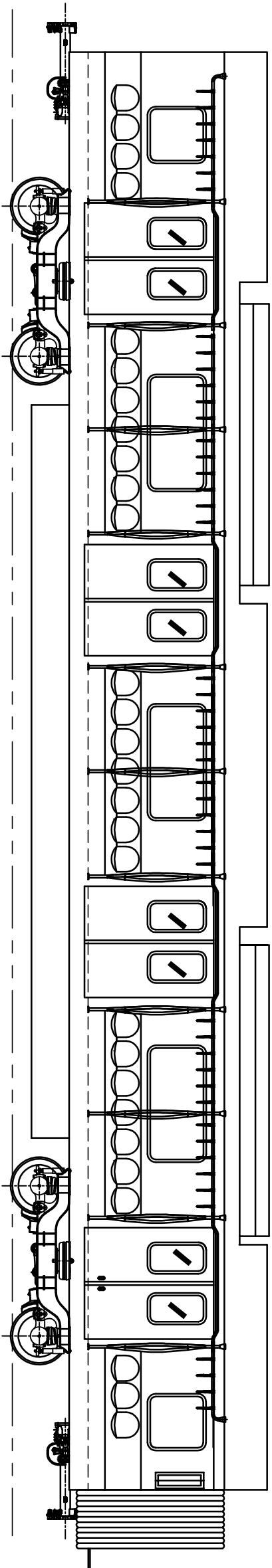
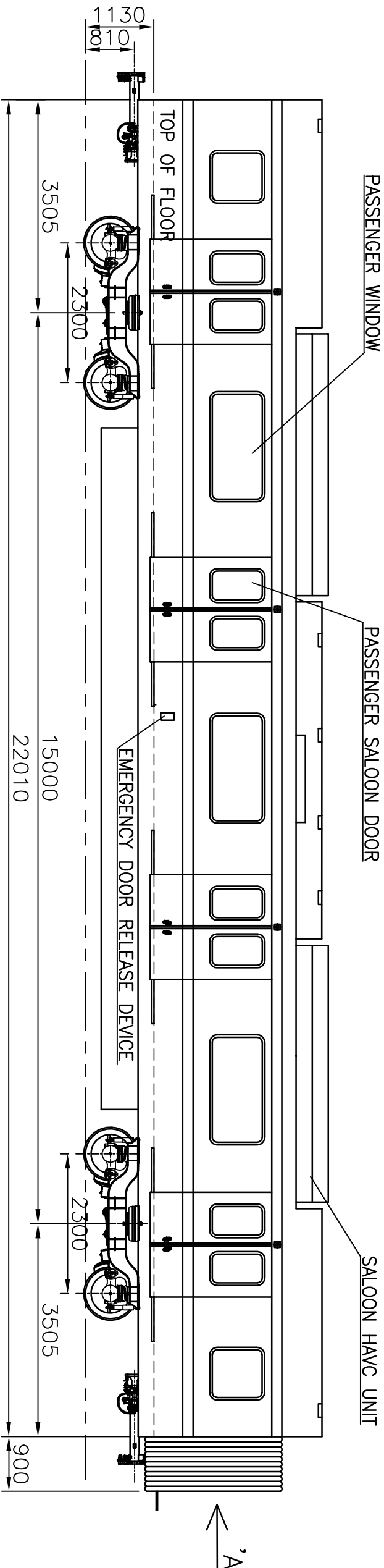
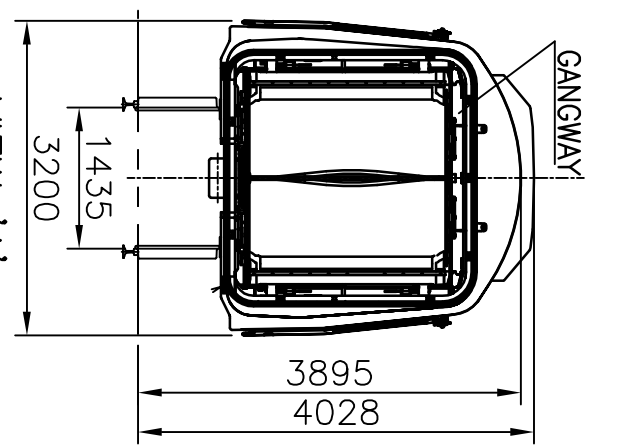
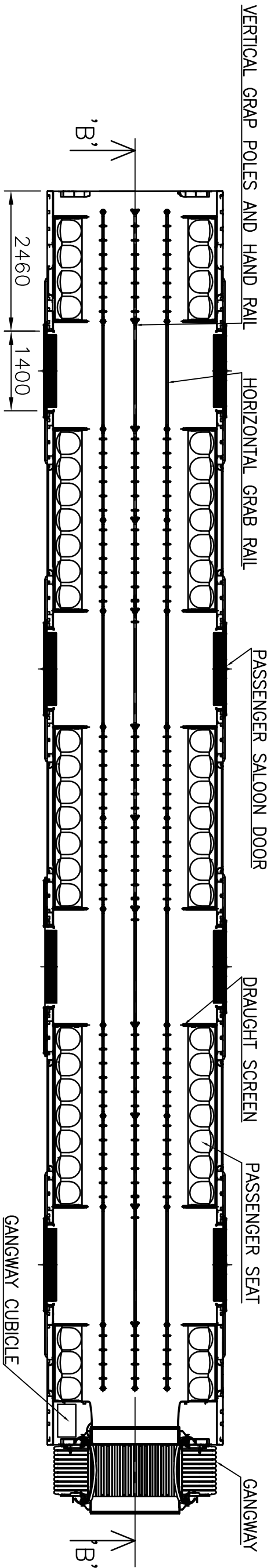
## 12. Submittals with Technical Offer

