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SURFACE VEHICLE RECOMMENDED PRACTICE

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Submitted for recognition as an American National Standard

(R) JOINT SAE/TMC RECOMMENDED ENVIRONMENTAL PRACTICES FOR ELECTRONIC EQUIPMENT DESIGN (HEAVY-DUTY TRUCKS)

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1. ***Scope***—The climatic, dynamic, and electrical environments from natural and vehicle-induced sources that influence the performance and reliability of vehicle and tractor/trailer electronic components, are included in this SAE Recommended Practice. Test methods that can be used to simulate these environmental conditions are also included. This information is applicable to diesel power trucks in Classes 6, 7, and 8.

1.1 **Purpose—**This guideline is intended to aid the designer of automotive electronic systems and components by providing material that may be used to develop environmental design goals.

2. ***References***

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

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

SAE J400—Test for Chip Resistance of Surface Coatings
SAE J726—Air Cleaner Test Code
SAE J1113 NEW DRAFT—Electromagnetic Susceptibility Procedures for Vehicle Components (Except Aircraft)
SAE J1211—Recommended Environmental Practices for Electronic Equipment Design
SAE J1812—Function Performance Status Classification for EMC Susceptibility Testing of Automotive Electronic and Electrical Devices

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM C 150-84—Specification for Portland Cement
ASTM B 117-73—Standard Method of Salt Spray (Fog) Testing
ASTM D 775-80—Method for Drop Test for Loaded Boxes
ASTM D 880-79—Method for Incline Impact Test for Shipping Containers

2.1.3 MILITARY PUBLICATIONS—Available from U.S. Government, DOD SSP, Subscription Service Division, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-810D, 19 July 1983—Environmental Test Methods and Engineering Guidelines
MIL-STD-202F, 01 April 1980—Test Methods for Electronic and Electrical Component Parts

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2.1.4 RELATED PUBLICATIONS—The following publications are provided for information purposes only and are not a required part of this document.

TAPPI T801-83
TAPPI T802-81

3. Application

3.1 Environmental Data and Test Method Validity—The information included in the following sections is based upon test results achieved by major North American truck manufacturers and component equipment suppliers. Operating extremes were measured at test installations normally used by manufacturers to simulate environmental extremes for vehicles and original equipment components. They are offered as a design starting point. Generally, they cannot be used directly as a set of operating specifications because some environmental conditions may change significantly with relatively minor physical location changes. This is particularly true of vibration, engine compartment temperature, and electromagnetic compatibility. Actual measurements should be made as early as practicable to verify these preliminary design baselines.

The proposed test methods are currently being used for laboratory simulation or are considered to be a realistic approach to environmental design validation. They are not intended to replace actual operational tests under adverse conditions. The recommended methods describe standard cycles for each type of test. The designer must specify the number of cycles over which the vehicle electronic components should be tested. The number of cycles will vary depending upon equipment, location, and function. While the standard test cycle is representative of an actual short term environmental cycle, no attempt is made to equate this cycle to an acceleration factor for reliability or durability. These considerations are beyond the scope of this document.

3.2 Organization of Test Methods and Environmental Extremes Information

3.2.1 The data presented in this document are contained in Sections 4 and 5. Section 4, Environmental Factors and Test Methods, describes the thirteen characteristics of the expected environment that have an impact on the performance and reliability of truck and bus electronic systems. These descriptions are titled:

a. Temperature
b. Humidity
c. Salt Spray Atmosphere
d. Immersion and Splash (Water, Chemicals, and Oils)
e. Steam Cleaning and Pressure Washing
f. Fungus
g. Dust, Sand, and Gravel Bombardment
h. Altitude
i. Mechanical Vibration
j. Mechanical Shock
k. General Heavy-Duty Truck Electrical Environment
l. Steady State Electrical Characteristics
m. Transient, Noise, and Electrostatic Characteristics
n. Electromagnetic Compatibility/Electromagnetic Interference

They are organized to cover three facets of each factor:

1. Definition of the factor
2. Description of its effect on control, performance, and long-term reliability
3. A review of proposed test methods for simulating environmental stress

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3.2.2 IN SECTION 5

a. Underhood

1. Engine (Lower Portion)
2. Engine (Upper Portion)
3. Bulkhead

b. Interior (cab)

1. Floor
2. Instrument Panel
3. Head Liner
4. Inside Doors

c. Interior (aft of cab)

1. Bunk Area
2. Storage Compartment

d. Chassis

1. Forward
2. Rear

e. Exterior of Cab

1. Under Floor
2. Rear
3. Top
4. Doors

3.3 Combined Environments—The vehicle environment consists of many natural and induced factors. Combinations of these factors are present simultaneously. In some cases, the effect of a combination of these factors is more serious than the effect of exposing samples to each environmental factor in series. For example, the suggested test method for humidity includes high- and low-temperature exposure. This combined environmental test is important to vehicle electronic components when proper operation is dependent on seal integrity. Temperature and vibration is a second combined environmental test method that can be significant to components. During design analysis a careful study should be made to determine the possibility of design susceptibility to a combination of environmental factors that could occur at the planned mounting location. If the possibility of susceptibility exists, a combined environmental test should be considered.

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3.4 Test Sequence—The optimum test sequence is a compromise between two considerations:

3.4.1 The order in which the environmental exposures will occur in operational use.

3.4.2 A sequence that will create a total stress on the sample that is representative of operation stress.

The first consideration is impossible to implement in vehicle testing since exposures occur in a random order. The second consideration prompts the test designer to place the most severe environments last. Many sequences that have been successful follow this general philosophy, except that the temperature cycle is placed or performed first in order to condition the sample mechanically.

4. *Environmental Factors and Test Methods*

4.1 Temperature

4.1.1 DEFINITION—Thermal factors are probably the most pervasive environmental hazard to vehicle electronic components. Sources for temperature extremes and variations include:

4.1.1.1 The vehicle's climatic environment, including the diumal and seasonal cycles—Variations in climate by geographical location must be considered. In the most adverse case, the vehicle that spends the winter in Canada may be driven in the summer in the Arizona desert. Temperature variations due to this source range from –54 to +85 °C (–65 to +185 °F).

4.1.1.2 Heat sources and sinks generated by the vehicle's operation—The major sources are the engine and drivetrain components, including the brake system. Wide variations are found during operation. For instance, temperatures on the surface of the engine can range from the cooling system 88 °C (190 °F) to the surface at the exhaust system at 816 °C (1500 °F). This category also includes conduction, convection, and radiation of heat because of the various modes of the vehicle's operation.

4.1.1.3 Self-heating of the equipment due to its internal dissipation—A design review of the worst case combination of peak ambient temperature (see 4.1.1.1 and 4.1.1.2), minimized heat flow away from the equipment, and peak-applied steady-state voltage should be conducted.

4.1.1.4 Vehicle operational mode and actual mounting location—Measurements should be made at the actual mounting site during the following vehicular conditions while they are subjected to the maximum heat generated by adjacent equipment, and while they are at the maximum ambient environment:

a. Engine start
b. Engine idle
c. Engine high speed
d. Engine turn off (Prior history important.)
e. Various engine/road conditions

4.1.1.5 Ambient conditions before installation due to storage and transportation extremes—Shipment in unheated aircraft cargo compartments may lower the minimum storage (nonoperating) temperature to –50 °C (–58 °F).

The thermal environmental conditions that are a result of these conditions can be divided into three categories:

a. Extremes - The ultimate upper and lower temperatures the equipment is expected to experience.
b. Cycling - The cumulative effects of temperature cycling within the limits of the extremes.
c. Shock - Rapid change of temperature. Figure 1 illustrates one form of vehicle operation that induces thermal shock and is derived from an actual road test of two vehicles. Thermal shock is also induced when vehicle electronic componentry at elevated temperature is exposed to sudden rain or road splash, or when it is moved from a heated shelter into a low (–40 °C/–40 °F) ambient temperature environment.

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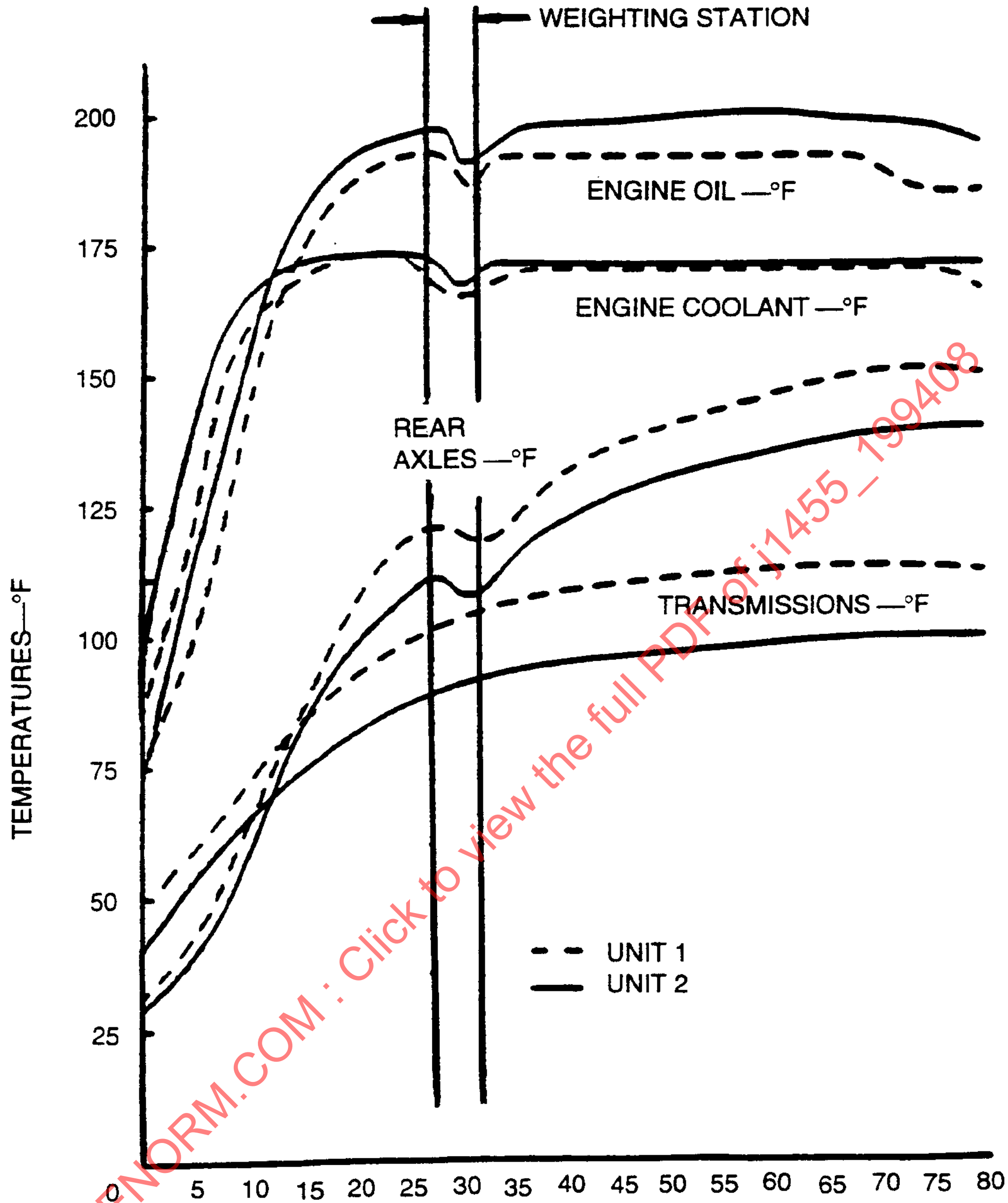

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Figure 1—TIME INTO RUN-MINUTES VEHICLE WARM-UP CHARACTERISTICS

The vehicle electronic component designer is urged to develop a systematic, analytic method for dealing with steady-state and transient thermal analysis. The application of many devices containing semiconductors is temperature limited. For this reason, the potential extreme operating conditions for each application must be scrutinized to avoid failure in the field.

4.1.2 Effect On Performance—The damaging effects of thermal stock and thermal cycling include:

4.1.2.1 Cracking of printed circuit board or ceramic substrates.

4.1.2.2 Thermal stress of fatigue failures of solder joints.

4.1.2.3 Delamination of printed circuit boards and other interconnect system substrates.

4.1.2.4 Seal failures, including the breathing action of some assemblies, due to temperature-induced dimensional variation that permits intrusion of liquid or vapor borne contaminants.

4.1.2.5 Failure of circuit components due to direct mechanical stress caused by differential thermal expansion.

4.1.2.6 The acceleration of chemical attack on interconnects, due to temperature rise, can result in progressive degradation of circuit components, printed circuit board conductors, and solder joints.

In addition to these phenomena, high temperature extremes can cause a malfunction by:

4.1.2.7 Exceeding the dissociation temperature of surrounding polymer or other packaging components.

4.1.2.8 Carbonizing of the packaging materials resulting in the eventual progressive failure of the associated passive or active components. This is possible in cases of excessively high temperature. In addition, noncatastrophic failure is possible because of electrical leakage in the resultant carbon paths.

4.1.2.9 Changing the active device characteristics with increased heat, including changes in gain, impedance, collector-base leakage, peak blocking voltage, collector-base junction second breakdown voltage, etc.

4.1.2.10 Changing the passive device characteristics, such as permanent or temporary drift in resistor value and capacitor dielectric constants, with increased temperature.

4.1.2.11 Changing the interconnect and relay coil performance due to the conductivity temperature coefficient of copper.

4.1.2.12 Changing the properties of magnetic materials with increasing temperature, including Curie point effects and loss of permanent magnetism.

4.1.2.13 Changing the dimensions of packages and components leading to the separation of subassemblies.

4.1.2.14 Changing the strength of soldered joints because of changes in the mechanical characteristics of the solder.

4.1.2.15 The severe mechanical stress caused by ice formation in moisture bearing voids or cracks.

4.1.2.16 The very rapid and extreme internal thermal stress caused by applying maximum power to semiconductor or other components after extended cold soak under aberrant operating conditions such as 36 V battery jumper starts.

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4.1.3 RECOMMENDED TEST METHODS

4.1.3.1 *Temperature Cycle Test*—Recommended thermal cycle profiles are shown in Figures 2a, b, and c and recommended extreme temperatures in Tables 1A and 1B. If temperature characterization has been performed according to 4.1.1.4 the measured temperature may be substituted for the values in Tables 1a and 1b for the purpose of this document. The test method of Figure 2a, a 24 h cycle, offers longer stabilization time and permits a convenient room ambient test period. Figure 2b, an 8 h cycle, provides more temperature cycles for a given test duration. It is applicable only to vehicle electronic components whose temperatures will reach stabilization in a shorter cycle time. Stabilization should be verified by actual measurements; thermocouples, etc. It is important that all parts of the test specimen be held at the specified maximum and minimum temperatures for at least 15 min, after reaching stability at that temperature. This is to maintain thermal or pressure stresses generated in the test specimen for a reasonable period of time. Figure 2c illustrates a test method for thermal shock.

