SAE International™ SURFACE VEHICLE RECOMMENDED PRACTICE

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Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications

RATIONALE

This document is being changed to allow more flexibility in testing load dump and to corrrect the reference from SAE J1113-2 and change it to ISO 11452-10.

1. SCOPE

The scope of this recommended practice encompasses the range of environments which influence the performance and reliability of the electronic equipment designed for heavy duty on and off road vehicles, as well as any appropriate stationary applications which also use these vehicle derived components. A few examples of such vehicles are on and off highway trucks, trailers, buses, construction equipment and agricultural equipment including implements.

1.1 Purpose

This document is intended to aid the designer of commercial vehicle electronic systems and components by providing guidelines that may be used to develop environmental design goals. Specific test requirements are to be agreed upon by the customer and supplier.

2. REFERENCES

2.1 Applicable Documents

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

2.1.1 SAE Publications

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

SAE J400 Test for Chip Resistance of Surface Coatings

SAE J726 Air Cleaner Test Code

SAE J1113 -1 Electromagnetic Compatibility Measurement Procedures and Limits for Components of Vehicles, Boats (up to 15 m), and Machines (Except Aircraft) (16.6 Hz to 18 GHz)

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
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SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical/standards/J1455_201101

SAE J1211 Handbook for Robustness Validation of Automotive Electrical/Electronic Modules

SAE J1812 Function Performance Status Classification for EMC Immunity Testing

2.1.2 ISO Publications

Available from International Organization for Standardization, 1, rue de Varembe, Case postale 56, CH-1211 Geneva 20, Switzerland, Ttel: +41-22-749-01-11, www.iso.org.

ISO 11452-8 Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 8: Immunity to magnetic fields

ISO 11452-10 Road vehicles - Component test methods for electrical disturbances from narrowband radiated electromagnetic energy - Part 10: Immunity to conducted disturbances in the extended audio frequency range

2.1.3 IEC Publications

Available from International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland, Tel: +44-22-919-02-11, www.iec.ch.

IEC CISPR 25 CORR 1 Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of on-board receivers CORRIGENDUM 1

2.1.4 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM C 150 Specification for Portland Cement

ASTM B 117 Standard Method of Salt Spray (Fog) Testing

ASTM D 5276 Method for Drop Test for Loaded Boxes

ASTM D 880 Method for Incline Impact Test for Shipping Containers

2.1.5 Military Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

MIL-STD-810F Environmental Test Methods and Engineering Guidelines MIL-STD-202G—Test Methods for Electronic and Electrical Component Parts

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

TAPPI T801 Impact Resistance of Fiberboard Shipping Container

TAPPI T802 Drop Test for Fiberboard Shipping Containers

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, as well as the specific pass and fail criterion for the conducted tests prior to testing. 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 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

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.

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.

3.5 Sample Size

3.5.1 The engineering team should consider factors that could influence the number of samples required to draw reasonable conclusions about system performance. Some factors might include cost, system application, relation to safety new or modified design, etc. This number should be determined at the beginning of the test process.

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.

4.1.1.2 Heat Sources and Sinks Generated by the Vehicle's Operation

The major sources are the engine and drive-train 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 Thermal Cycling

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 components 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.

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 all 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.

4.1.1.6 Ambient Conditions Before Installation Due to Storage and Transportation Extremes

Shipment in unheated aircraft cargo compartments may lower the minimum storage (non-operating) temperature to –50 °C (–58 °F). Under certain conditions the upper storage temperature may exceed the maximum ambient operating temperature (i.e., paint booth requirements). The thermal environmental conditions that are a result of these conditions can be divided into three categories:

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 Fatigue failures of solder joints.

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

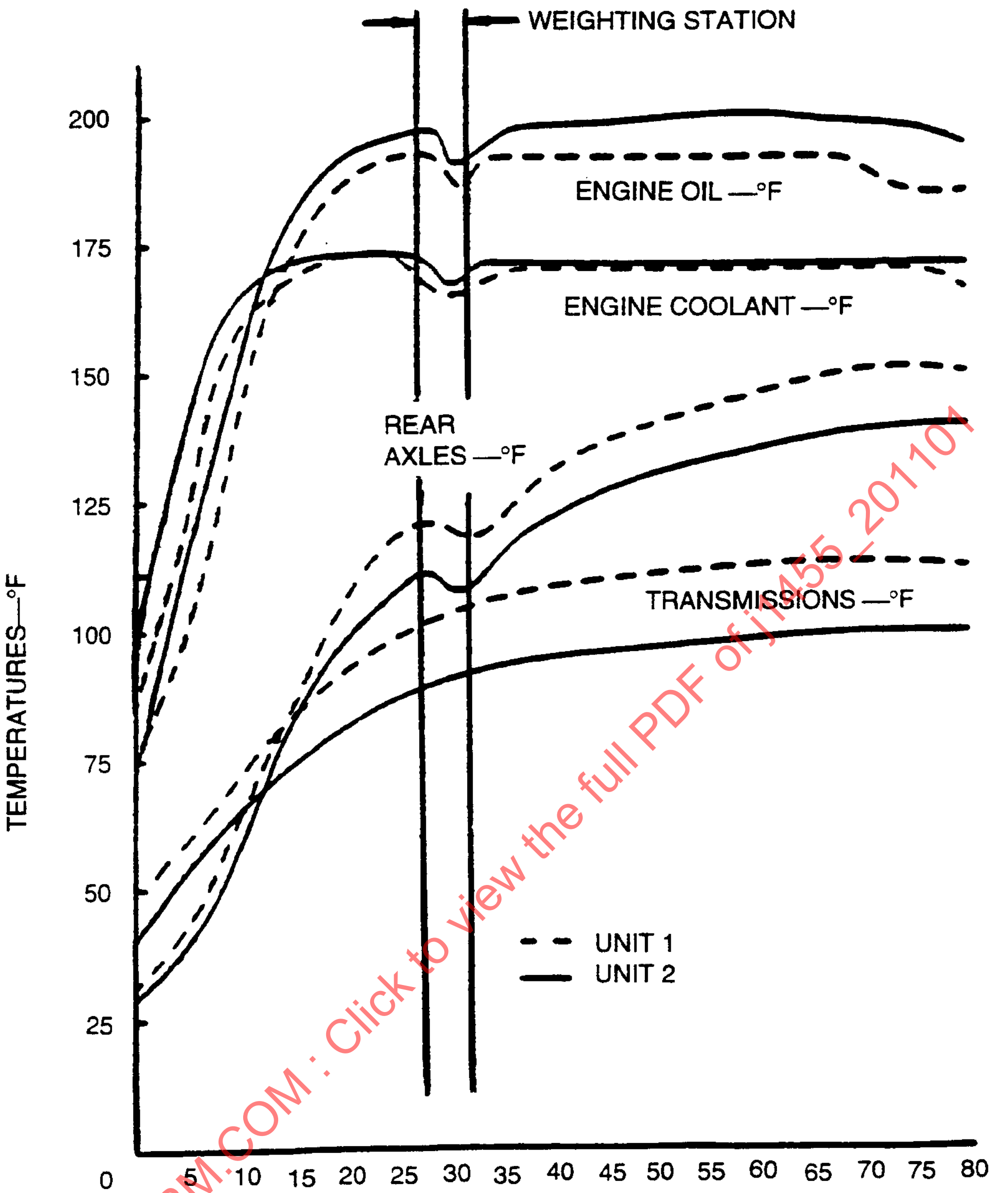


FIGURE 1 - TIME INTO RUN-MINUTES VEHICLE WARM-UP CHARACTERISTICS

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.

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, non-catastrophic failure is possible because of electrical leakage in the resultant carbon paths. Catastrophic failures can occur as well, in the form of thermal damage.

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 inter-connect 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.

4.1.3 Recommended Test Methods

Recommended temperature cycle profiles are shown in Figures 2A and 2B. Recommended extreme temperatures to be used with the profiles are shown in Table 1. If temperature characterization has been performed according to 4.1.1.4, the measured temperature may be substituted for the values in Table 1 for the purpose of this document. The recommended thermal shock profile is shown in Figure 2C. Separate test chambers may be used to generate the temperature environment described by the thermal shock profile. The number of cycles for each test is a function of the vehicle electronic component application. Temperature extremes for products designed for other applications, may need to be adjusted accordingly.

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 air stream, where there is substantially no obstruction to the flow of air across the specimen. Care must be exercised however 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 the test design (see Section 3).

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. Functional electrical testing during temperature transitions or immediately after temperature transitions, is a means of detecting poor electrical and mechanical connection integrity.

