SAE INTERNATIONAL

SURFACE VEHICLE RECOMMENDED PRACTICE

J2233™ DEC2024

Issued 1995-12
Revised 2011-02
Reaffirmed 2024-12

Superseding J2233 FEB2011

(R) Bus Body Heating System Test

RATIONALE

The current SAE J2233 test procedure provides two separate means of heating the coolant during testing, but these two approaches can provide very different results. If the engine is used to heat the coolant, the engine rpm and engine load criteria are neither clear nor consistent.

There are two distinct reasons to test a heating system:

a. To compare two or more alternative heating systems during the design process.

b. To compare the heater(s) performance of a specific vehicle and engine configuration to an established standard.

This revision recognizes these differences in the reasons for testing, and provides specific test conditions depending on the test intent.

The changes in this revision are made bring this standard to be in compliance for recently updated SAE J381 and SAE J1612 test procedures and performance requirements as well as Mid-Size Bus Heating System Performance Test procedure. Updated the test report template to match the procedure.

SAE J2233 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

This SAE Recommended Practice establishes uniform cold weather test procedures and performance requirements for engine coolant type heating systems of bus that are all vehicles designed to transport 10 or more passengers. The intent is to provide a test that will ensure acceptable comfort for bus occupants. It is limited to a test that can be conducted on uniform test equipment in commercially available laboratory facilities. Required test equipment, facilities, and definitions are included.

There are two options for producing hot coolant in this recommended practice. Testing using these two approaches on the same vehicle will not necessarily provide identical results. Many vehicle models are offered with optional engines, and each engine has varying coolant temperatures and flow rates. If the test is being conducted to compare the performance of one heater design to another heater design, then the external coolant source approach (Test A) will yield the most comparable results. If the test is being conducted to validate the heater installation on a specific vehicle model with a specific engine, then using the engine to heat the coolant (Test B) will be more appropriate.

Defrosting and defogging procedures and requirements are established by SAE J381 which is hereby included by reference.

This document will be reviewed and revised as required with advancements in technology and changes in environmental laws.

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https://www.sae.org/standards/content/J2233_202412/

1.1 Purpose

This procedure is designed to provide bus manufacturers with a cost-effective, standardized test methods to provide relative approximations of cold weather interior temperatures.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J381 Windshield Defrosting Systems Test Procedure and Performance Requirements - Trucks, Buses, and Multipurpose Vehicles

SAE J638 Motor Vehicle Heater Test Procedure

SAE J1612 Cab Heating Systems Test Procedure and Performance Requirements - Trucks, and Multipurpose Vehicles

2.1.2 School Bus Manufacturer's Technical Committee, Supplier Council, National Association for Pupil Transportation Publication

Available from NAPT, 1840 Western Avenue, Albany, NY 12203, Tel: 518 452-3611, www.napt.org.

School Bus Manufacturer's Technical Committee No. 001

3. DEFINITIONS

3.1 HEAT EXCHANGER SYSTEM

Means will exist for providing heating and windshield defrosting, and defogging, capability in a bus. The system shall consist of an integral assembly, or assemblies, having a core assembly or assemblies, blower(s), fan(s), and necessary duct systems and controls to provide heating, defrosting, and defogging functions. If the bus body structure makes up some portion of the duct system, this structure or a simulation of this structure must be included as part of the system.

3.2 HEAT EXCHANGER CORE ASSEMBLY

The core shall consist of a liquid-to-air heat transfer surface(s), liquid inlet, and discharge tubes or pipes.

3.3 HEAT EXCHANGER-DEFROSTER BLOWER

An air-moving device(s) compatible with the energies available on the bus body.

3.4 COOLANT

Liquid used for heat transfer composed of 50% ethylene glycol/50% water or other liquids specified by vehicle manufacturer for use in the heat transfer system.

3.5 HEAT EXCHANGER-DEFROSTER DUCT SYSTEM

Passages that conduct inlet and discharge air throughout the heat exchanger system. The discharge outlet louvers shall be included as part of the system.

3.6 HEATER TEST VEHICLE

The completed bus as designed by the manufacturer with, or without, a chassis, engine and drivetrain, including the defined heat exchanger system. If the vehicle is without a chassis, it shall be placed on the test site in such a way that the finished floor of the body is at a height, from the test site floor, equal to its installed height when on a chassis, and all holes and other openings normally filled when installed on a chassis will be plugged.

