SAE The Engineering Society For Advancing Mobility Land Sea Air and Space® INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

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BUS BODY HEATING SYSTEM TEST

1. ***Scope—***This SAE Recommended Practice, limited to liquid coolant systems, establishes uniform cold weather bus vehicle heating system test procedures for all vehicles designed to transport 10 or more passengers. Required test equipment, facilities, and definitions are included. Defrosting and defogging procedures and requirements are established by SAE J381 and SAE J382, which are hereby included by reference.

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

2. *References*

2.1 **Applicable Publications—**The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J381—Windshield Defrosting Systems Test Procedure—Trucks, Buses, and Multipurpose Vehicles
SAE J382—Windshield Defrosting Systems Performance Guidelines—Trucks, Buses, and Multipurpose Vehicles
SAE J638—Motor Vehicle Heater Test Procedure

2.1.2 SCHOOL BUS MANUFACTURER'S TECHNICAL COMMITTEE, SUPPLIER COUNCIL, NATIONAL ASSOCIATION FOR PUPIL TRANSPORTATION

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—A 50-50 (by volume) solution of commercially available glycol antifreeze and commercial purity water. Commercial purity water is defined as that obtained from a municipal water supply 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.

4. Equipment

4.1 Test Site—A suitable location capable of maintaining an average ambient temperature not to exceed –3.9 °C (25 °F) for the duration of the test period. The maximum air velocity across the vehicle shall be 8 km/h (5 mph).

4.2 Coolant Supply—A closed loop system, independent of any engine/drivetrain system, capable of delivering a 50-50 (by volume) solution of antifreeze-water, 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.

4.3 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.

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 99 cm ± 13 cm (39 in ± 5 in) from the rear of the body, at 91 cm ± 5 cm (36 in ± 2 in) from the finished floor of the body, and on the longitudinal centerline of the body.

5.1.2 AMBIENT—A set of four electrically averaged temperature measuring devices shall be placed 46 cm ± 13 cm (18 in ± 5 in) from the nearest body surface, 243 cm ± 13 cm (96 in ± 5 in) above the floor of test site. One measuring device 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 25 cm (10 x 10 in) square area, the rearmost edge of which begins 20 cm (8 in) forward of the front edge of, and centered on, the seat cushion. The devices shall be located 7.5 cm ± 1.3 cm (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 10 cm ± 2.5 cm (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 107 cm ± 5 cm (42 in ± 2 in) above the floor and 25 cm ± 5 cm (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 AND OUTLET TEMPERATURE—A minimum of four electrically averaged temperature measuring devices shall be used to measure the inlet air temperature of each heat exchange unit. Additionally, a minimum of four electrically averaged temperature measuring devices shall be used to measure the outlet air temperature of each heat exchange 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.

5.1.5 (OPTIONAL) DEFROST AIR TEMPERATURE—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 2.54 cm (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.

5.1.6 (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 2.54 cm (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, 10.2 cm (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 entering and leaving the heat exchanger/defrosting system shall be measured as close to the entrance and exit points of the bus body as possible with an immersion thermocouple or RTD device which can be read within ±0.3 °C (±0.5 °F).

5.3 Coolant Flow—The quantity of coolant flowing shall be measured by means of a calibrated flow meter or weighing tank to an accuracy of at least 2% of setpoint.

5.4 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.

5.5 Additional Instrumentation—Additional instrumentation required for vehicle heat exchanger system testing is 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.

6. Test Procedures—Install the heater test vehicle on the test site. Testing shall be conducted in such a way as to prevent the effects of solar heating. At an outdoor test site, testing shall commence and data shall be recorded during the hours following sunset and prior to sunrise, regardless of cloud cover or facility roof. Instrumentation is required to obtain the following readings:

a. Vehicle interior (5.1.1)
b. Inlet coolant temperature, at entrance to the bus body (5.2)
c. Discharge coolant temperature, at exit from the bus body (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 (5.1.5)
l. (Optional) Entrance Area Temperature (5.1.6)

Soak the test vehicle, with doors open, for the length of time necessary to stabilize the interior temperature for a 30 min period as recorded by the vehicle interior temperature measuring devices, and the coolant temperature as measured by the inlet and outlet coolant temperature measuring devices, at the test site temperature, ±2.5 °C (±5 °F), not to exceed –3.9 °C (25 °F). 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 2.5 cm (1 in) each. A maximum of two occupants may be in the body during the test period. Record all instrumentation readings at 5 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.

