Recommended Practice for Transit Bus HVAC System Instrumentation and Performance Testing

Approved 2004
APTA Bus Standards HVAC Working Group

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Abstract: This recommended practice provides guidelines for instrumentation and performance testing for coaches or transit buses with HVAC systems. These tests are intended for certification and evaluation for all new coach or transit bus HVAC systems. This practice includes 30-60 ft high and low floor heavy-duty transit vehicles. It is not intended for cutaway or light duty transit vehicles. It is intended for diesel or alternate fueled engines, hybrid electric, and full electric powered vehicles.

Keywords: air conditioning, HVAC, instrumentation, transit bus, performance testing, pulldown

Introduction

(This introduction is not a part of BTS-RP-003-04, *Recommended Practice for Transit Bus HVAC System Instrumentation and Performance Testing*)

This Recommended Practice for Transit Bus HVAC System Instrumentation and Performance Testing reflects the consensus of the APTA Bus Standards Program members on the items, methods, and procedures that have provided the best performance record based on the experiences of those present and participating in meetings of the program task forces and working groups. Recommended practices are voluntary, industry-developed, and consensus-based practices that assist equipment suppliers, vehicle and component manufacturers, and maintenance personnel in the construction, assembly, operation, and maintenance of transit bus vehicles. Recommended practices may include test methodologies and informational documents. Recommended practices are non-exclusive and voluntary; they are intended to neither endorse nor discourage the use of any product or procedure. All areas and items included therein are subject to manufacturers' supplemental or superceding recommendations. APTA recognizes that for certain applications, the practices, as implemented by operating agencies, may be either more or less restrictive than those given in this document.

This recommended practice provides guidelines for transit bus HVAC system instrumentation and performance testing. APTA recommends the use of this recommended practice by:

– Bus manufacturers

– Bus re-manufacturers

– HVAC manufacturers

– HVAC re-manufacturers

– Transit agencies

– Independent test companies

Participants

The American Public Transportation Association (APTA) greatly appreciates the contributions of the APTA Bus Transit Standards HVAC Working Group, who provided the primary effort in the drafting of the *Recommended Practice for Transit Bus HVAC System Instrumentation and Performance Testing.*

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Recommended Practice for Transit Bus HVAC System Instrumentation and Performance Testing

1. Overview

This document establishes a recommended practice for transit bus heating, ventilation, and air conditioning (HVAC) system instrumentation and performance testing.

1.1 Scope

This recommended practice provides guidelines for instrumentation and performance testing for coaches or transit buses with HVAC systems. These tests are intended for certification and evaluation for all new coach or transit bus HVAC systems. This practice includes 30-60 ft high and low floor heavy-duty transit vehicles. It is not intended for cutaway or light duty transit vehicles. It is intended for diesel or alternate fueled engines, hybrid electric, and full electric powered vehicles. This document does not include specifications for pass/fail criteria.

1.2 Purpose

The purpose of this recommended practice is to provide standardized test procedures for measuring the capability of a coach or transit bus, equipped with a HVAC system to maintain its interior climate within a predetermined set of conditions.

2. References

This recommended practice should be used in conjunction with the latest edition of the following publications.

APTA Standard Bus Procurement Guidelines.

ASHRAE Handbook of Fundamentals, Section 29.27, 1997.

ASHRAE Standard 41.6, 1982.

3. Definitions, abbreviations, and acronyms

For the purpose of this recommended practice, the following terms, definitions, abbreviations, and acronyms apply.

3.1 Definitions

3.1.1 ambient average: The average of all the air temperature probes located outside the vehicle (excluding air into and out of the condenser).

NOTE – High idle refers to that speed which would normally be used by a vehicle operator to pre-cool the vehicle and must not exceed manufacturer's recommended idle speeds. If a vehicle has no high idle setting then the standard low idle RPM should be used for the test. No special speeds or drive ratios should be used for this test, only those corresponding to standard production vehicles.

3.1.2 HVAC system: Includes all components dealing with heating, cooling, or providing ventilation to the passenger compartment, eg. the main unit, compressor, floor heaters, entrance/exit heaters, boost pumps. The HVAC system does not include the operator's defroster/heater unit but includes the operator's evaporator.

3.1.3 logic control point: the temperature at which a control event occurs.

3.1.4 U-factor: The heat gain or loss derived from a temperature difference per unit of time.

3.2 Abbreviations and acronyms

AAVT	ambient average air temperature
AC	alternating current
A/C	air conditioning
APTA	American Public Transportation Association
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
BTS	APTA bus transit standards
BTU	British thermal unit
CBD	central business district
DC	direct current
HVAC	heating, ventilation, air conditioning
IAVT	interior average air temperature
KW	kilowatts
OEM	original equipment manufacturer
RH	relative humidity
RPM	revolutions per minute
SBPG	Standard Bus Procurement Guidelines
SMT	seat mass temperature

4. Personal protective equipment

Applicable personal protective equipment should be worn at all times during testing.

5. Safety

Established safety practices, rules, and procedures should be followed at all times during testing.

6. Frequency

The tests should be conducted prior to acceptance of the vehicle configuration by the procuring agency.

7. Data collection

7.1 Methods

This standard was written with computerized data collection equipment in mind. However, hand recorded data would be acceptable. If the hand method is used, the time for each data set is greatly increased and a less accurate test will result.

7.2 Intervals

7.2.1 Each standard test will specify a data collection rate. This rate should be modified only at the direction of the test engineer.

7.2.2 Time intervals for other than standard tests will be established by the test engineer. Refer to Annex A for suggested data point description codes for computer data systems.

8. Preparation

8.1 Instrumentation set up

8.1.1 A/C Compressor clutch: ON/OFF

8.1.2 Water Valves: ON/OFF or %OPEN based on valve and control type

8.1.3 Booster Pumps: ON/OFF and Current Draw

8.1.4 Cabin Heaters: ON/OFF, Temperature IN/OUT for water and air, current draw, and fan speed (if variable).

8.1.5 Auxiliary Heaters: ON/OFF (from all sources i.e. multiplex electrical, HVAC unit, manual switches, etc.), temperature IN/OUT, exhaust temperature.

8.1.6 Main HVAC Unit: Evaporator fan speed, all auxiliary HVAC control outputs.

8.1.7 Multiplex System: All HVAC control outputs.

8.2 Visual checks

8.2.1 Compressor oil level should be verified in accordance with manufacturer's recommendations.

8.2.2 Refrigerant charge level should be verified in accordance with manufacturer's recommendations.

8.2.3 Refrigerant liquid line sightglass (if installed) at or near the thermostatic expansion valve should appear clear as if it were full of liquid. If bubbles are seen, this indicates system problem.

8.2.4 Compressor drive belts (if applicable) and any instruments mounted on or near moving machinery should be inspected for condition and proper adjustment to minimize problems during testing.

8.2.5 Vehicle fuel level and all other fluids should be checked daily.

8.2.6 Install new return air filters before the test.

8.3 Operating speeds

8.3.1 The vehicle manufacturer should be consulted for the proper engine and/or compressor speed for each test. The compressor speed for hybrid or electric buses may differ from that used for engine driven compressors.

8.3.2 It is important to verify and adjust, if necessary, the compressor speeds to ensure good comparable data.

8.3.3 Fan and blower speeds should be verified to be correct prior to each test.

8.3.4 Check ducts for obstructions, loose components, or unintended system air leaks.

8.4 Heat load

8.4.1 Calculations

8.4.1.1 Solar load

8.4.1.1.1 The solar heat gain must be determined by the vehicle manufacturer. This calculation is done for the glazing area only. The remaining side area is considered to be of small consequence in this calculation and should be disregarded for test purposes. The vehicle manufacturer should use the ASHRAE Handbook of Fundamentals, latest edition, test methodology for determining the solar heat gain.

8.4.1.1.2 The heat load to be applied in the following tests should be calculated from the average solar heat gain factor for N, E, S, and W at 4 PM on August 21 at the location of the procuring agency as taken from the ASHRAE Handbook of Fundamentals.

8.4.1.1.3 The average solar heat load = solar heat gain factor x glazing area x glazing transmittance factor. See Table 1.

8.4.1.1.4 Glazing transmittance factor should be supplied by the vehicle manufacturer.

Table 1 - Typical solar heat load calculation for 16° N latitude*

(* for other latitudes see Table 2)

	Glass area sq. ft.	Glass trans. factor	Heat gain factor *	SOLAR HEAT LOAD	
Windshield	32.0	0.78	74.25	**1,853**	
Operator's side window	8.0	0.78	74.25	**463**	
Roadside	130.0	0.40	74.25	**3,861**	
Curbside	120.0	0.40	74.25	**3,564**	
Front Door	9.0	0.40	74.25	**267**	
Rear Door(s)	7.0	0.40	74.25	**208**	
Rear window	0.0	0.00	74.25	**-**	
			Total solar heat load	**10,217**	**BTU/hr**

Where:
Solar Load = (Glass Area) (Glass Trans. Factor) (Heat Gain Factor)

* This heat gain value was selected as being the worst case scenario for North America.