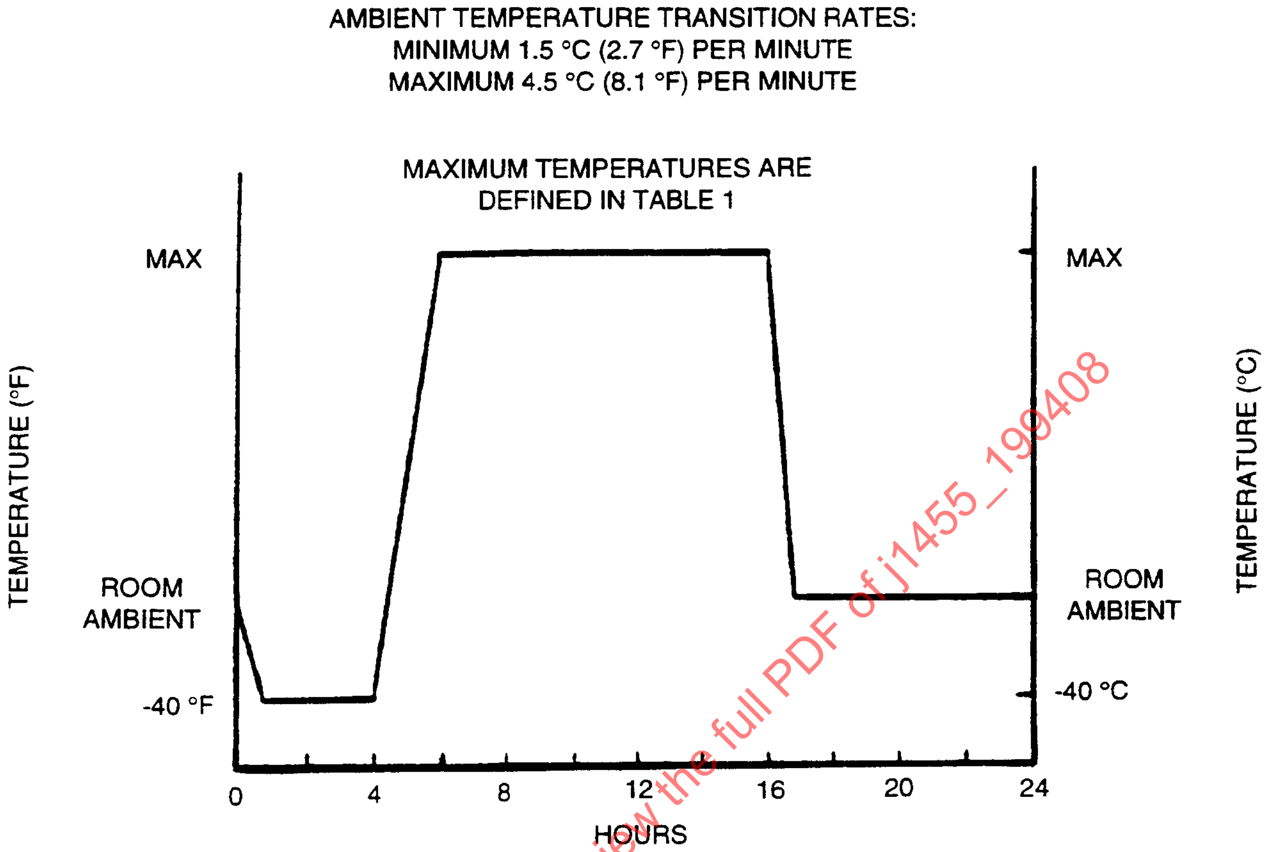

Figure 2A—24 HOUR THERMAL CYCLE

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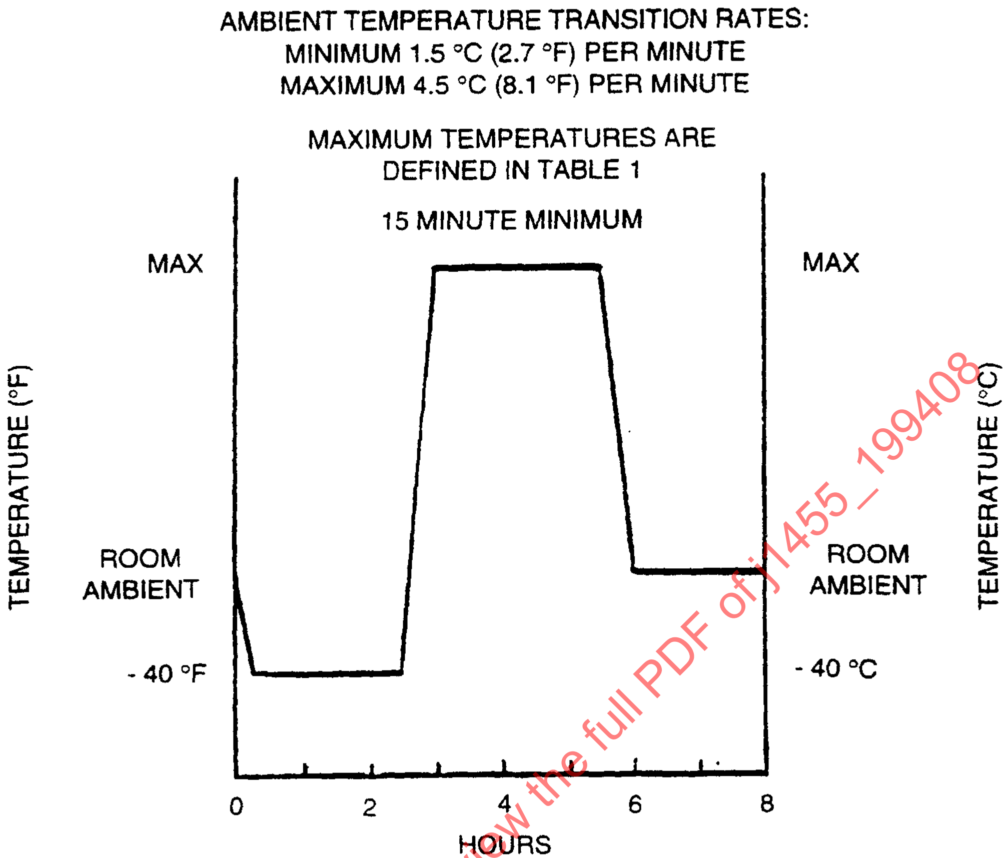

Figure 2B—SHORT (8 HOUR) THERMAL CYCLE

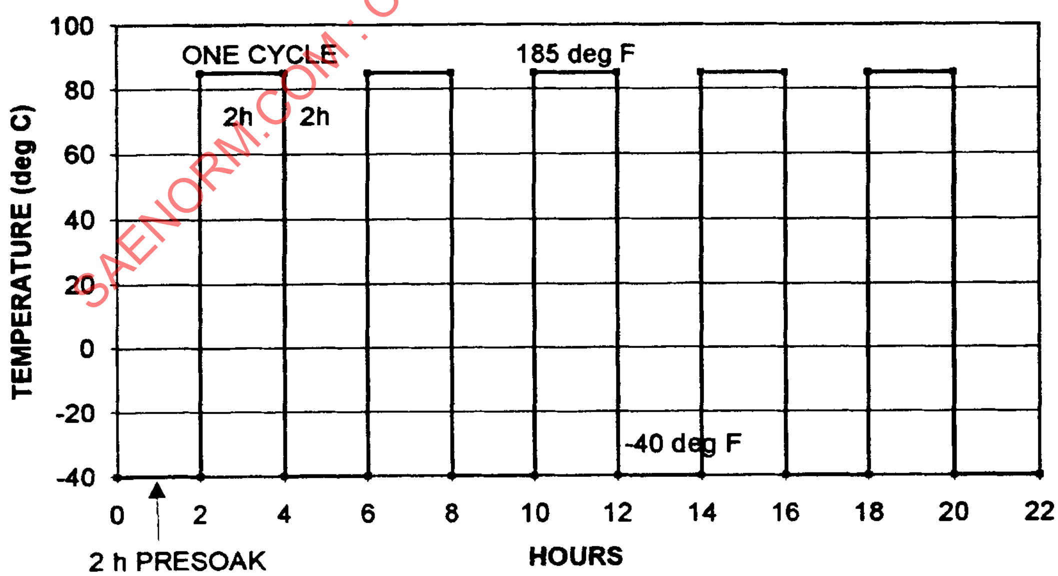

Figure 2C—THERMAL SHOCK

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TABLE 1A—ENVIRONMENTAL EXTREME SUMMARY HEAVY-DUTY CAB OVER ENGINE TRUCK/TRACTOR

	Location (1)	Temperatures Min	Temperatures Operating	Temperatures Max (2)
ENGINE	1a Underhood - Lower	–40 °C		56 °C over ambient
		–40 °F		100 °F over ambient
	1b Underhood - Upper (3)	–40 °C		222 °C over ambient
		–40 °F		400 °F over ambient
	1c Underhood Bulkhead	–40 °C		56 °C over ambient
		–40 °F		100 °F over ambient
INTERIOR:	2a Floor	–40 °C	27 °C	66 °C
		–40 °F	80 °F	150 °F
	2b Instrument Panel (4)	–40 °C	24 °C	85 °C
		–40 °F	75 °F	185 °F
	2c Headliner	–40 °C	24 °C	79 °C
		–40 °F	75 °F	175 °F
	2d Inside Door			
	3a Bunk Area	–40 °C	24 °C	93 °C
		–40 °F	75 °F	200 °F
	3b Storage Compartment	–40 °C	24 °C	74 °C
		–40 °F	75 °F	165 °F
CHASSIS:	4a Forward	–40 °C		120 °C
		–40 °F		248 °F
	4b Rear	–40 °C		95 °C
		–40 °F		203 °F
EXTERIOR:	5a Under	No Data		
	5b Back	No Data		
	5c Door	–40 °C		56 °C over ambient
		–40 °F		100 °F over ambient
	5d Top	No Data		
Maximum ambient temperature may reach 85 °C (185 °F)				

1. Figure 3 - Pictorial Description of Locations
2. If temperature characterization has been performed according to 4.1.1.4, the measured temperature may be substituted for the values in Tables 1a and 1b for the purpose of this document.
3. Exhaust Manifold 816 °C 1500 °F
4. Windshield (Daylight opening on top of instrument panel) Direct sunlight surface temperature 115 °C maximum 240 °F maximum

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TABLE 1B—ENVIRONMENTAL EXTREME SUMMARY HEAVY-DUTY CONVENTIONAL ENGINE TRUCK/TRACTOR

	Location (1)	Temperatures Min	Temperatures Operating	Temperatures Max (2)
ENGINE	1a Underhood - Lower	–40 °C		56 °C over ambient
			–40 °F	100 °F over ambient
	1b Underhood - Upper (3)	–40 °C		222 °C over ambient
			–40 °F	400 °F over ambient
	1c Underhood Bulkhead	–40 °C		56 °C over ambient
			–40 °F	100 °F over ambient
INTERIOR:	2a Floor	–40 °C	27 °C	75 °C
		–40 °F	80 °F	165 °F
	2b Instrument Panel (4)	–40 °C	24 °C	85 °C
		–40 °F	75 °F	185 °F
	2c Headliner	–40 °C	24 °C	79 °C
		–40 °F	75 °F	175 °F
	2d Inside Door			
	3a Bunk Area	–40 °C	24 °C	93 °C
		–40 °F	75 °F	200 °F
	3b Storage Compartment	–40 °C	24 °C	74 °C
		–40 °F	75 °F	165 °F
CHASSIS:	4a Forward	–40 °C		121 °C
		–40 °F		250 °F
	4b Rear	–40 °C		93 °C
		–40 °F		200 °F
EXTERIOR:	5a Under	No Data		
	5b Back	No Data		
	5c Door	–40 °C		56 °C over ambient
		–40 °F		100 °F over ambient
	5d Top	No Data		
Maximum ambient temperature may reach 85 °C (185 °F)				

1. Figure 3 - Pictorial Description of Locations
2. If temperature characterization has been performed according to 4.1.1.4, the measured temperature may be substituted for the values in Tables 1a and 1b for the purpose of this document.
3. Exhaust Manifold 816 °C 1500 °F
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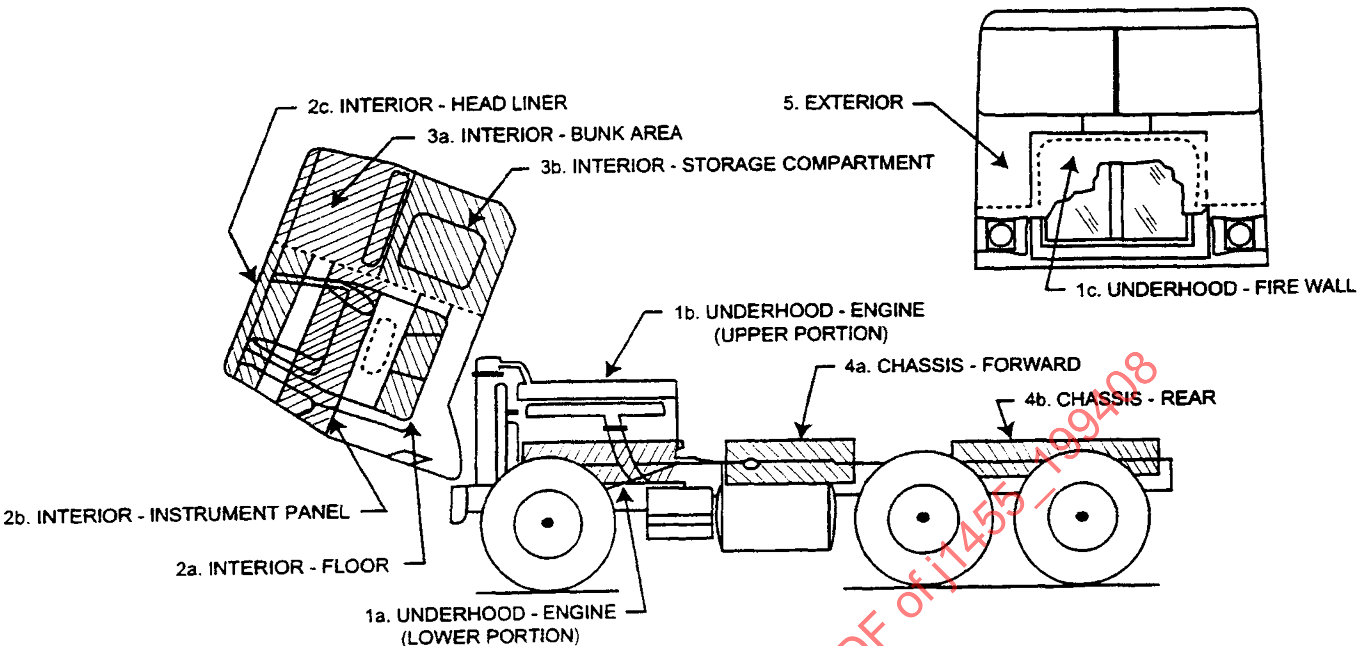
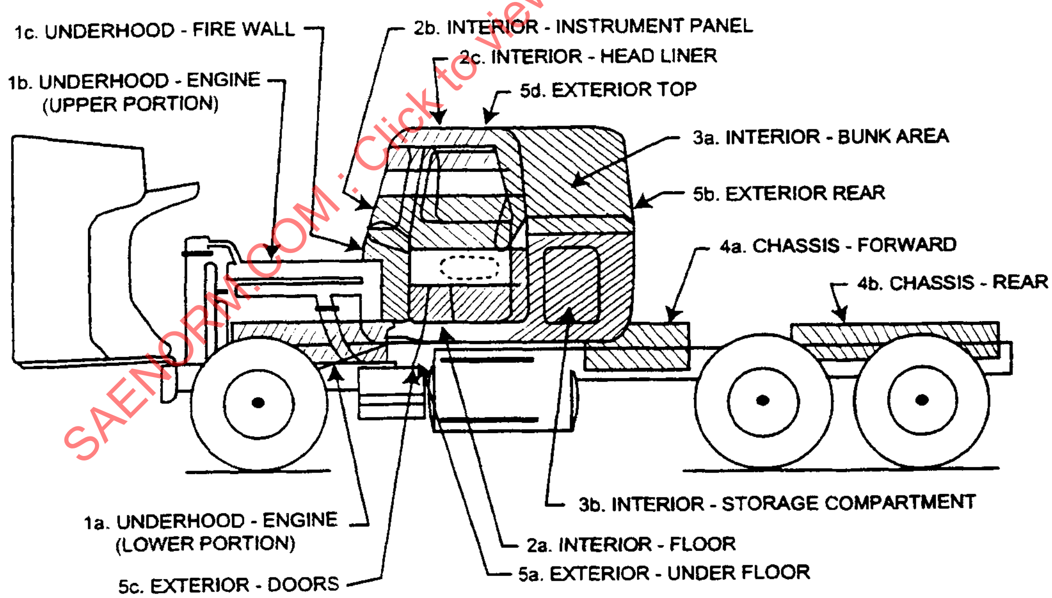