6.1 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. Computations

7.1 Chart and Computations—Metric Units—Data shall be recorded on the chart in Figure 1 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, 5.1.6) 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 1—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 1—DATA CHART 1 (CONTINUED)

7.1.1 OPTIONAL COMPUTATIONS JOULES/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

7.2 Chart and Computations—Customary Units—Data shall be recorded on the chart in Figure 2 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.

7.2.1 OPTIONAL COMPUTATIONS BTU/H COOLANT

a. Flow of Coolant (Ww)—lb/min—measured to ±2%
b. Temperature of Coolant into System (T-in)—°F—measured
c. Temperature of Coolant out of System (T-out)—°F—measured
d. Heat Removed from Coolant (Qw)—Btu/h—calculated

Qw = CpWw(T-in – T-out) x (60)
Cp = Specific Heat of Coolant—Given as 0.85 x 1.0018 Btu/lb/°F
= .8515
Ww = No. 1
T-in = No. 2
T-out = No. 3

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 - lb/min												
Flow pressure - PSID												
T-in °F												
T-out °F												
Air Temperature												
T1 - rear - °F												
T2 - °F												
T3 - °F												
T4 - °F												
T5 - °F												
T6 - front - °F												
T7 - ambient - °F												
T8 - Driver Ankle - °F												
T9 - Driver Knee - °F												
T10 - Driver Breath - °F												
Electrical System												
Volts												
Amps												

FIGURE 2—DATA CHART 2

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

FIGURE 2—DATA CHART 2 (CONTINUED)

PREPARED BY THE SAE INTERIOR CLIMATE AND AIR QUALITY SUBCOMMITTEE OF THE
SAE TRUCK AND BUS CAB AND OCCUPANT ENVIRONMENT COMMITTEE

Rationale

1. Scope—Support not Required

1.1 Purpose—Each school bus body manufacturer builds body/chassis variations often numbering in excess of 200, with each body type being supported by up to 40 different heating system combinations. The potential test requirements, therefore, represent an excessive cost burden. This procedure is designed to provide a standardized method of testing any given body/heating system combination, and then relating it to a base line temperature of –18 °C (0 °F) for the sake of comparison by both manufacturers and end users. The ability to test outside of a temperature regulated chamber is proposed in an effort to control the cost of the testing, while keeping the variations within specified limits to permit the data reduction.

2. References—Support not Required

3. Definitions

3.1 Heat Exchanger System—Support not Required

3.2 Heat Exchanger Core Assembly—Support not Required

3.3 Heat Exchanger-Defroster Blower—Support not Required

3.4 Coolant—The definition is written as glycol based to allow the use of either ethylene or propylene based glycol in the cooling system of the test vehicle. Environmental concerns are making a case for propylene glycol being an environmentally safer product. Preliminary testing indicates the performance of the two fluids are very nearly the same in both heat rejection and chemical performance.

3.5 Heat Exchanger-Defroster Duct System—Support not Required

3.6 Heater Test Vehicle—The test vehicle is defined to be the body, with or without chassis, as chassis and drivetrain combinations are varied. The test has been established to conform to standardized conditions making the presence of the chassis and drivetrain unnecessary. Installing the body on the test site at a height equal to its height when on a chassis will allow for heat loss from floor surfaces to realistically enter the test scheme.

3.7 Heat Transfer—This definition provides the basis for comparative testing using differing actual test temperatures and mathematically reducing them to a common baseline test temperature. The assumptions are made that, throughout the test, air and coolant flow will remain constant in terms of kilograms (pounds) per minute. Therefore, the higher the differential between the temperatures of these fluids, or process areas, the greater the rate of thermal transfer. It is further assumed that the thermal properties of the materials used in the construction of the heat exchangers and the bus bodies, as well as the fluids used in the coolant system, will remain effectively constant over the range of temperatures permitted. It is also taken that the first law of thermodynamics supports the conclusion that the heat removed from one fluid is equal to that absorbed by the second fluid. Thus, thermal energy removed from the coolant cannot be destroyed, but only converted, or transferred to another location, in this instance the air and the internal components of the bus body. The transfer process will continue through the walls of the bus body to the external environment, again at a rate proportional to the difference between the internal and external temperatures.