

# **PROCEDURE FOR TESTING AND RATING AUTOMOTIVE BUS HOT WATER AND HEATING AND VENTILATING EQUIPMENT**



**National Association of State Directors of Pupil Transportation Services  
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**Prepared by**

**School Bus Manufacturers Technical Committee**

**National Association of State Directors of Pupil  
Transportation Services**

## School Bus Manufacturers Technical Committee

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Procedure for Testing and Rating Automotive Bus Hot Water  
Heating and Ventilating Equipment

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**SCHOOL BUS MANUFACTURERS TECHNICAL COMMITTEE  
PROCEDURE FOR  
TESTING AND RATING AUTOMOTIVE BUS  
HOT WATER HEATING AND VENTILATING EQUIPMENT**

1. SCOPE-- This recommended practice, limited to liquid coolant systems, establishes uniform automotive bus heater test procedures. Required test equipment, facilities and definitions are included.

2. DEFINITIONS

2.1 HEATER SYSTEM-- The system shall comprise an integral assembly having a core assembly, or assemblies, air moving device or devices and the integrally attached shell/housing which contains or attaches to these components. This Unit heater shall extend to the point of interface between the unit under test and its point of attachment to the vehicle, excluding all external ducts and ducting.

2.2 HEATER CORE ASSEMBLY--The core shall consist of a liquid to air heat transfer surface, liquid inlet and discharge tubes or pipes.

2.3 HEATER-DEFROSTER BLOWER--An air moving device or devices powered by the energy available on the vehicle.

2.4 COOLANT--Commercial purity water is used to transfer heat from one point to another. Commercial purity water is defined as that obtained from a municipal water supply system.

2.5 HEATER-DEFROSTER DUCT SYSTEM-- Passages that conduct inlet and discharge air throughout the heater system. Any duct(s) and outlet(s) that are an integral part of the unit heater as defined in paragraph 2.1 shall be included in the test. Any external or interconnecting duct(s) or outlet(s) shall NOT be included.

2.6 HEATER SYSTEM TEST BUCK-- Unit heater as installed for testing as required in paragraph 2.1.

3. EQUIPMENT

3.1 COLD ROOM-- A facility capable of maintaining a temperature of  $0^{\circ} \pm 5^{\circ} \text{ F}$  ( $-18^{\circ} \pm 2.5^{\circ} \text{ C}$ ) and of sufficient size to contain the test set-up. If such a facility is not available, the air and water temperature shall be maintained in such a manner as to insure a minimum entering differential of not less than  $100^{\circ} \text{ F}$  ( $38^{\circ} \text{ C}$ ).

3.2 AIR MEASUREMENT DEVICE--A device capable of supplying and measuring total heater system air flow of a range of 100 to 1000 cfm. On some commercial units a greater range may be required. See Fig. 1.

3.3 COOLANT SUPPLY-- A closed loop system capable of supplying and measuring water at 150° F (66° C) and 50 pounds (22.68 kg) per minute flow. The coolant temperature for the test is 150° F (66°C) or a minimum of 100° F (38°C) above the entering air temperature. Coolant flow rate is 50 lbs (22.68kg) per minute. Optional testing at other flow rates may be done for comparison purposes only, not for nameplate rating tests.

3.4 POWER EQUIPMENT SUPPLY--A source capable of providing required test voltage and current for the heater system.

#### 4. INSTRUMENTATION

##### 4.1 AIR TEMPERATURE

4.1.1 DISCHARGE--Recommended air temperature measuring instrumentation is a grid of thermocouples or RTDs at the appropriate outlets to obtain an accurate average temperature. Thermometers are not recommended because of their slow response to rapid temperature changes. The number of thermocouples depends on the ability to obtain an average temperature even though stratification may be present in the flow. Whenever thermocouples are installed in a grid it is recommended that they be electrically averaged.