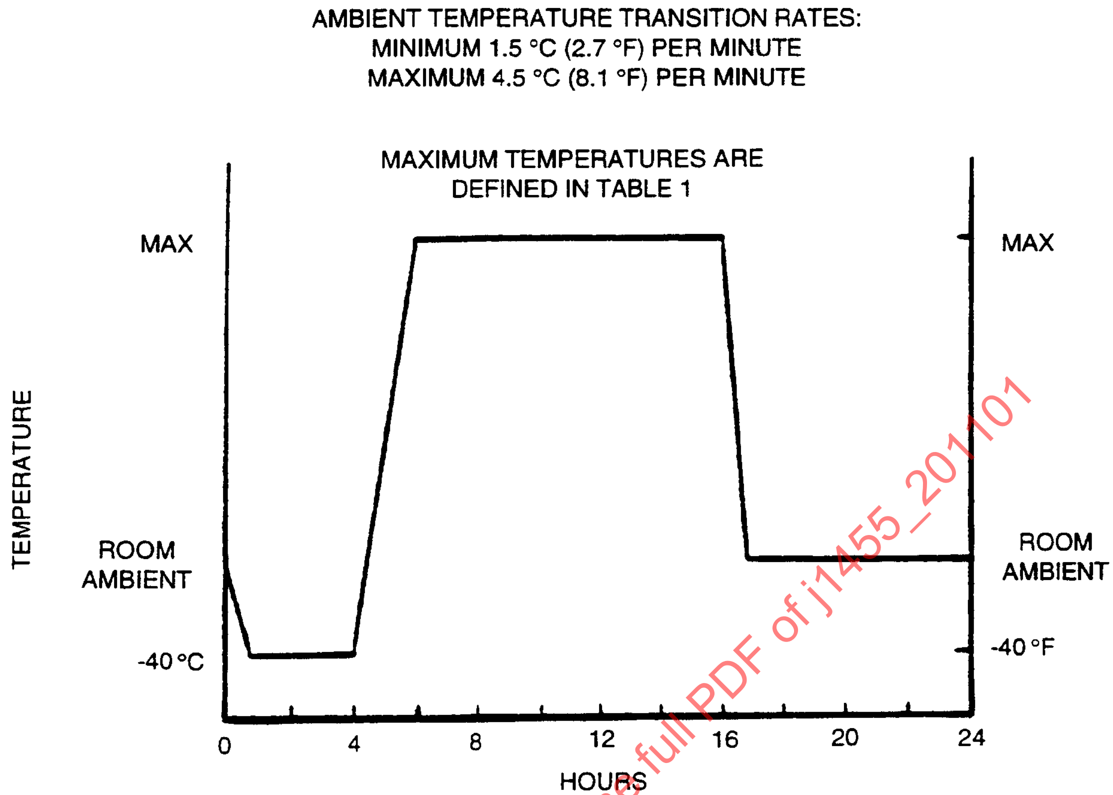


FIGURE 2A - 24 HOUR THERMAL CYCLE

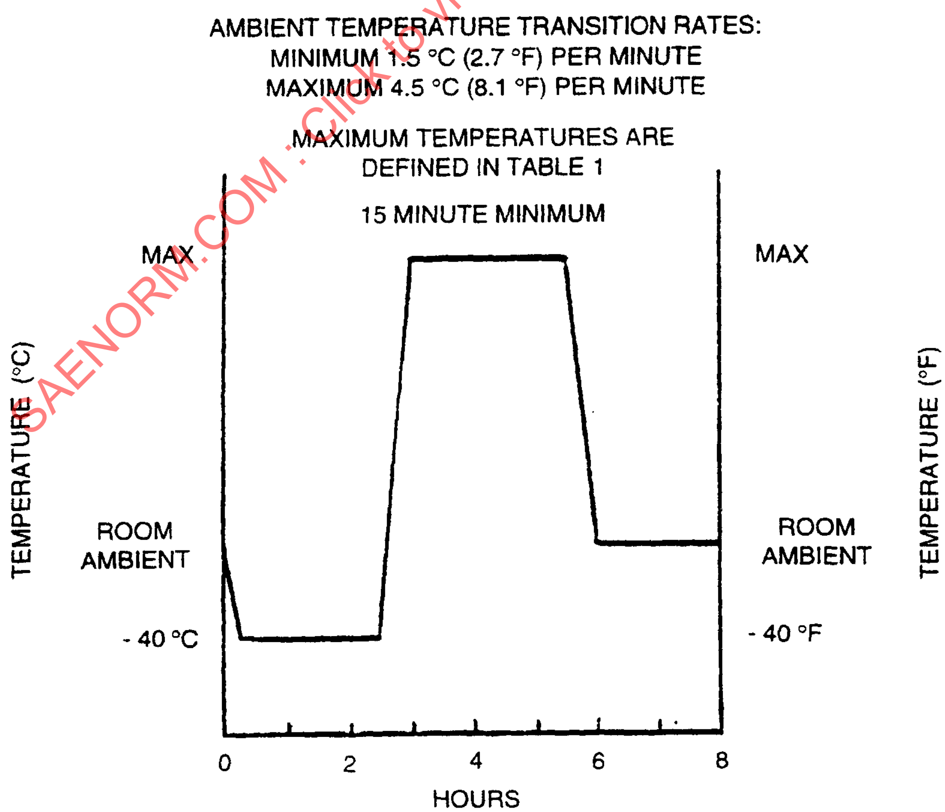


FIGURE 2B - SHORT (8 HOUR) THERMAL CYCLE

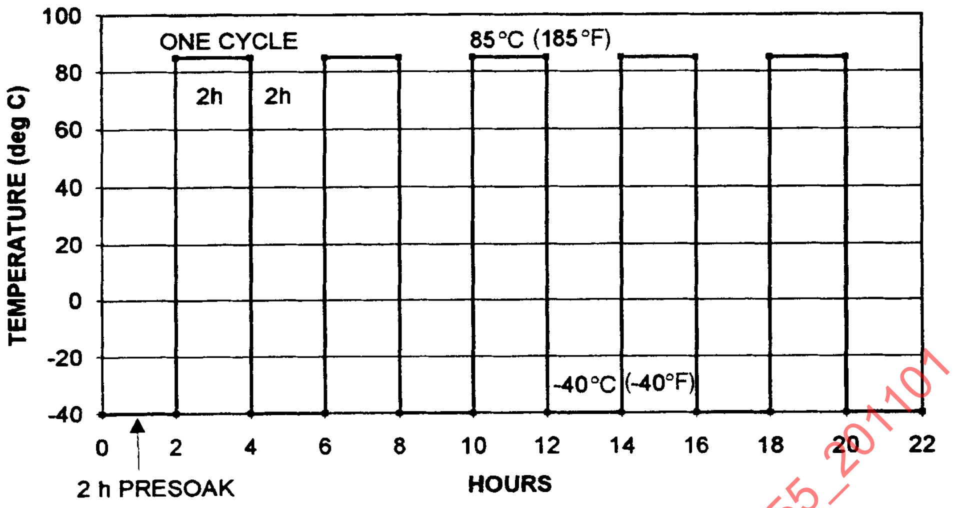
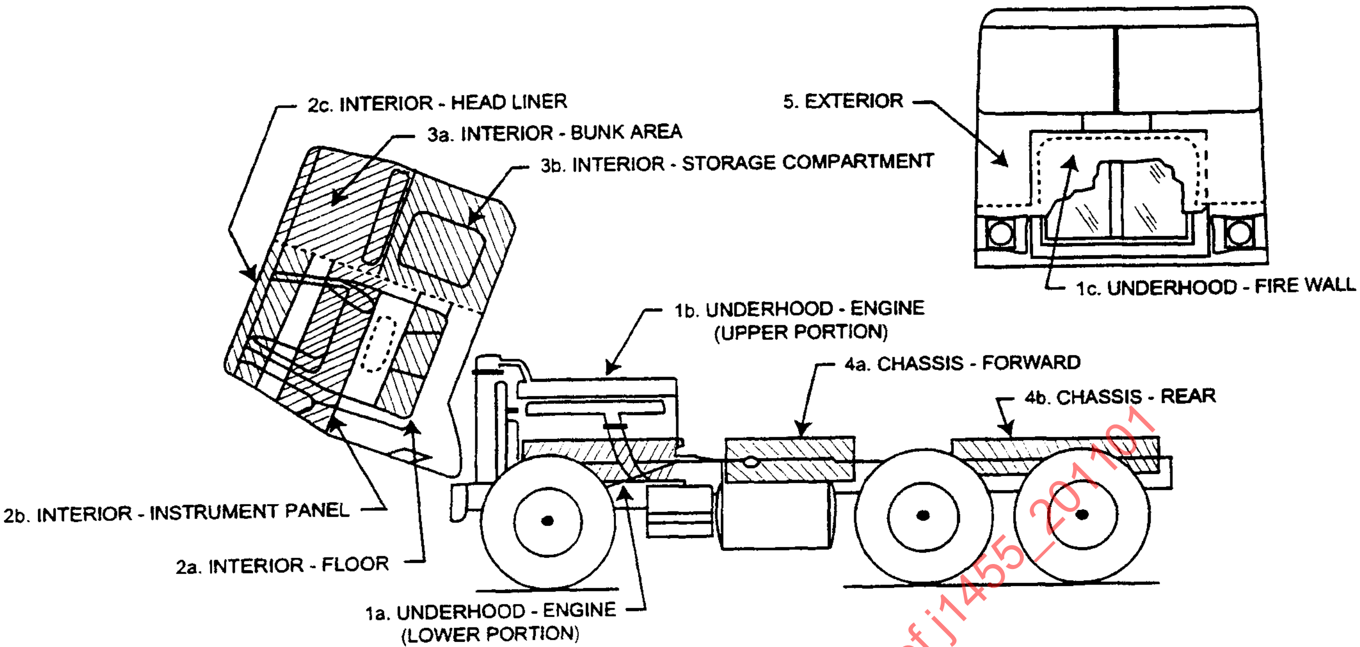