3.7 HEAT TRANSFER

The transfer of heat from liquid to air is directly proportional to the difference between the temperatures of the liquid and air entering the transfer system, for a given rate of liquid and air flow measured in kilograms (pounds) per minute, and that heat removed from liquid is equal to heat given to air.

3.8 HIGH IDLE

A feature provided by the vehicle OEM to run the engine above the normal idling speed, typically used to provide additional power during operation of power take-off equipment or for warming up the engine.

4. TEST EQUIPMENT

4.1 Test Site

A suitable location (cold environmental chamber) sufficiently large to contain the basic bus or basic bus body with provision for circulating air and capable of maintaining an average ambient temperature not to exceed −3.9 °C (25 °F) for the duration of the test period with or without vehicle engine on. The maximum air velocity across the vehicle shall be 8 km/h (5 mph).

4.2 Coolant Source

4.2.1 Test A

4.2.1.1 Independent Coolant Supply

A closed loop system, independent of any engine/drivetrain system, capable of delivering coolant (as defined in 3.4) at 65.5 °C ± 1.7 °C (150 °F ± 5 °F) above the test site ambient temperature, and 22.7 kg (50 lb) per minute flow. The coolant supply device shall be equipped with an outlet diverter valve to circulate coolant within the device during its warm-up period. The valve will then permit switching the coolant supply to the bus heat exchanger system at the start of the test.

4.2.2 Test B

Engine running at 1500 rpm ± 50 rpm in neutral gear or the high idle RPM set by the vehicle OEM, whichever is higher. An auxiliary means for preheating the engine is permissible to provide easier engine starting. Engine speed shall be maintained with no load (normal engine parasitic loads only) throughout the test. That flow resulting from engine operation as prescribed in 4.2.1.

4.3 Power Equipment Supply

A source capable of providing the required test voltage and current for the heater system.

4.4 Heat Exchange Units

The heat exchangers used shall be tested, and rated, as required by the procedures established by either SAE J638, or the School Bus Manufacturer's Technical Committee No. 001. The test rating of each unit, the method of determining its rating, and the quantity used, shall be recorded.

4.5 Thermometers, thermocouples, RTD, or other temperature measuring device with an accuracy of ±0.5 °C.

4.6 Stopwatch or other timing device.

4.7 Auxiliary power supply for blower motor.

4.8 Anemometer to measure air velocity (with a measuring accuracy of 2% of observed values).

4.9 Instrument for measuring voltage and amperage. It could be a voltmeter and a shunt type ammeter to read the voltage and current of the complete system. The ammeter and voltmeter shall be capable of an accuracy of ±1% of the reading.

4.10 Flow meter or other device to measure coolant flow with accuracy of ±2% of observed value.

4.11 VEC Temperature

Average chamber temperature: –18 °C ± 2 °C (0 °F ± 4 °F).

4.12 VEC Air Velocity

The maximum wind velocity shall not exceed 8 km/h (5 mph).

4.13 Heating and Defrosting System Controls

Set heater and defroster controls to maximum temperature and maximum fan settings, or the best combination to provide optimum heating performance.

5. INSTRUMENTATION

5.1 Air Temperature

5.1.1 Interior

Recommended air temperature measuring instrumentation are thermocouples or RTDs. Thermometers are not recommended because of their slow response to rapid temperature changes.

Measuring instrumentation shall be placed on alternate seat rows beginning 990 mm ± 130 mm (39 in ± 5 in) from the rear of the body, at 910 mm ± 50 mm (36 in ± 2 in) from the finished floor of the body.

Also, the longitudinal centerline of the body should be instrumented. Four thermocouples shall be placed in the interior of the vehicle:

- Test point 1 is located in the driver's area at a height of 760 mm ± 50 mm (30 in ± 2 in) inches above the center of the seat cushion at a distance of 150 mm ± 25 mm (6 in ± 1 in) in front of the headrest/seatback to approximate the driver's head location;

- Test point 2 is located a distance of 1220 mm (4 ft) rearward of the front windshield;

- Test point 3 is located at the midpoint of the body, and
- Test point 4 is located a distance of 1220 mm (4 ft) forward of the rear wall.

Except for Test point 1, all thermocouples shall be located 1220 mm (4 ft) above the floor at the longitudinal centerline of the bus.