Alternatively, the air temperature measuring instrumentation can be a grid of thermocouples installed at the outlet of the plenum to the air measurement device if the plenum is insulated with at least 2 inches of insulation to equal a total R15 rating. (See 4.3)

4.2 COOLANT TEMPERATURE--The temperature of the coolant entering and leaving the unit shall be measured as close to the core assembly as possible with an immersion thermocouple or RTD device which can be read within  $\pm 0.5^{\circ}\text{F}$  ( $\pm 0.3^{\circ}\text{C}$ ).

4.3 AIR FLOW-- Fabricate a plenum around all unit heater discharge points. The plenum must include an air pressure indicator (pitot tubes or other accepted devices) which is readable to 0.005 in H<sub>2</sub>O (1.0 Pa). The plenum shall be of sufficient size that the inside surfaces shall be a minimum of 6 in (15 cm) from the air discharge outlets in the direction of flow. This is to insure that there is no effect on air flow due to the proximity of plenum. The plenum can be fabricated from cardboard as shown in Fig 1 or fabricated from other suitable material if the plenum is to be insulated. If the plenum is made from cardboard and not insulated, the thermocouples for measuring the air temperature must be placed at the heater outlets. See Fig 1.

4.4 COOLANT FLOW--The quantity of coolant flowing shall be measured by means of a calibrated flow meter or a weighing tank to an accuracy of at least 2% of setpoint.

4.5 COOLANT PRESSURE--If the heater core assembly has a water valve as an integral part, it shall be included as a part of the core and set at its maximum flow rate. The coolant pressure drop across the heat exchanger and valve assembly shall be measured by means of suitable pressure connections as close as possible to the inlet and discharge pipes with a differential manometer that can be read within 0.20 in Hg (600 Pa).

4.6 ADDITIONAL INSTRUMENTATION--Additional instrumentation required for unit heater tests is a voltmeter and a shunt type ammeter to read the voltage and current at the heater motor. A means of measuring blower motor rpm is required. The ammeter and voltmeter shall be capable of an accuracy of  $\pm 1\%$  of the reading.

## 5. TEST PROCEDURES

5.1 BENCH TEST--Using the previously described equipment and instrumentation, install test unit heater (see Fig. 1). All capacity ratings are to be based on a calculated 150°F (66°C) temperature differential between inlet air and inlet coolant at a coolant flow rate of 50 lb. (22.68 kg)  $\pm 2\%$  per minute and a 0.00 in. H<sub>2</sub>O (0.0 Pa) static pressure condition at the air inlet to the heater and at all discharge points.

Test voltage should be within  $\pm 0.2$  volts of 13.8 volts for a 12 volt system and  $\pm 0.4$  volts of 27.6 volts for a 24 volt system, as measured within 6 inches (15cm) of the blower motor. For multiple blower motors, measure the voltage at the connector from the heater to the bus wiring. (Ref. paragraph 6.1). Maintain the air discharge plenum at 0.0 in. H<sub>2</sub>O (0.0 Pa) by suitable adjustment of the air machine. Take the following readings:

- (a) Dry bulb temperature (entering the nozzle).
- (b) Barometric pressure for density of test air.
- (c) Discharge coolant temperature.
- (d) Inlet coolant temperature.
- (e) Coolant flow rate.
- (f) Coolant pressure drop through heater core assembly.
- (g) Inlet air temperature (average).
- (h) Discharge air temperature (average).
- (i) Air temperature at nozzle (average).
- (j) Chamber static pressure.
- (k) Static pressure drop across nozzle.

- (l) Current consumption in amperes at test voltage.
- (m) (OPTIONAL) Air pressure drop across unit heater

The heat balance (air versus coolant) must be within 5% to be considered a satisfactory test. Rating should be the average of 4 readings taken at 5 minute intervals to show stability. See sample test charts.

## 6. BASIS OF RATING

6.1 HEATING BTU (J) RATING BUCK OR BENCH--All capacity ratings are to be based on 150°F (66°C) temperature differential (measured or calculated) between inlet air and inlet coolant at a coolant flow rate of 50 lb. (22.68 kg) per minute.