FIGURE 2C - THERMAL SHOCK

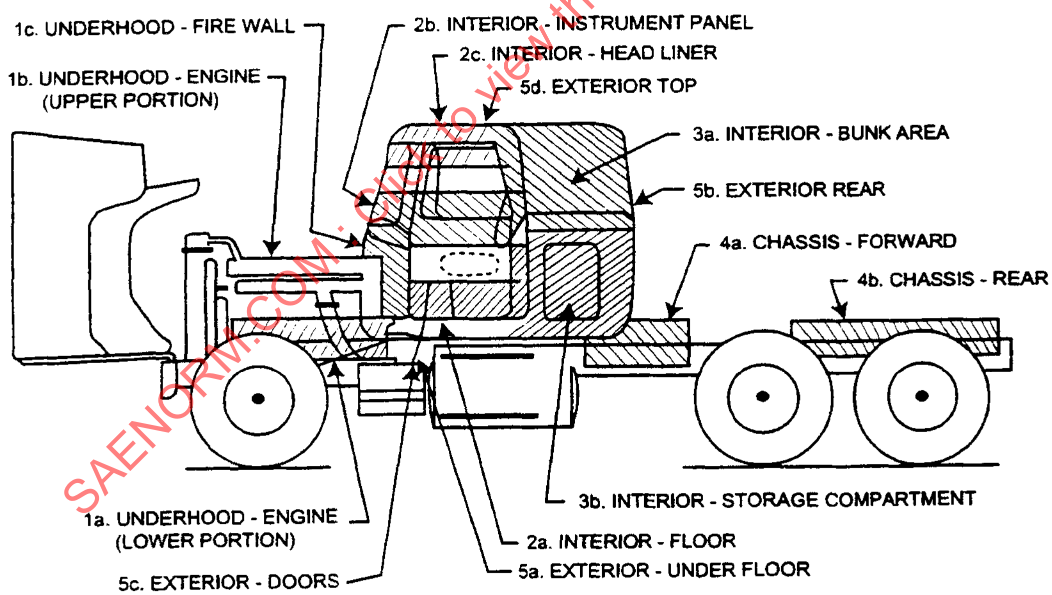
TABLE 1 - ENVIRONMENTAL EXTREME SUMMARY HEAVY-DUTY CAB OVER ENGINE TRUCK/TRACTOR

	Location[1]	Temperatures Min	Temperatures Max[2,4]
ENGINE	1a Underhood - Lower	–40 °C (–40 °F)	141 °C (285 °F)
	1b Underhood – Upper[3]	–40 °C (–40 °F)	307 °C (585 °F)
	1c Underhood Bulkhead	–40 °C (–40 °F)	141 °C (285 °F)
INTERIOR	2a Floor	–40 °C (–40 °F)	66 °C (150 °F)
	2b Instrument Panel[4]	–40 °C (–40 °F)	85 °C (185 °F)
	2c Headliner	–40 °C (–40 °F)	79 °C (175 °F)
	2d Inside Door		
	3a Bunk Area	–40 °C (–40 °F)	93 °C (200 °F)
	3b Storage Compartment	–40 °C (–40 °F)	74 °C (165 °F)
CHASSIS	4a Forward	–40 °C (–40 °F)	120 °C (250 °F)
	4b Rear	–40 °C (–40 °F)	85 °C (185 °F)
EXTERIOR	5a Under	No Data	
	5b Back	No Data	
	5c Door	–40 °C (–40 °F)	85 °C (185 °F)
	5d Top	No Data	

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)



HEAVY-DUTY CABOVER ENGINE TRUCK



HEAVY-DUTY CONVENTIONAL TRUCK

FIGURE 3 - VEHICLE ENVIRONMENTAL ZONES

4.1.3.1 Temperature Cycle Test

The test method of Figure 2A, a 24 h cycle, offers longer stabilization time and permits a longer room ambient test period. Figure 2B, an 8 h cycle, provides more temperature cycles for a given test duration. It is applicable to most vehicle electronic components whose temperatures will reach stabilization in a shorter cycle time. Stabilization should be verified by actual measurements with thermocouples or other means. 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 done to maintain thermal or pressure stresses generated in the test specimen for a reasonable period of time.

4.1.3.2 Thermal Shock Test

Thermal shock that can be expected in the vehicle environment is simulated by the rate of change shown on the recommended thermal shock profile portrayed in Figure 2C usually specified as no greater than 5 min. The thermal shock test should begin with a 2 h presoak at –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 back to the cold chamber (–40 °C/–40 °F) where it should remain for an additional 2 h. Each transfer should be accomplished in 1 min or less. The 2 h dwell in the hot chamber and 2 h dwell in the cold chamber constitute one thermal shock cycle.

4.1.3.3 Thermal Stress

Thermal stress fatigue failures are caused by repetitive cycling across the thermal profiles of Figures 2A, B, and C. The number of cycles to be conducted 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 and mechanical connection integrity, as well as providing information of any potential negative impact on the design due to components varying coefficients of expansion. 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 procedure for small part testing is defined in MIL-STD-202G, Method 107G, Thermal Shock, Test Condition A or B, alternately MIL-STD-810F, Method 503.4. 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 resulting moisture to be drawn into the enclosure.

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).

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.

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 non-operation induced frosting.

4.2.4 Related Specifications

Many related humidity specifications are recommended for review and reference. The first: MIL-STD-810F, Method 507.4, Procedures I through III, Humidity, is a system-oriented test method. The second, a modified version of MIL-STD-202G, Method 103B, Humidity (Steady State), is intended to evaluate materials. The third, MIL-STD-202G, Method 106F, Moisture Resistance, is a procedure for testing small parts.

4.3 Salt Spray Atmosphere

4.3.1 Definition

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. Historically salt has been a solution comprised of NaCl, but $MgCl^2$ is now in use as a road salt in some areas. New compounds should be considered for their corrosive potential as they come into use. 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. In addition to the effects of salt spray on the electronic components and connectors, mounting hardware and enclosures can also sustain corrosive damage if not properly designed, located, or protected.

4.3.2 Effect on Performance

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. Inadequate sealing of connectors and component enclosures can lead to failure of electronic components. Very severe corrosion conditions can lead to mounting failures.

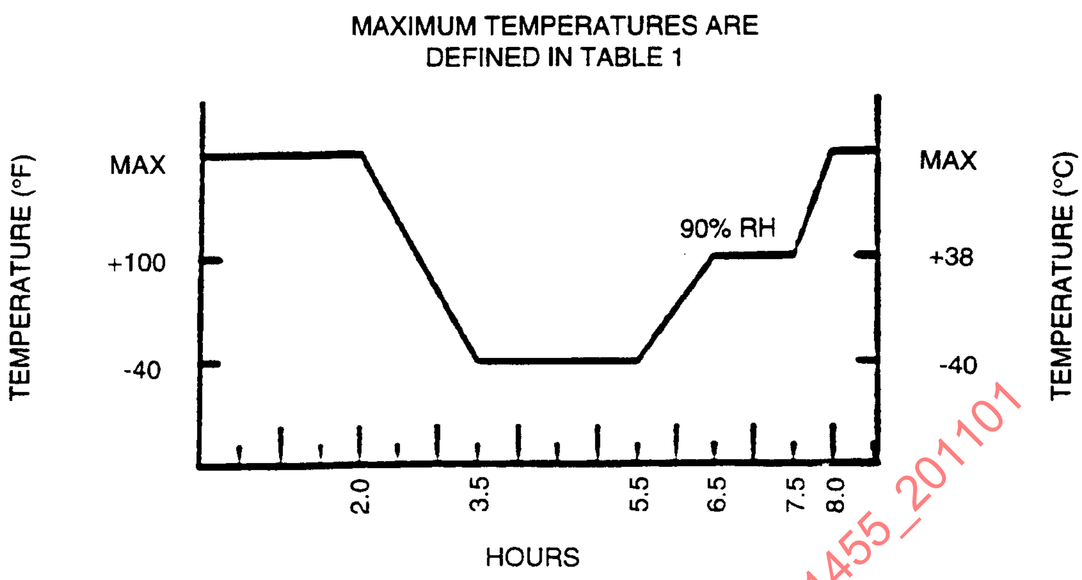


FIGURE 4a—8 h HUMIDITY CYCLE

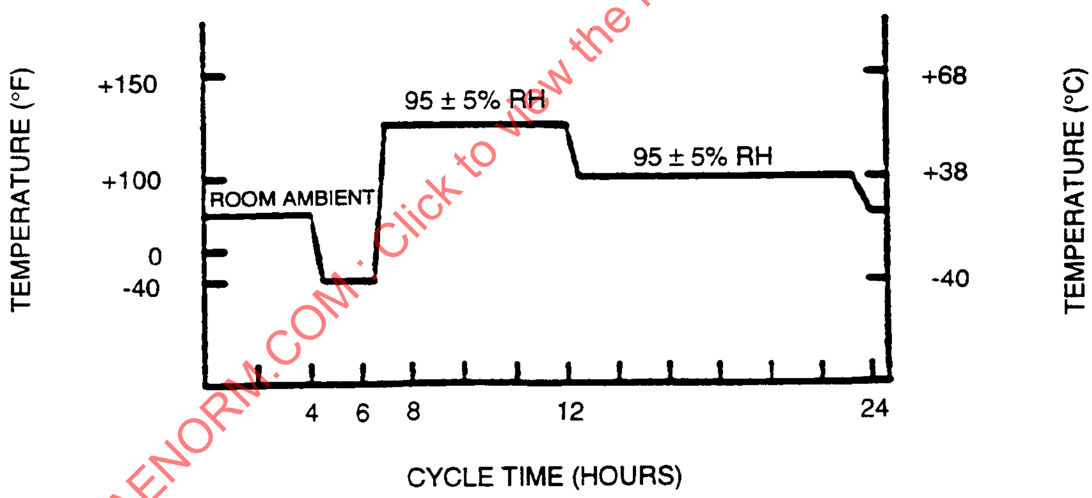


FIGURE 4b—24 h HUMIDITY CYCLE

FIGURE 4 - RECOMMENDED HUMIDITY CYCLES

4.3.3 Recommended Test Methods

4.3.3.1 Salt Spray (Fog)

One 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 117-97. Similar test methods are found in MIL-STD-202G, Method 101D, and MIL-STD-810F, Method 509.4. This test precipitates the effects of corrosion on exposed hardware and unsealed enclosures. However, salt spray alone may produce only moderate effects on sealed enclosures and connector integrity. Salt spray should be used as a general guide to salt water ingression susceptibility but should not replace immersion testing for components located in high splash areas.

