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SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

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RECOMMENDED ENVIRONMENTAL PRACTICES FOR ELECTRONIC EQUIPMENT DESIGN

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

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.

1.1 Scope—The climatic, dynamic, and electrical environments from natural and vehicle-induced sources that influence the performance and reliability of automotive electronic equipment are included. Test methods that can be used to simulate these environmental conditions are also included in this document.

The information is applicable to vehicles that meet all the following conditions and are operated on roadways:

1.1.1 Front engine rear wheel drive vehicles.

1.1.2 Vehicles with reciprocating gasoline engines.

1.1.3 Coupe, sedan, and hard top vehicles.

Part of the information contained herein is not affected by the above conditions and has more universal application. Careful analysis is necessary in these cases to determine applicability.

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 JUL68—Recommended Practice Test for Chip Resistance of Surface Coatings
SAE J726b—Air Cleaner Test Code
SAE J1113a—Electromagnetic Susceptibility Procedures for Vehicle Components (Except Aircraft) (June, 1978)
Paper 740017—O. T. McCarter, "Environmental Guidelines for the Designer of Automotive Electronic Components" (Presented at SAE Automotive Engineering Congress, Detroit, March 1974)
Paper 730045—G. B. Andrews, "Control of the Automotive Electrical Environment" (Presented at the SAE Automotive Engineering Congress, Detroit, January 1973)

2.1.2 OTHER PUBLICATION

Motorola CER-114—O. T. McCarter, "Environmental Guidelines for the Designer of Automotive Electronic Components" (1973)

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 automobile manufacturers and automobile original 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 practical to verify these preliminary design baselines.

The proposed test methods are either currently 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, however, describe standard cycles for each type of test. The designer must specify the number of cycles over which the equipment 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 has been made to equate this cycle to an acceleration factor for reliability or durability. These considerations are beyond the scope of this guideline.

3.2 Organization of Test Methods and Environmental Extremes Information—The data presented in this document is contained in Sections 4 and 5. Section 4, Environmental Factors and Test Methods, describes the 11 major characteristics of the expected environment that have an impact on the performance and reliability of automotive electronic systems. These descriptions are titled:

3.2.1 Temperature.

3.2.2 Humidity.

3.2.3 Salt Spray Atmosphere.

3.2.4 Immersion and Splash (Water, Chemicals, and Oils).

3.2.5 Dust, Sand, and Gravel Bombardment.

3.2.6 Altitude.

3.2.7 Mechanical Vibration.

3.2.8 Mechanical Shock.

3.2.9 Factors Affecting the Automotive Electrical Environment.

3.2.10 Steady State Electrical Characteristics.

3.2.11 Transient, Noise, and Electrostatic Characteristics.

They are organized to cover three facets of each factor:

a. Definition of the factor.
b. Description of its effect on control, performance, and long term reliability.
c. A review of proposed test methods for simulating environmental stress.

Section 5, Environmental Extremes by Location, summarizes the anticipated limit conditions at five general control sites:

a. Underhood
    1. Engine
    2. Bulkhead - dash panel
b. Chassis
c. Exterior
d. Interior
    1. Instrument Panel
    2. Floor
    3. Rear Deck
e. Trunk

3.3 Combined Environments—The automotive 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 much more serious than the effect of exposing samples to each environmental factor in series. For example, the suggested test method for humidity includes both high and low temperature exposure. This combined environmental test is very important to components whose proper operation is dependent on seal integrity. Temperature and vibration is a second combined environmental test that can be significant to some 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 the automotive case, since exposures occur in a random order. The second consideration prompts the test designer to place the more severe environments last. Many sequences that have been successful follow this general philosophy, except that temperature cycle is placed 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 automotive electronic equipment. Sources for temperature extremes and variations include:

4.1.1.1 The vehicle's climatic environment, including the diurnal and seasonal cycles. Additionally, 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 –40 – 80 °C (–40 – 185 °F).

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. Very wide variations are to be found during operation. For instance, temperatures on the surface of the engine can range from the cooling system's 88 – 650 °C (190 – 1200 °F) on the surface of the exhaust system. This category also includes conduction, convection, and radiation of heat due to various modes of vehicle operation.

4.1.1.3 Self-heating of the equipment due to its own internal dissipation. A design review of the worst case combination of peak ambient temperature (due to 4.1.1.1 and 4.1.1.2 above) 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 subjected to the maximum heat generated by adjacent equipment and at a maximum ambient environment:

4.1.1.4.1 Engine start.

4.1.1.4.2 Engine idle.

4.1.1.4.3 Engine high speed.

4.1.1.4.4 Engine Turn Off—Prior history important.

4.1.1.4.5 Various engine/road load 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 (non-operating) temperature to –50°C (–58°F).

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

4.1.1.5.1 Extremes—The ultimate upper and lower temperatures the equipment is expected to experience.

4.1.1.5.2 Cycling—The cumulative effects of temperatures cycling within the limits of the extremes.

4.1.1.5.3 Shock—Rapid change of temperature. Figure 1 illustrates one form of vehicle operation which induces thermal shock. Thermal shock is also induced when equipment at elevated temperature is exposed to sudden rain or road splash.

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

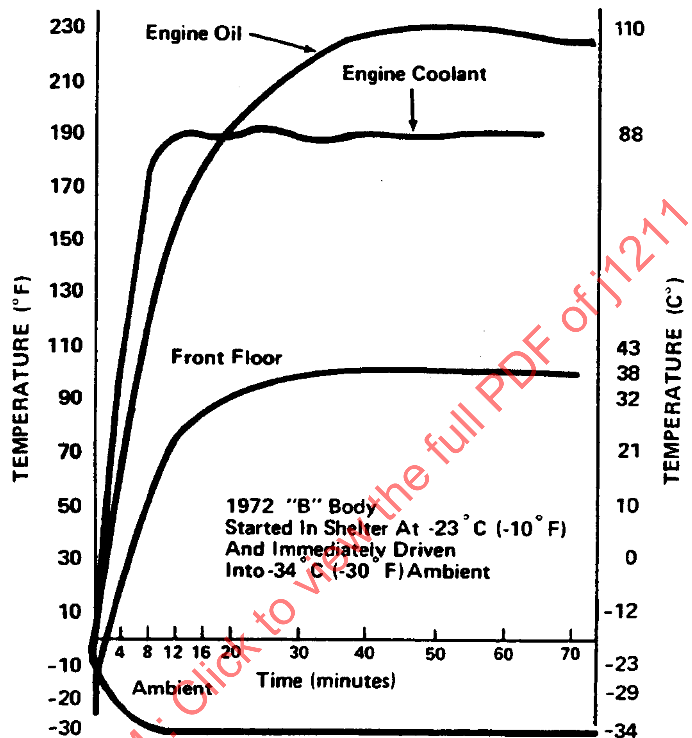


FIGURE 1—VEHICLE COLD WEATHER WARM-UP CHARACTERISTICS

4.1.2 EFFECT ON PERFORMANCE—The damaging effects of thermal shock and thermal cycling include:

4.1.2.1 Cracking of printed circuit board or ceramic substrates.

4.1.2.2 Thermal stress or fatigue failures of solder joints.

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

4.1.2.4 Seal failures, including the breathing action of some assemblies, due to temperature-induced dimensional variation which permit 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 this, 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 Carbonization of packaging materials with eventual progressive failure of the associated passive or active components. This is possible in cases of extreme overtemperature. In addition, non-catastrophic failure is possible due to electrical leakage in the resultant carbon paths.