Table 2 - Solar heat gain factors in BTU/h-ft^2 for latitudes as shown at 4 PM on Aug 21

Location	Average N E S & W
16° North Latitude	74.25
24° North Latitude	74.00
32° North Latitude	74.50
40° North Latitude	76.00
48° North Latitude	77.00
56° North Latitude	77.25
64° North Latitude	76.75

Based on Tables 15 through 21, chapter 29, section 29.27 of the 1997 ASHRAE Fundamentals Handbook.

8.4.1.2 Passenger load

8.4.1.2.1 Seated passenger heat load

The heat load is determined by the number of seats in the vehicle and the load per person is:

a) 230 BTU/hr. sensible

b) 190 BTU/hr. latent (seated, light work)

8.4.1.2.2 Standee passenger heat load

The heat load is determined by one standee passenger per 1.5 sq. ft. of free usable floor area (rectangular layout) unless otherwise defined by the purchasing agency.

The heat load per person is:

a) 315 BTU/hr. sensible

b) 325 BTU/hr. latent (standing, light work)

8.4.1.2.3 Operator heat load

The heat load for the operator is the same as a standee:

a) 315 BTU/hr. sensible

b) 325 BTU/hr. latent

Note: The manufacturer should determine the total load to be used based on one of the above procedures. The BTU/Hr. per person ratings were taken from the ASHRAE Handbook of Fundamentals, 1997 Edition, Section 26.60.

Table 3– Typical passenger and operator heat load calculation

	Seated	Standing	Operator	**TOTAL PASSENGER HEAT LOAD**	
# Of passengers	**40**	**20**	**1**		
Latent heat/passenger	190	325	325	**14,425**	
Sensible heat/passenger	230	315	315	**15,815**	
		Total passenger load		**30,240**	**BTU/ hr**
Where: *Passenger load = (# Of passengers) (Heat load/passenger)*					

8.4.2 Equipment and devices

8.4.2.1 Light bulb racks (see Figure 1) to generate a sensible heat load of 14 KW are needed. Other means may be used as long as they provide an even distribution of heating without disrupting the normal air flow within the passenger compartment.

SENSIBLE HEAT LOAD

TYPICAL LIGHT BULB RACK

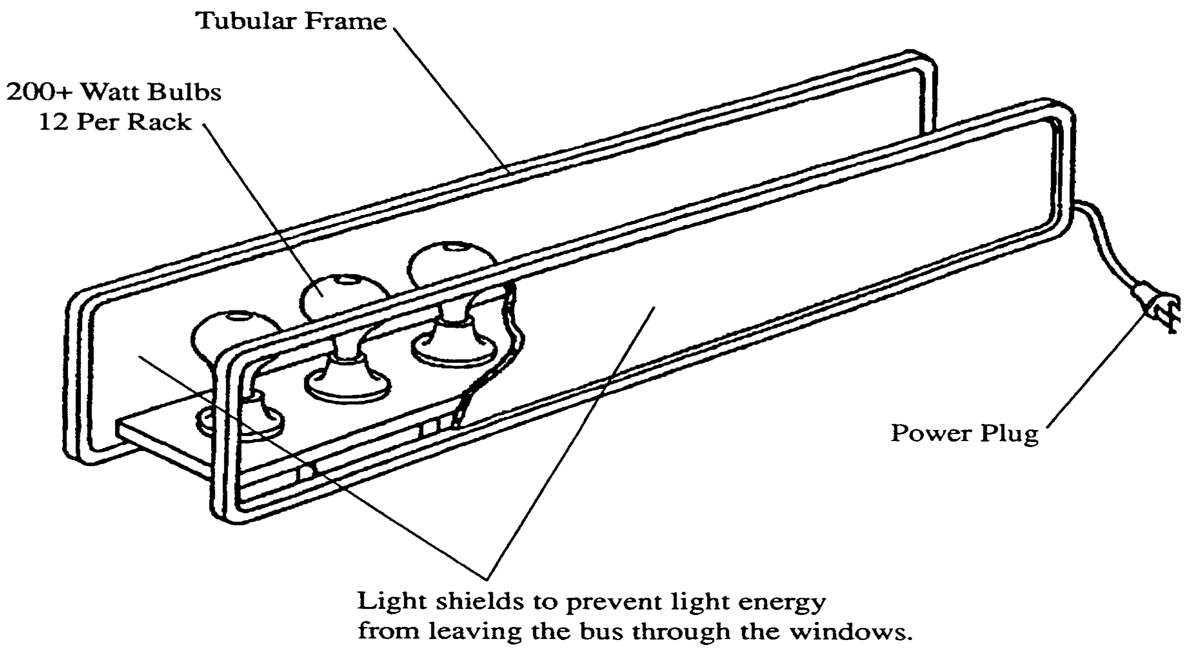


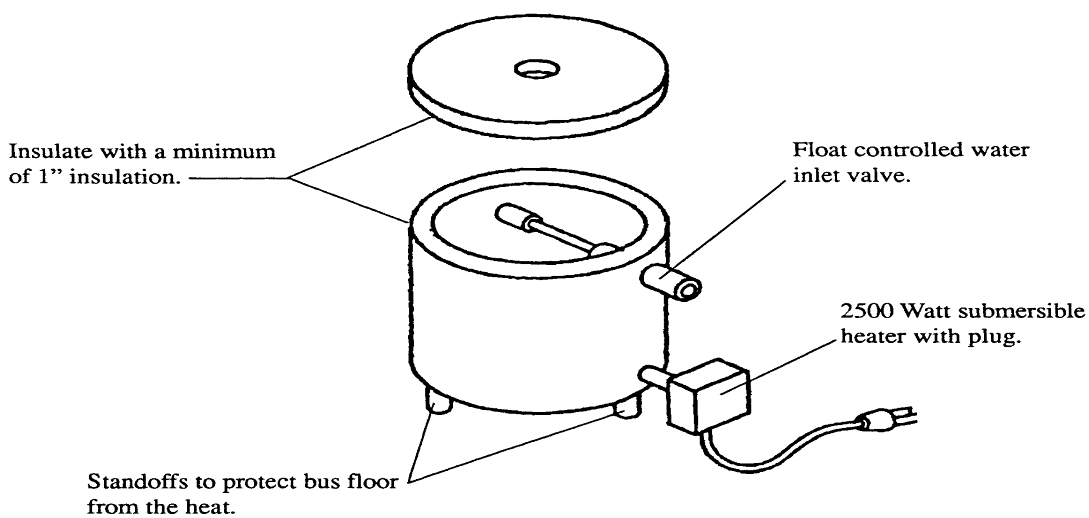
Figure 1 Typical Light Bulb Rack

8.4.2.2 Boiler pots (see Figure 2) to generate a latent heat load of 8 KW are needed. Other means of vapor generation may be used but must not disrupt the normal air circulation within the passenger compartment. Extreme care must be used to maximize the latent heat generation of these boiler pots. Therefore, it is recommended that an insulated cover be used on each pot with a hole for vapor outlet to minimize sensible heat input.

Note: No additional fans are to be used in the vehicle interior. Only the normal air conditioning unit and/or vehicle blowers are to be operated.

LATENT HEAT LOAD

TYPICAL BOILER POT



A cover must be supplied with a vapor release hole. The cover should be constructed so as to allow condensed vapor to drip back into the boiler pot.

Figure 2 Typical Boiler Pot

8.4.2.3 Electrical power to supply energy to the light racks and the boiler pots. The power supplied to both the must be variable to allow nearly infinite control of the heat output of these units. Any means may be used to adjust the energy input to the vehicle, but a true measure of that input must be made, eliminating any losses in the adjustment apparatus.

8.4.3 Placement of devices

8.4.3.1 The light bulb racks should be positioned at or near passenger head level, either by placing the racks on top of the seat backs or by supporting them with a stand or hangers. The light racks spacing must be such that an even distribution of heat is achieved.

8.4.3.2 Boiler pots should be positioned in the vehicle aisle so as to minimize their effect on the interior thermocouples.

Note: If interior thermocouples are close to any load generating equipment, care must be taken to minimize the effect of radiant heat on them. Refer to Section 8.5, Temperature Measurement for more details.

8.5 Temperature measurements

8.5.1 Tools, equipment, and devices

8.5.1.1 It is recommended that thermocouples be used for all temperature measurements, with the exception of the wet bulb temperature readings.

8.5.1.2 Other types of temperature measuring devices may be used such as, resistive temperature devices, thermistors, etc., however, because of the conditions under which these tests are conducted and the difficulty of maintaining calibration in a field type environment, these should be a secondary consideration. These other devices are primarily for a laboratory environment where handling and calibration is less of a problem.

8.5.2 Methods

8.5.2.1 An ongoing calibration program and a means of spot checking probes must be set up and used on a scheduled basis as well as when a problem is suspected. This must be done no matter which device is used to measure the temperatures.

8.5.2.2 Shielding from radiant and/or solar heat must be done to ensure correct readings. This should be done to all outside devices subjected to solar rays and any of the other devices which are placed within a few inches of a surface which is of a temperature much greater or less than the surrounding air temperature.

8.5.2.3 Shielding from ambient influence must also be done. When measuring surface temperatures, i.e., copper tubing, unit frame, motor case, etc., the influence of the surrounding air temperature must be eliminated by insulating over the temperature sensing device and extending the insulation for a minimum of one inch in all directions to minimize conduction of heat from ambient influence on surrounding material.

