

# Attachment 9: Heating Ventilation and Air Conditioning (HVAC)

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## 1 Introduction

This attachment provides specifications, test methods and limit values for the heating ventilation and air conditioning system as required by the main specification document.

The heating and cooling system should keep the bus saloon at a comfortable temperature throughout the day and year. This specification sets out a controlled test; however the TfL specification prefers that the heating system to work over a wider range of climate conditions to be capable of maintaining the bus saloon temperature to the desired setpoint and distributing this evenly throughout the vehicle. Whilst the heating system must be specified to meet the requirements set out in this specification, TfL may choose to set potentially less onerous requirements in service, particularly as we transition to zero tailpipe emission vehicles and range is an issue.

For full understanding of this Attachment it should be read in conjunction with the New Bus Specification, Section 8.3.

## Scope

This protocol applies to all new buses intended for service under contract to TfL that are passenger vehicles with a maximum mass exceeding 5 tonnes and a capacity exceeding 22 passengers. The passenger vehicles will be capable of carrying seated but unrestrained occupants and standing occupants. Such vehicles are categorised the Consolidated Resolution on the Construction of Vehicles (R.E.3) as M<sub>3</sub>; Class I.

## Purpose

The objective of this testing is to validate the saloon heating performance of all vehicles and the cooling performance of the upper saloon air cooling systems for double deck vehicles. This test is carried out simultaneously with a test to validate the cooling performance in the driver's cab.

The bus for testing provided either by the OEM or TfL from an operator shall be to the London specification and fitted with all equipment necessary for operation in London.

## Normative references

The following normative documents, in whole or in part, are referenced in this document and are indispensable for the correct application of this test and assessment protocol. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- London Bus Service Limited New Bus Specification Section 8.3

## Definitions

For the purpose of this Protocol:

- **AA: Approval Authority** – The Approval Authority is the body within TfL that certifies that a bus is approved for use in the TfL fleet and assigns its score under the bus safety standard for use in procurement processes
- **TS: Test Service** – The organisation undertaking the testing and certifying the results to the Approval Authority
- **OEM: Original Equipment Manufacturer** – The company responsible for the manufacture of a completed bus, delivered to a bus operator
- **Test Service:** The organisation undertaking the testing and certifying the results to the Approval Authority.
- **VUT: Vehicle Under Test** - means a vehicle that is being tested to this protocol.

## Test Conditions

### General Requirements

The Test Service is designated by TfL to ensure comparative standards and quality of testing is achieved.

OEMs and / or bus operator are permitted to be present during testing but are not permitted to interfere with or adjust the bus setting without full agreement of the Test Service and TfL. All adjustments will be noted by the Test Service.

Prior to commencement of testing, the OEM or HVAC system manufacturer shall provide the Test Service with evidence that the Driver's Heating and Air-conditioning system is completely separate from that of the Saloon. This includes evidence that the fresh air intake for the Driver's Heating and Air-conditioning system is external fresh air only.

### Instrumentation

The Test Service shall temporarily fit four thermocouples to single deck vehicles or seven to double deck vehicles, three on the lower deck, and three on the upper deck and one in the driver's cab. All thermocouples shall be positioned along the longitudinal centreline of the vehicle.

Thermocouples on the lower deck are to be fitted in the front, middle and rear centre line, 1.2 metres above floor level. The forward / rear position of the four thermocouples should be as follows:

- a) Thermocouple 1 (front) should be located at a position 1.0 m from the front windscreen.
- b) Thermocouple 2 (middle) should be located at the longitudinal centre of the vehicle
- c) Thermocouple 3 (rear) should be located at a position 1.0 m from the rearmost seating row.
- d) Thermocouple 4 will be located 1.2 metres above the floor for the driver's feet, on the centreline of the driver's seat base when the driver's seat is set to a mid-position on its forward / rearward slider.

The upper deck thermocouples will be located 1.2 metres above the floor of the upper saloon, along the longitudinal centreline of the bus (mid-gangway). The forward / rearward position of the three thermocouples should be as follows;

- a) Thermocouple 1 (front) should be located at a position aligning with the middle of the seat base of a seat at the very front of the upper saloon on the nearside.
- b) Thermocouple 2 (middle) should be located at a position aligning with the middle of the seat base of a seat on the 7th row (from front) of the upper saloon on the nearside.
- c) Thermocouple 3 (rear) should be located at a position aligning with the middle of the seat base of a seat at the very back of the upper saloon on the nearside.