The electrical system should be operated within  $\pm 0.2$  volts of 13.8 volts for a 12 volt system and  $\pm 0.40$  volts of 27.6 volts for a 24 volt system as measured within 6 inches (15 cm) of the blower motor. For multiple blower motors, measure the voltage at the connector from the heater to the bus wiring. The appliance tested should be with the normal vehicle wiring. If the test appliance is operated with an external voltage source, the test voltage should be within the same parameters. The ratings shall include:

- 6.1.1 Heat transfer in BTU (J) per hour at the stated temperature differential.
- 6.1.2 Air flow in cfm (L/s) standard air.<sup>1</sup>
- 6.1.3 (OPTIONAL) Air static pressure drop across unit in inches of water (Pa).<sup>1</sup>
- 6.1.4 Coolant static pressure drop across unit in inches of mercury (Pa).
- 6.1.5 Motor current
- 6.1.6 The rating label for this test should include the following information:
  - a) Free air delivery
  - b) XXXXX Btu/hr/150° I. T. D./50 lb/min/0.0" S. P.
  - c) Voltage (Nominal system voltage 12 or 24)
  - d) Heater Manufacturer's name, if different from body manufacturer.

7.1 COMPUTATIONS-- Computations shown are based upon using a calibrated nozzle as the air flow measurement device. Alternative air flow measuring devices will require differing calculations as specified by the manufacturer of those devices. In all cases the principal is to calculate the actual air flow volume at standard conditions of 70°F (21°C) at 29.92 in. Hg (548.6 Pa) barometric pressure.

For the purpose of these computations, the  $C_p$  of air is taken as 0.2415 Btu/Lb/°F (1011J/Kg/°C) and the  $C_p$  of water is taken as 1.0018 Btu/Lb/°F (4194J/Kg/°C).

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<sup>1</sup> Zero inches of water (0.0 Pa) static pressure shall be maintained at inlet and outlet of the unit heater as defined in 2.1.

## 7.2 CHART AND COMPUTATIONS-METRIC UNITS

### 7.2.1 COOLANT

1. Flow of Coolant ( $W_w$ )--kg/min--measured to within 2%.
2. Pressure Drop Through Unit ( $\Delta P_w$ )--Pa--measured.
3. Temperature of Coolant Into Unit ( $T_{in}$ )--°C--measured.
4. Temperature of Coolant Out of Unit ( $T_{out}$ )--°C--measured.
5. Heat Removed from Coolant ( $Q_w$ )--J/h--calculated.

$$Q_w = C_p W_w (T_{in} - T_{out}) \times (60)$$

$C_p$  = Specific heat of water--See 7.1

$W_w$  = No.1

$T_{in}$  = No.3

$T_{out}$  = No.4

### 7.2.2 AIR

6. Temperature of Air (Dry Bulb)--( $T_{db}$ )--°C--measured.
7. Corrected Barometer ( $P_b$ )--Pa--measured.
8. Density of Inlet Air ( $D_a$ )--kg/m<sup>3</sup>--calculated.

$$D_a = P_b / (287.4 \times T_a)$$

$P_b$  = No.7

$T_a = 273.2 + T_{db}$

9. Density of Nozzle Air ( $D_n$ )--kg/m<sup>3</sup>--calculated.

$$D_n = D_a \times (T_a / T_{nc})$$

$T_{nc} = T_n + 273.2$

$D_a$  = No.8

10. Temperature of Air at Nozzle ( $T_n$ )--°C--measured.
11. Static Pressure Drop Across Nozzle ( $\Delta P_n$ )--Pa--measured.
12. Actual Air Flow ( $V_{act}$ )--m<sup>3</sup>/s--measured by means of a calibrated nozzle.
13. Actual Air Flow ( $W_a$ )--kg/h--calculated.