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

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

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

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

4.1.2.13 Dimensional changes in packages and components leading to separation or subassemblies.

4.1.2.14 Changes in the strength of soldered joints due to changes in mechanical characteristics of the solder.

Further, low temperature extremes can cause failure due to:

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 semi-conductor or other components after extended cold soak under aberrant operating conditions such as 24-V battery jumper starts.

4.1.3 RECOMMENDED TEST METHODS

4.1.3.1 *Temperature Cycle Test*—A recommended thermal cycle profile is shown in Figure 2 and recommended extreme temperatures in Table 1. 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 modules whose temperatures will reach stabilization in a shorter cycle time. Stabilization should be verified by actual measurements. Thermocouples, etc.

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 ±2.8 °C (±5 °F) at each of the extreme temperatures. The test specimens should be placed in such a position, with respect to the air stream, that 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 subjected to temperature transition rates greater than that defined in Figure 2. Direct heat conduction from the temperature chamber heating element to the specimen should be minimized.

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 will provide insight into electrical variations with temperature.

Thermal shock normally expected in the automotive environment is simulated by the maximum rates of change shown on the recommended thermal cycle profile shown in Figure 2. The proper thermal shock cycle should be determined by analysis of component power dissipation, expected rate of temperature change at its location in the system and the overall ambient operating temperature. In general, thermal shock is most severe when equipment is operated intermittently in low temperature environments. The effects of thermal shock include cracking and delamination of substrates, seal failures, wire bond breaks, and operating characteristic changes.

Thermal stress is caused by repeating cycling through the thermal profile of Figure 2. The number of cycles required is a function of the equipment application. Functional electrical testing during temperature transitions or immediately after temperature transitions, is a means of detecting poor electrical connections. The effects of thermal stress are similar to thermal shock but are caused by fatigue.

NOTE—Although uniform oven temperatures are desirable, in some vehicle environments the only means of heat removal 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.)

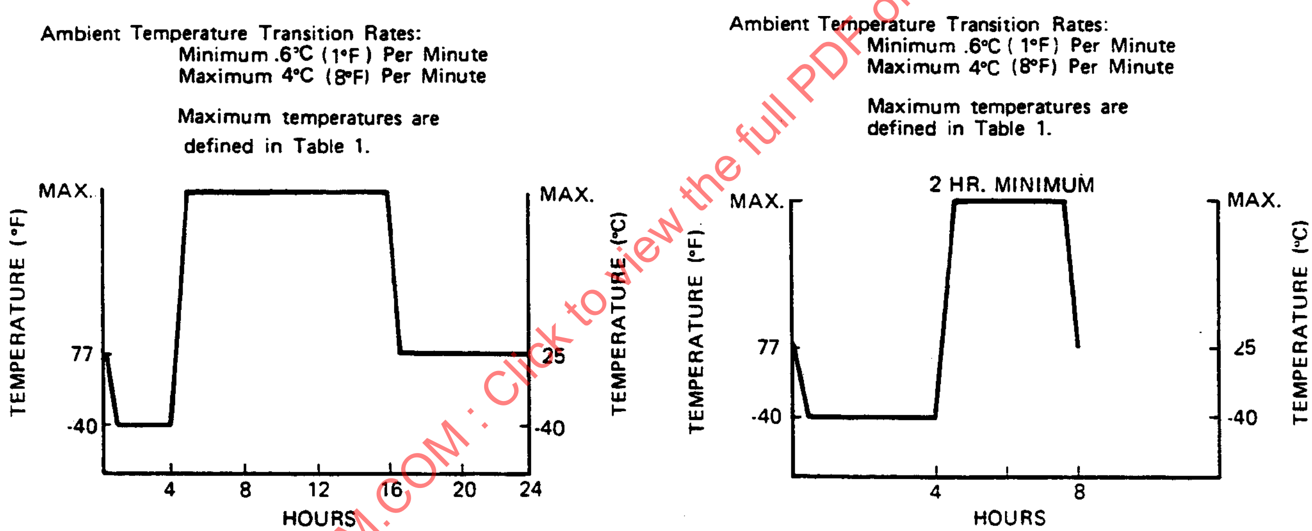


FIGURE 2A - 24-h Cycle

FIGURE 2B - 8-h Cycle

FIGURE 2—RECOMMENDED THERMAL CYCLES

TABLE 1—RECOMMENDED TEMPERATURE EXTREMES

Location		Maximum Temperature
Chassis	-- Isolated Areas	+ 85 °C (+185 °F)
	-- Exposed to Heat Sources	+121 °C (+250 °F – 1200 °F)
	-- Exposed to Oils	+177 °C (+350 °F)
Exterior		+121 °C (+250 °F)
Underhood	-- Dash Panel	140 °C (285 °F)
	-- Engine (Typical)	150 °C (300 °F)
	-- Choke Housing	205 °C (400 °F)
	-- Starter Cable Near Manifold	205 °C (400 °F)
	-- Exhaust Manifold	650 °C (1200 °F)
Interior	-- Floor	85 °C (185 °F)
	-- Rear Deck	107 °C (225 °F)
	-- Instrument Panel (Top)	113 °C (236 °F)
	-- Instrument Panel (Other)	85 °C (185 °F)
Door Interior	-- No data available	
Trunk		85 °C (185 °F)
Minimum Temperature		–40 °C (–40 °F)

4.1.4 RELATED SPECIFICATIONS—A generally accepted method for small part testing is defined in MIL-STD-202E, Method 102A, Temperature Cycling. The short dwell periods at extreme temperature are satisfactory where temperature stabilization has been verified by actual measurements, thermocouples, etc.

4.2 Humidity

4.2.1 DEFINITIONS AND 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 seal.

The actual relative humidity in the vehicle depends on location due to 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 due to galvanic and electrolytic action, as well as corrosion due to interaction with water and due to adverse pH changes. Other failure modes include changes in electrical properties, surface bridging between circuits, and decomposition of organic matter.

4.2.2 RECOMMENDED TEST METHODS—The most common way to determine the effect of humidity on electronic equipment is to overtest and examine any failures for relevance to the more moderate actual operating conditions. Three general test methods are recommended. The most common is an active temperature humidity cycling under accelerated conditions. The second is a 10-day soak at 95% relative humidity and 38 °C (100 °F) temperature. A third method is an 8 – 24 h exposure at 103.4 kPa gauge pressure [15 lbf/in^2 (gage)] in a pressure vessel. This is a quick and effective method of uncovering defects in plastic encapsulated semi-conductors.

There are many acceptable accelerated humidity test cycles, including MIL-STD-202E, Method 103B; however, the test cycles in Figure 3 are recommended as the most useful.

An optional frost condition may be incorporated during one of these humidity cycles (Figure 3A). 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 and induced frosting.

The 10-day soak is normally conducted with equipment non-operating. Equipment that operates with standby voltage excitation and a low current drain when the ignition is off is a significant exception. Examples of this type include seat belt interlocks and electronic clocks. Samples of such equipment should be tested with normal standby conditions. Accelerated humidity effects should be expected under the conditions of high temperature, high humidity, and excitation voltage.