Above indicated thermocouples for measuring vehicle interior temperatures will be used to determine heating system performance. Additional temperature measurements may be recorded at the discretion of the testing party to achieve further information related to the vehicle heating system. Recommended measurements include air temperature into the heater (fresh air and re-circulated air measured separately) and air temperature out of the main heater unit.

5.1.2 Vehicle Exterior Ambient Temperature

The vehicle test chamber temperature should be measured by four exterior thermocouples. Two thermocouples are to be placed along the centerline of the vehicle, half way between the ground and the highest point of the vehicle (excluding bolt on items), 915 mm (3 ft) forward of the front of the vehicle and 915 mm (3 ft) away from the back of the vehicle. Left and right side vehicle ambient should be measured at a point 150 mm (6 in) away from left side and right side of the vehicle. If a vehicle does not have mirrors, take measurement 450 mm (18 in) outward from left and right side window.

Optional measuring devices shall be placed at each of the following locations:

a. Mid-line of body forward of windshield

b. Mid-line of body aft of the rear surface

c. Mid-way between the axles on the right and left sides of the body

5.1.3 Driver

Measuring devices shall be placed at appropriate locations to measure ankle, knee, and breath level temperatures with the driver's seat in rearmost, lowest, and body centermost position.

a. Ankle Level - Place a minimum of four electrically averaged temperature measuring devices at the corners of a 25 x 250 mm (10 x 10 in) square area, the rearmost edge of which begins 200 mm (8 in) forward of the front edge of, and centered on, the seat cushion. The devices shall be located 75 mm ± 13 mm (3 in ± 0.5 in) above the floor surface.

b. Knee Level - Place a minimum of one measuring device at the height of the front top edge of the seat cushion and on the centerline of the seat. This measurement shall be 100 mm ± 25 mm (4 in ± 1 in) forward of the extreme front edge of the seat cushion and parallel to the floor.

c. Breath Level - Place a minimum of one measuring device 1070 mm ± 50 mm (42 in ± 2 in) above the floor and 250 mm ± 50 mm (10 in ± 2 in) forward of the seat back. The forward dimension shall be measured from the extreme upper edge of the seat back and parallel to the floor.

d. Additional temperature measuring devices, if used, shall be documented as to their type, quantity, and geometric location. The measurements obtained from these devices shall be included in the final report as additional results and not combined with the specific locations described in paragraphs a through b.

5.1.4 (Optional) Heat Exchanger Inlet, Outlet, and Defrost Temperatures

Additional temperature measurements may be recorded at the discretion of the testing party to achieve further information related to the vehicle heating system. Recommended measurements include air temperature into the heater (fresh air and re-circulated air measured separately) and air temperature out of the main heater unit. These sensors shall be placed no closer than 5.1 cm (2.0 in) from the face of any heater core, to prevent any incidence of radiant heat transfer. Outlet sensors shall be distributed throughout the outlet airstream(s) 2.5 cm ± 0.6 cm (1.0 in ± 0.25 in) from the outlet aperture(s) of the unit heater.

The temperature of the defrost air shall be measured at a point in the defroster outlet(s) that is in the main air flow and which is at least 25.4 mm (1 in) below (upstream of) the plane of the defroster outlet opening. At least one temperature measurement shall be made in each outlet unit. The interior surface temperature(s) of the windshield shall be measured at a point located on the vertical and horizontal centerline(s) of the windshield.

5.1.5 (Optional) Entrance Area Temperature

The temperature of the vehicle entrance area shall be measured by two sets of three each electrically averaged temperature measuring devices. One set of three devices shall be placed 25.4 mm (1 in) above the lowest tread of the entrance step, equally spaced on the longitudinal centerline of the tread. The second set of devices shall be placed on the next horizontal surface above the lowest entrance step, 102 mm (4 in) from the outboard edge of that surface, spaced identically to the first set of sensors, and placed parallel with the outboard edge of the surface being measured.

5.2 Coolant Temperature

The temperature of the engine coolant shall be measured as near to the inlet and outlets of the heater core as possible, but not farther than 6 in from the heater inlet and outlet tubes. For those systems using more than one heater, it shall be measured at the inlet of the heater unit getting the first coolant flow, and the outlet of the heater unit getting the last coolant flow with an immersion thermocouple or RTD device.