HEAVY-DUTY CABOVER ENGINE TRUCK



HEAVY-DUTY CONVENTIONAL TRUCK

Figure 3—VEHICLE ENVIRONMENTAL ZONES

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Separate or single test chambers may be used to generate the temperature environment described by the thermal cycles. By means of circulation, the air temperature should be held to within ±3 °C (±5 °F) at each of the extreme temperatures. The test specimens should be placed in a position, with respect to the airstream, where there is substantially no obstruction to the flow of air across the specimen. If two test specimens are used, care must be exercised to assure that the test samples are not subject to temperature transition rates greater than that defined in Figures 2a and 2b. Direct heat conduction from the temperature chamber heating element to the specimen should be minimized.

NOTE— Airflow is a function of actual equipment location. Simulation of actual airflow and thermal transfer operation conditions should be considered in test design.

Electrical performance should be measured under the expected operational minimum and maximum extremes of excitation, input and output voltage, and load at both the cold and hot temperature extremes. These measurements provide insight into electrical variations with temperature.

4.1.3.2 *Thermal Shock Test*—Thermal shock that can be expected in the vehicle environment is simulated by the maximum rates of change shown on the recommended thermal cycle profile portrayed in Figure 2c. The thermal shock test should begin with a 2 h presoak (–40 °C/–40 °F). The test item should be transferred to the hot chamber (85 °C/185 °F) where it should remain for 2 h, then transferred to the cold chamber (–40 °C/–40 °F) for 2 h. This cycle should be repeated at least five times. Each transfer should be accomplished in 1 min or less.

4.1.3.3 *Thermal Stress*—Thermal stress is caused by repeat cycling through the thermal profiles of Figures 2a, b, and c. Many failures are due to fatigue. Slow cycles not repeated often will not demonstrate this. The number of cycles is a function of the vehicle electronic component application. Functional electrical testing during temperature transitions or immediately after temperature transitions, is a means of detecting poor electrical connections. The effect of thermal stress is similar to thermal shock but is caused by fatigue.

NOTE— Although uniform oven temperatures are desirable, the only means of heat removal in some vehicle environments may be by special heat sinks or by free convection to surrounding air. It may be necessary to use conductive heat sinks with independent temperature controls in the former case and baffles or slow speed air stirring devices in the latter to simulate such conditions in the laboratory (see Section 3).

4.1.4 RELATED SPECIFICATIONS—A generally accepted method for small part testing is defined in MIL-STD-202F, Method 107F, Thermal Shock, Method A or B, alternately MIL-STD-810D, Method 503.2. The short dwell periods at high temperature are satisfactory where temperature stabilization is verified by actual measurements.

4.2 Humidity

4.2.1 DEFINITIONS—(Contained in 4.2.2)

4.2.2 EFFECTS ON PERFORMANCE—Both primary and secondary humidity sources exist in the vehicle. In addition to the primary source externally applied ambient humidity, the cyclic thermal-mechanical stresses caused by operational heat sources introduce a variable vapor pressure on the seals. Temperature gradients set up by these cycles can cause the dew point to travel from locations inside the equipment to the outside and back, resulting in additional stress on the seals.

The actual relative humidity in the vehicle depends on factors such as operational heat sources, trapped vapors, air-conditioning, and cool-down effects. Recorded data indicates an extreme condition of 98% relative humidity at 38 °C (100 °F).

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Primary failure modes include corrosion of metal parts because of galvanic and electrolytic action, as well as corrosion caused by interaction with contaminated water and oxygen. Other failure modes include changes in electrical properties, surface bridging corrosion products and condensation between circuits, decomposition of organic matter because of attacking organisms (for example, mildew), and swelling of elastomers.

4.2.3 RECOMMENDED TEST METHODS—The most common way to determine the effect of humidity on vehicle electronic components is to over test and examine any failure for relevance to the more moderate actual operating conditions. The most common test is an 8 h active temperature humidity cycling under accelerated conditions (Figure 4a). A second test is an 8 to 24 h exposure at 103.4 kPa gage pressure (15 lbf/in^2 gage) in a pressure vessel (Figure 4b). This is a quick and effective method for uncovering defects in plastic encapsulated semiconductors.

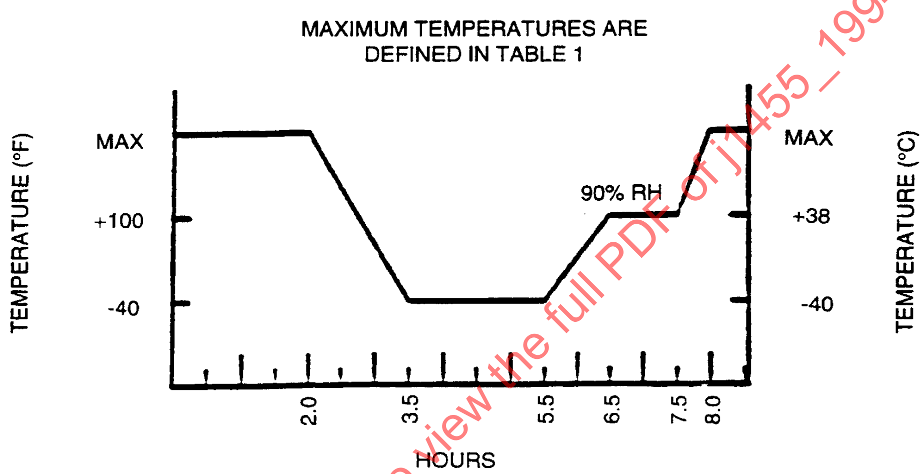

FIGURE 4a—8 h HUMIDITY CYCLE

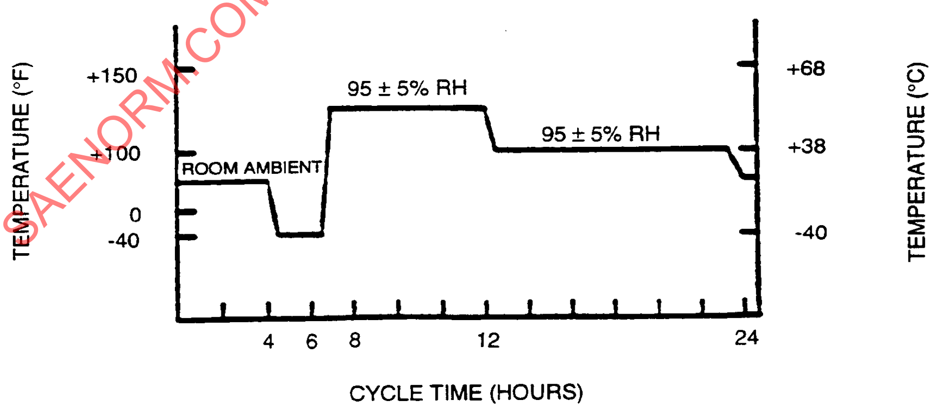

FIGURE 4b—24 h HUMIDITY CYCLE

Figure 4—RECOMMENDED HUMIDITY CYCLES

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An optional frost condition may be incorporated during one of these humidity cycles. Electrical performance should be continuously monitored during these frost cycles to note erratic operation. Heat-producing and moving parts may require altering the frost condition portions of the cycle to allow a period of nonoperation induced frosting.

4.2.4 RELATED SPECIFICATIONS—Many related humidity specifications are recommended for review and reference. The first: MIL-STD-810D, Method 507.2, Procedures I through III, Humidity, is a system-oriented test method. The second, a modified version of MIL-STD-202F, Method 103B, Humidity (Steady State), is intended to evaluate materials. The third, MIL-STD-202F, Method 106E, Moisture Resistance, is a procedure for testing small parts.

4.3 Salt Spray Atmosphere

4.3.1 DEFINITION—(Contained in 4.3.2)

4.3.2 EFFECT ON PERFORMANCE—Vehicle electronic components mounted on the chassis, exterior, and underhood are often exposed to a salt spray environment. In coastal regions, the salt is derived from sea breezes, and in colder climates, from road salt. Although salt spray is generally not found in the interior of the vehicle, it is advisable to evaluate the floor area for potential effects of saline solutions that were transferred from the outside environment by vehicle operators, passengers, and transported equipment.

Failure modes due to salt spray are generally the same as those associated with water and water vapor. However, corrosion effects and alteration of conductivity are accelerated by the presence of saline solutions and adverse changes in pH.

4.3.3 RECOMMENDED TEST METHODS—The recommended test method for measuring susceptibility of vehicle electronic component to salt spray is the American Society for Testing and Materials (ASTM) Standard Method of Salt Spray (Fog) Testing Number B 117-73. Similar test methods are found in MIL-STD-202, Method 101D, and MIL-STD-810D, Method 509.2.

The test consists of exposing the vehicle electronic component to a solution of five parts salt to 95 parts water, atomized at a temperature of 35 °C (95 °F). The component being tested should be exposed to the salt spray for a period of 24 to 96 h. The actual exposure time must be determined by analysis of the specific mounting location. When the tests are concluded, the test specimens should be gently rinsed in clean running water, about 38 °C (100 °F), to remove salt deposits from the surface, and then immediately dried. Drying should be done with a stream of clean, compressed dry air at about 175.8 to 241.3 kPa gage pressure (35 to 40 lbf/in^2 gage). The vehicle electronic component should be tested under nominal conditions of voltage and load throughout the test.

NOTE—The Pascal (Pa) is the designated SI (metric) unit for pressure and stress. It is equivalent to 1 N/m^2.

Where leakage resistance values are critical, appropriate measurements under wet and dry conditions may be necessary.

4.3.4 RELATED SPECIFICATIONS—ASTM B 117-73 is the recommended test method.

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4.4 Immersion and Splash (Water, Chemicals, and Oils)

4.4.1 DEFINITION—Vehicle electronic component mounted on or in the vehicle are exposed to varying amounts of water, chemicals, and oil. A list of potential environmental chemicals and oils includes:

Engine Oils and Additives
Transmission Oil
Rear Axle Oil
Power Steering Fluid
Brake Fluid
Axle Grease
Washer Solvent
Gasoline
Diesel Fuel
Fuel Additives
Alcohol
Anti-Freeze Water Mixture
Degreasers
Soap and Detergents
Steam
Battery Acid
Water and Snow
Salt Water
Waxes
Kerosene
Freon
Spray Paint
Paint Strippers
Ether
Dust Control Agents (magnesium chloride)
Moisture Control Agents (calcium chloride)
Vinyl Plasticizers
Undercoating Material
Muriatic Acid
Ammonia

The modified chemical characteristics of these materials when degraded or contaminated should also be considered.

4.4.2 EFFECT ON PERFORMANCE—Loss of the integrity of the container can result in corrosion or contamination of vulnerable internal components. The chemical compatibility can be determined by laboratory chemical analysis. Devices such as sensors, that may be immersed in fluids for a long period, should be subjected to laboratory life tests in these fluids.

4.4.3 RECOMMENDED TEST METHODS—The vehicle electronic component designer should first determine whether the parts must withstand complete immersion or splash, and which fluids are likely to be present in the application. Immersion and splash tests are generally performed following other environmental tests because this sequence tends to aggravate incipient defects in seals, seams, and bushings that might otherwise escape notice.

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Splash testing should be performed with the equipment mounted in a normal operating position with any drain holes open. Any integral parts, such as electrical connectors, shall be in place. Areas of the equipment not subject to splash testing may be sealed or otherwise isolated. The test apparatus should be designed to provide 100% coverage of the test surface using 80 degrees flat fan nozzles located 20 to 25 cm (10 to 12 in) from the test surface. The apparatus should provide a source pressure of approximately 200 kPa gauge (29 psig) with a flow rate of 2650 cm^3/min (0.7 gal/min). The equipment should be exposed to the spray for 5 min of a 10 min period for a total of two cycles.

During immersion testing, utilizing water as the fluid, the component ordinarily is not operated due to setup logistics and techniques of this test. In this test, the vehicle electronic component in its normal exterior package is immersed in tap water at about 18 °C (65 °F). The test sample should be completely covered by the water. The sample is first positioned in its normal mounting orientation. It remains in this position for 5 min and then rotated 180 degrees. It should remain in this position for 5 min and then rotated 90 degrees about the other axis where it remains for 5 min. Immediately after removal, the sample should be exposed to a temperature below freezing until the entire mass is below freezing. The sample is then returned to room temperature, air dried, functionally tested, and inspected for damage.