$$W_a = V_{act} D_n (3600)$$

$V_{act}$  = No.12

$D_n$  = No.9

14. Air Flow Corrected to Standard Air Conditions ( $V_{std}$ )--m<sup>3</sup>/s.



$$V_{std} = V_{act} (D_n/1.20)$$

15. Average Temperature of Air Into Unit ( $T_{in}$ )--°C--measured.
16. Average Temperature of Air Out of Unit ( $T_{out}$ )--°C--measured.
17. Actual Heat Gained by Air ( $Q_{act}$ )--J/h--calculated.

$$Q_{act} = W_a C_p (T_{out} - T_{in})$$

$C_p$ =specific heat of air-See 7.1

NOTE: If the optional insulated plenum and thermocouple location are used, then the heat loss through the insulated plenum must be accounted for in the heat gained by the air calculations.

18. Heat Dissipation--J/h/66°CΔT

$$\text{Heat Dissipation} = (Q_{act} \times 66) / \Delta T$$

$\Delta T$  = Temperature difference between inlet air and inlet coolant--°C (Item 3 minus Item 15.)

19. (OPTIONAL) Pressure drop across unit ( $\Delta P_a$ )--Pa--measured.
20. Fan--volts--measured.
21. Fan--amps--measured.
22. Fan speed--rpm--measured.

### 7.3 CHART AND COMPUTATIONS--CUSTOMARY UNITS

#### 7.3.1 COOLANT

1. Flow of coolant ( $W_w$ )--lb/min--measured to within 2%.
2. Pressure Drop Through Unit ( $\Delta P_w$ )--in Hg--measured.
3. Temperature of Coolant Into Unit ( $T_{in}$ )--°F--measured.
4. Temperature of Coolant Out of Unit ( $T_{out}$ )--°F--measured.
5. Heat Removed From Coolant ( $Q_w$ )--Btu/h--calculated.

$$Q_w = C_p W_w (T_{in} - T_{out})(60)$$

$C_p$ =Specific heat of water-See 7.1  
 $W_w$ =No.1  
 $T_{in}$ =No.3  
 $T_{out}$ =No.4

#### 7.3.2 AIR

6. Temperature of Air (Dry Bulb)--( $T_{db}$ )--°F--measured.
7. Corrected Barometer ( $P_b$ )--in Hg--measured.

8. Density of Inlet Air ( $D_a$ )--lb/ft<sup>3</sup>--calculated.

$$D_a = P_b / (0.754 T_a)$$
$$P_b = \text{No. 7}$$
$$T_a = 459.6 + T_{db}$$

9. Density of Nozzle Air ( $D_n$ )--lb/ft<sup>3</sup>--calculated.

$$D_n = D_a \times (T_a / T_c)$$
$$T_c = T_n + 459.6$$
$$D_a = \text{No. 8}$$

10. Temperature of Air at Nozzle ( $T_n$ )--°F--measured.  
11. Static Pressure Drop Across Nozzle ( $\Delta P_n$ )--in H<sub>2</sub>O--measured.  
12. Actual Air Flow ( $V_{act}$ )--cfm--measured by means of calibrated nozzle.  
13. Actual Air Flow ( $W_a$ )--lb/h--calculated.

$$W_a = V_{act} D_n (60)$$
$$V_{act} = \text{No. 12}$$
$$D_n = \text{No. 9}$$

14. Air Flow Corrected to Standard Air Conditions ( $V_{std}$ )--cfm--calculated.

$$V_{std} = V_{act} (D_n / 0.075)$$

15. Average Temperature of Air Into Unit ( $T_{in}$ )--°F--measured.  
16. Average Temperature of Air Out of Unit ( $T_{out}$ )--°F--measured.  
17. Actual Heat Gained by Air ( $Q_{act}$ )--Btu/h--calculated.

$$Q_{act} = W_a C_p (T_{out} - T_{in})$$
$$C_p = \text{specific heat of air - See 7.1}$$

NOTE: If the optional insulated plenum and thermocouple location are used, then the heat loss through the insulated plenum must be accounted for in the heat gained by the air calculations.