8.5.2.4 In addition to the above, care must be taken to ensure that the proper size probe is used for the jobs. Too large a probe will give ambient isolation problems in contact measurements; too small a probe may not give a good sampling of conditions in some cases. When there is a question, use a second method to check for accurate results. A good rule of thumb is that 99 1/2% of the heat being measured by the probe must come from the source intended.

8.5.2.5 When devices are placed inside a hose or tube to measure the temperature of the substance being carried through it, care must be used to ensure that the sensing device remains in the main stream and does not contact the side wall of the hose or tube.

8.5.3 Probe placement/locations

The recommended locations of temperature probes are only guidelines and may require slight modifications to address actual vehicle design. Care must be taken to avoid placement of sensing devices in immediate path of air duct outlet. In general, the locations are intended to accurately represent the interior passenger area.

8.5.3.1 Interior air temperature probes (See Figure 3)

8.5.3.1.1 Primary locations for the main temperature probes on two axle vehicles:

a) Over the front axle. Move outer bottom thermocouples rearward to clear wheel well.

b) Centered between the two axles.

c) Over the rear axle. Move outer bottom thermocouples rearward to clear wheel well.

8.5.3.1.2 Primary locations for the main temperature probes on three axle vehicles:

a) Over the front axle. Move outer bottom thermocouples rearward to clear wheel well.

b) Centered between the front and center axles.

c) Over the center axle. Move outer bottom thermocouples rearward to clear wheel well.

d) Over the rear axle. Move outer bottom thermocouples rearward to clear wheel well.

8.5.3.1.3 At each of the primary locations, nine (9) temperature sensing devices are used. Their locations are:

a) 72 inches above the floor (aisle location), 48” above the floor (roadside/curbside location)

b) Just above the seat cushion

c) 6 inches above the floor

8.5.3.1.4 These places are located at three points across the vehicle:

a) The centerline of the forward facing seat pair on the curbside.

b) The center line of the vehicle (aisle).

c) The center line of the forward facing seat pair on the roadside.

8.5.3.1.5 Operator area temperature probes are located:

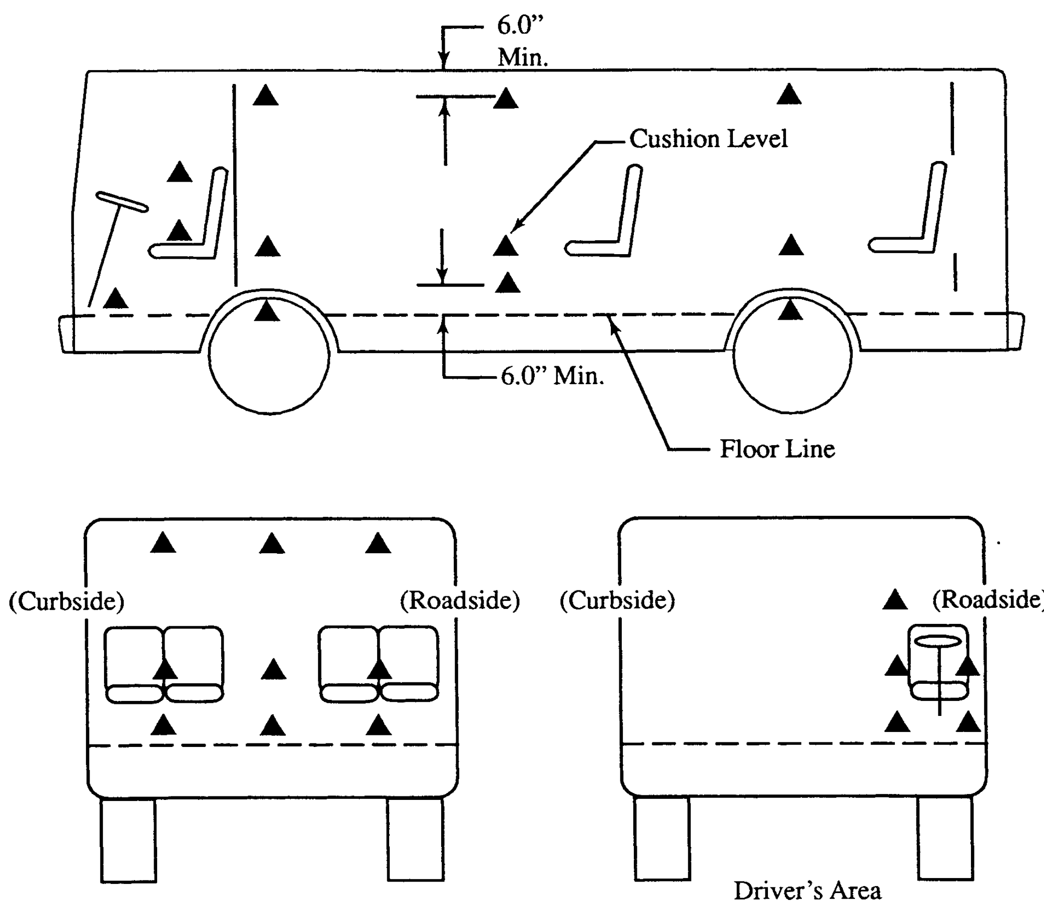
a) Even with the center of the operator's head.

b) Even with the center of the operator's seat at 6 inches above cushion.

c) 6 inches above the floor between brake pedal and accelerator.

8.5.3.1.6 Entrance/Exit temperature probes are located at the center of all entrance and exit door openings, 6 inches from the outer edge, touching the floor.

LOCATION OF INTERIOR TEMPERATURE PROBES



Note: Floor probes which cannot be placed properly because of interference with body parts (such as wheel wells) shall be moved to a location within the same plane as the other probes in the common grouping, i.e., floor probes would move inboard and maintain a dimension of 6 inches from the floor and 6 inches from the inside of the wheel well.

Figure 3 Location of Interior Temperature Probes

8.5.3.2 Ambient air temperature probes (See Figure 4)

Note: Ambient temperature probe locations may be substituted only if their position, because of component location, is in the direct flow of condenser or engine air outlet. This condition may occur with a rooftop, skirt mount or other condenser locations. The probe should only be moved far enough to remove it from the high temperature air. The new location must then be clarified within the submitted test data. All other temperature probes should be properly located.

Ambient temperature probes are located at specified points around the vehicle body. Each probe is placed on a standoff which holds the sensor at a distance of 12 inches from the surface of the vehicle. This minimizes the effect of radiant heat on the probes.

a) Center of the front of the vehicle body.

b) Centerline of roof 6 feet behind the front edge of the roof.

c) Centerline of roof 6 feet ahead of rear edge of roof.

d) Centerline of vehicle body on the roadside 6 feet ahead of rear of vehicle near the rear axle.

e) Centerline of vehicle body on the curbside 6 feet ahead of rear of vehicle near the rear axle.

f) Under floor, near the front axle. (Approx. 6 ft. to 8 ft. behind the front bumper).

g) Centerline of the vehicle body on the roadside 6 feet behind front of vehicle near the front axle.

h) Centerline of the vehicle body on the curbside 6 feet behind front of vehicle near the front axle.

Note: Ambient wet bulb measurement and the corresponding dry bulb temperature (sampling device) should be placed at the front of the vehicle and outside the flow of any unmixed high temperature air.

Compressor ambient temperature probe (1) is located 3 to 4 inches from the compressor body. The preferred point is above the compressor centered over the body. Some applications do not allow this and judgment must be used to set the probe at a point that will measure the true ambient (watching for radiant heat).