The thermocouples are connected to a data logger capable of recording the temperature at each point at a maximum of 1 minute intervals. The results from the data logger shall be the only results utilised to evaluate the test procedure.

## Ventilation Test

The OEM must demonstrate that the HVAC system is capable of providing 10L/s of fresh air ventilation to all legally permitted passengers. HOW???

1. CO2 supply and measurement of control?
2. Measurement of air flows
3. Pressurisation of vehicle?

## Heating Test

The heating test is to be undertaken in a climatic chamber with the temperature set at 0°C. In order to simulate the heating effect from passenger loading, 14 x 130 W heaters are to evenly distributed across the front, middle and rear seats (to include upper deck where applicable by applying 7 to the lower deck and 7 to the upper deck).

## Heating (non-zero emission buses)

The heating system shall be capable of raising the temperature from 0°C to 15°C in 45 minutes, rising to and maintaining 17°C within 90 minutes. The test should include both doors opening for 10 seconds at a time to simulate 15 bus stops evenly distributed in the first 25 minutes and 13 evenly distributed in the next 20 minutes. Maximum air vents velocity of 5 m/s. Ventilation requirements of 10L/s X the maximum number of passengers permitted of fresh air should be incorporated as part of this test.

## Heating (zero emission buses)

Zero emission buses are required to have a pre-heat function. Testing shall follow the timings set out in Figure 9\_1 below. The vehicle is to be pre-heated from zero to 15°C ( $T_2$ ) and maintained at 15°C for 1 hour ( $T_3$ ). The zero emission bus should maintain a temperature of 15°C whilst doors are cycled ( $T_4$ ). A  $\pm 1^\circ\text{C}$  degree test tolerance is to be applied to all temperatures. A current clamp will be connected to the HVAC unit to calculate power consumption. The test should include the opening of both doors for 10 seconds every two minutes for one hour. The maximum air vent velocity is 5 m/s. Ventilation requirements of 10L/s X the maximum number of passengers permitted of fresh air should be incorporated as part of this test.

The testing authority will produce a graph of the test showing the temperature recorded by each individual thermocouple – temperature against time. Ambient chamber temperature will also be included on each graph. A spreadsheet showing the results from each thermocouple and ambient chamber temperature will accompany the graphs.

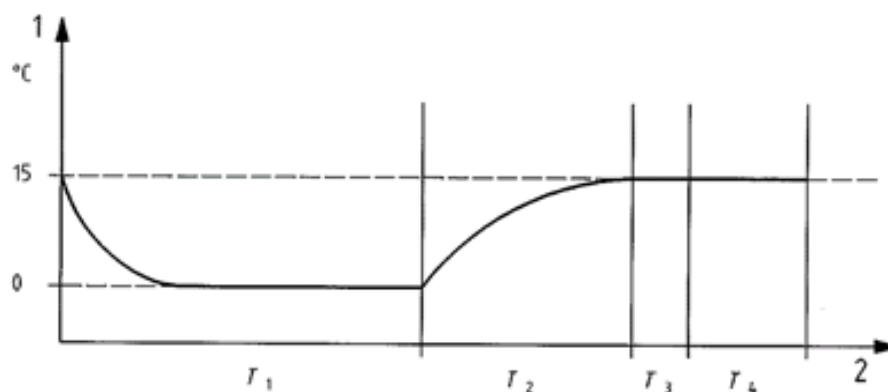


Figure 9\_1 – Zero emission bus heating test time profile

## Key

1 – Ambient temperature ( $^\circ\text{C}$ )

2 – Time (T, hr)

$T_1$  – cooling time, >1hr from the point at which all internal temperatures show  $0^\circ\text{C}$

T<sub>2</sub> – is the heating time

T<sub>3</sub> – is the stabilising time, 1hr from the point at which all internal temperatures show 15°C

T<sub>4</sub> – is the measuring time, 1hr

## Drivers Cab Air conditioning

### Cab / Drivers Screen Demisting

Control should be by manual driver selection, capable of independent operation at all times and raising the temperature from 0°C to 20°C within 25 minutes. The test should include both doors opening for 10 seconds at a time to simulate 15 bus stops in the first 25 minutes and 13 in the next 20 minutes. The maximum air vent velocity is 5 m/s. For zero emission buses, this test can be undertaken during T<sub>2</sub> in Figure 9\_1 above, provided that the internal temperature of the bus is returned to 15°C immediately after the completion of the test, prior to T<sub>3</sub> beginning.