More severe tests such as combined temperature, pressure, and continuous fluid contact must be considered for equipment subjected to extreme environments; for example, exposure to coolant water, brake fluid, and transmission oil. Caution must be used in specifying combined tests because they may be unrealistically severe for many applications.

4.4.4 RELATED SPECIFICATIONS—None

4.5 Steam Cleaning and Pressure Washing

4.5.1 DEFINITION—(Contained in 4.5.2)

4.5.2 EFFECTS ON PERFORMANCE—The intense heat from cleaning sprays and the caustic nature of chemical agents used in washing solutions create a severe environment for devices and associated wiring and connectors mounted in the engine, chassis, and exterior areas. This exposure can cause a degradation of insulation and seals as well as cracking of vinyl connectors and component packaging. High pressure wash-down may produce results similar to salt spray in many truck interior.

4.5.3 RECOMMENDED TEST METHOD—The electronic component under test shall be mounted in its normal operating position with drain holes, if used, open. If an integral connector is used, it shall be mated. The test apparatus should be designed to provide 100% coverage of the exposed surface of the electronic component using flat fan spray nozzles located 20 to 30 cm (7.9 to 11.8 in) away. This apparatus should provide a source pressure of approximately 1400 kPa gage (203 lbf/in^2 gage) with a flow rate of 9460 cm^3/min (150 gal/h). For the steam cleaning, the water temperature should be at 93 °C (200 °F). The test item should be exposed to the spray for 3 s of a 6 s period for a total of 375 cycles.

A sample test device is illustrated in Figure 5.

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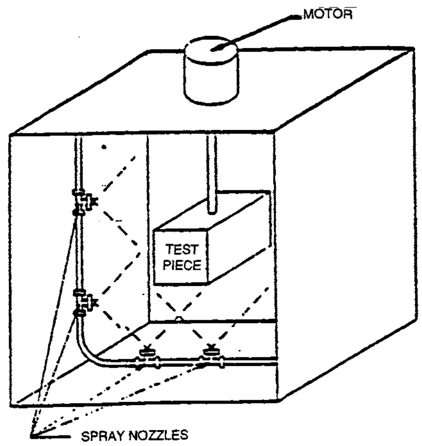

Figure 5—STEAM CLEAN/PRESSURE WASH CHAMBER

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For pressure washing with water/detergent, the previous test should be run at 40 °C (104 °F) and 7000 kPa gage (1020 lbf/in^2 gage) with a flow rate of approximately 9460 cm^3/min (150 gal/h).

4.5.4 RELATED SPECIFICATIONS—None.

4.6 Fungus

4.6.1 DEFINITION—The fungus test is used to determine the resistance of the vehicle electronic component to fungi and to determine if it is adversely affected by fungi under conditions favorable for their development; for example, high humidity, warm atmosphere, and inorganic salts.

4.6.2 EFFECTS ON PERFORMANCE

a. Microorganisms digest organic materials; thus, degrading the substrate, reducing the surface tension, and increasing moisture penetration.
b. Products of cellular metabolism diffuse out of the cells and cause physical and chemical changes to the materials.
c. Microorganisms produce bridges across components which may result in electrical failure.
d. Resistance to biological attack can be determined by chemical analysis of the nutritive value of materials and material decomposition products used in the equipment.

4.6.3 RECOMMENDED TEST METHOD—The most common way to determine the effect of fungal growth on electronic equipment is to inoculate the test item with a fungal spore solution, incubate the inoculated component to permit fungal growth, and examine and test the item. Incubation normally takes place under cyclic temperature and humidity conditions that approximate environmental conditions and assure suitable fungal growth.

NOTE— Conductive solutions used as a spore media and growth accelerator may affect operational tests.

4.6.4 RELATED SPECIFICATIONS—None.

4.7 Dust, Sand, and Gravel Bombardment

4.7.1 DEFINITION—Dust creates a harsh environment for chassis, underhood, and exterior-mounted devices; and can be a long-term problem in interior locations, such as under the dash and seats. Sand, primarily windblown, is an important environmental consideration for components mounted in the chassis, exterior, and underhood areas. Bombardment by gravel is significant for chassis, lower engine, and exterior-mounted electronic components.

4.7.2 EFFECT ON PERFORMANCE—Exposure to fine dust causes problems with moving parts, forms conductive bridges, and acts as an absorbent material for the collection of water vapor. Some electromechanical components may be able to tolerate fine dust, but larger particles may affect, or totally inhibit, their mechanical action. While the exposure in desert areas is severe, exposure to a reasonable amount of road dust is common to all areas.

4.7.3 RECOMMENDED TEST METHODS—Dust, sand, and gravel bombardment tests should be at room temperature. The sample need not be operating, although functional tests should be performed prior to and after testing.

Dust conforming to that defined in SAE J726 MAY81 as coarse grade should be used. If this dust packs or seals openings in the test sample cr if the sample contains exposed mechanical elements, the following alternate dust mixture may be used:

a. J726 Coarse or Equivalent 70%
b. 120 Grit Aluminum Oxide 30%

Components should be placed in a dust chamber with sufficient dry air movement to maintain a concentration of 0.88 g/m^3 (0.025 g/ft^3) for a period of 24 h.

An alternate method is to place the component sample about 15 cm (6 in) from one wall in a 91.4 cm (3 ft) cubical box. The box should contain 4.54 kg (10 lb) of fine powdered cement in accordance with ASTM C 150–56. At intervals of 15 min, the dust must be agitated by compressed air or fan blower. Blasts of air for a 2 s period in a downward direction assure that the dust is completely and uniformly diffused throughout the entire cube. The dust is then allowed to settle. The cycle is repeated for 5 h.

Condensation may be induced on electronic component following dust testing for a combined environment and operational test.

The recommended test for susceptibility of vehicle electronic component to damage from gravel bombardment is SAE J400 JUN80. This document is intended to detect susceptibility of surface coatings to chipping, but the basic test equipment and procedures are useful for evaluation of the electronic component. The test consists of exposing the test component sample to bombardment by gravel 0.96 to 1.6 cm (3/8 to 5/8 in) in diameter for a period of approximately 2 min. The sample is positioned about 35 cm (13-3/4 in) from the muzzle of the gravel source. A volume of 470 cm^3 (approximately 1 pt) of gravel (250 to 300 stones) is delivered under a pressure of 483 kPa gage (70 lbf/in^2 gage) over an approximate 10 s period. The process is repeated 12 times for a total exposure of 2 min. Judgment must be used in determining which sides should be exposed to the bombardment. Certainly all forward-facing surfaces not shielded by other parts are included. In many cases, the bottom and sides should also be exposed.

4.7.4 RELATED SPECIFICATION—Three specifications are referenced. The first: MIL-STD-202F, Method 110A, Sand and Dust, is a piece part test and is included for information and comparison. MIL-STD-810D, Method 510.2, is another reference. The second is SAE J726 MAY81, which defines the recommended dust. It also describes test apparatus. The third specification is SAE J400 JUN80, which is recommended in part as a gravel bombardment guide. Continued integrity at the conclusion of the exposure is the passing criteria.

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4.8 Altitude

4.8.1 DEFINITION—With the exception of air shipment of unenergized controls, operation in a vehicle should follow the anticipated operating limits. Completed controls are expected to be stressed over these limits of absolute pressure as in Table 2:

TABLE 2—AMBIENT PRESSURE RANGE

Condition	Altitude	Atmospheric Pressure
Operating	3.6 km (12 000 ft)	62.0 kPa absolute pressure (9 lbf/in^2 absolute)
Nonoperating	12.2 km (40 000 ft)	18.6 kPa absolute pressure (2.7 lbf/in^2 absolute)

4.8.2 EFFECT ON PERFORMANCE—With increased altitude, the following effects are generally observed:

4.8.2.1 Reduction in convection heat transfer efficiency.

4.8.2.2 Change in mechanical stress on packages that have internal cavities. The reference cavity of an absolute pressure sensor is an example of this.

4.8.2.3 A noticeable reduction in the high voltage breakdown characteristics of systems with electrically stressed insulator, conductor, or air surfaces. This may result in surface cracking with eventual component failure.

4.8.3 RECOMMENDED TEST METHODS—The recommended test method is to operate the electronic component during the thermal cycles described in the Temperature Test Section, but with the added parameter of 62.0 kPa absolute pressure (9 lbf/in^2 absolute pressure). The equipment should operate under maximum load. Failure effects will be similar to those experienced with thermal cycle and shock. Nonoperating tests should be done at a minimum temperature of –50 °C (–58 °F), if possible.

4.9 Mechanical Vibration

4.9.1 DEFINITION—Mechanical vibration is another key factor in vehicle electronic component design for the truck environment. For diesel powered trucks, mechanical vibration is likely the most important factor to consider in truck electronics design. Vibration levels may vary during vehicle operation from low severity to high severity when traversing rough roads at high speeds. The vibration characteristics may vary with the mounting location in addition to the vehicle mode of operation. Vibration levels and frequency content are significantly different for various mounting locations. Power spectral density profiles for various mounting locations on heavy-duty trucks illustrate the wide variance in this vibration energy. See Figures 6 through 11.

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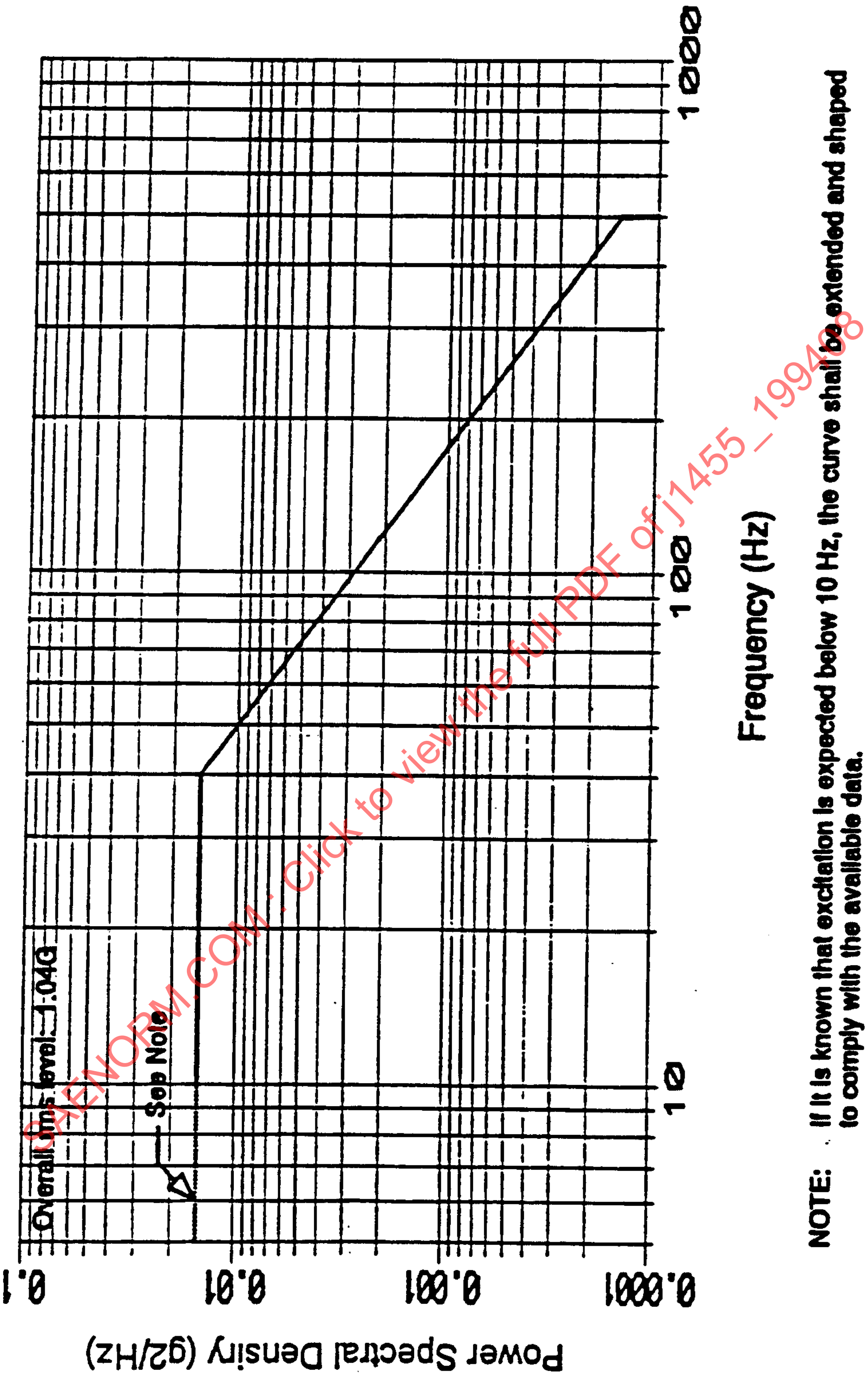

Figure 6—SAMPLE CAB MOUNTED VIBRATION PSD CLASS 8 TRUCK, VERTICAL AXIS

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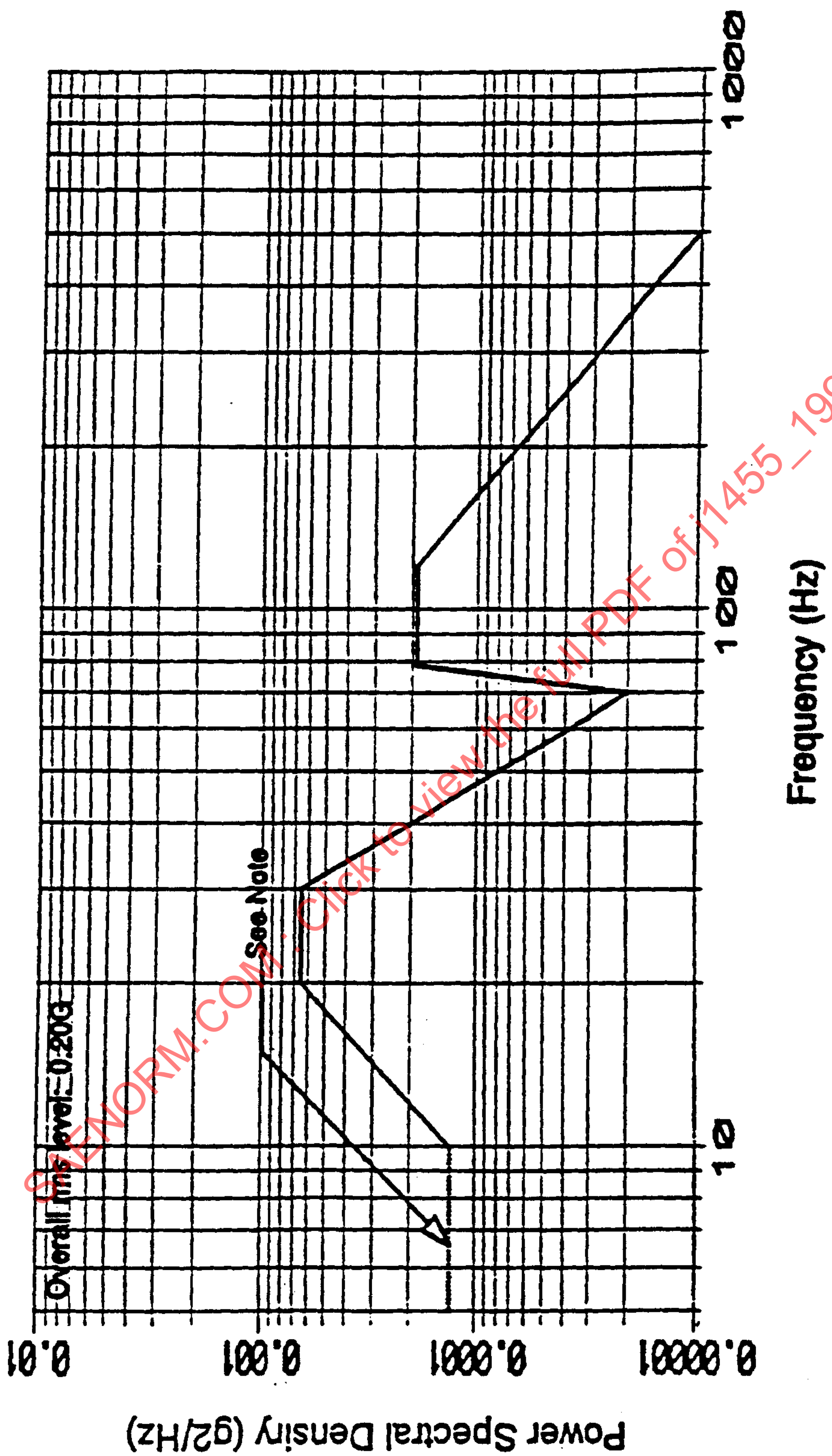

NOTE: If it is known that excitation is expected below 10 Hz, the curve shall be extended and shaped to comply with the available data.