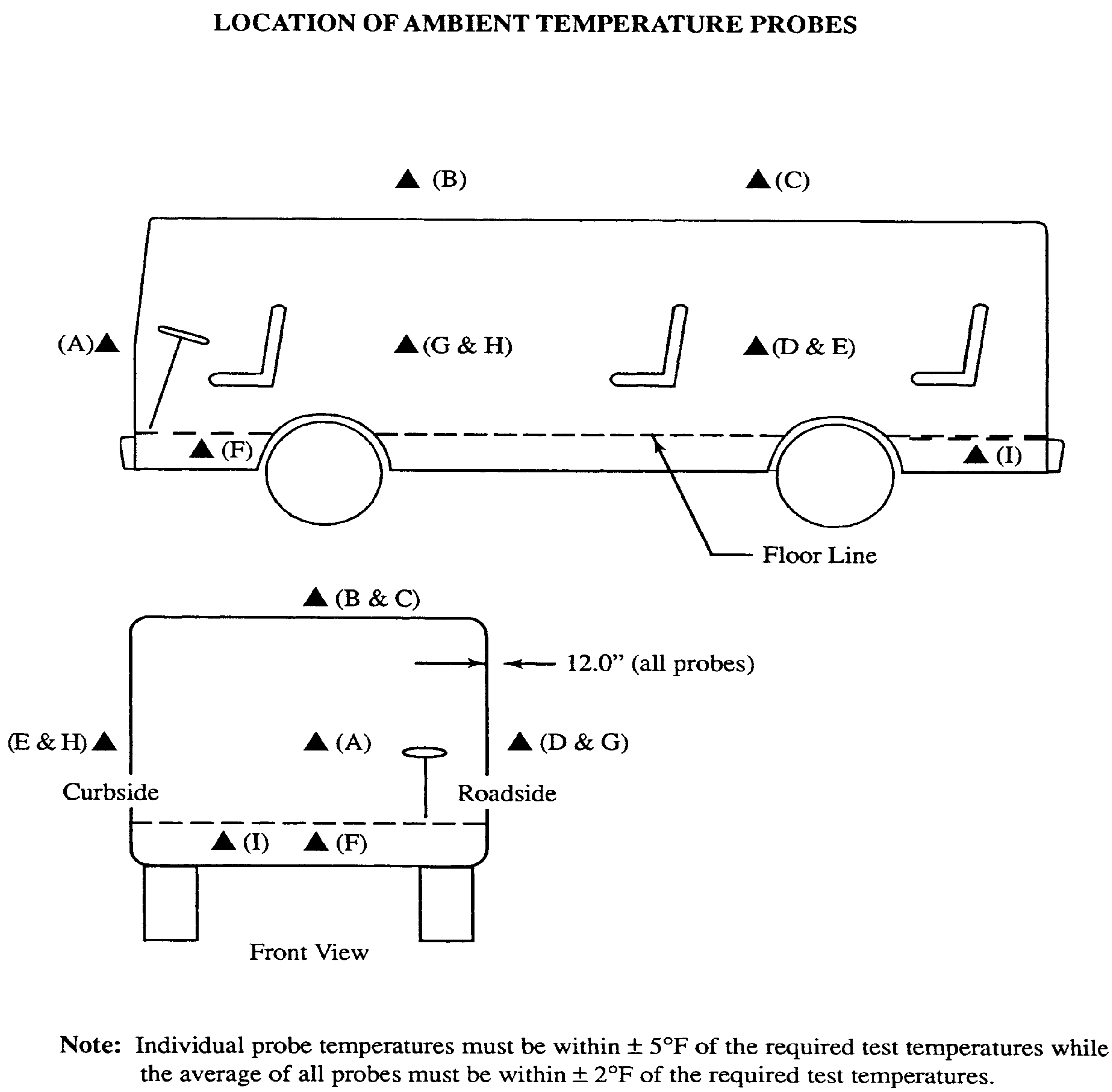


Figure 4 Location of Ambient Temperature Probes

8.5.3.3 Air temperature probes

8.5.3.3.1 Air temperature entering the evaporator coil should be a grid of 4 probes placed near the air conditioning unit return air grill.

8.5.3.3.2 Air temperature leaving the evaporator coil may be measured within the air conditioning unit or in the connecting air duct anywhere within the air stream. The probe placement shall not exceed a distance of 3 feet from the air conditioning unit evaporator blower outlet.

8.5.3.3.3 (Optional) Air temperature inside the vehicle air ducts.

a) Curbside rear

b) Curbside middle

c) Curbside front

d) Roadside rear

e) Roadside middle

f) Roadside front

Locate these inside the air duct 6 inches from the outlets in the approximate same location as the primary interior temperature probes, referred to in Section 8.5.3.1/Figure 3

8.5.3.3.4 Air entering the condenser coil should be a grid (minimum of 4 probes).

8.5.3.3.5 Air leaving the condenser coil should be a grid (minimum of 4 probes).

NOTE– Condenser air temperatures should be taken 6 inches from the coil surface when possible. Ensure that all vehicle shrouding and seals are in place to prevent short cycling of hot condenser outlet air or engine air into the inlet air side of the condenser coil. Only ambient air should enter the condenser coil.

8.5.4 Data needed

8.5.4.1 Refrigerant temperature

a) Compressor discharge- vapor temperature

b) Vapor as it enters the condenser coil

c) Liquid as it leaves the condenser coil

d) Liquid as it enters the thermal expansion valve

e) Vapor as it leaves the evaporator coil

f) Vapor as it enters the compressor.

NOTE– Refer to Section 8.5.3 for application of those probes.

8.5.4.2 Engine coolant temperature

Data points that may be used on an optional basis for heating tests or as a reference point during cooling tests are:

a) Engine coolant temperature entering the main unit heater coil.

b) Engine coolant temperature leaving the main unit heater coil

c) Engine coolant temperature entering the vehicle radiator

d) Engine coolant temperature entering the auxiliary heater unit coil

e) Engine coolant temperature leaving the auxiliary heater unit coil.

NOTE 1–Refer to Section 8.5.2 for caution in installation of temperature probes.

NOTE 2–Vehicle engine coolant is to contain a mixture of 50% ethylene glycol and 50% water.

NOTE 3–These temperature data points may also be important during the air conditioning cooling tests as they indicate whether the unit flow control values are opening/closing or leaking.

8.5.4.3 Wet bulb temperature

Three wet bulb temperature measurements may be informative at various times during the tests for development information or troubleshooting. However, only the wet bulb temperature of air entering the evaporator is necessary for this testing evaluation.

a) Air entering the evaporator (required on all tests)

b) Air leaving the evaporator

c) Ambient wet bulb

NOTE–The wet bulb measurement is specified in ASHRAE Standard 41.6-1982. Distilled (or as a minimum, demineralized water must be used. Alternate devices which are acceptable for testing wet bulb temperatures, when used in the manner described by the manufacturer, and having an accuracy of +2% of total measurement, are a sling psychrometer or state-of-the-art electronic devices.

8.5.4.4 Ambient temperature

8.5.4.4.1 The difference between ambient temperature probes should be maintained so that no single probe varies by more than ± 5°F from the average ambient. The average of all the ambient probes should be within ± 2°F of the desired ambient. Fans or other means should be used to ensure a good mix of the air.

8.5.4.4.2 Air into the condenser (average) should be kept within ± 3°F of the ambient average.

8.5.4.5 Average temperatures

8.5.4.5.1 Interior average temperature is the result of averaging all the interior air temperatures described in Section 8.5.3.1

8.5.4.5.2 Ceiling average temperature is the result of averaging all the interior air temperatures located 72 inches above the floor and described in Section 8.5.3.1.3, Item A.

8.5.4.5.3 Seat cushion temperature average is the result of averaging all the interior air temperatures located at cushion level and described in Section 8.5.3.1.3, Item B.

8.5.4.5.4 Floor average temperature is the result of averaging all the interior air temperatures located 6 inches above the floor and described in Section 8.5.3.1.3, Item C.

8.5.4.5.5 Ambient average temperature is the result of averaging all the ambient air temperatures described in Section 8.5.3 2, Items A through H.

8.6 RPM measurements

8.6.1 Devices

Speed of rotating devices may be measured using one of the following devices:

a) Magnetic pickups

b) Photo cells or fiber optical pickups

c) Strobes

d) Proximity devices

e) Mechanical tachometer

8.6.2 Data needed

Regular monitoring and RPM measurements are needed for the following components:

a) Vehicle engine

b) Dynamometer stand (when used)

c) Compressor

d) Evaporator fan

e) Condenser fan

8.7 Voltages and current measurements

8.7.1 Tools, equipment, and devices

State-of-the-art devices are to be utilized that ensure accurate, reliable data for both AC or DC power.

8.7.2 Data needed

Depending on the test(s) being conducted, voltage and current measurements are needed for the verification of test conditions. Electrical data may be informative for other tests for development information or troubleshooting. Electrical measurements may include voltage and current for:

a) Evaporator fan motors

b) Condenser fan motors

c) Compressor clutch

d) Power to the simulated sensible load inside the vehicle

e) Power to the simulated latent load inside the vehicle

f) Heater booster pump

g) Auxiliary blowers

h) Battery voltage

i) Miscellaneous components as required to complete the test

8.8 Pressure and flow rate measurements

8.8.1 Tools, equipment, and devices

State-of-the-art devices are to be utilized that ensure accurate, reliable data.

8.8.2 Data needed

8.8.2.1 Pressures

Monitoring and pressure measurements are needed for the following components:

a) Compressor discharge

b) Compressor suction

c) Evaporator outlet (usually on thermal expansion valve equalizer connection)

d) Other refrigeration system points as required to develop, monitor or troubleshoot the air conditioning system

e) Air static pressures, in inches of water, as required, to develop, monitor or troubleshoot the air conditioning system or component therein

f) Miscellaneous pressures as required to complete the test

8.8.2.2 Flow rates

Depending on the test(s) being conducted, flow rate measurements are needed for the verification of test conditions. Flow rate data may be informative for other tests for development information or troubleshooting. Flow rate data may include:

a) Engine coolant flow rate entering the main unit heater.

b) Engine coolant flow rate entering the auxiliary heater unit coil.

c) Air flow of the main A/C unit fans as installed in the A/C system.

d) Air flow of auxiliary fans for heating and/or cooling.

e) Air flow of induced air as used in fresh air exchange ports.

NOTE–Fluid flow of glycol for heating purposes should be measured with an in-line flow device that will not greatly affect the rate of flow being measured. Accurate air flow measurement inside a vehicle is not practical for all tests. A hot wire type device or its equivalent, may be used to estimate air flows. The results of which may be compared to and/or substantiated by component development air flow data.