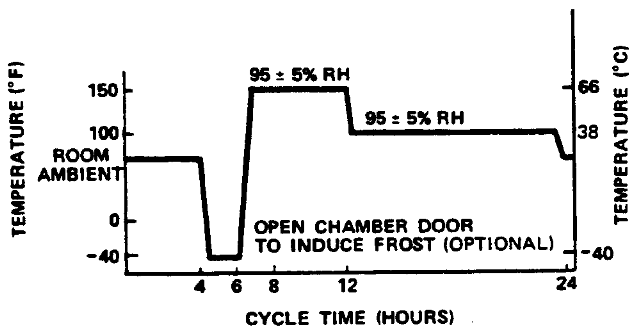


FIGURE 3A - 24-h Cycle

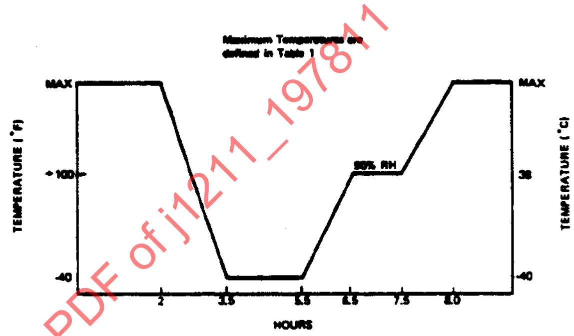


FIGURE 3B - 8-h Cycle

FIGURE 3—RECOMMENDED HUMIDITY CYCLES

4.2.3 Related Specifications—A number of related humidity specifications are recommended for review and reference. The first: MIL-STD-810B, Method 507, Procedure 1, Humidity; is a system-oriented test method. The second; a modified version of MIL-STD-202E, Method 103B, Humidity (Steady State); is intended to evaluate materials. The third; MIL-STD-202E, Method 106D, Moisture Resistance; is a procedure for testing small parts.

4.3 Salt Atmosphere

4.3.1 Definition and Effect on Performance—Electronic equipment 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 and trunk of the vehicle, it is advisable to evaluate the potential effects of saline solutions on the floor area as the result of transfer 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.

4.3.2 RECOMMENDED TEST METHODS—The recommended test method for measuring susceptibility of electronic equipment to salt spray is the American Society for Testing and Materials (ASTM) Standard Method of Salt Spray (Fog) Testing-Number B 117–73.

The test consists of exposing the electronic equipment to a solution of 5 parts salt to 95 parts water atomized at a temperature of 35 °C (95 °F). The equipment being tested should be exposed to the salt spray for a period of from 24 – 96 hours. The actual exposure time must be determined by analysis of the specific mounting location. When the tests have been concluded, the test specimens should be gently rinsed in clean running water, about 38 °C (100 °F) to remove salt deposits from their surface and then immediately dried. Drying should be done with a stream of clean, compressed dry air at about 241.3 – 275.8 kPa gauge pressure [35 – 40 lbf/in^2 (gage)]. The equipment should then 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 in both the wet and dry states may be necessary.

4.3.3 RELATED SPECIFICATIONS—ASTM B 117–73, Salt Spray (Fog) Testing, is the recommended test method.

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

4.4.1 DEFINITION—Electronic equipment mounted on or in the vehicle is 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
Anti-Freeze Water Mixture
Degreasers
Soap and Detergents
Steam
Battery Acid
Water and Snow
Salt Water
Waxes
Freon
Spray Paint
Ether
Vinyl Plasticizers
Undercoating Material

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

4.4.2 EFFECT OF 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 that may be immersed in fluids for a long period, such as sensors, should be subjected to laboratory life test in these fluids.

4.4.3 RECOMMENDED TEST METHODS—The equipment 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 will tend to aggravate any incipient defects in seals, seams, and bushings which might otherwise escape notice.

Splash testing should be done with the equipment mounted in its normal operating position with all drain holes, if used, open. The sample is subjected to precipitation of 0.25 cm (0.1 in)/min delivered at an angle 45 deg below and above the sample with a nozzle having a solid cone spray.

During immersion testing, most commonly utilizing water as the fluid, the equipment ordinarily is not operated due to setup logistics and techniques of testing. Electrical tests should, therefore, be performed immediately before and after this test. In this test, the electronic equipment in its normal exterior package is immersed in tap water 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 be rotated 180 degrees. It should remain in that position for 5 min and then be rotated 90 deg about the other axis where it remains for 5 minutes. Immediately after removal, the sample should be exposed to some 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 as in the case of exposure to coolant water, brake fluid, and transmission oil. Caution must be used in specifying combined tests as they may be unrealistically severe for many applications.

4.5 Dust, Sand, and Gravel Bombardment

4.5.1 DEFINITION—Dust is a significant 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 chassis, exterior, and underhood. Bombardment by gravel is significant for chassis and exterior-mounted equipment.

4.5.2 EFFECT ON PERFORMANCE—Exposure to fine dust can cause problems with moving parts, form conductive bridges, and act 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.

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

Dust conforming to that defined in SAE J726b, 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:

J726b Coarse or Equivalent	70%
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 hours.

An alternate method is to place the sample about 15 cm (6 in) from one wall in a 3-ft cubical box. The box should contain 4.54 kg (10 lb) of fine powdered cement in accordance with ASTM C 150–56, specification for portland cement. 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 hours.

The recommended test for susceptibility of equipment to damage from gravel bombardment is SAE J400 JUL68, Recommended Practice Test for Chip Resistance of Surface Coatings. 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 equipment. The test consists of exposing the test sample to bombardment by gravel 0.96 – 1.6 cm (3/8 – 5/8 in) in diameter for a period of approximately 2 minutes. The sample is positioned about 35 cm (13–3/4 in) from the muzzle of the gravel source. 470 cm^3 (approximately 1 pt) of gravel (250 – 300 stones) is delivered under a pressure of 483 kPa gauge pressure [(70 lbf/in^2 (gage)] over an approximate 10-s period. The process is repeated 12 times for a total exposure of 2 minutes. 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.

4.5.4 RELATED SPECIFICATIONS—Three specifications are referenced. The first: MIL-STD-202E, Method 110A, Sand and Dust, is a piece part test and is included for information and comparison. The second is SAE J726b, Air Cleaner Test Code, which defines the recommended dust. It also describes some test apparatus. The third specification is SAE J400 JUL68, Test for Chip Resistance for Surface Coatings, which is recommended in part for a gravel bombardment guide. Continued integrity at the conclusion of the exposure is the passing criteria.

4.6 Altitude

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

Condition	Altitude	Atmospheric Pressure
Operating	3.7 km (12 000 ft)	62.1 kPa absolute pressure [9 lb/in^2 (absolute)]
Non-operating	12.2 km (40 000 ft)	18.6 kPa absolute pressure [2.7 lb/in^2 (absolute)]

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

4.6.2.1 Reduction in convection heat transfer efficiency.

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

4.6.2.3 A very noticeable reduction in the high voltage breakdown characteristics of system with electrically stressed insulator, conductor or air surfaces; this may result in setup of surface tracking with eventual component failure.

4.6.3 Recommended Test Methods—The recommended test method is to operate equipment during the thermal cycles described in the Temperature Test Section, but with the added parameter of 62.1 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 –51 °C (–60 °F) if possible.