The subcontractor shall provide as a minimum, the following along with their proposal.

1. Following details about test facility
  - i) Details of the climatic chamber including size of climatic chamber and preparation hall,
  - ii) Available test facilities,
  - iii) Details of instruments like data acquisition system, temperature sensors, humidity sensors
  - iv) Heat load simulation devises

	<b>Procurement Technical Specification for HVAC Vehicle Level Test in Climatic Chamber</b>	Doc. No.	GR/TD/8091
		Date	06.09.2025
		Rev. No.	0
		Page No.	34/34

2. Supporting documents for Pre-Qualification Criteria compliance. (Clause 3)
3. Clause-wise comments against the PTS Doc
4. Brief test procedure
5. Day wise test schedule and total expected test duration
6. Earliest available test slots



PASSENGER CAPACITY	SEATED	56
	STANDEES(8PERSONS/m <sup>2</sup> )	324
	TOTAL	380


## Annexure - B

Declared Schedule Speed (As per conditions at ERTS Cl. No. 3.22.2 & 3.24)							
Operational condition		Route	Distance (km)	Time (Minutes)			Schedule Speed (km/h)
				Run	Stop	Total	
Line 2	All-out mode / AW3 (Healthy)	DAHISAR - MANDALA	41.55	56.95	18.5	75.45	35.1
		MANDALA - DAHISAR	41.55	56.88	18.5	75.38	35.2
		Round trip	83.1	107	43	156.83	33.3

**NOTE:**

- One way DSSP is calculated with a dwell time of 30 seconds (including door opening and closing time) at each station except terminal station.
- Round trip DSSP is calculated with a dwell time of 30 seconds at each station except terminal station and 3 minutes turnaround time (including dwell time) at each terminal station.
- DSSP and Time values provided above are based on the preliminary simulation data. Details to be followed will be provided during testing stage.

## Annexure - C

	<b>TECHNICAL OFFER SUBMITTALS CHECK SHEET</b>	<b>Project MRS1</b>	
<b>Aggregate :</b>	<b>SALOON HVAC SYSTEM- Climatic chamber test</b>	<b>PTS DOC No.: GR/TD/8091</b>	
<b>BEML Enquiry/ RFQ Reference :</b>			
SL.NO.	DETAILS	SUBMITTED	NOT SUBMITTED
1	Details of the climatic chamber including size of climatic chamber and preparation hall, available test facilities, details of instruments and test setup to be used	<input type="checkbox"/>	<input type="checkbox"/>
2	Supporting documents for Pre-Qualification Criteria compliance	<input type="checkbox"/>	<input type="checkbox"/>
3	Details of instruments like data acquisition system, temperature sensors, humidity sensors	<input type="checkbox"/>	<input type="checkbox"/>
4	Clause-wise comments against this PTS Doc.	<input type="checkbox"/>	<input type="checkbox"/>
5	Brief test procedure	<input type="checkbox"/>	<input type="checkbox"/>
6	Tentative test schedule	<input type="checkbox"/>	<input type="checkbox"/>
7	Day wise test schedule and total expected test duration	<input type="checkbox"/>	<input type="checkbox"/>

**Note : Incomplete submissions are liable for Rejection.**

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Signature of the Bidder with Seal