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). Components in low splash areas should be exposed to the salt spray for a period of 24 to 96 h. Electronic components that are mounted on the chassis or other high splash areas should be exposed to a minimum of 240 h of salt fog. The actual exposure time must be determined by analysis of the specific mounting location and amount of splash encountered. The vehicle electronic component should be tested under nominal conditions of voltage and load throughout the test. Where possible, mounting hardware should be included in the test.

When the tests are concluded, the test specimens should be evaluated for visual evidence of unwanted salt precipitation or accumulation. The samples should then 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). A performance test on the specimens should be completed within 1 h of completion of the test to prevent a drying out of the product prior to testing. Care should be taken to keep all interface connections intact at the conclusion of the test. An inspection of the enclosure, connectors, mounting hardware, and surface finish should be performed to determine the resistance of salt spray on the test samples. There should be no degradation of performance or function, and only minimal traces of corrosion should be allowed.

4.3.3.2 Immersion Testing

Immersion testing provides an enhanced analysis of sealed connector and sealed enclosure integrity. During immersion testing, utilizing a 5% by weight salt water solution as the fluid, the component should be operational during the test. All connectors and seals should be intact in a configuration that resembles as close as possible the actual field. In this test, the vehicle electronic component is in its normal exterior package is immersed in salt water at about 74 °C (165 °F). The test sample should be completely covered by the salt water. The component should remain immersed for a period of 1 h. The component shall then be transferred to a salt water solution maintained at about 0 °C within 2 min of leaving the hot salt water bath. The unit shall be left to soak in the cold bath for a period of 1 h. This constitutes one hot-cold ‘dunk’ soak cycle. A total of three ‘dunk’ soak cycles should be performed.

At the completion of the dunk soak cycles, the test units should be subject to the combined environmental profile in figure (14). Vibration and humidity are optional but recommended to reduce the number of test cycles. Vibration activates a ‘percolating’ effect and accelerates sealing failures. Humidity decreases the drying effect of the high temperature extremes.

The total number of dunk cycles and combined environmental cycles is determined by the severity of the mounting location. Multiple dunk and combined environmental cycles should be performed on components mounted in frame rail, chassis, and other high splash areas.

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, appropriated measurements under wet and dry conditions may be necessary.

4.3.4 Related Specifications

ASTM B 117 is the recommended test method.

4.4 Exposure to Chemicals and Oils

4.4.1 Definition

Vehicle electronic components mounted on or in the vehicle are exposed to varying amounts of 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
Window Washer Solvent
Gasoline
Diesel Fuel
Fuel Additives
Alcohol
Anti-Freeze Water Mixture
Degreasers
Soap and Detergents
Steam
Battery Acid
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
Diesel Exhaust Fluid (DEF) is 32.5% solution of high-purity urea in de-mineralized water.

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 enclosure can result in corrosion or contamination of vulnerable internal components causing reduced performance or possible loss of function. Connector seals may deform and become ineffective in protecting the connector cavity resulting in corroded connector pins. Over extended periods of time, performance degradation, shorts, or opens can be expected. Non-metallic enclosures may become brittle or lose rigidity. Certain non-metallics may exhibit fractures or cracking when subject to solvents. The aesthetics of the packaging may also be effected and unacceptable by the customer. The chemical compatibility can be determined by laboratory chemical analysis.

4.4.3 Recommended Test Methods

The vehicle electronic component designer should first determine what level of exposure 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 enclosure materials, seals, seams, and bushings that might otherwise escape notice.

4.4.3.1 High Exposure Splash Testing

This test should be performed on components that would see a high level of exposure to specific chemicals. This test should be limited to non-hazardous materials only. The test 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.

Devices such as sensors and other electronic components that may be immersed in fluids for long periods of time, should be subjected to laboratory life tests in these fluids. This would also facilitate the use of hazardous chemicals.

4.4.3.2 Hazardous and Light to Moderate Splash Test

For hazardous materials and light to moderate exposure, brush application or full immersion testing may be performed.

Brush testing consists of liberally applying the chemical by means of a chemically compatible brush. 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 selected chemicals are applied to the component allowing for a 5 to 10 min period between application of the various chemicals. The chemicals should be left on the test sample, allowed to stand for a minimum of 24 h, and inspected for physical abnormalities or damage. The test samples should then be functionally tested. Multiple test samples should be used for this test using different random orders of application.

Immersion testing consists of immersing the test sample into the selected chemical. 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 component is dipped into the selected chemical and allowed to stand for 5 to 10 min prior to the immersion in the next chemical. The chemical should be left on the test sample, allowed to stand for a minimum of 24 h, and inspected for physical abnormalities or damage. The test sample should be functionally tested. Multiple test samples should be used for the test using different random orders of application.

NOTE: That some chemicals may provide a chemical barrier to the subsequently applied chemicals (i.e., spray paints). In those cases, separate samples must be used.

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

The intense heat from cleaning and 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.

4.5.2 Effects on Performance

Exposure to high heat, extreme water pressure and caustic detergents can cause a degradation of insulation and seals as well as cracking of vinyl connectors and component packaging. Intrusion into connector areas and exterior packaging can cause degraded or loss of function and performance.

4.5.3 Recommended Test Method

4.5.3.1 Mounting

The 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.

4.5.3.2 Test Equipment

The test equipment used for this testing shall be determined by agreement between the testing and contracting parties.

Level 1 (Standard Test) - The component under test should be sprayed using a flat fan spray nozzle that provides 100% coverage of the exposed surface. The nozzles shall be located 20 to 30 cm (7.9 to 11.8 in) away from the component under test. The 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) with non heated ambient cold tap water. The test item should be exposed to the spray for 3 s on each surface a total of 378 times (63 times on each surface of a six sided device under test). If a round component is used, spray for 3 s a total of 63 times on the top and bottom and the remainder of the allotted time equally distributed around the circumference.

Level 2 (Standard Test w/Detergent) - Using a wash solution with detergent heated to 40 °C (104 °F) the component under test should be sprayed using a flat fan spray nozzle that provides 100% coverage of the exposed surface located 20 to 30 cm (7.9 to 11.8 in) away from the component under test. The apparatus should provide a source pressure of approximately 7000 kPa gage (1020 lbf/in^2 gage) with a flow rate of approximately 9460 cm^3/min (150 gal/h). The test item should be exposed to the spray for 3 s on each surface a total of 378 times (63 times on each surface of a six sided device under test). If a round component is used, spray for 3 s a total of 63 times on the top and bottom and the remainder of the allotted time equally distributed around the circumference.

Level 3 (Harsh Test) - Each exposed surface of the component under test should be sprayed with water heated to 80 °C (176 °F) using a 30 degree fan spray nozzle. The nozzles shall be located 20 to 30 cm (7.9 to 11.8 in) away from the component under test. The apparatus should provide a source pressure of approximately 10 000 kPa gage (1450 lbf/in^2 gage) with a flow rate of 14 511 cm^3/min (230 gal/h). Each exposed surface should be exposed to the spray for 30 s on each surface Reference DIN 40-050. If a round component is used, spray for 30 s on the top and 30 s on the bottom and 120 s equally distributed around the circumference.

Level 4 (Extreme Test) High Pressure Steam Cleaning - Each exposed surface of the component under test should be sprayed with water heated to 93 °C (200 °F) using a 15 degree fan spray nozzle. The nozzles shall be located 20 to 30 cm (7.9 to 11.8 in) away from the component under test. The apparatus should provide a source pressure of approximately 24 000 kPa gage (3500 lbf/in^2 gage) with a flow rate of 22 712 cm^3/min (360 gal/h). Each exposed surface should be exposed to the spray for 30 s. If a round component is used, spray for 30 s a on the top and 30 s on the bottom and 120 s equally distributed around the circumference.

NOTE: Those applications where pressure washing is expected should consider the potential effects of the latest higher pressure washers that are available and mounting location in the severity of the test implemented.

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.

A typical fungal spore mixture consists of Aspergillus flavus, A. versicolor and Penicillium funiculosum. A 30 day growth period is allowed.

Any fungal growth that does occur shall be examined and a determination made as to the long term effects. If a clear and certain determination is made that no degradation of performance shall occur over the life of the product and that the fungal growth will not detract from the appearance of visible portions of the product, then the fungal growth is allowed. Otherwise, it is not allowed.

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

4.6.4 Alternate to Test

The testing described by the recommended test method in 4.6.3 may not need to be performed if the product can comply by design. The most common way to determine this is to review the product material and component datasheets to ensure they are non-nutritive to fungus.

4.6.5 Related Specifications

None.

4.7 Dust and Sand

4.7.1 Definition

Dust creates a harsh environment for chassis, under-hood, 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 under-hood areas.

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 and sand 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 as coarse grade should be used. If this dust packs or seals openings in the test sample, or if the sample contains exposed mechanical elements, the following alternate dust mixture may be used:

a. SAE 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.

4.7.4 Related Specification

Three specifications are referenced. The first: MIL-STD-202G, Method 110A, S and Dust, is a piece part test and is included for information and comparison. MIL-STD-810F, Method 510.4, is another reference. The second is SAE J726, which defines the recommended dust. It also describes test apparatus.

4.8 Gravel Bombardment

4.8.1 Definition

Bombardment by gravel is significant for chassis, lower engine, and exterior-mounted electronic components. Gravel from unimproved roads, gravel from gravel haulers, and highway salt dispersing equipment are just some of the sources of gravel damage.

4.8.2 Effects on Performance

Gravel damage can cause immediate loss of function of the components due to high shock loads and breakage. Loss of connector or enclosure integrity can occur. However, some superficial or cosmetic damage is acceptable if functional, and packaging integrity is not affected.