9. Air conditioning tests

9.1 Pull-down test

9.1.1 Purpose

The purpose of the pull-down test is to measure the amount of time required to reduce the vehicle's interior temperature to a specified value.

This procedure may be used for all types of pull-down tests (including the "Houston Pulldown test").

9.1.2 Preparation

9.1.2.1 Instrument the test vehicle according to Section 8.1 "Instrumentation for Set up"

9.1.2.2 Heat soak the test vehicle in a closed environmental chamber with the chamber temperature control set to maintain the specified initial interior temperature. Open doors, windows, and vents in the test vehicle as necessary to allow air to circulate throughout the vehicle.

9.1.2.3 The soaking of the test vehicle is the single most important factor in ensuring fair and comparable results. The recommended heat soak will ensure that all parts of the test vehicle are at a uniform starting point.

9.1.2.4 For pulldown tests with an applied solar load and a starting interior temperature higher than the ambient temperature, the interior temperature may be achieved by setting the environmental chamber temperature at the desired vehicle interior temperature and then soaking the entire vehicle at this temperature. Prior to starting the pulldown test, and after confirming that the vehicle interior has been thoroughly heat soaked, the test chamber temperature control is set to the specified ambient test temperature.

9.1.2.5 An alternative procedure would be to heat soak the test vehicle in the specified ambient test temperature, and apply a sensible heat load to the vehicle interior to achieve the desired internal heat soak temperature. This procedure may be necessary if the test chamber is not capable of rapidly reducing the test chamber temperature from the heat soak temperature to the ambient test temperature.

9.1.2.6 Fans should be employed to ensure even temperature distribution throughout the test chamber. The temperature differential within the test chamber must be as low as can be achieved.

9.1.2.7 At the beginning of the soak period, the ambient temperature may be raised to increase the heat flow into the vehicle structure. Care should be taken to not over soak the vehicle when this procedure is done. The test vehicle doors, windows and/or roof vents may be opened to speed up the heat soak process.

9.1.2.8 A temperature sensor should be used to indicate a complete heat soak of the interior mass. The sensor should be installed on a seat and insulated from the influence of the surrounding air by a 2 in. x 2 in. x ½ in. thick closed-cell neoprene foam.

9.1.2.9 When the seat mass temperature (SMT) indicates that the vehicle is completely heat soaked to the desired temperature, close the doors, windows, and vents and record the interior temperatures for a period of 10 minutes. If the interior air average (IAVT) or SMT change by +/- 2 ºF, the soak is not stable. Open the doors, windows, and vents and allow additional time to complete the soak.

9.1.2.10 Record data for a minimum period of 30 minutes to demonstrate a stable soaked temperature. (Monitor seat cushion mass sensor).

9.1.2.11 Set the data recorder to record at 1-minute intervals.

9.1.3 Pretest checks

9.1.3.1 The operator's defroster fans should be off for the test but the operator's cooling blower (if installed) should be on and set to its maximum speed setting.

9.1.3.2 The main fresh air intake must be closed off by any means possible to ensure no air leakage. Be sure to note on the data sheets the condition of all vents and auxiliary fans.

9.1.3.3 If applicable, start the vehicle engine and allow it to reach a normal operating temperature before starting the HVAC system.

9.1.3.4 Verify the operating speeds (per manufacturer) as outlined by Section 8.3.

9.1.3.5 Verify that the engine speed control is functional and that the engine speed is the correct test speed.

9.1.3.6 Visually check temperature probes, room fans, windows and vents, HVAC unit thermostat (set to its lowest setting) and data recorder to ensure all channels are operating. Humidity conditions are not specified for this test, however the humidity should be monitored and recorded.

9.1.4 Test

NOTE–Humidity conditions are not specified for this test, however the humidity should be monitored and recorded.

9.1.4.1 Start the data recorder to begin recording data.

9.1.4.2 For pulldown tests with applied solar load, turn on the predetermined solar load. Refer to Section 8.4.1.1 for a description of the correct solar load to be used.

9.1.4.3 Turn on the HVAC system. If HVAC system control is actuated from within the vehicle, exit the vehicle as quickly as possible, ensuring all doors, windows, and vents are closed.

9.1.4.4 Once the HVAC system is on, allow the test chamber temperature to drop (as quickly as possible) to the specified ambient test temperature. The test chamber must maintain that temperature for the remainder of the test.

9.1.4.5 Record data for 40 minutes.

9.2 Air conditioning stabilization test

9.2.1 Purpose

The purpose of the air conditioning stabilization test is to determine the ability of the air conditioning system to maintain the interior temperature at a specific set point and to determine the temperature distribution within the test vehicle.

9.2.2 Preparation

9.2.2.1 Instrument the test vehicle per Section 8.1

9.2.2.2 Set the vehicle HVAC system thermostat to 70°F.

9.2.2.3 The main fresh air intake must be closed off by any means possible to ensure no air leakage. Be sure to note on the data sheets the condition of all vents and auxiliary fans.

9.2.2.4 If applicable, start up the vehicle engine and operate at high idle.

9.2.2.5 Turn on the air conditioning system.

9.2.2.6 Turn on the full seated and standee heat load and the solar heat load.

9.2.2.7 Maintain ambient temperature at 100°F and allow the air conditioning system to run until the interior temperature is near stabilization.

9.2.2.8 Set the data recorder to record at 1-minute intervals.

9.2.3 Test

NOTE–Humidity conditions are not specified for this test, however the humidity should be monitored and recorded.

9.2.3.1 Maintain ambient temperature at 100°F and allow the air conditioning system to run until the interior temperature is near stabilization.

9.2.3.2 Maintain the ambient condition within 0.5°F of the specified temperature and allow the air conditioning system to run until the interior temperature has stabilized.

9.2.3.3 Start the data recorder to begin recording data.

9.2.3.4 Maintain the ambient condition within 0.5°F of the specified temperature for a minimum of 20 minutes.

9.3 Cooling profile test (95° and 115°F ambients)

The profile test is optional and should be used for reference only.

9.3.1 Purpose

The purpose of this test is to verify that the vehicle air conditioning maintains interior temperatures while operating on the design operating profile.

9.3.2 Preparation

9.3.2.1 Instrument the test vehicle, per Section 8.1

9.3.2.2 Allow the test vehicle interior temperature to stabilize at its lowest temperature with the full seated and standee passenger load and the solar load. The vehicle engine is to be set at high idle and ambient temperature held at 95° and 115°F.

9.3.2.3 Confirm with the vehicle manufacturer what engine speeds are experienced at idle, fast idle, 20 MPH, 40 MPH and 55 MPH. Also verify transmission shift points as they relate to engine RPM.

9.3.2.4 Start the profile test. Simulate the operating profile by using the door controls and engine speeds.

9.3.2.5 Set the data recorder to record at 1-minute intervals.

9.3.3 Test

9.3.3.1 Start the data recorder to begin recording data.

9.3.3.2 Begin the test per Table 4 and Figure 4 at the beginning of a recording cycle. This makes comparison curves possible.

9.3.3.3 The CBD (Central Business District) cycle consists of accelerating to an engine speed equal to a vehicle speed of 20 mph. Acceleration time is equal to 10 seconds, then hold the 20 mph speed for 18.5 seconds followed by a deceleration time of 4.5 seconds. When the engine reaches idle, the vehicle doors must open (both doors). The dwell time at idle is 7 seconds and the doors must close to then allow the start of the next cycle. The cycle described in Table 4 must be run for 14 consecutive times for each CBD phase.

9.3.3.4 The idle phase consists of sitting with the vehicle engine on high idle for 5 minutes.

9.3.3.5 The arterial cycle consists of accelerating to an engine speed equal to a vehicle speed of 40 mph. Acceleration time is equal to 29 seconds, then hold the 40 mph for 22.5 seconds, followed by a deceleration time of 9 seconds. When the engine reaches idle the vehicle doors must open (both doors). The dwell time at idle is 7 seconds and the doors must close to then the start of the next cycle. The arterial cycle described in Table 4 must be run for 4 consecutive times for each arterial phase.

9.3.3.6 The commuter cycle consists of accelerating to an engine speed equal to 55 mph or maximum governed rpm, whichever occurs first. Hold the 55 mph for 188 seconds, then take 12 seconds to decelerate with an idle dwell with doors open for 20 seconds to complete the cycle. The commuter cycle described in Table 4 occurs only once in the profile test.

9.3.3.7 Figure 4 is a visual illustration of the test cycles.

9.3.3.8 The exterior humidity is not controlled, but it should be less than 50% RH and should be recorded in the test data.

9.3.3.9 Interior humidity should be measured at the beginning and the end of the test.

Table 4 - Design operating duty cycle

Phase	Top speed (mph)	Cruise time (Sec.)	Deceleration time (Sec.)	Dwell time (Sec.)	Dwell time (Sec.)	Cycle time (Min./Sec.)	Total stops
CBD	20	10	18.5	4.5	7	9-20	14
Fast idle				--	--	5-0	--
Arterial	40	29	22.5	9	7	4-30	4
CBD	20	10	18.5	4.5	7	9-20	14
Arterial	40	35	22.5	9	7	4-30	4
CBD	20	10	18.5	4.5	7	9-20	14
Commuter	Max. or 55	90	188	12	20	5-10	1
Note: CBD = Central Business District **Average speed - 17.8 mph**					**Total**	**47-10**	**51**

10. Heating tests

NOTE–In this document the heating pull up test and stabilization test are described as two separate tests. However, the stabilization test may instead be recorded as a continuation of the heating pull up test.