5.3 Coolant Flow

The quantity of coolant flowing shall be measured by means of a calibrated flow meter or weighing tank.

5.4 (Optional) Coolant Pressure

The coolant differential pressure shall be measured by suitable connection as close as possible to the inlet and outlet of the heat exchanger/defrosting system. Pressure may be read as inlet and outlet pressure and the differential calculated, or read directly as PSID. Pressure readings shall be made with the use of gauges, manometers, or transducers capable of reading within ±689.5 Pa (±0.1 psi), accurate to ±0.5% of full scale.

6. TEST PROCEDURES

Install the heater test vehicle on the test site. Instrumentation is required to obtain the following readings:

a. Vehicle interior (5.1.1)

b. Inlet coolant temperature, at entrance to the heat exchanger (if multiple heat exchangers in parallel or series, then the first heat exchanger) (5.2)

c. Discharge coolant temperature, at exit from the heat exchanger (if multiple heat exchangers in parallel or series, then the last heat exchanger) (5.2)

d. Voltage and current at main bus bar connection of driver's control panel

e. Ambient temperature (5.1.2)

f. Rate of coolant flow (5.3)

g. Coolant flow pressure (5.4)

h. Elapsed time (stop watch)

i. Driver's station temperatures (5.1.3)

j. (Optional) Heat exchanger inlet and outlet temperatures (5.1.4)

k. (Optional) Defrost air temperature (5.1.4)

l. (Optional) Entrance area temperature (5.1.5)

The vehicle shall stand inoperative at the specified test temperature to soak for a period of not less than 10 h. Vehicle hood, doors, and windows should be open during soak time.

NOTE: If instrumentation is available to assure that on average the cab and HVAC system with ductwork are stabilized at the test temperature, a shorter soak time may be used.

6.1 The recorded vehicle interior temperature should not exceed –17.8 °C ± 1.5 °C (0 °F ± 3 °F).

6.2 Test A

The coolant temperature as measured by the inlet and outlet coolant temperature measuring devices at the test site temperature should be within +3 °C / –0 °C (+5 °F / –0 °F) of required coolant temperature (e.g., if required temperature is 65 °C, then temperature to be maintained at 65 °C + 3 °C/–0 °C (150 °F + 5 °F/–0 °F) for the entire test period).

6.3 Test B

To be at 65 °C ± 3 °C (150 °F ± 5 °F) at the start of the test, or the maximum temperature that the engine can produce at the test conditions if it cannot reach this value. Coolant temperature after the start of the test is to be a function of the engine temperature control characteristics at the test conditions.

6.4 Test A

Warm up the coolant device to the test temperature immediately prior to the start of the test. Use the coolant supply outlet diverter valve to prevent heated coolant from entering the bus heating system prior to the start of the test. At this time, set the heater controls and all fan controls at maximum, close all doors. A maximum of two windows may be left open a total of 25 mm (1 in) each. A maximum of two occupants may be in the body during the test period. Record all instrumentation readings at least 1 min intervals for a period of 1 h. Recording time shall begin with the initial introduction of heated coolant from the independent coolant supply. The electrical system shall be operated at a maximum of 115% of nominal system voltage ±0.2 V, for example: 13.8 VDC ± 0.2 V for a 12 VDC system, and the heat exchanger system shall be wired with the normal vehicle wiring.

6.5 Optional

Additional flow rates and/or coolant temperatures may also be used to generate supplementary data. Test procedures described in Section 6 shall be repeated for each additional flow rate and/or coolant temperature change.

7. PERFORMANCE CRITERIA

The heating and defrosting system shall have sufficient capacity to raise the average bus temperature: from: -18 °C (0 °F) to: +20 °C (68 °F) within 30 min.

At the end of the test, the temperature at driver head shall not exceed the temperature at the feet.

The duration of the test shall be measured until the lesser of 30 min from engine or supplemental heater startup occurs or until such time as the average temperature of all thermocouples is 68 °F or more, including a maximum range of ±3 °F of the average for all internal thermocouple temperatures. *If temperatures of all thermocouples are within the specified range of 68 °F ± 3 °F or above, the average temperature statement will not apply*. Explanations of this italiced issue are in Table 1.