18. Heat Dissipation--Btu/h/150°FΔT--calculated.

$$\text{Heat Dissipation} = (Q_{act} \times 150) / \Delta T$$

$$\Delta T = \text{Temperature difference between inlet air and inlet water--°F. (Item 3 minus Item 15.)}$$

19. (OPTIONAL) Pressure Drop Across Unit ( $\Delta P_a$ )--in H<sub>2</sub>O--measured.
20. Fan--volts--measured.
21. Fan--amps--measured.
22. Fan speed--rpm--measured.

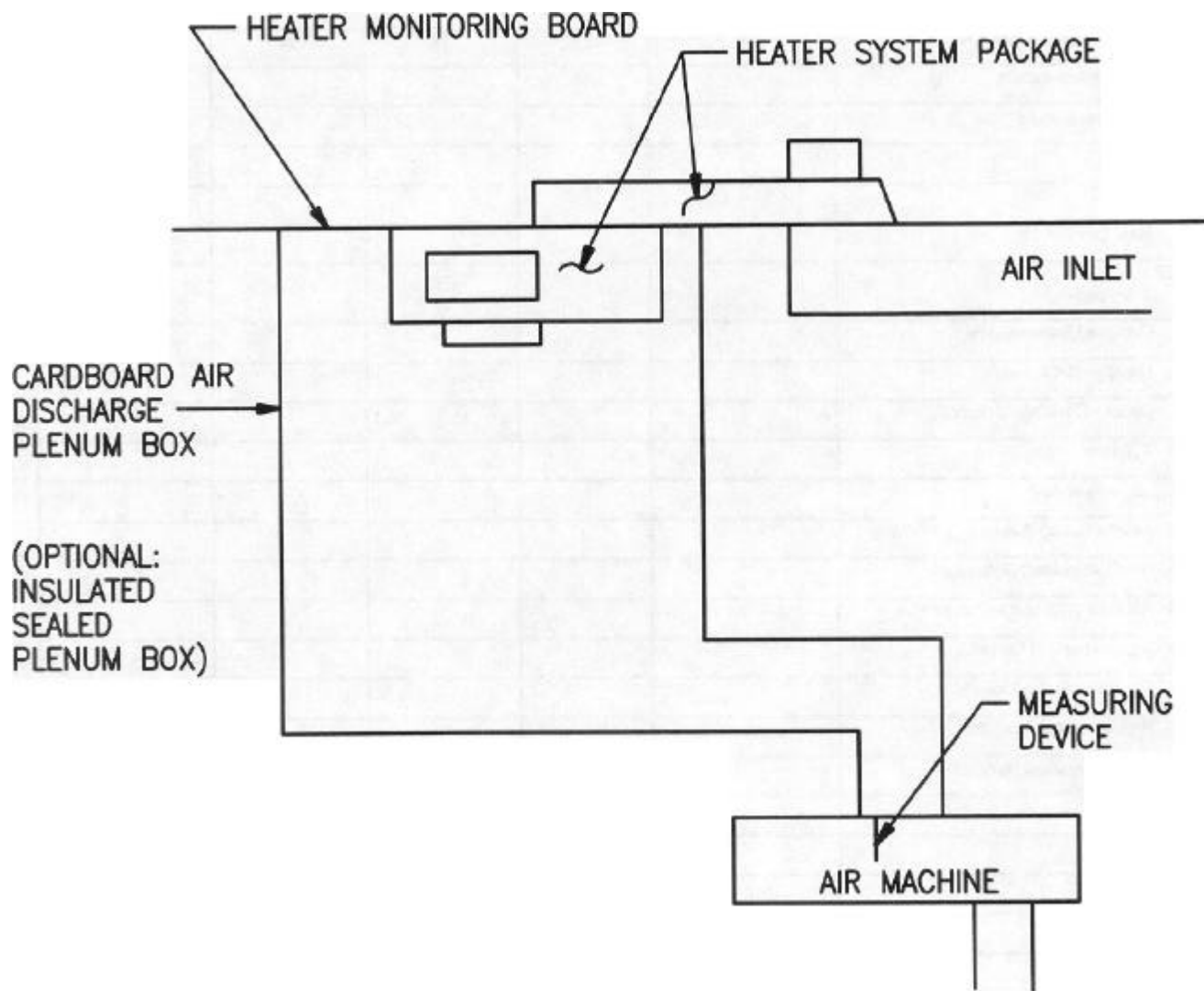


FIG. 1 ~ TEST SET-UP

Description of Unit _____					
Purpose of Test _____					
Nozzle Coefficient _____					
Date _____ Location _____ Observers _____					
	<b>Test Time (minutes)</b>				
<b>Readings/Computations</b>	<b>5</b>	<b>10</b>	<b>15</b>	<b>20</b>	<b>Avg.</b>
1. Flow Coolant-lb/min					
2. $\Delta P_w$ thru core-in Hg					
3. $T_{in}$ -°F					
4. $T_{out}$ -°F					
5. Heat Transfer-Btu/h					
AIR					
6. T dry bulb-°F					
7. Corrected Barometer-Hg					
8. Density-Inlet Air-lb/ft <sup>3</sup>					
9. Density-Chamber Air-lb/ft <sup>3</sup>					
10. $T_a$ (Nozzle)-°F					
11. $\Delta P_a$ -At nozzle-in H <sub>2</sub> O					
12. Air Flow (actual) Outlet-cfm					
13. Air Flow (actual) Outlet-lb/h					
14. Air Flow (standard)-Outlet-cfm					
15. $T_{in}$ (average) of Core-°F					
16. $T_{out}$ (average) of Core-°F					
17. Heat Gained (actual)-Btu/h					
18. Heat Dissipation-Btu/h/150°FΔT					
19. $\Delta P_a$ -across unit-in H <sub>2</sub> O					
20. Fan-volts					
21. Fan-amps					
22. Fan-rpm					