4.7 Mechanical Vibration

4.7.1 Definition—Vibration, which is prevalent whenever the vehicle engine or suspension system is in motion, is a key factor in the automotive environment. The intensity varies from low severity at smooth engine idle to extreme severity when traversing rough roads at high speed. Vibration also varies with location. Detailed data is included in Figures 11, 12, 13, 14, 15, 16, 17 and 18.

4.7.2 Effect on Performance—A number of modes of degradation or failure are possible under applied vibration. A partial list includes:

4.7.2.1 Loss of wiring harness electrical connection due to improper connector design and/or assembly.

4.7.2.2 Excitation of tuned mass harmonic vibration within the equipment which eventually leads to failure due to metal fatigue at stress concentration points.

4.7.2.3 Failure of mounting structure due to the added acceleration forces acting on the mass of the equipment.

4.7.2.4 Mechanical flexure at seal and other interface areas which promotes the intrusion of other environmental factors, such as moisture, in a manner similar to the phenomena described under temperature cycling effects.

4.7.2.5 Temporary aberration of equipment performance due to acceleration forces on control component masses. Two examples illustrate this:

4.7.2.5.1 Sensor measurement error due to motion of the sense element. An example of this is a pressure sensor which gives incorrect information under some applied frequencies due to the mass of a diaphragm-spring mechanism.

4.7.2.5.2 False operation of electromechanical components - for example, a relay whose contacts close or open, due to vibratory movement of its armature's mass.

The designer should be particularly alert to failures which are intermittent or which cause faulty operation during applied vibration. Many malfunctions of this type revert to normal operation after the vibration excitation is removed. It is, therefore, recommended that electronic performance tests be conducted during vibration tests for those functions which must perform under this condition. In most cases, this is only practical under laboratory simulation of the road test situation.

4.7.3 Recommended Test Methods—A typical test for this environmental factor has been operation of a test vehicle over a group of severe road test track conditions. These include surfaces described as the Belgium Block Road, the Hop, the Tramp, the Square Block Test course, and other complex surfaces. These courses are excellent test beds for complete transportation packages installed in the vehicle. Unfortunately, they are relatively inconvenient for electronic control evaluation during the design phase. In many cases, electronic equipment exhibits intermittent or degraded performance during vibration and returns to normal operation when the excitation is removed.

Failure of electronic equipment in a vibratory environment may be the result of fixed frequency or random vibrations. Current practice within the industry is to conduct a resonant search up to 1000 Hz and then dwell at the major resonances if they are applicable to the operating environment spectrum.

Figure 4 shows the recommended amplitude and sweep rate for this search. This profile is primarily gravity unit-oriented. A second recommended procedure is to sweep from 10 – 55 Hz and return in 1 min at an amplitude determined by measurements taken at the proposed mounting location. The test is conducted in each of three mutually perpendicular planes.

Experience has shown that in some cases random vibration may be a valuable approach in uncovering electronic equipment failure modes. While random testing is more difficult and costly, consideration should be given to this approach where required.

In the time sweep and resonant dwell, vibration must be conducted in each of three mutually perpendicular axes. Test duration must be determined by the equipment designer.

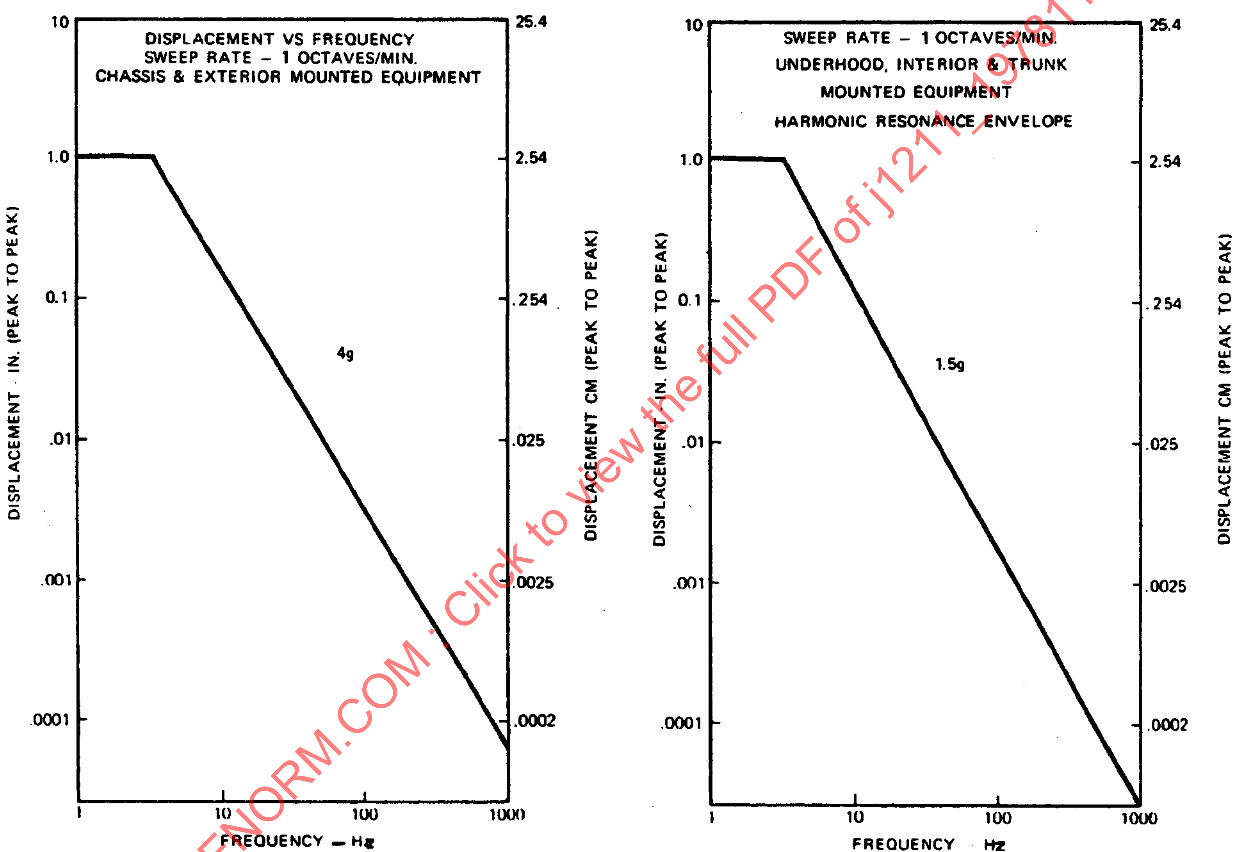


FIGURE 4—RECOMMENDED RESONANT SEARCH VIBRATION PROFILE

4.7.4 RELATED SPECIFICATIONS—Three specifications are referenced. The first, MIL-STD-202E, Method 201A, Vibration, and the second, MIL-STD-202E, Method 204C, Vibration, High Frequency, are concerned with sine vibration and offer procedural details and information on resonant dwell periods. The third, MIL-STD-202E, Method 214, Random Vibration, offers similar information on the random vibration approach.

4.8 Mechanical Shock

4.8.1 DEFINITION AND EFFECT ON PERFORMANCE—The automotive shock environment is logically divided into four classes:

Shipping and handling shock.
Installation shock.
Operational shock.
Crash shock.