4.8.3 Recommended Test Methods

The recommended test for susceptibility of vehicle electronic component to damage from gravel bombardment is SAE J400. 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.

4.9 Altitude

4.9.1 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 - ALTITUDE - PRESSURE MATRIX

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)

4.9.2 Effect on Performance

With increased altitude, the following effects are generally observed:

4.9.2.1 Reduction in convection heat transfer efficiency.

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

4.9.2.3 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.

4.9.3 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. Non-operating tests should be done at a minimum temperature of –50 °C (–58 °F), if possible.

4.10 Mechanical Vibration

4.10.1 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.

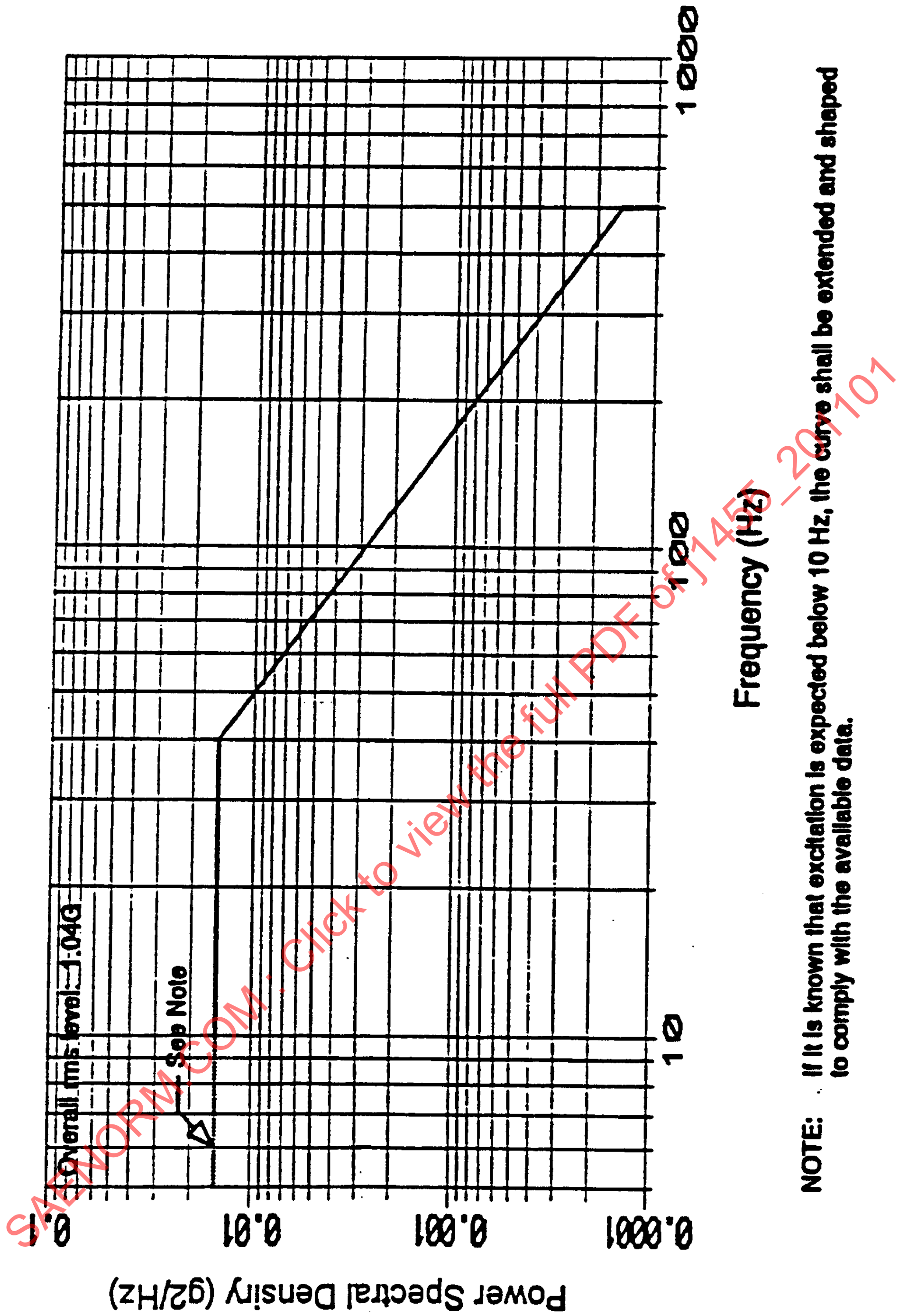


FIGURE 6 - SAMPLE CAB MOUNTED VIBRATION PSD CLASS 8 TRUCK, VERTICAL AXIS

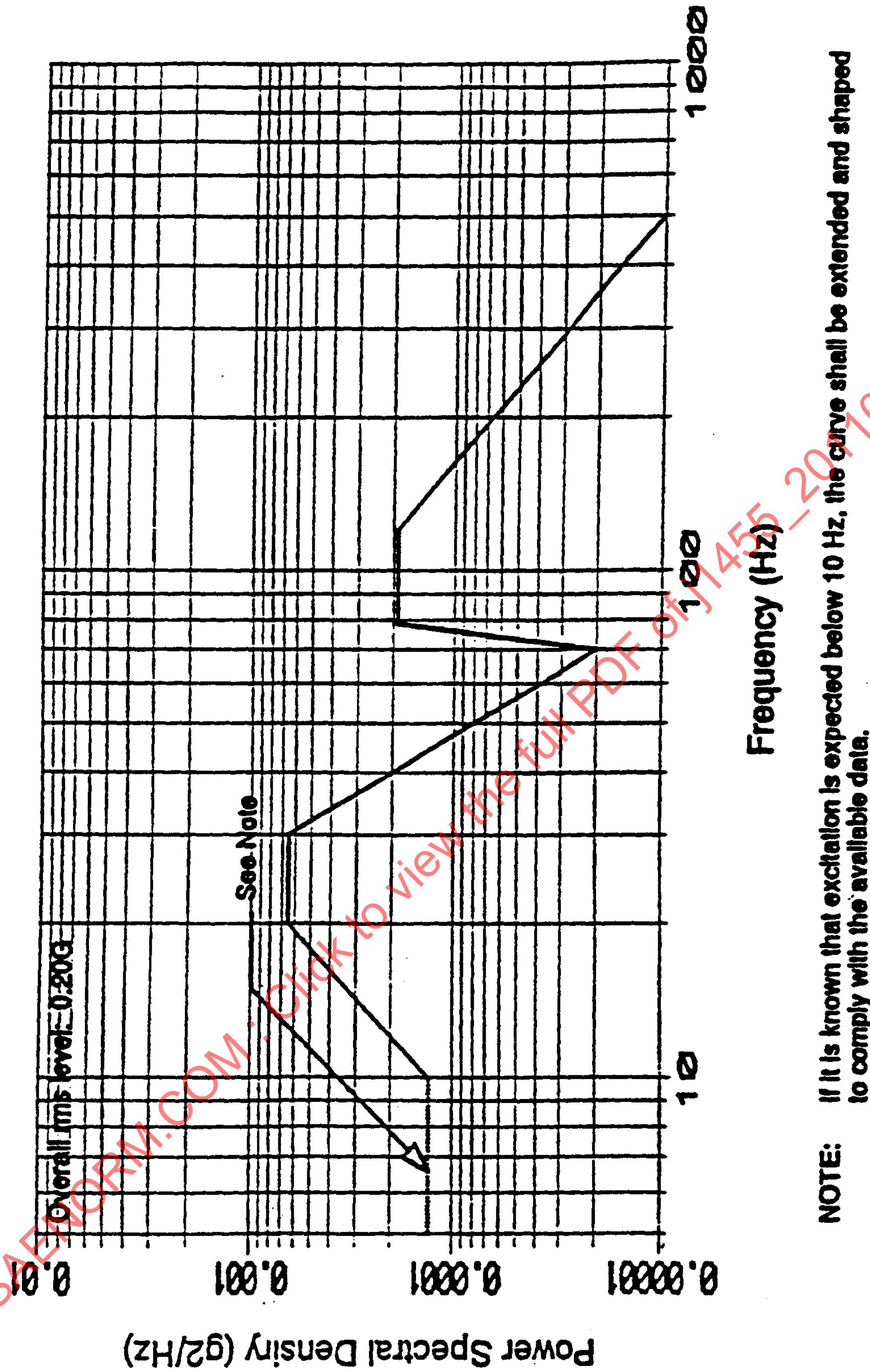


FIGURE 7 - SAMPLE CAB MOUNTED VIBRATION PSD TRANSVERSE AXIS

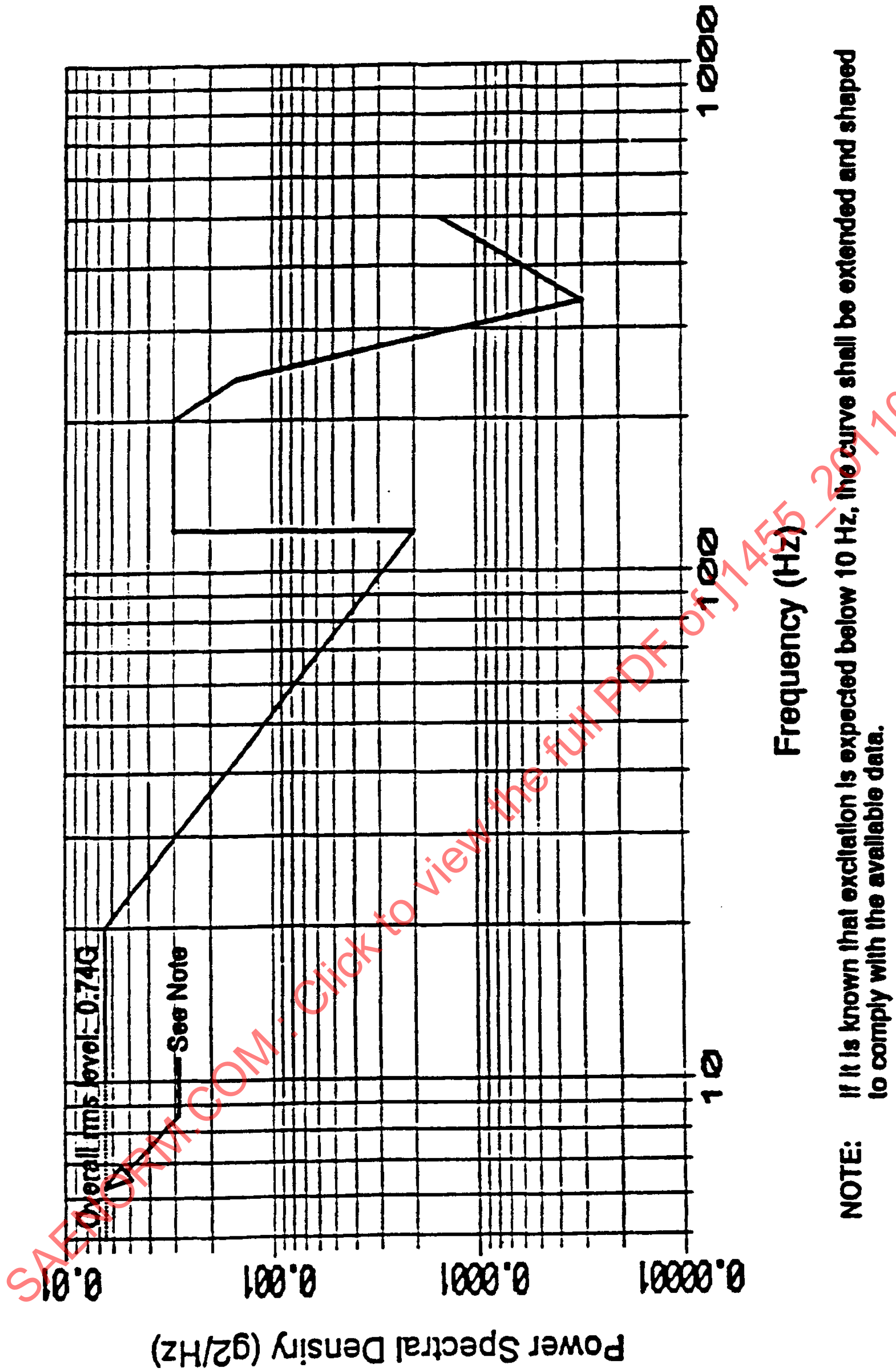


FIGURE 8 - SAMPLE CAB MOUNTED VIBRATION PSD CLASS 8 TRUCK, LONGITUDINAL AXIS

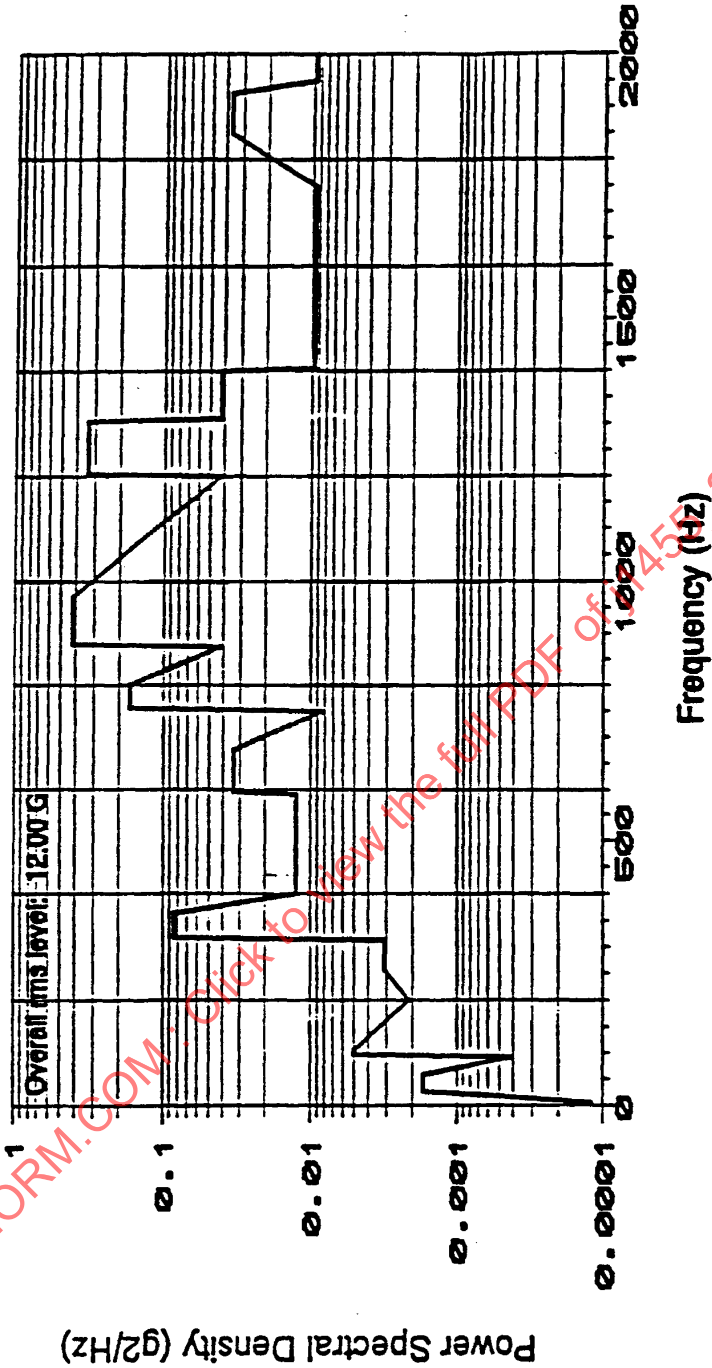


FIGURE 9 - SAMPLE ENGINE VIBRATION DATA (VERTICAL), HEAVY-DUTY TRUCK

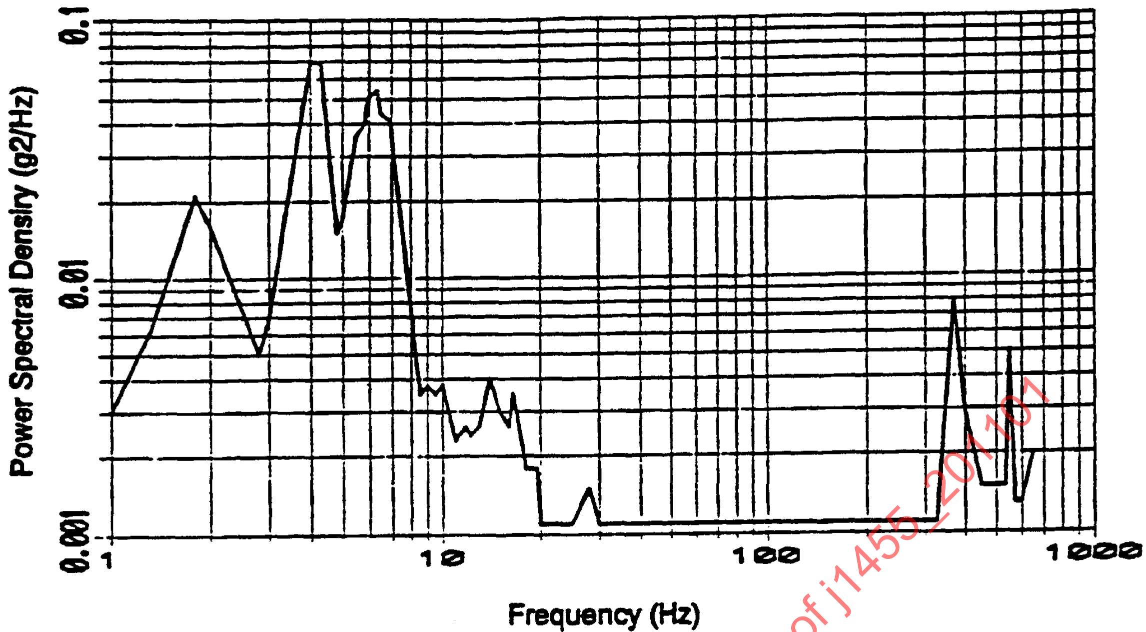


FIGURE 10 - CHASSIS VIBRATION DATA, PSD, BOBTIL VERTICAL MID FRAME, HEAVY-DUTY TRUCK

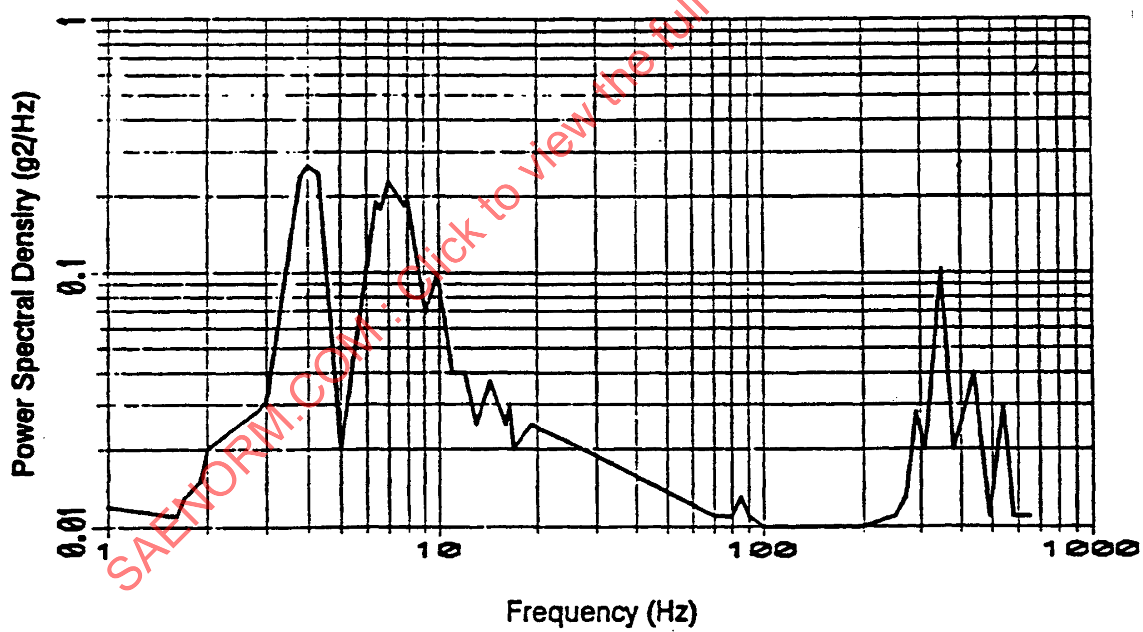


FIGURE 11 - CHASSIS VIBRATION DATA, PSD, BOBTAIL VERTICAL REAR FRAME, HEAVY-DUTY TRUCK

4.10.2 Effect on Performance

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

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

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

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

4.10.2.4 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.

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

Examples:

4.10.2.5.1 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.

4.10.2.5.2 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.

4.10.3 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.

4.10.3.1 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.