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Figure 7—SAMPLE CAB MOUNTED VIBRATION PSD TRANSVERSE AXIS

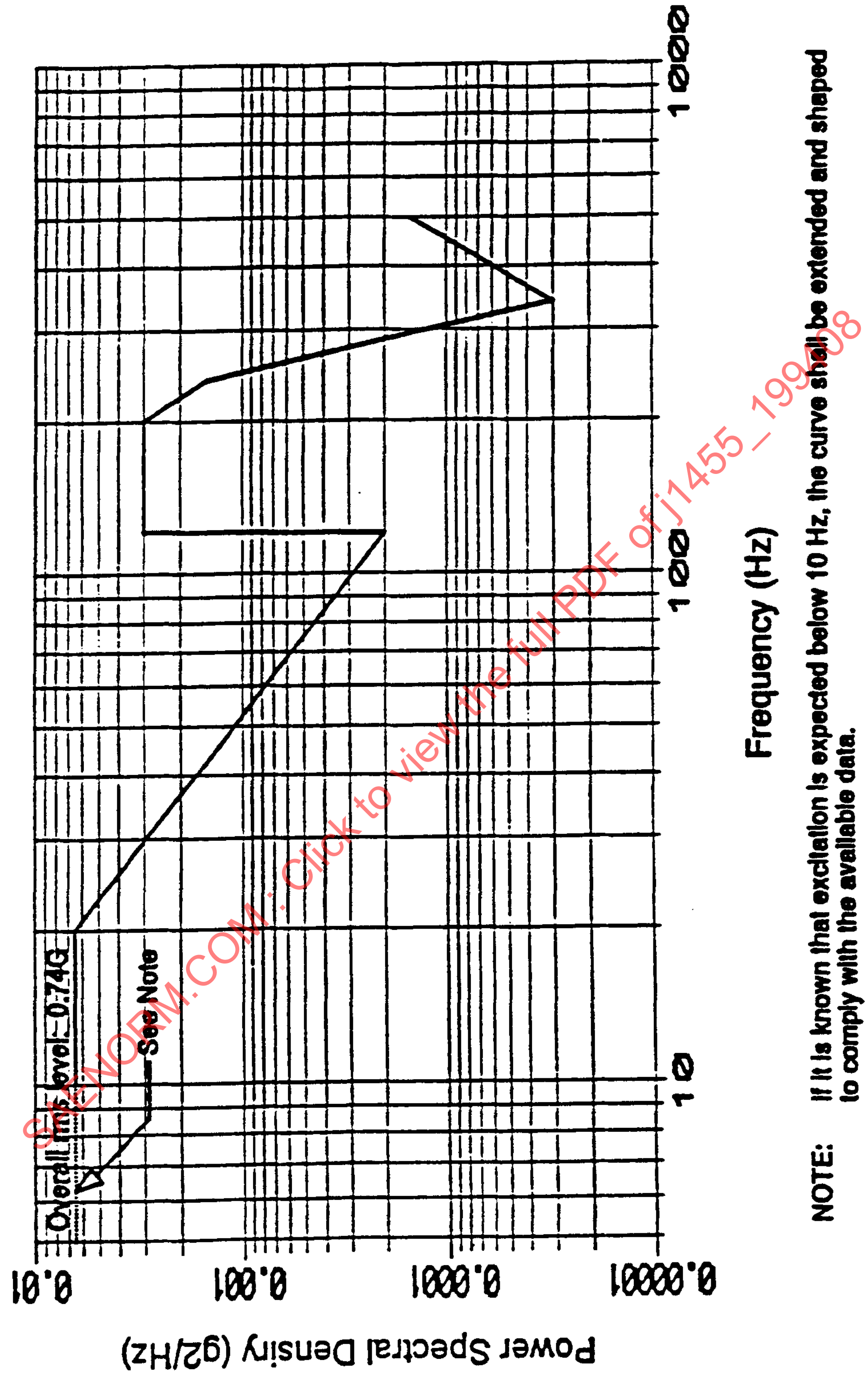

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Figure 8—SAMPLE CAB MOUNTED VIBRATION PSD CLASS 8 TRUCK, LONGITUDINAL AXIS

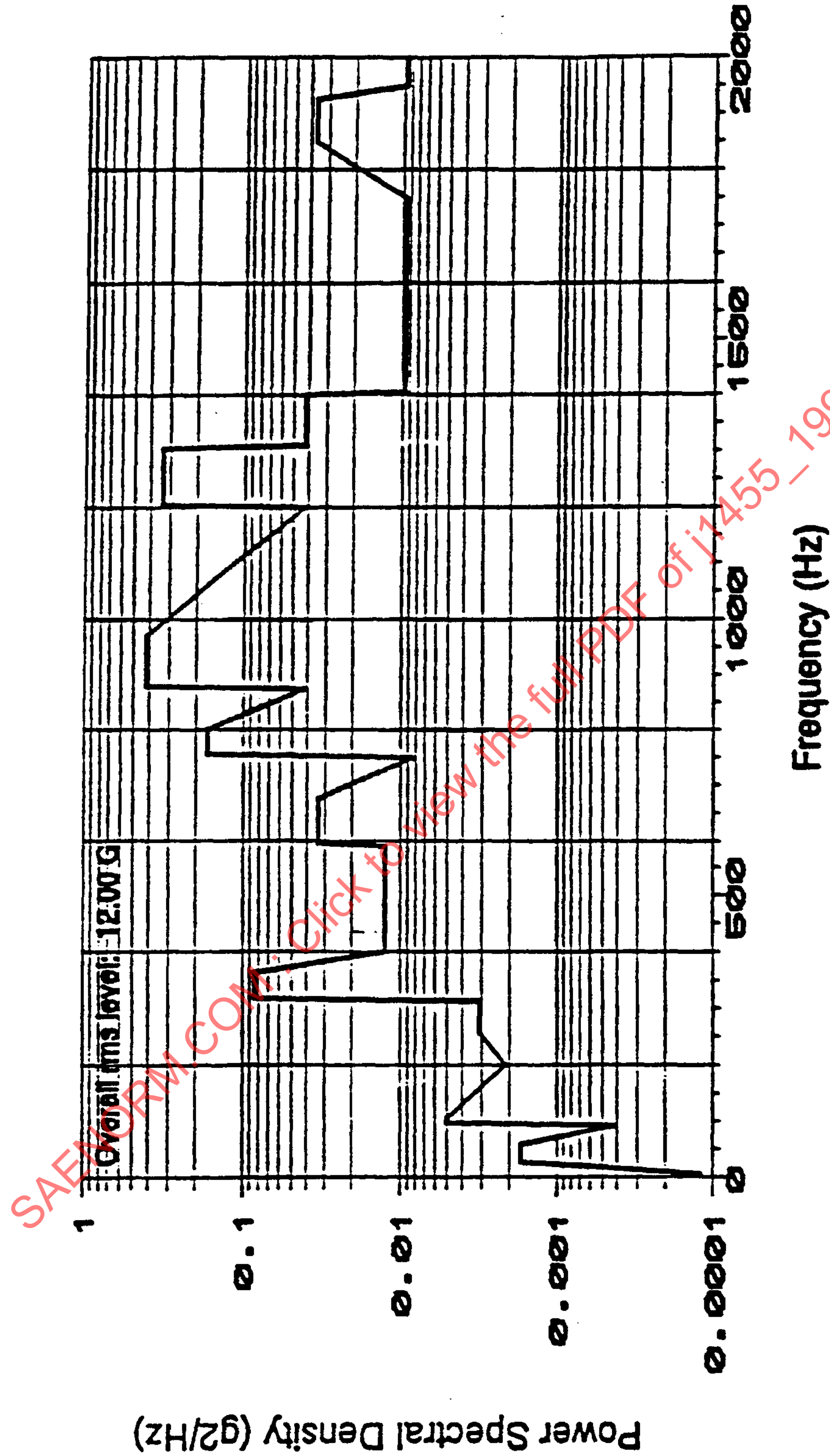

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Figure 9—SAMPLE ENGINE VIBRATION DATA (VERTICAL), HEAVY-DUTY TRUCK

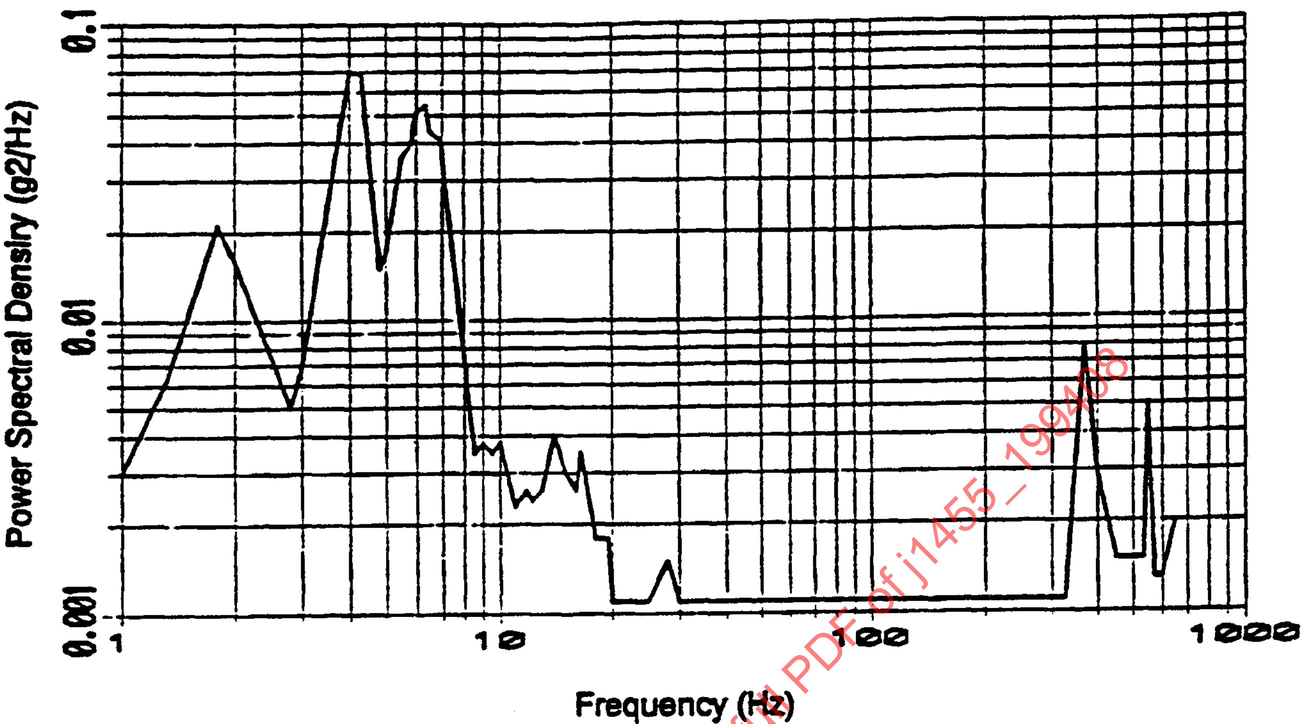

Figure 10—CHASSIS VIBRATION DATA, PSD, BOBTAIL VERTICAL MID FRAME, HEAVY-DUTY TRUCK

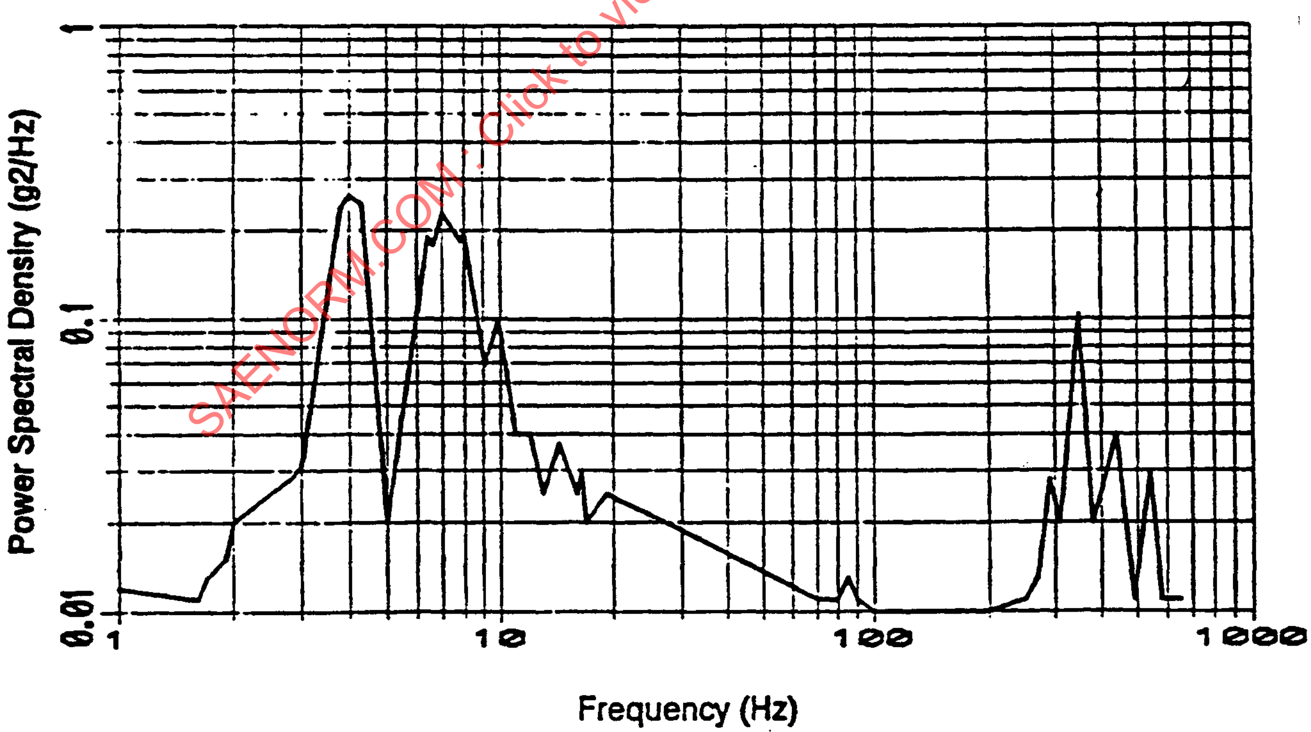

Figure 11—CHASASIS VIBRATION DATA, PSD, BOBTAIL VERTICAL REAR FRAME, HEAVY-DUTY TRUCK

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4.9.2 EFFECT ON PERFORMANCE—A number of electronic component failure modes or performance degradations are possible during applied vibration. A partial list includes:

4.9.2.1 Loss of wiring harness electrical connection due to improper connector design or assembly, or both, or due to fretting corrosion.