Use the vehicle engine and auxiliary coolant heaters (if applicable) to perform the heating test(s) unless the test chamber cannot limit the rise of the test temperature to less than 10 °F. If the test chamber cannot limit the temperature rise to less than 10° F, the test(s) may be performed using a house glycol system in order to reduce the waste heat the test chamber would need to absorb during the test.

10.1 Heating pull up test

10.1.1 Purpose

The purpose of the pull up test is to measure the amount of time required to raise the vehicle's interior temperature to a specified value.

10.1.2 Preparation

10.1.2.1 If not using the engine and auxiliary coolant heater, determine the flow rate for the pull up test using either the on road method (see Section 10.1.2.2) or the in-house method (see Section 10.1.2.3). Either method may be used, but must be presented as part of the test report. Run the tests at a flow rate corresponding to engine high idle.

10.1.2.2 On road method

a) Install a flow meter of ±1% (total flow) accuracy in the heating glycol loop on the vehicle.

b) Record the glycol flow rate with the vehicle stationary at idle and while driving at speeds of 10, 15, and 20 mph on flat level ground.

c) Record flow rates using all possible heating unit combinations.

10.1.2.3 In-house method

a) Install pressure transducers to measure the pressure difference across the heating glycol loop on the vehicle.

b) Run the vehicle engine at rpm equivalents of idle, high idle, 10, 15, and 20 mph.

a) NOTE–Consult vehicle manufacturer for gearing and speed ratios.

b) Record pressure differences with all combinations of heaters on.

c) Use the recorded data to create a graph demonstrating the pressure differences of the vehicle system.

d) Disconnect the engine and cooling system from the passenger compartment heating system.

e) Connect the house glycol system in its place.

f) Provide coolant flow through the vehicle heating system, duplicating pressures seen under normal on road operation.

g) Record the flow rate that corresponds to each of the delta-Ps previously recorded.

h) Use this recorded data to create a graph demonstrating the engine speed vs. the glycol flow rate. Unless otherwise specified by the customer, use a flow rate corresponding to the average engine rpm during the design operating profile (see Section 8.6).

10.1.2.4 Instrument the test vehicle according to Section 8.1

10.1.2.5 Close off the main fresh air intake to prevent air leakage. If the system does not have a damper, use other means to close off the air intake.

10.1.2.6 Connect a battery charger or power supply to the vehicle battery. This will maintain the battery during the soaking period and supply power for the vehicle' electrical systems during the tests.

10.1.2.7 Use fans to ensure even temperature distribution throughout the test chamber. The ambient temperature sensors should be within a range of 10°F.

10.1.2.8 If you are going to record the pull up and stabilization tests as a continuous test, set the HVAC system thermostat to 70°F. If you are going to perform the pull up and stabilization tests as separate tests, set the HVAC thermostat to its highest setting.

10.1.2.9 Cold soak the test vehicle in a closed environmental chamber with the chamber temperature control set to maintain the specified initial interior temperature. Open doors, windows, and vents in the test vehicle as necessary to allow air to circulate throughout the vehicle.

NOTE–Soaking the test vehicle is the single most important factor in ensuring that all parts of the test vehicle are at a uniform starting point. This is necessary for fair and comparable results between different vehicles.

10.1.2.10 Use a temperature sensor to indicate a complete cold soak of the interior mass. Install the sensor on a seat and insulate from the influence of the surrounding air by a 2 in. x 2 in. x ½ in. thick closed-cell neoprene foam.

10.1.2.11 When the seat mass temperature (SMT) indicates that the vehicle is completely cold soaked, close the doors, windows, and vents and record the interior temperatures for a period of 10 minutes. If the interior air average (IAVT) or SMT change by +/- 2 ºF, the soak is not stable. To stabilize the soak, open doors, windows, and vents and allow additional time to complete the soak.

10.1.2.12 Record data for 30 minutes after stabilization. Monitor the SMT to ensure that the soak remains stable.

10.1.3 Pretest checks

10.1.3.1 Ensure that the operator's defroster fans are on for the test. If the operator's blower is installed, ensure that it is on and set to its maximum speed setting.

10.1.3.2 Ensure that the main fresh air intake is closed off.

10.1.3.3 Check that all necessary vents are open.

10.1.3.4 Check that auxiliary fans function properly.

10.1.3.5 Check that heating coils are unblocked and free of debris.

10.1.3.6 Check that pumps, valves, and fans function properly.

10.1.3.7 Ensure the battery voltage level is at the OEM-specified value.

10.1.3.8 Ensure the operating speeds are at the OEM-specified levels (see Section 4.5).

10.1.3.9 Ensure that temperature probes and room fans are in their proper locations.

10.1.3.10 Check that doors, windows, and escape hatches are closed.

10.1.3.11 Ensure data recorder is functioning properly.

10.1.3.12 Set the data recorder to record at 1-minute intervals.

10.1.4 Test

NOTE–Humidity conditions are not specified for this test, however the humidity should be monitored and recorded.

10.1.4.1 If using the vehicle engine and auxiliary coolant heaters to run the pull up test, start the engine and coolant heater and allow them to warm the coolant to a normal operating temperature.

10.1.4.2 If using the house glycol system, open the bypass valve and begin circulating the hot glycol through the test vehicle heating system.

10.1.4.3 With the data recorder set to record at one-minute intervals, Start the data recorder to begin recording data. The first reading will be your baseline.

10.1.4.4 Turn on the HVAC system and the operator's defroster/heater. If HVAC system control is actuated from within the vehicle, exit the vehicle as quickly as possible, ensuring all doors, windows, and vents are closed.

10.1.4.5 Maintain the ambient condition within 10°F of the specified temperature.

10.1.4.6 If using a house glycol system, monitor and adjust the glycol flow rate when different coil combinations occur during the test to the values recorded in Section 10.1.2.1.

10.1.4.7 Record data for 90 minutes.

10.1.4.8 If you are going to record the pull up and stabilization tests as a continuous test, continue to record data for 30 minutes after it has stabilized.

10.2 Heating stabilization test

10.2.1 Purpose

The purpose of the heating stabilization test is to determine the ability of the heating system to maintain the interior temperature at a specific set point without the operator's defroster/heater on and to determine the temperature distribution within the test vehicle.

10.2.2 Preparation and pretest checks

Complete the Heating Pull-Up Test as specified in Section 10.1, using the same setting except with the operator defroster/heater off and with the thermostat set to 70°F.

10.2.3 Test

10.2.3.1 Maintain the ambient condition within 0.5°F of the specified temperature and allow the heating system to run until the interior temperature has stabilized.

10.2.3.2 Start the data recorder to begin recording data.

9.2.3.5 Maintain the ambient condition within 0.5°F of the specified temperature for a minimum of 20 minutes.

10.3 Heating profile test

The profile test is optional and should be used for reference only.

10.3.1 Purpose

The purpose of this test is to verify that the vehicle heating system maintains interior and entrance/exit area temperatures while operating on the design operating profile.

10.3.2 Preparation

10.3.2.1 Instrument the test vehicle, per Section 8.

10.3.2.2 Use an in-house glycol supply system set at 150°F and a flow rate as determined in Section 10.1.2.1.

10.3.2.3 Allow the test vehicle interior temperature to stabilize at its highest temperature with no passenger or solar load in an ambient of -10°F.

10.3.2.4 Start the profile test. Simulate the operating profile by using the door controls.

10.3.2.5 Set the data recorder to record at 1-minute intervals.

10.3.3 Test

10.3.3.1 Start the data recorder to begin recording data.

10.3.3.2 Begin the test per Table 4 and Figure 4 at the beginning of a recording cycle. This makes comparison curves possible.

10.3.3.3 Cycle the doors as described in Section 9.3.3. Engine cycling is not required for this test.

11. U-factor test

11.1 Purpose

The purpose of the U-Factor test is to provide information concerning the quality and efficiency of the vehicle insulation.

11.2 Preparation

11.2.1 The vehicle must be instrumented for adequate sampling of both interior and exterior temperatures. Instrumentation Specification Figure 3 and Figure 2) for interior temperatures and Figure 4) for ambient temperatures.

11.2.2 The interior heat source should be spread out evenly throughout the vehicle such that no hot spots occur. It is recommended that the light racks described in the instrumentation standard be used as a heat source. See Figure 1

11.2.3 Interior air circulation should be provided by natural convection or by the air conditioning system blowers. If fans must be added to keep the interior temperature within a range of 15°F then their power input must be considered in the final calculation - and the air flow caused by them must approximate the normal flow of air in the vehicle.

11.2.4 Exterior air circulation is required to maintain the room ambient within the temperature gradient as specified in 8.5.4.4.1. Several fans may be necessary to provide circulation. Care in placement of external fans is required to minimize air scrubbing of vehicle side walls. That scrubbing will increase U-factor.