4.8.1.1 *Shipping and Handling Shocks*—These are similar to those encountered in non-automotive applications.

4.8.1.2 *Installation Shock*—It is common production-line practice to lift and carry equipment by its harness. Therefore, it is recommended that the harness design assure for secure fastening and suitable strain relief.

4.8.1.3 *Operational Shocks*—The shocks encountered during the life of the vehicle that are caused by curbs, pot holes, etc., can be very severe. These vary widely in amplitude, duration and number, and the test condition can only be generally simulated.

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

4.8.2 RECOMMENDED TEST METHODS

4.8.2.1 *Bench Handling Shock*—The component shall be placed on a solid wooden bench top at least 3.4 cm (1-5/8 in) thick. The test shall be performed as follows: using one edge as a pivot, lift the opposite edge of the component until one of the following conditions shall first occur:

a. The component forms a 45 deg angle with bench top.
b. The lifted edge is just below the balance point. The component shall be allowed to drop to the bench top. Repeat using other practical edges of the same face as pivot points. The procedure is then repeated with the component resting on other faces until it has been dropped on each face that the component might normally be placed when bench handling or servicing.

4.8.2.2 *Transit Drop Test*—The drop shall be from a height of 122 cm (48 in) onto a solid 5 cm (2 in) thick plywood base backed by concrete or a rigid steel frame with the test sample properly installed in its shipping container. The drop shall be performed on each face, edge, and corner.

4.8.2.3 *Installation Shock Test*—A recommended test is to support the device and the far end of the harness at the same elevation, then release the device. 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 strain relief area inspected for damage.

4.8.2.4 *Operation Shock*—With the possible exception of collision, the most severe shock anticipated after production line installation is encountered when driving over complex road surfaces. The complex profile that was used to derive this test profile consists of a rise in the roadway followed by a depression or dip. Upon leaving the dip at 48 km/h (30 mph), the vehicle will often become airborne. The severe shock is experienced when the vehicle returns to the roadway. Figure 5 shows the shock measured on a steering column just below the steering wheel. The accelerometer was mounted with its sensitive axis perpendicular to the axis of the column and in the vertical plane.

While this location is not typical of component mounting locations, it probably 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.

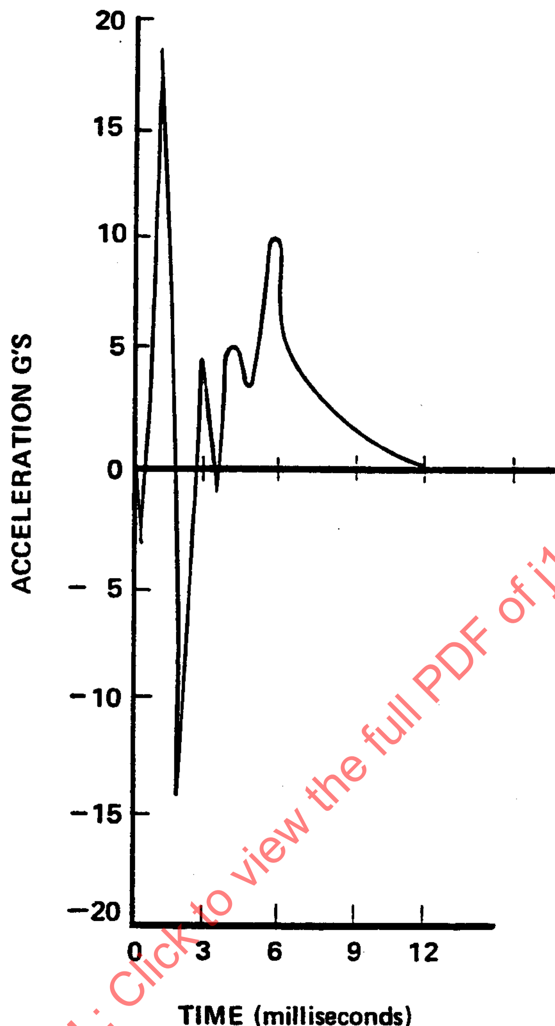


FIGURE 5—OPERATIONAL SHOCK PROFILE

4.8.2.5 *Crash Shock Test*—Only limited and preliminary data on the effects of crash shock on the electronic equipment environment are available. However, a representative deceleration profile for a 48 km/h (30 mph) barrier crash is shown in Figure 6. The following factors vary with each installation and should be considered in pretest analysis:

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

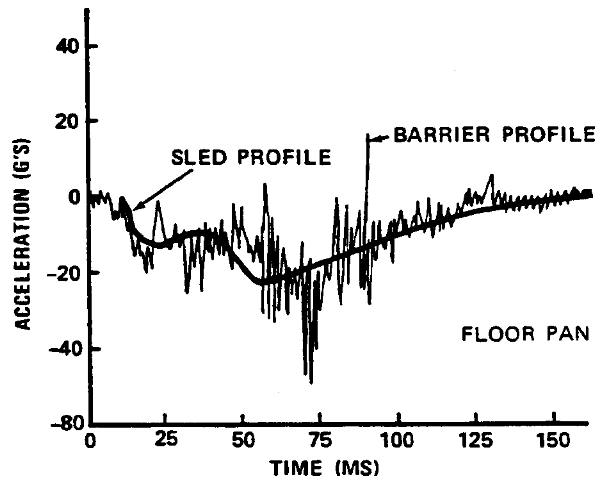


FIGURE 6—48 KM/H (30 MPH) BARRIER AND SLED SHOCK PROFILES

4.8.3 RELATED SPECIFICATIONS—Two specifications are recommended for consideration. The first, MIL-STD-202E, 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-202E, 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.

4.9 General Automatic Electrical Environment—Factors unique to the automobile that make the vehicular environment more severe than that encountered in most electrical equipment applications are:

Interaction with other vehicular electronic/electrical systems.
Voltage variations.
Customer added equipment.
Lack of maintenance.
Complex external electromagnetic fields.

Discussion of the electrical environment falls into two categories:

a. Electrical, Steady-State: Including variations in applied vehicle DC voltages with a characteristic frequency of below 1 Hz.
b. Electrical, Transient, and Noise: Including all noise and high voltage transient with characteristic frequencies above 1 Hz.

These conditions are discussed in Sections 4.10 and 4.11 respectively.

4.10 Steady-State Electrical Characteristics

4.10.1 DEFINITION—A normally operating vehicle will maintain supply voltage ranging from +11 – +16 VDC. However, under certain conditions, the voltage may fall to approximately 9 VDC. This might happen in an idling vehicle which has a heavy electrical load (lights and air conditioning) and a partially depleted battery. Therefore, depending upon the application, the designer/user may wish to specify the +9 – +16 VDC range. For specific equipment such as those that must be functioning during engine start, voltage may be specified as appropriate. Cold starting with a partially depleted battery charge at –40 °C (–40 °F) can reduce the nominal 12 V voltage to between 4.5 and 6 VDC.

Another condition affecting the DC voltage supply is developed when the vehicle voltage regulator fails, causing the alternator to drive the system 18 V. Extended 18-V operation will eventually cause boil-off of the battery electrolyte resulting in voltages as high as 75 – 130 V. Other charging system failures could result in lower than normal battery voltages. The general steady-state voltage regulation characteristics are shown in Table 2.