4.9.2.2 Metal fatigue failure at stress concentration points due to resonant excitation of tuned mass structures in the electronic component.

4.9.2.3 Mount structure failures due to acceleration forces acting on the equipment mass.

4.9.2.4 Seal leakage due to mechanical flexing at the seal or other interface areas, which promotes intrusion of unwanted environmental factors such as moisture, in a similar phenomenon as described under temperature cycling effects.

4.9.2.5 Temporary aberration of equipment performance due to acceleration forces on control component masses.

Examples:

4.9.2.5.1 Sensor measurement error due to motion of the sensor element, such as a pressure sensor, which gives incorrect information at applied frequencies because of the acceleration of the diaphragm and spring mechanism masses.

4.9.2.5.2 False operation of electromechanical components, such as a relay whose contacts open or close due to vibration-induced motion of the armature mass. The designer should be particularly alert to intermittent failures or faulty operation during applied vibration that may revert to normal operation after the vibration excitation is removed. Electronic performance tests conducted during vibration tests are recommended for functions that must perform during these conditions. In most cases, this is only practical under laboratory simulation of road tests.

4.9.3 VIBRATION LEVELS—Vibration levels seen by electronic assemblies installed in commercial vehicles vary considerably depending on the particulars of the mounting arrangement and the design of the truck or bus. Wherever possible, the vibration environment should be characterized prior to design of the electronic equipment.

Depending on the purpose and methodology of the tests, two different types of laboratory vibration specifications are common in the industry: maximum expected acceleration levels and vibration power spectral density profiles.

Power spectral density (PSD) profiles define the excitation into the electronic equipment more accurately than maximum expected acceleration specifications, and is a more useful technique in laboratory validation.

4.9.3.1 *Maximum Expected Acceleration Levels*—For development testing where the target mounting location is not well characterized, maximum expected acceleration levels may be specified. These specifications are used in conjunction with swept sine vibration testing, where characterization of the assembly's susceptibilities and resonant frequencies are the principal test objective.

NOTE— When the electronic equipment is installed in the target application, careful consideration should be given to the method used in mounting the assembly so that it is not subject to major resonance input vibration. This may be achieved by either insuring that the major resonance is outside the operating frequency range or by incorporating adequate damping techniques.

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4.9.3.2 Vibration Power Spectral Density Profile—This specification requires information about the vibrational energy contained in the excitation as a function of frequency. If this information is available, then the vibration power spectral density (PSD) of the location can be used for both design development and durability testing. The PSD profile for a mounting location relates the vibrational energy to specific frequency bands over a relevant frequency range.

Figures 6, 7, and 8 are examples of the PSD of the mechanical vibration measured in the cab of a class 8 truck on paved and improved roads.

Figure 9 shows an example of the PSD of engine vibrations on a heavy-duty truck, measured near an accessory drive on two different engines under loaded and unloaded conditions. A composite PSD was generated from the data. This PSD varies widely from application with mounting arrangement and engine operating point and should be measured for each vehicle prior to testing.

Figures 10 and 11 show examples of the PSD profiles of a heavy-duty truck chassis, measured vertically on a bobtail truck operating on a durability road test course. The data was collected at the extreme rearward location of the frame rail (Figure 10) and at a point located midway between the front tandem and steer axle (Figure 11).

4.9.4 RECOMMENDED TEST METHODS—Three methods for vibration testing are common in the industry: Swept sine vibration, random vibration testing, and vehicle testing.

4.9.4.1 Swept Sine Vibration Tests—The first method in current industry practice is to conduct a swept sine vibration test, then optionally dwell at the major resonances (if they are applicable to the operating spectrum) to determine the electronic equipment failure modes due to vibration. These tests must be conducted in each of three mutually perpendicular planes. Test severity and duration must be determined for the application to assure adequate life for the vehicle electronic component. Generally, the nonresonant amplitude of the test is determined by the maximum expected vibration level specification. Multiple axis excitation may be necessary to realistically simulate the equipment environment and mounting orientation.

The swept sine test must traverse the frequency range, slow enough to excite each resonance to its maximum amplitude. A sweep rate of 1/2 octave per minute is generally used. For accelerated life testing, amplitudes should be larger than actually measured at the mounting points. Acceleration factors should take material properties and failure modes into account to prevent spurious test results. (See Appendix for a sample test procedure for base level design criteria.)

4.9.4.2 Random Vibration Testing—The second method of testing requires that the vibration modes, transmissibilities, and resonant frequencies of the equipment and mounting system are known so that random vibration testing may be used. A test spectrum (PSD) can be used for durability testing and incorporate acceleration factors for a shorter test time. Random vibration is a more effective screening method because of the simultaneous excitation of the equipment at various frequencies. Since amplitudes are time varying, the power spectral densities are plotted for the three mutually perpendicular axes. The amplitudes are in G^2/Hz and are proportional to the vibration power at each frequency. The square root of the area under the curve is the RMS amplitude (see Figures 6, 7, 8, 9, 10, and 11).

Vibration which contains discrete frequency components (e.g., engine/driveline) as well as random components must be modeled by a combination of random and sinusoidal vibration spectra. In this case the peak discrete frequency amplitudes are superimposed on the broadband random spectrum, creating "sine-on-random" form of excitation. In the case of engine-mounted components, for instance, the peak spectra from the expected torque speed point would appear as narrow "lines" on the engine vibration power spectrum generated by all-wheel towing of the vehicle over the representative course. An alternate, though a less representative and more severe method, is to "envelope" the major discrete components to produce a "synthetic" test PSD profile. As in the sinusoidal case, multiaxis excitation may be necessary to

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accurately model vehicle conditions.

NOTE— The magnetic field above electromagnetic exciters can be strong. It is therefore recommended that swept sine and random vibration tests be carried out on an exciter incorporating a degaussing coil.

4.9.4.3 *Vehicle Testing*—The last method is to operate a vehicle over a group of test tracks utilizing complex surfaces. These courses are excellent test beds for complete transportation packages installed in a vehicle. Unfortunately, they are inconvenient for electronic equipment evaluation during the design phase since intermittent failures are difficult to detect and evaluate once the vibration excitation is removed.

4.9.5 RELATED SPECIFICATIONS—Three methods in MIL-STD-202F relate to vibration testing. Method 201A refers to tests between 10 and 55 Hz. Method 204D Vibration, High Frequency covers the ranges 10 to 500 Hz, 10 to 2000 Hz, and 10 to 3000 Hz, with several levels selected to suit expected service conditions. Both tests use swept sine vibration and offer procedural details and information on resident dwell periods. Method 214 Random Vibration, in MIL-STD-202F, covers a wide range of test conditions that may be appropriate to body, chassis, and axle mounted equipment. Guidance to test procedures and acceleration factors can be found in MIL-STD-810D, Method 514.3.

4.10 Mechanical Shock

4.10.1 DEFINITIONS—(Contained in 4.11.2)

4.10.2 EFFECT ON PERFORMANCE—The automotive shock environment is logically divided into four classes:

4.10.2.1 *Shipping and Handling Shocks*—These are similar to those encountered in nonvehicle applications.

4.10.2.2 *Installation Harness Shock*—It is common production line practice to lift and carry components by their harness. Therefore, it is recommended that the hamess design incorporate secure fastening and suitable strain relief.

4.10.2.3 *Operational Shock*—The shocks encountered during the life of the vehicle that are caused by curbs, potholes, etc., can be very severe. These vary widely in amplitude, duration, and number, and test conditions can only be generally simulated.

4.10.2.4 *Crash Shock*—This is included as an operating environment for safety systems. The operational requirements for these systems are limited to longitudinal shock at the present time.

4.10.3 RECOMMENDED TEST METHODS

4.10.3.1 *Handling Drop Test*—Drop the vehicle electronic equipment from a height of 1 m onto a level concrete surface one time in each of the three mutually perpendicular planes (three drops total). Choose different impact surfaces for each test sample, to assure that every surface is impacted during the test. Examine the equipment. If there is no visible damage, or only minor scratches, then the component must pass all functional tests. If there is obvious damage which would cause rejection of the component, such as a cracked housing or broken connector, then the component does not have to function.

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4.10.3.2 Transit Drop Test

4.10.3.2.1 Test Equipment—Shall comply with ASTM D 775 and D 880; TAPPI T-801 and T-802.

a. Drop tester, or hoist with suitable sling and tripping device, for packaged-products weighing less than 27 kg (60 lb). (The surface on which the packaged-product is to be dropped must provide a flat, firm, non-yielding base such as steel, concrete, etc.)
b. Incline impact tester, or alternative equipment, for packaged-products weighing from 28 to 45 kg (61 to 100 lb).

4.10.3.2.2 Test Procedure

a. Step 1: With the packaged-product in its normal shipping position, face one end of the container and identify the surfaces as follows:

   top, 1
   right side, 2
   bottom, 3
   left side, 4
   near end, 5
   far end, 6

b. Step 2: Identify edges by the number of those surfaces forming that edge, for example, the edge formed by the top and right side is identified as 1–2.
c. Step 3: Identify the corners by the numbers of three surfaces that meet to form that corner; for example, the corner formed by the right side, bottom, and near end is identified as 2–3–5.
d. Step 4: The drop height shall be as follows:

   1. Packaged-products up to 45 kg (100 lb):

   0.45–9.52 kg (1.00–20.99 lb) - 76 cm (30 in)
   9.53–18.59 kg (21.00–40.99 lb) - 61 cm (24 in)
   18.60–27.66 kg (41.00–61.99 lb) - 46 cm (18 in)
   27.67–53.31 kg (62.00–100 lb) - 31 cm (12 in)

   2. As an alternative, when the packaged-product's configuration is such that dropping is impractical, ten incline impacts from a height necessary to achieve a minimum impact velocity of 1.75 m/s (5.75 ft/s) may be performed in lieu of the 31 cm (12 in) drops. The impact sequence is delineated under Step 5.

e. Step 5: Drop or impact the packaged-product as specified under Step 4 in the following sequence:

   1. the 2-3-5 corner
   2. the shortest <u>edge</u> radiating from that corner
   3. the next longest <u>edge</u> radiating from that corner
   4. the longest <u>edge</u> radiating from that corner
   5. flat on one of the smallest faces
   6. flat on the opposite small face
   7. flat on one of the medium faces
   8. flat on the opposite medium face
   9. flat on one of the largest faces
   10. flat on the opposite large face

f. Step 6: Inspect both package and the product. The packaged-product shall be considered to have satisfactorily passed the test it, upon examination, the product is free from damage and the container still provides reasonable protection to the contents.

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4.10.3.3 *Installation Hamess Shock Test*—A recommended test is to support the electronic component and the far end of the installation harness at the same elevation, then release the component. Care should be taken to prevent the equipment from striking another object during this test. The drop should be repeated and the harness terminals or main relief area inspected for damage.

4.10.3.4 *Operational Shock*—With the possible exception of collision, the most severe vertical shock anticipated after production line installation may occur when driving over complex road surfaces. Trailer coupling or low speed loading dock collision provide the most severe horizontal shock in truck operation. The complex profile used to derive an operational shock test consists of a rise in the roadway followed by a depression or dip. Upon leaving the dip at 48 km (30 mph), the vehicle can become airborne. Severe shock may be experienced when the vehicle returns to the roadway. Another severe vertical shock is encountered in dump body trucks when loaded with rock and soil. Figure 12 illustrates the shock measured on a steering column just below the steering wheel.

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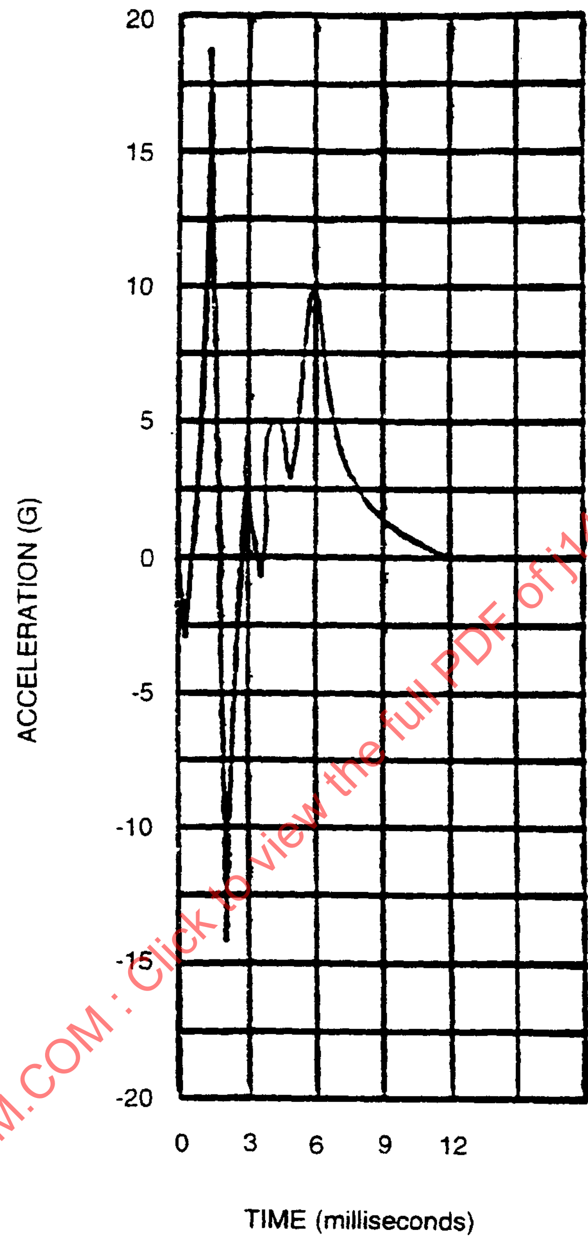

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Figure 12—OPERATIONAL SHOCK PROFILE

While this location is not typical of component mounting locations, it represents the most severe operational shock environment. This information is provided for guidance only; there are no generally accepted test procedures at the present time.