### Drivers Cab Air conditioning

Drivers cab air conditioning must be manual driver selection, capable of independent operation at all times and capable of reducing the temperature from 35°C to 25°C within 25 minutes. Test should include the both doors opening for 10 seconds at a time to simulate 15 bus stops in the first 25 minutes. The ambient temperature in the test chamber should be 35°C with a tolerance of 1°C.

If the drivers cab air conditioning is on, the air-cooling may function on a reduced setting to balance the cooling system. It must maintain capability of reducing the temperature from 30°C to 25°C within 20 minutes. Test should include both doors opening for 10 seconds at a time to simulate 15 bus stops in the first 25 minutes. The ambient temperature in the test chamber should be 30°C with a tolerance of 1°C. Ventilation requirements of 10L/s X the maximum number of passengers permitted of fresh air should be incorporated as part of this test.

### Air Cooling

Air cooling requirements apply to all vehicle types, including both decks where applicable. If Driver's cab air conditioning is off, air-cooling will function independently on its automatic temperature settings. Air cooling should control the vehicle saloon temperature to the requirements listed in the ambient vs saloon target temperature profile. A maximum cooling capacity capable of a reduction of 5°C is required when interior saloon temperature is 30°C over a 30 minute pull down test as described below. Ventilation requirements of 10L/s X the maximum number of passengers permitted of fresh air should be incorporated as part of this test.

All bus models will be tested in a temperature controlled chamber with an ambient temperature of 30°C and must achieve the pull down procedure shown below to validate settings and efficiencies.

In order to simulate the heating effect from passenger loading, 14 x 130 W heaters are to evenly distributed across the front, middle and rear seats by applying 7 to the lower deck and 7 to the upper deck.

The bus will be put in a closed climate control chamber set at a temperature controlled to hold 30°C ( $\pm 1^\circ\text{C}$ ). It is permissible to open the vehicle windows, doors or roof vents as considered necessary to speed up the soak time.

The soak condition is considered to be met when all three thermocouples record a steady state of 30°C ( $\pm 1^\circ\text{C}$ ) for a duration of 15 minutes after a minimum soak time of 1 hour. A minimum of 15 minutes of data should be recorded to demonstrate a stable soaked temperature. During this time if the temperature of any sensor drops below 30°C ( $\pm 1^\circ\text{C}$ ) the 15 minutes should be reset.

The bus should be powered on when the following preparations checks have been completed:

- a) All windows, roof vents and doors are closed
- b) The thermocouples are correctly positioned
- c) The data recorder is running.

When the bus is switched on the upper saloon air cooling should come on automatically as per the defined temperature control logic. The driver's cab air conditioning should be turned on, set to maximum capacity, maximum fan speed and if there is a control to direct the airflow it should be directed to the driver position rather than the windscreen. If possible all dashboard vents, floor vents or ceiling vents in the driver's cab should be directed towards the sensor position as far as practical. If the cab air conditioning has a damper flap to select between fresh air and recirculated air then the recirculated air function should be selected. The drivers windscreen demist system should be turned off and any associated vents closed.

For the complete duration of the test, the bus should be powered on and should be run at the bus engine idle speed, where applicable. If any recirculation air supply is optional or variable the system should be set to maximum fresh air supply. Any demisting or other system that provides air to the upper saloon must be isolated to not interfere with the test results.

The data logger timer should then start.

The test will measure the temperature drop delivered by the system over a 30 minute period on a minute by minute basis.

All saloon thermocouples should achieve the target reduction temperature of 25°C within the first 20 minute period and be capable of holding the temperature below the 25°C for the remaining 10 minutes. Averaging the results is not acceptable over time or between the sensors.

The testing authority will produce a graph of the Pull Down showing the temperature recorded by each individual thermocouple – temperature against time. Ambient chamber temperature will also be included on each graph. A spreadsheet showing the results from each thermocouple and ambient chamber temperature will accompany the graphs.