Emergency starts by garages and emergency road services sometime utilize 24 V sources, and there have been reports of 36 V being used for this purpose. High voltage such as these are applied for up to 5 min and sometimes even with reverse polarity. The use of voltages which are above the vehicle system voltage can damage components in a vehicular electrical system, and the higher the voltage, the greater the likelihood of damage. A designer cannot cope with ever-increasing excitation potentials, and the above values usually are not a part of his design criteria. The possibility of the use of voltages above system voltage is included here for information only.

TABLE 2—AUTOMOTIVE 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)	4.5 – 6.0 V
Jumper Starts	+24 V
Reverse Polarity	–12 V
Charging System Failure	<9 – 18 V
Battery Electrolyte Boil-Off	75 – 130 V

1. See paragraph 4.10.1 for a definition of normal voltage.

4.10.2 EFFECT ON PERFORMANCE—Equipment that must operate during the starting condition is 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 non-performance. Conditions must be carefully examined to determine the true temperature and excitation voltage of the equipment.

4.10.3 RECOMMENDED TEST METHODS—Critical automotive equipment is performance-tested for operation within predetermined limits. Samples are also subjected to combinations of temperatures and supply voltage variation which are designed to represent the worst case stresses on control components. A typical cycle for this form of test is shown in Figure 7.

The voltage applied and removed at the two points shown in Figure 7 is generally 16 V, the maximum normal voltage. If the test is performed for the high voltage booster battery start condition of 24 V, a narrower temperature range is used. This is a destructive test which 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 equipment being considered.

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

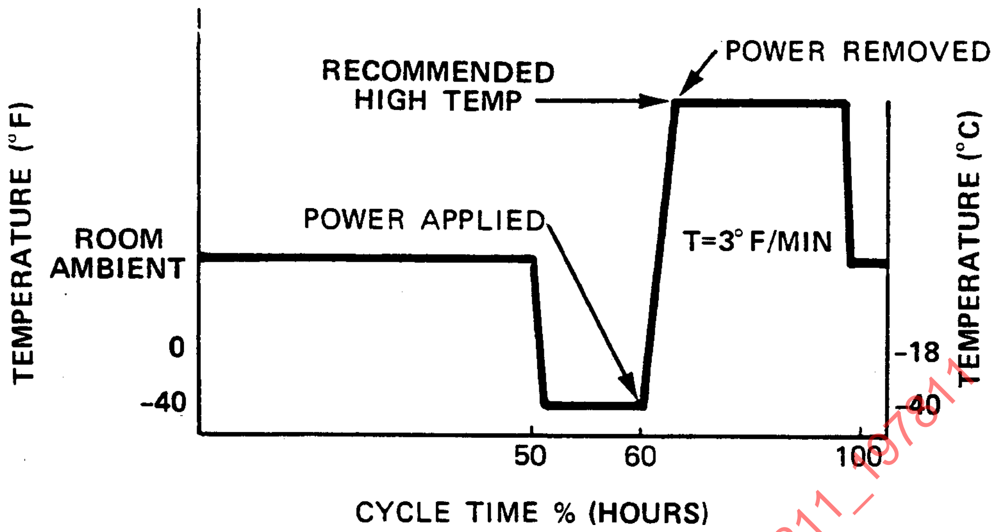


FIGURE 7—COMBINED THERMAL AND ELECTRICAL STRESS PROFILE

4.11 Transient Noise and Electrostatic Characteristics

4.11.1 Definition and Effect on Performance—Four principal types of transients are encountered on automobile wire harnesses. These are load dump, inductive switching transients, alternator field decay, and mutual coupling. Generally, they occur singly, but there are cases where the latter two could occur simultaneously. EMC characteristics vary considerably with type of vehicle and wiring harness. The equipment user and/or designer should determine the actual values of peak voltage, peak current, source impedance, repetition rate, frequency of occurrence at the interface between his equipment and the electrical distribution system, then design and test the electronic equipment to withstand values consistent with the expected use. Table 3 summarizes typical transient characteristics.

TABLE 3—AUTOMOTIVE TRANSIENT VOLTAGE CHARACTERISTICS

Type	Max Amplitude (V)	Characteristic	Remarks
Load Dump	120	$106\,e^{-t/0.188} + 14$	Damage Potential
Inductive Load Switching	–286	$-300\,e^{-t/0.001} + 14$ followed by +80 Volt excursion	Logic Errors
Alternator Field Decay	–90	$-90\,e^{-t/0.038}$	Occurs at Shutdown Only
Mutual Coupling	214	$+200\,e^{-t/0.001} + 14$	Logic Errors

4.11.1.1 Load Dump Transient—Load dump occurs when the alternator load is abruptly reduced. This sudden reduction in current causes the alternator to generate a positive voltage spike. The worst 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:

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.

This transient may be the most severe encountered in the automobile and can result in component damage. In the practical case, it is most often initiated by defective battery terminal connections. Transient voltages of as high as 125 V or more have been reported with rise times of approximately 100 µs. Reports of decay time vary from 100 µs – 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 8 shows oscillograms of more typical load dump transients.

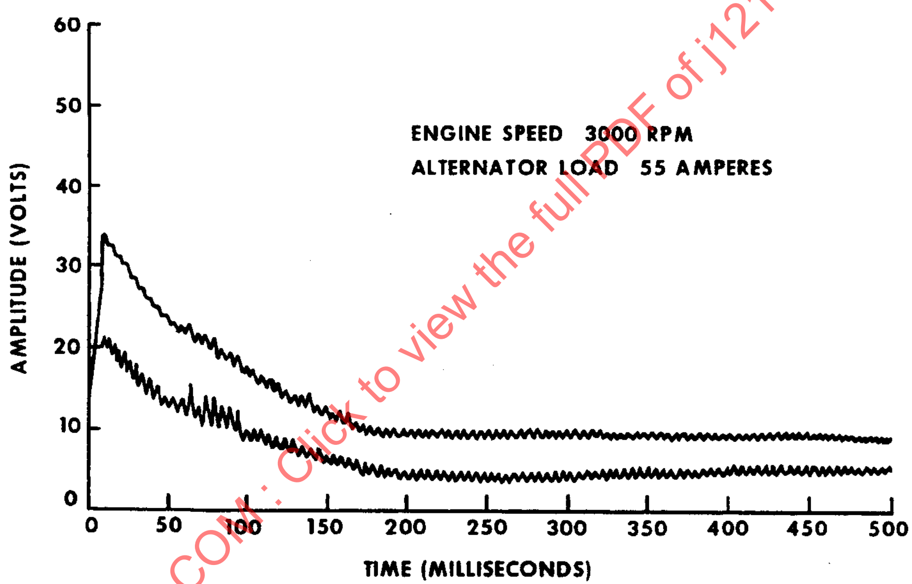


FIGURE 8—LOAD DUMP TRANSIENT

The load dump transient contains considerable electrical energy which must be safety dissipated to prevent damage to electronic equipment. This transient occurs randomly in time appearing as individual or repetitive pulses at random unknown rates due to vibration.

4.11.1.2 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. The 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 a large negative peak, followed by the smaller damped positive excursion. The highest reported by the data acquisition task force is –300/+80 V with an effective duration of 320 ms. Transients of this nature may cause component damage or introduce logic or functional computational errors.