4.10.3.5 Crash Shock Test—Only limited and preliminary data on the effects of crash shock on the vehicle electronic component environment are available. However, a representative deceleration profile for a 48 km/h (30 mph) barrier crash is shown in Figure 13. The following factors vary with each installation and should be considered in pretest analysis:

a. Vehicle electronic component
b. Mounting system
c. Structure of the associated vehicle (crash distance, rate of collapse, etc.)
d. Particular engine package
e. Direction of crash

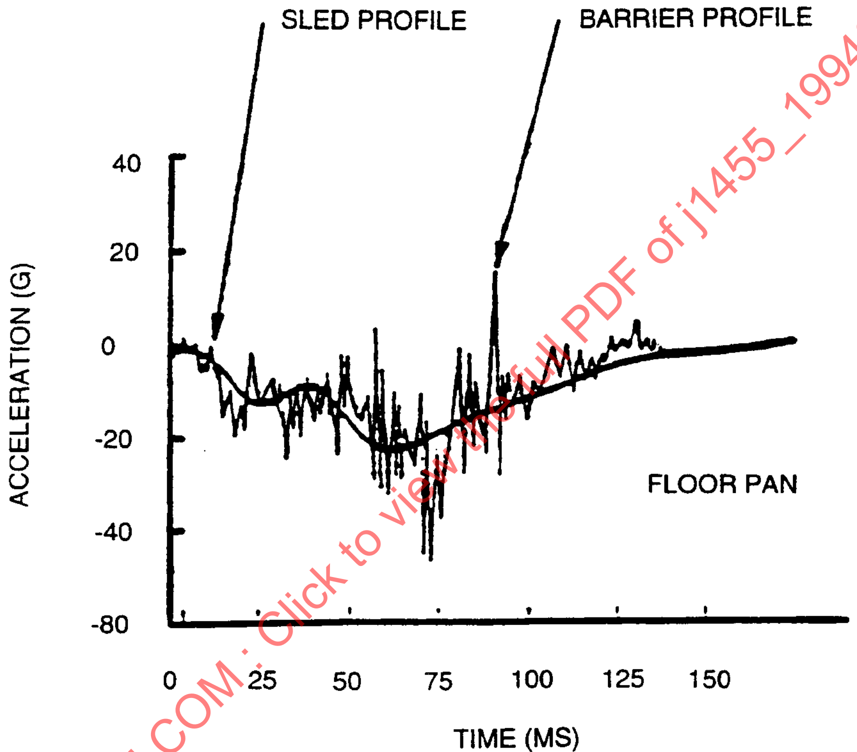

Figure 13—48 km/h (30 mph) BARRIER AND SLED SHOCK PROFILES

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4.10.4 RELATED SPECIFICATIONS—Two specifications are recommended for consideration. The first, MIL-STD-202F, Method 203B, Random Drop, is designed to uncover failures that may result from the repeated random shocks that occur in shipping and handling. It is an endurance test. The second, MIL-STD-202F, Method 213B, Shock (Specified Pulse), is intended to measure the effect of known or generally accepted shock pulse shapes. It is intended that operational shock be reduced into a standard pulse shape to achieve a repeatable test method. Other valuable guidance can be found in MIL-STD-810D, Method 516.3.

4.11 General Heavy-Duty Truck Electrical Environment—Factors unique to the truck/tractor that make the vehicular environment more severe than those encountered in most electrical component applications are:

a. Interaction with other vehicular electronic/electrical systems on the truck
b. Voltage variations
c. Customer added equipment
d. Lack of maintenance
e. Complex external electromagnetic fields

Discussion of the electrical environment falls into three categories:

1. Electrical, Steady-State—Including variations in applied vehicle DC voltages with a characteristic frequency at or below 1 Hz.
2. Electrical Transient, and Noise—Including all noise and high voltage transients with characteristic frequencies above 1 Hz.
3. Electromagnetic Compatibility and Electromagnetic Interference.

These conditions are discussed in Sections 4.11.1, 4.11.2, and 4.11.3, respectively.

4.11.1 STEADY STATE ELECTRICAL CHARACTERISTICS

4.11.1.1 Twelve Volt Systems

4.11.1.1.1 Definition—A normally operating vehicle will maintain supply voltages ranging from +11 to +16 V DC. However, under certain conditions, the voltage may fall to approximately 9 V DC. This might happen in an idling vehicle with a heavy electrical load (lights and air-conditioning) and a fully discharged battery. Therefore, depending upon the application, the designer/user may specify the +9 to +16 V DC range. For specific vehicle electronic components, such as those that must function during engine start, voltage may be specified as appropriate.

Cold cranking of the engine with a partially depleted battery at –40 °C (–40 °F) can reduce the nominal 12 V to 6.5 V minimum at the battery terminals. At the starter motor terminals, because of the voltage drop on the battery cabling, the voltage typically varies sinusoidally from 5.2 to 7.8 V at a low frequency about 4 Hz (56 rpm, 8 cylinder engine) due to the engine compression load variation during the crank cycle.

Another condition affecting the DC voltage supply occurs when the voltage regulator fails, causing the alternator to drive the system at 18 V or higher. Extended 18 V operation will eventually cause boil-off of the battery electrolyte, resulting in voltages as high as 75 to 130 V. Other charging system failures can result in lower than normal battery voltages. General steady-state voltage regulation characteristics are shown in Table 3A.

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TABLE 3A—TRUCK/TRACTOR (12 V SYSTEM) VOLTAGE REGULATION CHARACTERISTICS

Condition	Voltage
Normal operating vehicle	16 V max. 14.2 V nominal 9 V min. (1)
Cold cranking at –40 °C (–40 °F)	
-At the starter motor terminals	5.2 V to 7.8 V
-At the battery terminals	6.5 V min.
Jumper starts	+24 V
Reverse polarity	–12 V
Voltage regulator failure	9 to 18 V
Battery electrolyte boil-off	75 to 130 V

1. See 4.11.1 for a definition of normal voltage.

TABLE 3B—TRUCK/TRACTOR (24 V SYSTEM) VOLTAGE REGULATION CHARACTERISTICS

Condition	Voltage
Normal operating vehicle	32 V max. 28.4 V nominal 18 V min. [1]
Cold cranking at –40 °C (–40 °F)	
-At the starter motor terminals	10.6 V to 16 V
-At the battery terminals	13.3 V min.
Jumper starts	+48 V
Reverse polarity	–24 V
Voltage regulator failure	18 to 36 V
Battery electrolyte boil-off	75 to 130 V

1. See 4.11.1 for a definition of normal voltage.

Garages and emergency road services have been known to utilize 24 V sources for emergency starts, and there are reports of 36 V being used for this purpose. High voltages such as these are applied for up to 5 min and sometimes with reverse polarity. The use of voltages that exceed the vehicle system voltage can damage electrical components, and the higher the voltage, the greater the likelihood of damage.

NOTE— Since a design cannot preclude every contingency, this discussion of the application of voltage above normal system voltage is included for information only.

4.11.1.1.2 Effect on Performance—Vehicle electronic components that must operate during the starting condition are generally designed to perform with slight degradation over a wide range of voltage. The designer is alerted to the possibility of failure from the combination of voltage and temperature variation. Over-voltage and high temperature, both from the external environment and internal dissipation, may cause excessive heat and result in failure. Under-voltage will probably result in degraded or nonperformance. Conditions must be carefully examined to determine the true temperature and excitation voltage of the vehicle electronic component.

4.11.1.1.3 Recommended Test Methods—Critical vehicle electronic components are performance-tested for operation within predetermined limits. Samples are also subjected to combinations of temperatures and supply voltage variations that are designed to represent the worst case stresses on control components. A typical cycle for this form of test is shown in Figure 14.

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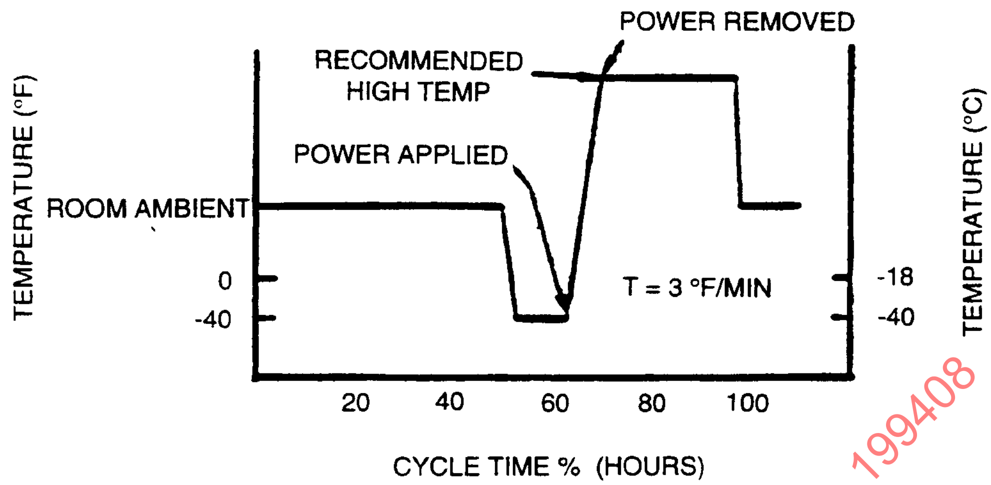

Figure 14—COMBINED THERMAL AND ELECTRICAL STRESS PROFILE

The voltage applied and removed at the two points shown in Figure 14 is generally 16 V, the maximum normal voltage. If the test is performed for the high voltage battery jump start condition of 24 V, a narrower temperature range is used. This is a destructive test that is often used as an indication of basic design environmental capability. The number of cycles expected before failure, the actual limit values for temperature and voltage, and the period of each cycle are dependent on the design goals for the electronic component being considered.

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Samples of finished units are generally tested for extended operation at the peak voltage/temperature combination expected at the component's location. In the absence of an actual temperature combination, the values in Table 1A and 1B are recommended. These tests often run for extended periods and are particularly stringent for electronic components in the underhood environment.

4.11.1.2 Twenty-four Volt System

4.11.1.2.1 Definition—A normally operating vehicle will maintain supply voltages ranging from +22 to +32 V DC. However, under certain conditions, the voltage may fall to approximately 18 V DC. This can happen in an idling vehicle that has a heavy electrical load (lights and air-conditioning) and a fully discharged battery. Therefore, depending upon the application, the designer/user may specify the +18 to +32 V DC range. For specific equipment that must function during engine start, voltage may be specified.

Cold cranking of the engine with a partially depleted battery at –40 °C (–40 °F) can reduce the nominal 24 V to 13.3 V minimum at the battery terminals. At the starter motor terminals, because of the voltage drop on the battery cabling, the voltage typically varies sinusoidally from 10.6 V to 16 V at about 4 Hz (50 rpm, 8 cycle) due to the engine compression load variation during the crank cycle.

Another condition affecting the DC voltage supply occurs when the voltage regulator fails, causing the alternator to drive the system at 36 V. Extended 36 V operation will eventually cause boil-off of the battery electrolyte, resulting in voltages as high as 75 to 250 V. Other charging system failures could result in lower than normal battery voltages. General steady-state voltage regulation characteristics are shown in Table 3B.

4.11.1.2.2 Effect on Performance—Vehicle electronic components that must operate during the starting condition are generally designed to perform with slight degradation over a wide range of voltage. The designer is alerted to the possibility of failure from a combination of voltage and temperature variation. Over-voltage and high temperature, both from the external environment and internal dissipation, may cause excessive heat and result in failure. Under-voltage will probably result in degraded or nonperformance. Conditions must be carefully examined to determine the true temperature and excitation voltage of the electronic equipment.

4.11.1.2.3 Recommended Test Methods—Critical vehicle electronic components are performance tested for operation within predetermined limits. Samples are also subjected to combinations of temperatures and supply voltage variation that are designed to represent the worst case stresses on control components. A typical cycle for this form of test is shown in Figure 14.

The voltage applied and removed at the two points shown in Figure 14 is generally 32 V, the maximum normal voltage. If the test is performed for the high voltage battery jump start condition of 48 V, a narrower temperature range is used. This is a destructive test that is often used as an indication of basic design environmental capability. The number of cycles expected before failure, the actual limit values for temperature and voltage, and the period of each cycle are dependent on the design goals for the electronic component being considered.

Samples of finished units are generally tested for extended operation at the peak voltage/temperature combination expected at the electronic component's location. In the absence of actual temperature measurements, the values in Tables 1A and 1B are recommended. These tests often run for extended periods and are particularly stringent for components in the underhood environment.

4.11.2 TRANSIENT, NOISE, AND ELECTROSTATIC CHARACTERISTICS FOR 12 AND 24 V

4.11.2.1 Definition—Three principal types of transients are encountered on truck/tractor wire harnesses. There are load dump, inductive switching, and mutual coupling. Generally, they occur simultaneously. The vehicle electronic component user and/or designer should determine the actual values for peak voltages, peak current, source impedance, repetition rate, and frequency of occurrence at the interface between his component and the electrical distribution system, then design and test the electronic component to withstand values consistent with the expected use.

4.11.2.2 Effect on Performance—Testing should be done at the maximum rated temperature of the vehicle electronic component. Tables 4A and 4B summarize typical transient characteristics for 12 V and 24 V systems, respectively.

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TABLE 4A—TYPICAL 12 V VEHICLE TRANSIENT VOLTAGE CHARACTERISTICS

Lines	Type	Source (ohms)	Rise (µs)	Open Circuit	Repetition	Energy
Power	Load Dump	0.4	100	14 + 86e(–t/0.4)	5 Pulses 10 s Int.	Notes 2 and 3
I/O Note 1	Inductive Switching	20	1	14 ± 600e∧(–t/0.001)	10 Pulses at 1 s Int.	Notes 1 and 3
I/O All	Mutual	50	1	14 ± 300e∧(–t/0.000015)	10 Pulses at 1 s int.	Note 3

NOTE 1— This transient applies to those I/O lines which may be connected to unclamped inductive loads in addition, the energy available will be 0.5LI^2 where I is the current through the inductor amps and L is the inductance in henries.