4.10.3.2 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 point located midway between the front tandem and steer axle (Figure 10) and at the extreme rearward location of the frame rail (Figure 11).

4.10.4 Recommended Test Methods

Three methods for vibration testing are common in the industry: Swept sine vibration, random vibration testing, and vehicle testing.

4.10.4.1 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 for a sample test procedure for base level design criteria.)

4.10.4.2 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 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.

4.10.4.3 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.

4.10.5 Related Specifications

Three methods in MIL-STD-202G 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 214A Random Vibration, in MIL-STD-202G, 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-810F, Method 514.5

4.11 Mechanical Shock

4.11.1 Definitions

(Contained in 4.11.2.)

4.11.2 Effect on Performance

The automotive shock environment is logically divided into four classes:

4.11.2.1 Shipping and Handling Shocks

These are similar to those encountered in non-vehicle applications as a result of the shipping and handling processes.

4.11.2.2 Installation Harness Shock

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

4.11.2.3 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.

4.11.2.4 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.

4.11.3 Recommended Test Methods

4.11.3.1 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.

4.11.3.2 Transit Drop Test

4.11.3.2.1 Test Equipment

Shall comply with ASTM D 5276 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).

4.11.3.2.2 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 edge radiating from that corner

   3. the next longest edge radiating from that corner

   4. the longest edge 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.

4.11.3.3 Installation Harness 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.

4.11.3.4 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 collisions 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.

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.

4.11.3.5 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

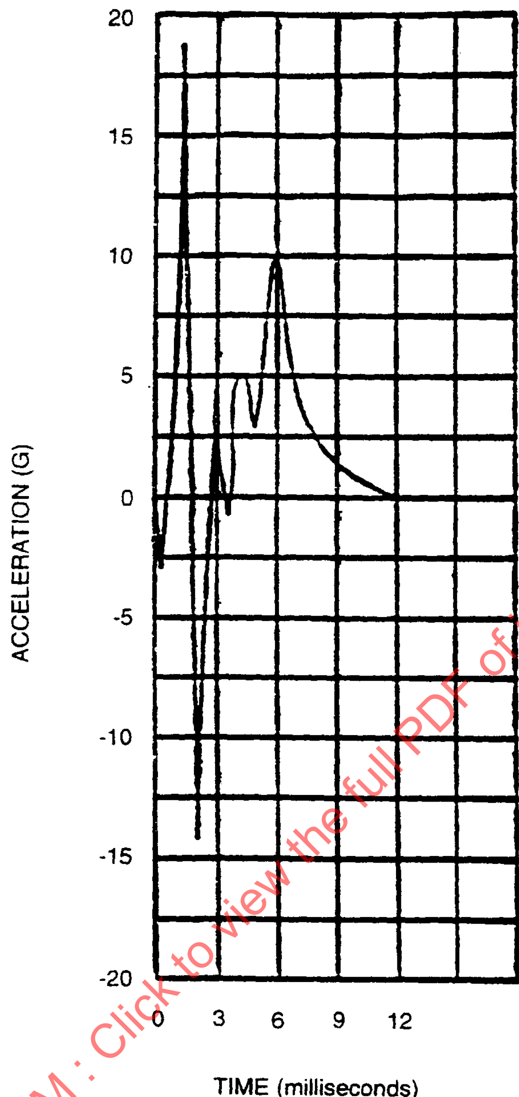


FIGURE 12 - OPERATIONAL SHOCK PROFILE

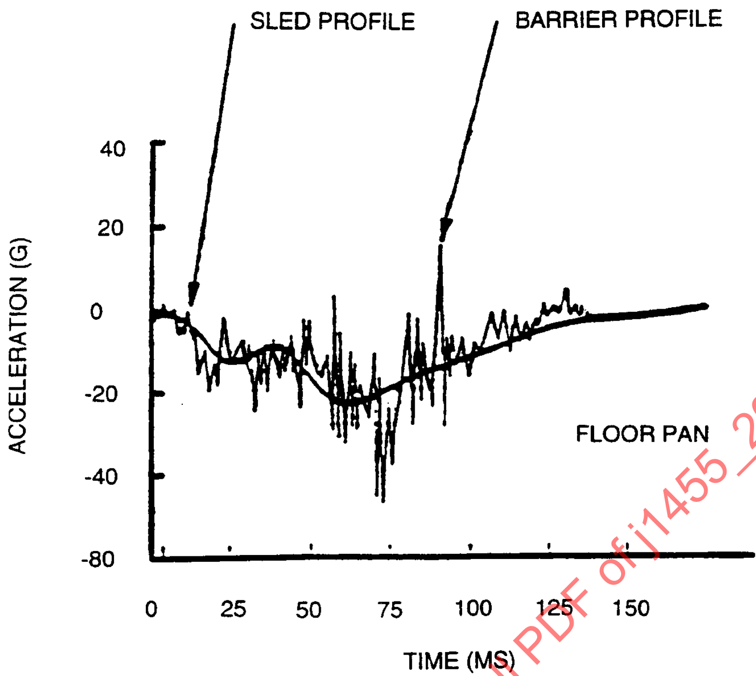