4.11.1.3 *Alternator Field Decay Transient*—This is a special case of the inductive load switching transient. It is a negative pulse caused by alternator field decay and may occur when the field is disconnected from the battery as the ignition switch is turned to the off position. The amplitude is dependent on the voltage regulator cycle and load at the time of shutdown, varying from –40 to –100 V and a duration of 200 ms.

4.11.1.4 *Coupling*—Coupling is not, strictly speaking, a generator of transients, but a mechanism which is capable of introducing transients into circuits not directly connected to the transient source. There are three general coupling modes in the automobile: magnetic, capacitive, and conducted. Briefly, the automobile 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 automobile (Reference 2). 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.

4.11.1.5 *Other Effects*—It is possible that inductive switching of certain solenoids and the alternator decay transient condition occur simultaneously. This hypothesis would account for the higher voltage transients that have been reported, but not explained. Measurement of 600 V transients on engine shutdown 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 interference on the entertainment radio. In some cases, these capacitors may form turned circuits with automotive 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 of time after the ignition is shut off. Some equipment 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 equipment.

4.11.1.6 *Electrical Noise*—Noise will normally have a repetition rate which is dependent on the characteristics of the interfering device or engine speed. There are four general types as summarized in Table 4. A typical oscillogram of automotive electrical noise is shown in Figure 9.

TABLE 4—SUMMARY OF AUTOMOTIVE ELECTRICAL CONTINUOUS NOISE CHARACTERISTICS

Type	Max Amplitude	Duration	Repetition Rate	Remarks
Normal Accessory Noise	1.5 V Peak	Frequency	50 Hz – 10 kHz	Total Pulse Height is 3 V-PP
Normal Ignition Pulses	3 V Peak	10 – 15 µs	Dependent on engine speed	Total Pulse Height is 6 V-PP
Abnormal Ignition Pulses	75 V Peak	~ 90 µs	Dependent on engine speed	
Transceiver Feedback	15 – 20 mV	Carrier	Frequency	Sinusoid

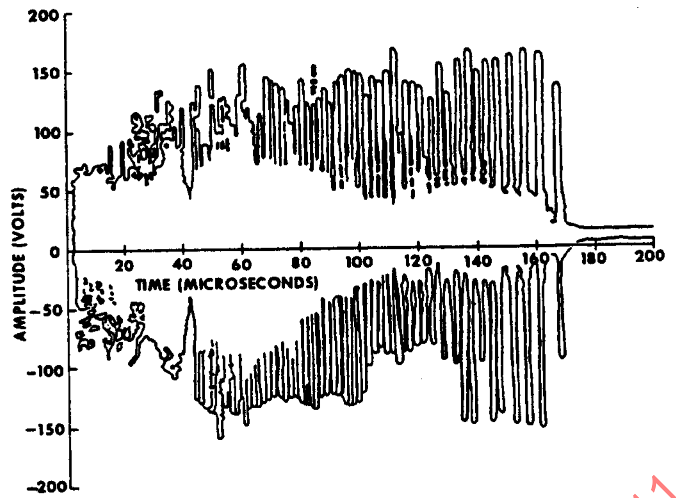


FIGURE 9—POWER LINE ELECTRICAL NOISE

4.11.1.7 *Normal Accessory Noise*—Generally, the normal compliment of accessories contributes less than 1.5 V peak over a frequency range of 50 Hz – 10 kHz.

4.11.1.8 *Normal Ignition Pulses*—Normal ignition pulses can cause 3 V peak pulses of 10 – 15 µs duration at a repetition rate dependent on engine speed.

4.11.1.9 *Abnormal Ignition Pulses*—Normally, the battery acts as a low impedance path to ground for the voltage pulse caused by the primary and secondary windings of the ignition coil. If the battery is disconnected, the repetitive voltage pulses will increase to a significant amplitude. Under this condition, there have been reports of voltages as high as 75 V peak and 90 ms duration with the repetition rate dependent on engine speed. The energy level is substantial and component damage is possible.

Since this condition can occur simultaneously with load dump, consideration should be given to testing both conditions together.

4.11.1.10 *Transceiver Feedback*—Some automotive transceivers feedback energy to the power line at carrier frequency when the transmitter is keyed. These potentials are small, 15 – 20 mV peak, and are mentioned here only because they are at a predictable frequency.

4.11.1.11 *Electrostatic Discharge*—The electrostatic charge stored by the human body and then discharged in to a device may cause operating anomalies. Recent investigations indicate that discharging a 300 pF capacitor that has been charged to a potential of 15 kV through a 5 k Ω resistor is adequate to simulate this effect.

4.11.1.12 *External Sources of Radiated Energy*—The vehicle is exposed to radiated energy from a multitude of sources which have the potential to disrupt normal system operation.

A more detailed discussion of these transient and noise effects is available in Reference 3 and 4.

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

5. Environmental Extremes By Location—This section quantifies guidelines for the extreme operating conditions for five major in-vehicle equipment mounting sites:

a. Underhood

1. Engine Compartment
2. Bulkhead - dash panel

b. Chassis
c. Exterior
d. Interior

1. Instrument Panel
2. Floor
3. Rear Deck

e. Trunk

The physical locations of these sites are given in Figure 10. Each site (denoted by shaded section) is individually discussed together with the following detail:

a. A table listing extremes of temperature; humidity; salt spray; sand, dust, and gravel; oil and chemical; mechanical shock and vibration and electrical steady and transient; operating conditions.
b. Comments germane to other operating conditions of interest.
c. Charts and other information pertaining to the vibration environment.

This section contains data from environmental measurements made by North American vehicle manufacturers or automotive original equipment suppliers. Decisions concerning each environmental factor and the test methods used to determine equipment performance and durability, should only be arrived at after examining the information in Section 4 of this report. In addition, the designer should be satisfied, by referring to pertinent test data, that the particular application falls within the described operating extremes. (See Section 3.)

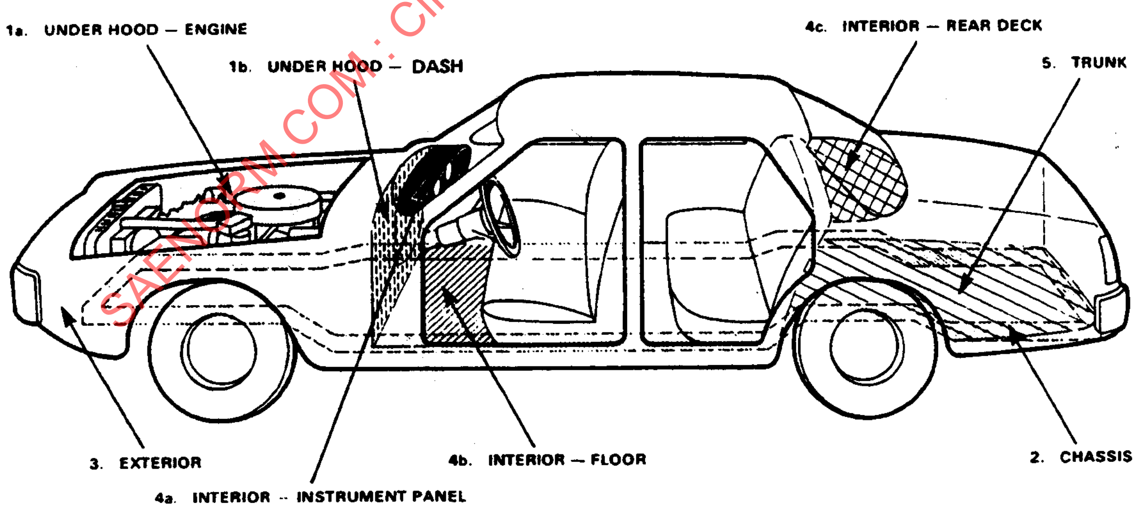
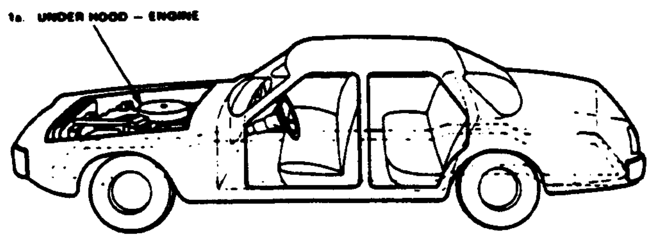