NOTE 2— The alternator is capable of outputting much more energy than can be absorbed by used electronic clamping devices. Therefore, when clamping devices are used in electronic modules, caution must be used in the design of the vehicle electrical system to insure the energy limitations of each clamping device are observed (see Appendix B).

NOTE 3— The transient waveforms described previously in mathematical form may actually be implemented by diode O-ring a DC and transient voltage.

TABLE 4B—TYPICAL 24 V VEHICLE TRANSIENT VOLTAGE CHARACTERISTICS

Lines	Type	Source (ohms)	Rise (µs)	Open Circuit	Repetition	Energy
Power	Load Dump	0.8	100	28 + 122e∧(–t/0.4)	5 Pulses 10 s Int.	Notes 2 and 3
I/O Note 1	Inductive Switching	20	1	28 ± 600e∧(–t/0.001)	10 Pulses at 1 s Int.	Notes 1 and 3
I/O All	Mutual	50	1	28 ± 300e∧(–t/0.000015)	10 Pulses at 1 s Int.	Note 3

NOTE 1— This transient applies to those I/O lines which may be connected to unclamped inductive loads. In addition, the energy available will be 0.5LI^2 where I is the current through the inductor and amps and L is the inductance in henries.

NOTE 2— The alternator is capable of outputting much more energy than can be absorbed by commonly used electronic clamping devices. Therefore, when clamping devices are used in electronic modules, caution must be used in the design of the vehicle electrical system to insure the energy imitations of each clamping device are observed (see Appendix B).

NOTE 3— The transient waveforms described previously in mathematical form may actually be implemented by diode O-ring a DC and transient voltage.

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4.11.2.2.1 Load Dump Transient—Load dump occurs when the alternator load is abruptly reduced. This sudden

a. The battery normally acts like a capacitor and absorbs transient energy when it is in the circuit.
b. The partially discharged battery forms the single greatest load on the alternator and, therefore, disconnecting it creates the greatest possible step load change.

reduction in current causes the alternator to generate a positive voltage spike. The most severe case load dump is caused by disconnecting a discharged battery when the alternator is operated at rated load. Using the discharged battery load to create the load dump creates the worst situation for two reasons:

This transient may be the most severe encountered in the vehicle and can result in component damage or fuse opening. It is most often initiated by defective battery terminal connections. On 12 V systems, transient voltages as high as 100 V or more have been reported with rise times of approximately 100 ms. However 60 to 80 V are most likely. Reports of decay time vary from 100 ms to 4.5 s. The long duration decay occurs during vehicle turn off with a disconnected or dry vehicle battery. However, even the shortest time (100 ms) is relatively long, requiring that significant energy must be dissipated. Figure 15 shows typical load dump transients for both 12 V and 24 V systems.

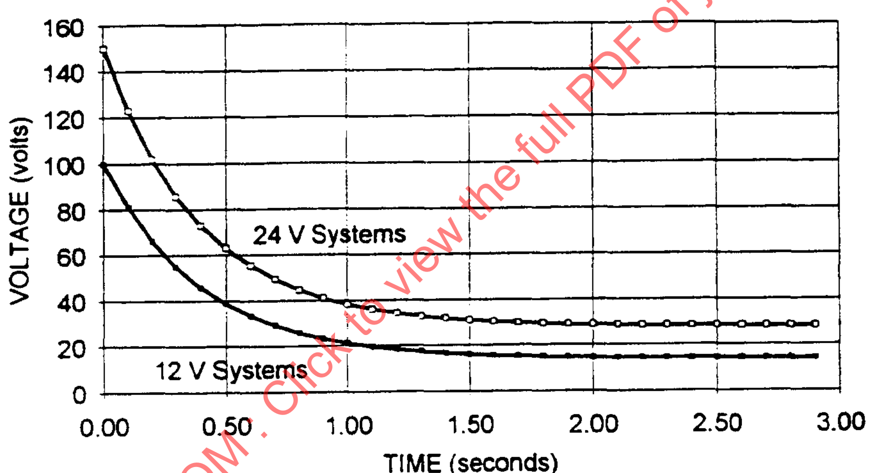

Figure 15—LOAD DUMP TRANSIENT

The load dump transient contains considerable electrical energy which must be safely dissipated or blocked to prevent damage to electronic component. This transient occurs randomly in time appearing as individual or repetitive pulses at random unknown rates due to vibration. See Appendix for more information.

4.11.2.2.2 Inductive Load Switching Transient—Inductive transients are caused by solenoid, motor field, air-conditioning clutch, and ignition system switching. These occur during vehicle operation whenever an inductive accessory is turned off. Severity is dependent on the magnitude of switched inductive load and line impedance. Unfortunately, measurements to date have not been taken with standardized procedures and were most probably observed with different loads.

These transients generally take the form of large positive or negative peaks, followed by the smaller damped excursions of the opposite polarity. Transients of this nature may cause component damage or introduce logic or functional computational errors. Table 4A illustrates typical values for 12 V systems and Table 4B shows typical values for 24 V systems.

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4.11.2.2.3 Mutual Coupling—Coupling is not, strictly speaking, a generator of transients but a mechanism that is capable of introducing transients into circuits not directly connected to the transient source. There are three general coupling modes in the vehicle: magnetic, capacitive, and conductive. Briefly, the coupling problems are caused by long harnesses, nonshielded conductors, and common ground return impedances. Long harnesses are one of the principal coupling media that distribute transients throughout the vehicle. When a number of wires are bundled into a harness and a step change in current or voltage occurs, inductive or capacitive coupling between the conductor experiencing the change and the other wires can result. Multiple ground returns with different potentials cause "ground loops" and result in conductive coupling of transients.

4.11.2.2.4 Electrical Noise—Normal accessory noise and vehicle transceiver feedback are two common interference sources which have been historically identified. These are more comprehensively covered under J1113 sections on conducted susceptibility. For applicable definition, test methodology and test levels refer to this document.

4.11.2.2.4.1 Chattering Relay—For applicable definition, test methodology, and test levels refer to Appendix A, SAE J1113/12 Coupled Transients.

4.11.2.2.5 Electrostatic Discharge—Electrostatic charge stored by the human body and then discharged through an arc into a component may cause operating anomalies.

4.11.2.2.5.1 Handling—Discharging a 150 pF capacitor that has been charged to a potential of 15 kV through a 150 Ω resistor is adequate to simulate this effect at the terminals or other areas subject to handling (See J1211).

4.11.2.2.5.2 In Vehicle—For applicable definition, test methodology and test levels refer to SAE J1113/13.

4.11.2.2.6 Other Effects—It is possible that inductive switching of certain solenoids and the alternator decay transient condition can occur simultaneously. This hypothesis would account for the higher voltage transients that have been reported, but not explained. Measurement of greater than 600 V transients have been reported. Also to be considered are noise suppression capacitors that are sometimes placed on the fuse block, and some accessories that are applied to quiet radio interference. In some cases, capacitors may form tuned circuits with inductive loads, causing high voltage transient conditions.

Certain devices with high levels of stored energy, such as coasting permanent magnetic motors, may maintain line voltage for a finite interval after the ignition is shut off. Some electronic components may perform in an unsatisfactory mode of operation under such conditions.

NOTE— Direct conduction through common circuits constitutes the most frequent path by which transients are introduced into electronic components.

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4.11.3 ELECTROMAGNETIC COMPATIBILITY (EMC)—The condition which prevails when electrical components, subsystems, or systems are performing their individually designed functions in a common electromagnetic environment without causing or suffering unacceptable degradation due to electromagnetic interference from other components, subsystems, or systems in the same environment.

4.11.3.1 Electromagnetic Interference (EMI)—Electromagnetic energy which interrupts, obstructs, or otherwise degrades or limits the effective performance of components, subsystems, systems. EMI may be transient, intermittent, or continuous in nature arising from sources such as transmitters or other equipment located either on-board or adjacent to the vehicle.

4.11.3.2 *Effect on Performance*—This EMI usually affects vehicle electronic components when they are operational by causing degradation of performance, malfunction, or deviation from specified tolerances beyond those indicated. It is desired that all electronic components meet the level of EMC recommended by this document.

Electrical devices can either be susceptible to EMI and/or emit EMI, i.e., cause other devices to malfunction due to EMI radiated (emitted) from with the device. Both emission levels and susceptibility levels are specified in the following sections.

NOTE— The mechanisms governing the introduction of transients into an electronic assembly or its interrelated components are very complex. Thus, the vehicle electronic component designer/ packager must be familiar with the configuration of the total vehicle electrical system; for example, wire routing, shielding, grounding, filtering and decoupling practices, and vehicle electronic component location.

4.11.3.3 *Recommended Test Procedures and Levels*—To aid in determining performance regions for EMI/EMC for vehicle electronic components and determine to what extent the component has been affected, it is recommended to classify the functional status of vehicle electronic components upon application of the test procedures and levels found in SAE J1113. Performance regions have been defined and should be used in conjunction with the functional status classification.

4.11.3.3.1 Radiated Emissions—For applicable definition, test methodology, and test levels refer to SAE J1113/41.

4.11.3.3.2 Susceptibility—For applicable definitions, test methodology, and test levels refer to SAE J1113/21–23.

5. Designer's Reference by Location—This section identifies, by location, applicable guidelines used in the design of vehicle electronic components. These major vehicle electronic component mounting sites are identified in Figure 3 and include:

a. Underhood

1. Engine (Lower Portion)
2. Engine (Upper Portion)
3. Bulkhead

b. Interior (Forward)

1. Floor
2. Instrument Panel
3. Headliner
4. Inside Doors

c. Interior (Rear)

1. Bunk Area
2. Storage Compartment

d. Chassis

1. Forward
2. Rear

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e. Exterior of Cab

1. Under Floor
2. Rear
3. Top
4. Doors

Each site is discussed individually with the following detail:

a. A table listing applicability of design issues identified in Section 4.
b. Comments germane to other operating conditions are unique to that mounting location. Decisions concerning each environmental factor and the test methods used to determine vehicle electronic component performance and durability, should only be arrived at after examining the information in Section 4 of this document. In addition, the designer should be satisfied, by referring to the pertinent test data, that the particular application falls within the described operating extremes. See Section 3.

5.1 Underhood Engine and Bulkhead—Caution should be exercised in applying electronic components in the underhood region because of the wide range of environments. Applicable design guidelines are referenced in Table 5.

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TABLE 5—ENGINE—ENVIRONMENTAL DATA

Temperature	Min	Max	Humidity	Salt Spray	Immersion and Splash	Direct Spray Steam Clean Pressure Wash	Gravel Sand & Dust	Mechanical Shock Vibration	Altitude	Electrical
Underhood	(over ambient)									
Lower	–40 °C (–40 °F)	56 °C (100 °F)	Sect. 4.2	Sect. 4.3	Sect. 4.4	Sect. 4.5	Sect. 4.7	Sect. 4.9	Sect. 4.8	Sect. 4.11
Upper	–40 °C (–40 °F)	222 °C (400 °F)								
Bulkhead	–40 °C (–40 °F)	56°F (100 °F)								

5.1.1 TEMPERATURE

5.1.1.1 Temperature-Engine—Vehicle electronic components in the vicinity of the exhaust system may experience temperature peaks that are beyond the survival limits of many insulation materials and discrete components.

Investigators have found that the lowest peak temperature areas are often forward in the lower compartment, near the interior or exterior radiator support hardware. The exterior has the disadvantage of being subject to more splash with resultant potential for moisture intrusion, corrosion, or thermal shock.

The temperature control mechanism for typical engine-mounted electronic components relies heavily on the conduction of heat via the engine mass rather than convection via fins projecting into the airflow. Units which have a built-in source of heat energy may operate at temperatures above the highest coolant temperature. Vehicle electronic components thermally interlocked by conduction with the engine have two advantages during normal operation:

a. During engine operation, the upper temperature limit is set by the coolant peak temperature, which is in turn controlled by the thermostat.
b. The time rate of change if temperature is limited by the combined engine and coolant system thermal mass.

Thermal shock as it is usually thought of for electronic components would not occur in engine-mounted electronics (assuming good thermal connection to the engine) in normal vehicle operation (normal engine warm-up and cool-down) because of the large mass except for transient phenomena such as ice water splash in the winter or steam cleaning.

Consideration should also be given to the applications where fuel cooling is used. Fuel temperature can remain at ambient temperature plus 22 °C (40 °F) fairly constant throughout operation. Stabilization rates shown in Figures 2a, 2b, and 2c are not precise and must be experimentally or analytically determined for a given application.

5.1.1.2 *Temperature-Bulkhead*—Temperature conditions are similar to the underhood-engine intake manifold, except that the primary method of heat flow is convection rather than conduction, and the resultant temperature slew rate is less. Vehicle electronic components in this area generally rely heavily on convection due to the relatively low thermal conduction characteristics and unpredictable thermal interface between the component and the bulkhead sheet metal. The rate of change in temperature is therefore set by the thermal mass of the component itself, and convection due to air movement rather than conduction via the mounting surface.

Thermal shock due to the impact of cold mud, slush, etc., is not likely in the upper bulkhead location. Consideration should be given to melted snow and ice leakage from the hood/windshield area.

Investigators have experienced peak temperatures of 121 °C (250 °F), although one data source expects this to be 140 °C (285 °F). Locations on the bulkhead near or just above the exhaust manifold(s) which is at 649 °C (1200 °F), will experience higher temperatures. The effects of underhood exhaust processing components (catalytic reactors, etc.) will also raise the peak temperatures.

5.1.2 PEAK TEMPERATURE (HEAT SOAK)—The temperature profile varies widely with individual engine/body combinations. Therefore, it is impossible to specify all conditions. Generally, worst case temperature operating conditions should be obtained by instrumenting a proposed location for the following operating conditions:

a. The largest engine installation expected in that body style.
b. Peak ambient temperature.
c. Air condition ON.

5.1.2.1 The vehicle is driven at highway speed at rated GCVW for about 60 min and then parked. Underhood temperatures are monitored for the heat soak conditions as the thermal energy stored in the engine system is released in the absence of underhood airflow. Design modifications that contribute thermal energy to the underhood area, such as secondary air thermal reactors, engine charge air coolers (aftercoolers) or catalytic reactors, should be in place and operating for this test.

Test methods of this type have revealed that the region to the rear of the engine compartment, and locations near radiated and conducted heat from the exhaust/reactor manifold tend to be high temperature areas. Present control practice has limited the location of electronic components to temperature situations similar to those shown for the intake manifold, although operation in the vicinity of the alternator heat source will probably add about 10 °C (18 °F) to the peak 121 °C (250 °F) shown for the intake manifold. Some experimenters expect the temperature near the radiator support structure to be no higher than 93 °C (200 °F).

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