11.3 Test

11.3.1 Heat the vehicle interior to a minimum of 30°F above the ambient temperature for at least five hours, (best over night) with the maximum interior temperature not to exceed 150° average. Vehicle power input will be approximately 6 KW or more.

> **Note**: Caution The vehicle manufacturer should be consulted to determine the maximum safe interior temperature for the vehicle, as some plastic parts may distort under high temperature.

11.3.2 After a minimum of five hours heating, record temperature data at 15 minute intervals until nine consecutive sets of readings (two hour period) indicates that steady state conditions have been maintained within ±2°F in ambient and ±1°F in the interior.

11.3.3 All electrical input is to be recorded such as:

a) Power to the unit blowers.

b) Power to any internal fans.

c) Power to light racks (interior load).

d) Power to any miscellaneous load items.

e) Record this data for the same 2 hour period

11.4 Data calculation

11.4.1 This specification was written with the computerized data system in mind, however, any means of recording the data is permissible as long as a data sheet is generated to outline the conditions, load, fan speeds. extra fans. etc. and the temperature data, in 15 min. intervals is also recorded.

11.4.2 Electrical measuring instruments must be accurate within ±1 percent of the quantity measured for electrical input to heaters and within ±2 % for electrical input to fan motors and other accessories.

11.4.3 Barometric pressure should also be recorded and measured with an accuracy of 0.1" of mercury.

11.4.4 Time measurements are to be made with apparatus whose accuracy is within ± 0.2 percent of the time interval being measured.

11.4.5 Heat leakage (U-factor) should be figured by the following procedure:

$$Qx = \frac{3.413\left(P + Pm + Pf\right)}{\left(AAVT - IAVT\right)}$$

P, P_M, P_F, AAVT, IAVT are all average values obtained from the 2 hours of data recorded.

P = Power input to light racks (load) (watts).

P_M= Power input to the unit fan motor (watts).

P_F = Power input to all other fans and accessories (watts).

AAVT = Ambient Average Temperature in °F.

IAVT = Interior Average Temperature in °F.

Q_X = Heat transfer coefficient in BTU/Hr/ºF of difference in interior to exterior temp. (U-factor).

For typical expected values see Annex B.

11.5 Variation of test

Variations of this test could be:

a) Test run with the vehicle engine running.

b) Test run with the unit (evap.) blowers on.

c) Test run with the unit (evap.) blowers off.

This would determine the various effects these items would have on the heat loss coefficient.

12. System functionality tests

12.1 Purpose

The purpose of the system functionality test is to ensure that the control system is functional and enables all the components within the HVAC system to operate properly.

12.2 Preparation

12.2.1 Define the operating characteristics and the inputs and outputs of each component within the HVAC system.

12.2.2 Define the interaction between the individual HVAC system components and between the components and controls, using diagrams and schematics that include logic if applicable.

12.2.3 Using the data defined in the diagrams and schematics from Section 12.2.2, create a Functionality Data Table (see Table 5). The table should cover the range of operation for +100° F to -20° F.

12.2.4 Set the HVAC control at 70 °F.

12.2.5 Set the data recorder to record at 1-minute intervals.

Table 5 – HVAC functionality data table

HVAC Functionality Data Table	Date:

Vehicle Mfg / Description: ____

AC Unit: Manufacturer: ______________________ **Model:**______________________.

□ Roof Mount □ Rear Mount □ Fully Electric

AC Compressor: Manufacturer: ______________________ **Model:** ______________________ **.**

□ with unloader □ without unloader

Supplemental Heater: Manufacturer:______________________ **Model:**______________________**.**

Fuel: □ Diesel □ Natural Gas **Configuration:** □ Engine Preheat □ Bus Interior Heat

Interior Heat:

□ **Make-up from AC Unit: Rated Capacity:** ______________________ □ Hot Water □ Electric

□ **Floor Heat: No. of Units** _____________**Total Rated Capacity** ______________________□ Hot Water □ Electric

□ Radiant □ Forced Air ____

□ UnderSeat □ UnderFloor ____

____

HVAC set-point: Range: ________**°F to** ________**°F During Testing:** ___________**°F**

Decreasing ambient temperature – summer/fall operation

LOGIC CONTROL POINTS		**Device**	**Event**
Ambient temp. (°F)	**Interior temp. (°F)**		

Increasing ambient temperature – winter/spring operation

LOGIC CONTROL POINTS		**Device**	**Event**
Ambient temp. (°F)	**Interior temp. (°F)**		

12.3 Test for increasing ambient temperature

12.3.1 Cool the room to -10° F ambient.

NOTE – Running the Heating Stabilization Test in Section 5.2.2 will achieve these test conditions.

12.3.2 Turn on the vehicle and operate the HVAC system until the interior temperature is stabilized at 70° F ±5° F.

12.3.3 Start the data recorder to begin recording data.

12.3.4 Raise the temperature in the test cell as quickly as possible from -20° F to 10° F below the lowest logic control point (refer to the Functionality Data).

12.3.5 Raise the ambient temperature at a rate of 5 to 10° F per hour until the ambient temperature reaches 10° F above the highest logic control point (refer to the Functionality Data Table). If auxiliary controls and/or overrides exist, they should be exercised at the appropriate time or temperature so that their effect can be identified and verified.

12.4 Test for decreasing ambient temperature

12.4.1 Heat the room to 100° F ambient.

NOTE – Running the Air Conditioning Stabilization Test in Section 9.2 will achieve these test conditions.

12.4.2 Turn on the vehicle and operate the HVAC system until the interior temperature is stabilized at 70° F ±5° F.

12.4.3 Start the data recorder to begin recording data.

12.4.4 Lower the temperature in the test cell as quickly as possible from 100° F to 10° F above the highest logic control point (refer to the Functionality Data).

12.4.5 Lower the ambient temperature at a rate of 5-10° F per hour until the ambient temperature reaches 10° F below the lowest logic control point (refer to the Functionality Data Table). If auxiliary controls and/or overrides exist, they should be exercised at the appropriate time or temperature so that their effect can be identified and verified.

13. Documentation

Test documentation should include but not be limited to the following

a) Purpose

b) Scope

c) Test criteria (specifications)

d) Summary, conclusions, and recommendations

e) Vehicle descriptions (pictures recommended)

f) Air conditioning system description

g) Environmental room details

h) Test instrumentation details

i) Test conditions

j) Test details

   – Relevant descriptors of the test vehicle

   – Tabulated results showing measured data and specified requirement

   – Data review, calculations, and observations

   – List of test witnesses

Annex A

(informative)

Bibliography

[B1] The information compiled for this APTA publication and the original draft have been provided by Thermo King, Minneapolis, MN., October, 1994.

[B2] References to ASHRAE publication data noted in this publication have been taken from HVAC Applications, 1991, and Fundamentals, 1993.

Annex B

(informative)

Typical test data points master list for vehicle testing

Section #	Description	Number of sensors	Identifier*
#1 Interior:	(TO BE USED AS STANDARD DATA POINTS FOR ALL TESTS)		
	Top = 72 inches above the floor		
	Middle = 2 inches above lower seat cushion		
	Bottom = 6 inches above the floor		
	Roadside front top	(single)	= 12TT
	Roadside front middle	(single)	= 12MT
	Roadside front bottom	(single)	= 12BT
	Interior front top	(single)	= IFTT
	Interior front middle	(single)	= IFMT
	Interior front bottom	(single)	= IFBT
	Curbside front top	(single)	= I1TT
	Curbside front middle	(single)	= I1MT
	Curbside front bottom	(single)	= I1BT
	Roadside middle top	(single)	= I4TT
	Roadside middle middle	(single)	= 14MT
	Roadside middle bottom	(single)	= 14BT
	Interior middle top	(single)	= IMTT
	Interior middle middle	(single)	= IMMT
	Interior middle bottom	(single)	= IMBT
	Curbside middle top	(single)	= 13TF
	Curbside middle middle	(single)	= 13MT
	Curbside middle bottom	(single)	= 13BT
	Roadside rear top	(single)	= 16TT
	Roadside rear middle	(single)	= 16MT
	Roadside rear bottom	(single)	=16BT
	Interior rear top	(single)	= IRTT
	Interior rear middle	(single)	= IRMT
	Interior rear bottom	(single)	= IRBT
	Curbside rear top	(single)	= 15TT
	Curbside rear middle	(single)	= 15MT
	Curbside rear bottom	(single)	= 15BT
	Operators head area inboard	(single)	= ID1T
	Operators head area outboard	(single)	= ID2T
	Operators seat area inboard	(single)	= ID3T
	Operators seat area outboard	(single)	= ID4T
	Operators foot area inboard	(single)	= ID5T
	Operators foot area outboard	(single)	= ID6T

Section #	Description	Number of Sensors	Identifier*
#2 Air Out Ducts:			
	Air curbside rear	(single)	= ECRT
#3 Unit Data Heating:			
	Air into heater coil	(grid of 4)	= HI1T
	Air out of heater coil	(grid of 4)	= H01T

Coolant into heater coil	(single)	= CI1T
Coolant out of heater coil	(single)	= C01T
Motor volts at the motor	(qty. as required)	= MVIV
Motor amps. at the positive terminal	(qty. as required)	= MC1C

#4 Auxilliary Heating Unit Data:

Air into auxillary heater coil	(grid of 4)	= H12T
Air out of auxilliary heater coil	(grid of 4)	= H02T
Coolant into auxilliary heater	(single)	= C12T
Coolant out of auxillary heater	(single)	= C02T
Motor volts at the motor	(qty. as required)	= MV2V
Motor amps. at the positive terminal	(qty. as required)	= MC2C

Note:

1. Use identifiers for auxilliary or operator defroster/heater units by changing the last number (ie: H13T, HI4T etc.)
2. Generally, the numbering should be done in accordance with the importance of the heater unit.