TABLE 1

T1	T2	T3	T4	Average	Pass/Fail	Comments
68	70	65	66	67.5	Pass	All TC's within 68 °F ± 3 °F
68	66	71	73	69.5	Fail w/o italiced statement	73 °F(T2) – 69.5 °F(Avg) = 3.5 °F
68	69	71	64	68.0	Fail with and w/o underlined statement	64 °F(T4) is below specified range of 68 °F ± 3 °F

The heater and the defroster may be used in any combination that provides optimum heating performance.

8. COMPUTATIONS

8.1 Chart and Computations - Metric Units

Data shall be recorded on the chart in Figures 1A and 1B or equivalent. Temperature data shall be recorded at the actual temperatures occurring at the time of testing. Air temperature data shall then be adjusted to a –18 °C base prior to the construction of graphs. This data reduction shall be directly proportional to the difference between the actual ambient temperature, at time of test, and –18 °C, i.e., actual ambient of –7.8 °C shall result in a reduction of all air temperatures by 10.2 °C, actual ambient temperature of –22.2 °C shall result in an increase of all air temperatures by 4.2 °C. Temperature data shall be presented in graph form as well as tabular form. One graph shall be constructed for the body interior air temperatures (5.1.1) wherein the recording intervals shall be the X-axis and °C the Y-axis. A separate graph shall be constructed for the driver's temperatures (5.1.3) using the same units for the axes. Optional temperature data (5.1.4, 5.1.5) may be similarly graphed separate from the interior data.

Description of Unit

Purpose of Test

Date Location Observers

Readings/Calculations	5	10	15	20	25	30	35	40	45	50	55	60
Water												
Flow - kg/min												
Flow - kg/min												
Flow - kg/min												
Flow - kg/min												
Air Temperature												
T1 - rear - °C												
T2 - °C												
T3 - °C												
T4 - °C												
T5 - °C												
T6 - front - °C												
T7 - ambient - °C												
T8 - Driver Ankle - °C												
T9 - Driver Knee - °C												
T10 - Driver Breath - °C												
Electrical System												
Volts												
Amps												

FIGURE 1A - DATA CHART 1

Readings/Calculations	5	10	15	20	25	30	35	40	45	50	55	60
T11 - Windshield CL Left - °C												
T12 - Windshield CL Right - °C												
T13 - Defrost Outlet Left - °C												
T14 - Defrost Outlet Right - °C												
T15 - Heater - Inlet °C												
T15 - Heater - Outlet °C												
T16 - Heater - Inlet °C												
T16 - Heater - Outlet °C												
T17 - Heater - Inlet °C												
T17 - Heater - Outlet °C												
T18 - Heater - Inlet °C												
T18 - Heater - Outlet °C												
T19 - 1st Entrance Step												
T20 - 2nd Entrance Step												
Heat Transfer - J/h - coolant												

FIGURE 1B - DATA CHART 1 (CONTINUED)

8.1.1 Optional Computations J/h Coolant

a. Flow of Coolant (Ww) - kg/min - measured to ±2%

b. Temperature of Coolant into System (T-in) - °C - measured

c. Temperature of Coolant out of System (T-out) - °C - measured

d. Heat Removed from Coolant (Qw) - J/h - calculated

Qw = CpWw(T-in - T-out) x (60)
Cp = Specific Heat of Coolant—Given as (0.85 x 4187 J)/(kg/c)
Ww = No. 1
T-in = No. 2
T-out = No. 3

8.2 Chart and Computations - Customary Units

Data shall be recorded on the chart in Figures 2A and 2B or equivalent. Temperature data shall be recorded at the actual temperatures occurring at the time of testing. Air temperature data shall then be adjusted to a 0 °F base prior to the construction of graphs. This data reduction shall be directly proportional to the difference between the actual ambient temperature, at time of test, and 0 °F, i.e., actual ambient of 18 °F shall result in a reduction of all air temperatures by 18 °F, actual ambient temperature of –8 °F shall result in an increase of all air temperatures by 8 °F. Temperature data shall be presented in graph form as well as tabular form. One graph shall be constructed for the body interior air temperatures (5.1.1) wherein the recording intervals shall be the X-axis and °F the Y-axis. A separate graph shall be constructed for the driver's temperatures (5.1.3) using the same units for the axes. Optional temperature data (5.1.4, 5.1.5, 5.1.6) may be similarly graphed separate from the interior data.