Note 1: All pressure measurements, except  $\Delta P_w$ , accurate to within 0.005 in H<sub>2</sub>O.  $\Delta P_w$  accurate to within  $\pm 0.2$  Hg.

Note 2: All temperature measurements accurate to within 0.5°F for air and coolant.

Description of Unit _____					
Purpose of Test _____					
Nozzle Coefficient _____					
Date _____ Location _____ Observers _____					
	Test Time (Minutes)				
Readings/Computations	5	10	15	20	Avg.
1. Flow Coolant-kg/min					
2. $\Delta P_w$ thru core-Pa					
3. $T_{in}$ -°C					
4. $T_{out}$ -°C					
5. Heat Transfer-J/h					
AIR					
6. T dry bulb-°C					
7. Corrected Barometer-Pa					
8. Density-Inlet Air-kg/m <sup>3</sup>					
9. Density-Chamber Air-kg/m <sup>3</sup>					
10. $T_a$ (Nozzle)-°C					
11. $\Delta P_a$ -At nozzle-Pa					
12. Air Flow (actual) Outlet-m <sup>3</sup> /sX10 <sup>3</sup> =L/s					
13. Air Flow (actual) Outlet-kg/h					
14. Air Flow (standard)-m <sup>3</sup> /sX10 <sup>3</sup> =L/s					
15. $T_{in}$ (average) of Core-°C					
16. $T_{out}$ (average) of Core-°C					
17. Heat Gained (actual)-J/h					
18. Heat Dissipation-J/h/66°CΔT					
19. $\Delta P_a$ -across unit-Pa					
20. Fan-volts					
21. Fan-amps					
22. Fan-rpm					

Note 1: All pressure measurements, except  $\Delta P_w$ , in Pascals, accurate to within 1.0 Pa (0.005 in H<sub>2</sub>O).  $\Delta P_w$  accurate to within ± 680 Pa (± 0.2 Hg).

Note 2: All temperature measurements accurate to within 0.25°C (0.5°F) for air and coolant

Note 3: 1 Pa = 10 dyne/cm<sup>2</sup>