FIGURE 13 - 48 km/h (30 mph) BARRIER AND SLED SHOCK PROFILES

4.11.4 Related Specifications

Two specifications are recommended for consideration. The first, MIL-STD-202G, 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-202G, 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-810F, Method 516.5.

4.12 Combined Environmental Testing

4.12.1 Definition

The vehicle environment consists of many natural and induced factors. Combinations of these factors are more serious than the effect of exposing samples to each environmental factor in series. The most common combination test elements include temperature cycling, humidity, vibration, and operating voltage. Other elements may be added but become increasing complicated by the additional setup needs. 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. Additional benefits of performing combined testing are the reduction of overall test time and a closer simulation of real world events.

4.12.2 Effect on Performance

The damaging effects from combined environmental testing can be greater than any of those noted in the individual elements. Additional effects on performance can include cracking of material and leakage paths not noted in series testing due to the combined effects of maximum temperature extremes and vibration. As an example, a controller with a cracked package is more vulnerable to corrosion cause by humidity.

4.12.3 Recommended Test Methods

The recommended combined environmental test profile is shown in Figure 14. If temperature characterization has been performed according to 4.1.1.4, the measured temperature may be substituted for the values in Table 1 for the purposes of this test. Stabilization should be verified by actual measurements (i.e., thermocouples, etc.). It is important that all parts of the device under test be held at the specified maximum and minimum temperatures for at least 15 min after reaching temperature stability. This is to assure that all components reach the required temperature and to maintain thermal and pressure stresses generated in the test specimen for a reasonable period of time.

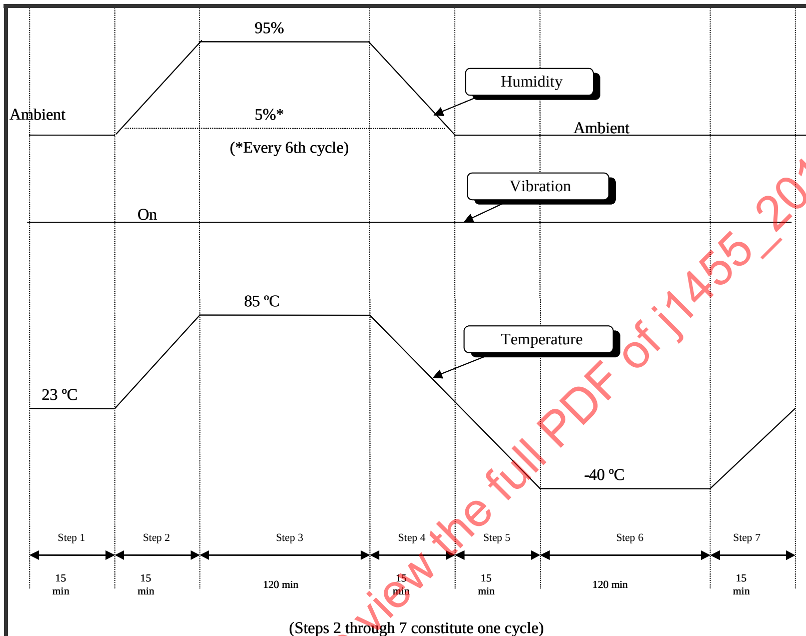


FIGURE 14 - COMBINED TEST PROFILE

4.13 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 4.13.1, 4.13.2, and 4.13.3, respectively.