For example: Main heater = Unit #1
Auxilliary Heaters = Unit #2, #3, etc. (from front to rear)
Defroster = Unit # (number is to follow the main and auxilliary unit numbers)

#5 Miscellaneous Heating Unit Data:

(Use with the present system of engine coolant flow measurement, which is to use a single coolant flow meter and create a coolant flow chart for the vehicle heating system using the pressure drop information - [HPDP].) (HPDP = heat or pressure differential pressure)

Coolant temperature into vehicle	(single)	= CIBT
Coolant temperature out of vehicle	(single)	= C0BT
Coolant flow rate (gpm)	(single)	= WFRR

Section #	Description	Number of Sensors	Identifier*

#6 Main A/C Unit Cooling Data:

Air into evaporator	(grid 4)	= EA1T
Air out of evaporator	(grid 4)	= EA0T
(two Sensors at inlet to each blower)		
Air into condenser	(grid 4)	= CAIT
Air out of condenser	(grid 4)	= CA0T
(6" from coil when possible per)		
Vapor out of compressor	(single)	= VCDT
Vapor into condenser	(single)	= VICT
Liquid out of condenser	(single)	= L0CT
Liquid into expansion valve	(single)	= LIXT
Vapor out of evaporator	(single)	= VOET
Vapor into compressor	(single)	= VCST
Compressor discharge pressure	(psig)	= CDPP
Compressor suction pressure	(psig)	= CSPP
Evaporator outlet pressure	(psig)	= EDPP
Evaporator motor volts	(volts)	= NVIV

Evaporator motor amps	(amps)	= MCIC
Condenser motor volts	(volts)	= CFVV
Condenser motor amps	(amps)	= CFAC
Total unit power	(amps)	= TUAC
Unit thermostat bulb	(double)	= TBAT

When both heating and air conditioning are done with the same unit, the air in/out may be called either EAIT or HI1T EA0T or H01T.

Section #	Description	Number of Sensors	Identifier

#7 Miscellaneous Data:

These data points are used to monitor test parameters, make cross check calculations, and confirm system conditions.

Seat mass temperature	(single)	= SMTT
Floor mass temperature	(single)	= FMTT
Ice water temperature	(single)	= ICET
Power input to lights (KW)	(sensible)	= KSTE
Power input to boilers (KW)	(latent)	= KLHE
Ambient wet bulb	(probe)	=AWBT
Interior wet bulb	(probe)	= IWBT
Compressor ambient	(grid 2)	= CATT
Engine water pump outlet	(single)	= EWOT
Coolant returning to engine	(single)	= EWIT
Entrance area temperature	(single)	= ENAT
Exit area temperature	(single)	= EXAT

Engine water out and coolant returning may also be used to monitor the coolant supplied to the vehicle from the house glycol system. In this case the designation of EWOT and EWIT should change to CIBT and COBT respectively. These identifiers are found in the section for heating data.

Engine RPM's	(pick up)	= ENRS
Evaporator fan RPM's	(pick up)	= EFRS
Condenser fan RPM's	(pick up)	= CFRS

#8 Special Data Points: (Houston Test)

4 foot level front	(single)	= 4FFT
4 foot level middle	(single)	= 4FMT
4 Foot level rear	(single)	= 4FRT
Operator's head (4)	(single)	= 4DHT

Section #	Description	Number of Sensors	Identifier *

Ambient Temperatures: These temperatures are measured 12 inches out from the vehicle surface.

Top front of vehicle	(single)	=ATFT
Top rear of vehicle	(single)	= ATRT
Center front of vehicle	(single)	= AFFT
Side rear of vehicle, curbside	(single)	= ARCT
Side rear of vehicle, roadside	(single)	=ARRT

Side front of vehicle curbside	(single)	= ACFT
Side front of vehicle roadside	(single)	=ARFT
Bottom front of vehicle	(single)	= ABFT

Temperature Averages Required: (These averages may not be required on all tests.)

Ambient average	(all 8 ambients)	= AAVT
Interior average	(all 27 interior temperatures)	= IAVT
Ceiling average	(all 9 ceiling temperatures)	= CAVT
Seat cushion avg.	(all 9 cushion temperatures)	= MLAT
Floor average	(all 9 floor temperatures)	= FAVT
4 foot level average	(only four 4 foot level temperatures)	= 4AVT

Note: Operator's area sensors (except 4 foot probe) are to be excluded from averages.

*Identifiers are suggested to establish uniformity, to simplify and to allow more rapid comparison of test results.

Four Letter Identifier, Fourth Letter Meaning:

T = Temperature	V = Voltage
E = Electrical Data	C = Current
S = Speed	P = Pressure
R = Rate	

Annex C

(informative)

Safety precautions

C.1 General

C.1.1 When working with or around a refrigeration system or battery, always wear goggles or safety glasses. Refrigerant or battery acid can cause permanent damage if it comes in contact with your eyes.

C.1.2 Never operate the unit with the compressor discharge valve closed.

C.1.3 Keep your hands and loose clothing clear of fans and belts at all times when the unit is running or when opening or closing compressor service valves.

C.1.4 If you must drill holes in your unit for any reason, use extreme caution. You could be weakening structural components. Drilling into electrical wiring or refrigerant lines could cause a fire.

C.1.5 It is recommended that any service work on evaporator or condenser coils be left for a certified technician. When working around the coils, use extreme caution as exposed coil fins can cause painful lacerations.

Be sure to turn the unit On/Off switch to Off before opening doors or inspecting any part of the unit.

C.2 Electrical hazard

Units with electrical standby present a potential electrical hazard. Disconnect the high voltage power cable before working on the unit.

C.3 Refrigerant

C.3.1 Although fluorocarbon refrigerants are classified as safe, observe caustion when working with refrigerants or around areas where they are being used in the servicing of your unit.

C.3.2 If accidentally released into the atmosphere from the liquid state, fluorocarbon refrigerants evaporate rapidly, freezing anything they contact.

C.3.3 In the presence of an open flame or electrical short, fluorocarbon refrigerants used in refrigeration units may produce toxic gases. These gases are severe respiratory irritants capable of causing death.

C.3.4 Fluorocarbon refrigerants tend to displace air and can cause oxygen depletion which could result in death by suffocation. Observe caution at all times when working with or around refrigerant or refrigeration systems which contain refrigerant, especially in enclosed or confined areas.

C.4 First aid - refrigerant

C.4.1 **EYES**: For contact with liquid, immediately flush eyes with large amounts of water and get prompt medical attention.

C.4.2 **SKIN**: Flush areas with large amounts of warm water, do not apply heat. Wrap burns with dry, sterile, bulky dressing to protect from infection/injury. Get medical attention.

C.4.3 **INHALATION**: Move victim to fresh air and restore breathing if necessary. Stay with victim until arrival of emergency medical personnel.

C.5 Refrigerant oil

Observe the following precautions when working with or around refrigeration oil:

a) Do not allow refrigerant oil to contact your eyes.

b) Do not allow prolonged or repeated contact with skin or clothing. Rubber gloves are recommended.

c) To prevent irritation, wash thoroughly immediately after handling.

C.6 First aid - refrigerant oil

C.6.1 EYES: Immediately flush eyes with large amounts of water for at least 15 minutes while holding the eyelids open. Get prompt medical attention.

C.6.2 SKIN: Remove contaminated clothing. Wash thoroughly with soap and water. Get medical attention if irritation persists.

C.6.3 INHALATION: Move victim to fresh air and restore breathing if necessary. Stay with victim until arrival of emergency personnel.

C.6.4 INGESTION: Do not induce vomiting. Contact local poison control center or physician immediately.

Annex D

(informative)

Typical values of U-factors

a) For a 30 ft high floor vehicle, the U-factor should be less than 500 BTU/hr/°F.

b) For a 30 ft low floor vehicle, the U-factor should be less than 550 BTU/hr/°F.

c) For a 35 ft high floor vehicle, the U-factor should be less than 625 BTU/hr/°F.

d) For a 35 ft low floor vehicle, the U-factor should be less than 700 BTU/hr/°F.

e) For a 40 ft high floor vehicle, the U-factor should be less than 750 BTU/hr/°F.

f) For a 40 ft low floor vehicle, the U-factor should be less than 825 BTU/hr/°F.

g) For a 60 ft high floor vehicle, the U-factor should be less than 1100 BTU/hr/°F.

h) For a 60 ft low floor vehicle, the U-factor should be less than 1210 BTU/hr/°F.