4.13.1 Steady State Electrical Characteristics

4.13.1.1 Twelve Volt Systems

4.13.1.1.1 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.

Cold cranking of the engine with a partially depleted battery at –40 °C (–40 °F) can reduce the nominal 12 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. Other charging system failures can result in lower than normal battery voltages. General steady-state voltage regulation characteristics are shown in Table 3A.

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 to 7.8 V
- At the battery terminals	6.5 V min.
Jumper starts	+24 V
Reverse polarity	–24 V
Voltage regulator failure	9 to 18 V

1. See 4.13.1.1.1 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 - At the battery terminals	 10.6 to 16 V 13.3 V min.
Jumper starts	+48 V
Reverse polarity	–24 V
Voltage regulator failure	18 to 36 V

1. See 4.13.1.2.1 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.

4.13.1.1.2 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. Overvoltage 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.

4.13.1.1.3 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.

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 1 are recommended. These tests often run for extended periods and are particularly stringent for electronic components in the underhood environment.

4.13.1.2 Twenty-Four Volt System

4.13.1.2.1 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 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 to 16 V at 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 36 V. Extended 36 V operation will eventually cause boil-off of the battery electrolyte. Other charging system failures could result in lower than normal battery voltages. General steady-state voltage regulation characteristics are shown in Table 3B.

4.13.1.2.2 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.

4.13.1.2.3 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 is designed to represent the worst case stresses on control components. A typical cycle for this form of test is shown in Figure 14.

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 1 are recommended. These tests often run for extended periods and are particularly stringent for components in the underhood environment.

4.13.2 Transient, Noise, and Electrostatic Characteristics for 12 and 24 V

4.13.2.1 Definition

Various types of transients are present on truck and tractor wire harnesses. Power supply transients on the DC bus can cause disturbances to steady state power. Other transient effects result from electromagnetic coupling among the conductors within a grouped cable or harness. Voltage, current, circuit impedance, and repetition rates can all vary dramatically among products. Field data can be used to support modification of the basic limits referenced in this practice.

4.13.2.2 Effect on Performance

Usually transient testing is conducted at room ambient conditions (+25 °C); however, the maximum operating temperature can be helpful to evaluate power dissipation issues or component thermal margins. Most adverse effects from conducted transients result in momentary disruption to normal functional performance of electronics, although load dump and field decay contain sufficient energy to cause permanent damage to unprotected electronics.

4.13.2.2.1 Conducted Transients

The transient environment for heavy-duty truck electronics is similar to that of light duty or passenger vehicles. The general requirements of SAE J1113-11 are appropriate for most applications and represent a good baseline for performance. The parameter tables have ranges that allow flexibility with the requirement; however, low-end source resistance settings and selecting voltages/pulse widths at or near the high ends are recommended to ensure the broadest coverage of customer requirements. Equipment capable of 12 and 24 V operation should be tested to both sets of transient limits.

a. Load Dump (Pulse 5C) - 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. The load dump transient contains considerable energy that must be dissipated or blocked to prevent damage to electronic components. This transient occurs infrequently; however, the high energy content and potential for permanent product damage requires robust validation at both component and vehicle level. The alternator is capable of more energy than can be absorbed by electronic clamping devices. When clamping circuits are used in electronics, the vehicle integrator should ensure that each circuit operates within its individually specified rating. See Appendix B in this document or Appendix E in SAE J1113-11 for more information.

b. Inductive Switching (Pulse 1 and Pulse 2) - Inductive transients are caused by solenoid, motor field, air-conditioning clutch, and ignition system switching. Inductive transients normally result in intermittent, or momentary functional problems for electronics. Pulse widths up to 2 ms are normally sufficient to demonstrate a robust design.

c. Burst Transients (Pulse 3a and Pulse 3b) - Burst transients simulates disturbances on the power leads. It is similar to other forms of fast transient verification that are capacitively coupled to interface harnesses.

d. Starter Motor Engagement (Pulse 4) - During engine start, devices can experience a voltage transient. Battery charge state, temperature, starter/engine characteristics will determine the voltage waveform. Microprocessor reset circuitry, voltage regulators, or other circuits may be sensitive to voltage fluctuations during engine start.

4.13.2.2.2 Coupled Transients

a. Electrical Fast Transients - For applicable definition, test methodology, and test levels, refer to SAE J1113-12.

b. Chattering Relay - For applicable definition, test methodology, and test levels refer to SAE J1113-12, Appendix A.

4.13.2.2.3 Electrostatic Discharge (ESD)

When a component is exposed to ESD, processing anomalies or permanent damage can occur. Most often ESD affects equipment during handling and service when contact to interface pins can more easily occur. Inside the passenger compartment, certain accessible controls and displays are frequently exposed to ESD events.

4.13.2.2.3.1 Handling

For applicable definition, test methods, and test levels refer to SAE J1113-13.

4.13.2.2.3.2 In Vehicle

For applicable definition, test methods, and test levels refer to SAE J1113-13.

4.13.2.2.4 Other Effects

Most applications will have certain peculiarities that prompt additional requirements to ensure system level compliance. For instance, suppression capacitors used to reduce radio interference may form tuned circuits with other inductive loads and cause a resonant condition. Coasting motors result in slowly decaying bus voltage after ignition shut off. Voltage difference between case and –Vbatt can cause other common mode stresses on electronics.

4.13.3 Electromagnetic Compatibility (EMC) Requirements

4.13.3.1 Electromagnetic Compatibility (EMC)

The condition which prevails when electrical and electronic components and systems are performing their individual functions within the vehicle electromagnetic environment. The electromagnetic environment is not only limited to equipment onboard the vehicle, but it also includes external sources and victims of interference, both mobile and fixed land based.

4.13.3.2 Electromagnetic Interference (EMI)

Electromagnetic energy which interrupts, obstructs, or otherwise degrades or limits the performance of components, subsystems, and systems. EMI can occur intermittently or continuously depending on the characteristics of the interference source, victim, and coupling mechanism.

4.13.3.3 Effect on Performance

Vehicle integration is a complex task. Equipment procured from a variety of suppliers must be installed such that each works within its performance specification. To ensure this end, equipment must demonstrate proper operation when exposed to various environments as well as minimizing potential effects on other electronics that may be located nearby. Interference that is not attributed to powerline distortion, conducted transients, or cross-talk is usually referred to as EMI. Antenna-connected equipment is typically involved as either the source or victim of interference. As a source, transmitters operating nearby other vehicle electronics can generate high fields that usually rolls off to a benign environment several meters away. Conversely, communication equipment designed to receive very low amplitude signals can easily be degraded by electromagnetic noise from other equipment or interface cables located only a few feet away.

4.13.3.4 Recommended Test Procedures and Levels

SAE J1113-1 contains guidance information regarding particular functions and how to classify equipment for immunity requirements.

4.13.3.4.1 Radiated Emissions

For applicable definition, test methodology, and test levels refer to Section 6 of CISPR 25.

4.13.3.4.2 Radiated Electric Field Immunity

For applicable definitions, test methods, and functional classification status refer to SAE J1113-21.

4.13.3.4.3 Radiated Magnetic Field Immunity

For applicable definitions, test methods, and functional classification status refer to ISO 11451-8.

4.13.3.4.4 Conducted Emissions, DC Power Leads

For applicable definition, test methodology, and test levels refer to Section 6 of CISPR 25.

4.13.3.4.5 Conducted Immunity, DC Power Leads

For applicable definition, test methodology, and test levels refer to ISO 11452-10.

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. Under-hood

   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

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. Applicability of design guidelines is referenced in Table 4.

TABLE 4 - ENGINE - ENVIRONMENTAL DATA

Temperature	Min	Max	Humidity	Salt Spray	Immersion and Splash	Direct Spray Steam Clean Pressure Wash	Sand Dust & Gravel	Mechanical Vibration & Shock	Altitude	Electrical
Underhood Lower	–40 °C (–40 °F)	141 °C (285°F)	Sect. 4.2	Sect. 4.3	Sect. 4.4	Sect. 4.5	Sect. 4.7 & 4.8	Sect. 4.10 & 4.11	Sect. 4.9	Sect. 4.13
Upper	–40 °C (–40 °F)	307 °C (585 °F)								
Bulkhead	–40 °C (–40 °F)	141 °C (285 °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 engine 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.

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. Peak temperatures of 121 to 140 °C (250 to 285 °F) can be experienced in this area. 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 conditioning ON.

The vehicle is driven with the engine at full/maximum power until engine temperature is stabilized 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.

Consideration should also be given to heat flow into the engine compartment from the front wheel suspension/brake and tire combination. Some consideration has been given to electronic components thermally interlocked with the engine cooling system, although the high pressure-temperature combination experienced during coolant boiling off may cause unacceptable catastrophic failure.

Rate of temperature change with time is also a consideration in this area, since cold starts will result in very rapid changes, as shown in Figure 1.

High speed running with power take-off loads can cause maximum cooling system temperatures due to lack of ram air.

5.1.3 Mechanical Vibration and Shock

Refer to 4.10 and 4.11.

5.1.4 Humidity

This condition is discussed in 4.2. The possibility of snow and ice intrusion, and hot ethylene glycol and water mixtures, due to cooling system failure, should be considered.

5.1.5 Salt Fog and Spray

This condition is often a factor, particularly on the lower outboard portions where the bulkhead joins the forward floor.