FIGURE 10—VEHICLE ENVIRONMENTAL ZONES

5.1 Underhood - Engine—Caution should be exercised in applying electronics equipment in the underhood region because of the wide range of environments. Data is summarized in Table 5.

UNDERHOOD-ENGINE ENVIRONMENTAL EXTREME DATA



	TEMPERATURE			HUMIDITY (%RH)			SALT SPRAY	IMMERSION	SAND, DUST & GRAVEL	OIL & CHEMICAL	MECHANICAL SHOCK & VIBRATION	ELECTRICAL	
	LOW	HIGH	SLEW RATE	HIGH	LOW	FROST						STEADY-STATE	TRANSIENT
Choke Housing	-40°C (-40°F)	204°C (400°F)											
Exhaust Manifold	-40°C (-40°F)	649°C (1200°F)	-7°C/Min. (20°F/Min.)	95% at 38°C (100°F)	0	yes	Sect. 4.3	Splash present	Sect. 4.5	Sect. 4.4	Figure 11	Table 2 & Table 4	Table 3
Intake Manifold	-40°C (-40°F)	121°C (250°F)											

TABLE 5

5.1.1 TEMPERATURE—Equipment in the vicinity of the exhaust system may experience temperature peaks that are beyond the survival limits of many insulation materials and electronic 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 heat flow temperature control mechanism for typical engine-mounted equipment relies heavily on the conduction of heat via the engine mass rather than convection via fins projecting into the airflow. Equipment thermally interlocked by conduction with engine has two advantages during normal operation:

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

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

5.1.2.1 The largest engine installation expected in that body style.

5.1.2.2 Peak ambient temperature.

5.1.2.3 Air condition ON.

The vehicle is driven at highway speed for about 20 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 which contribute thermal energy to the underhood area, such as secondary air thermal reactors or catalytic reactors, should be in place and operating for this test.

Test procedures of this type have revealed that the region to the rear of the engine compartment, and the locations near radiated and conducted heat from the exhaust/reactor manifold, tend to be much higher in temperature.

Present control practice has limited the location of electronic equipment 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 100 °C (212 °F).

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 equipment thermally interlocked with the engine cooling system, although the high pressure-temperature combination experienced during coolant boil-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.

5.1.3 VIBRATION—Vibration profiles recorded on the intake manifold are shown in Figure 11, together with the equivalent power spectral density profiles.

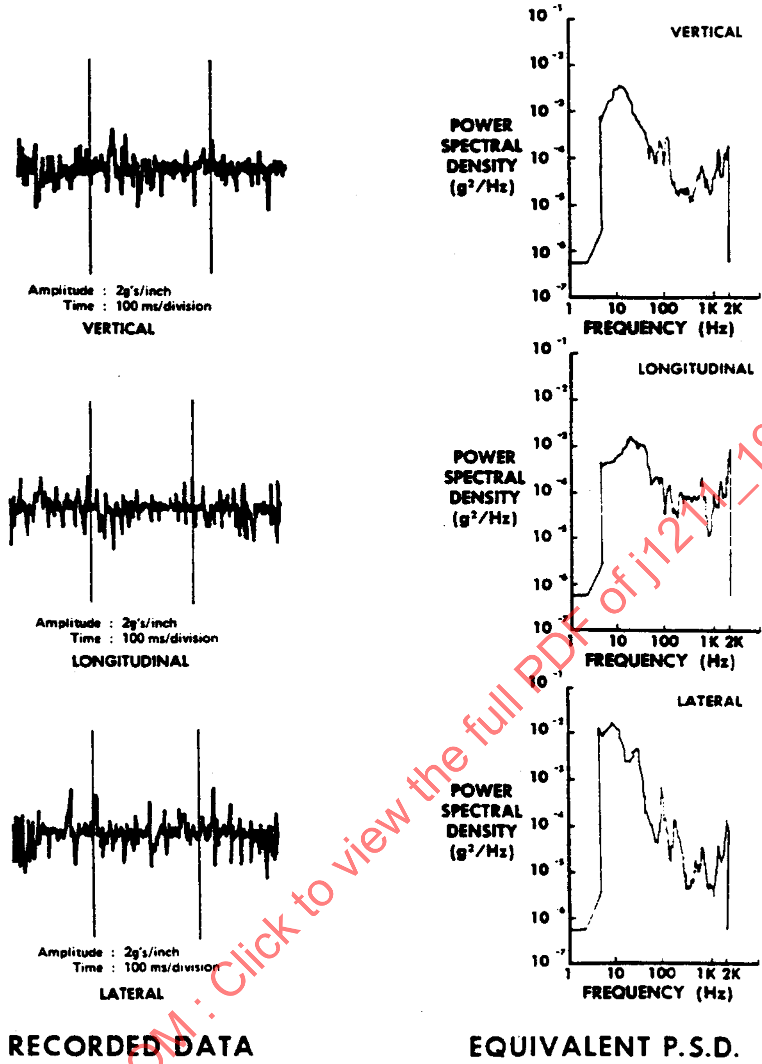
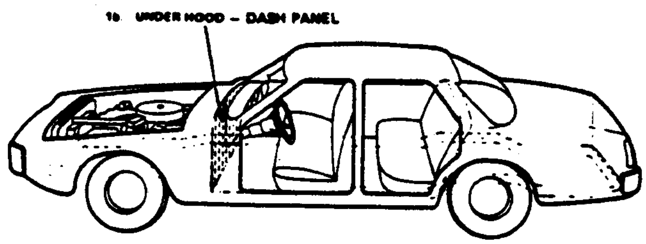


FIGURE 11—ENGINE INTAKE MANIFOLD VIBRATION MEASUREMENTS

5.2 Underhood - Dash Panel—Data is summarized in Table 6.

UNDERHOOD-DASH PANEL ENVIRONMENTAL DATA



	TEMPERATURE			HUMIDITY (%RH)			SALT SPRAY	IMMERSION	SAND, DUST & GRAVEL	OIL & CHEMICAL	MECHANICAL SHOCK & VIBRATION	ELECTRICAL	
	LOW	HIGH	SLEW RATE	HIGH	LOW	FROST						STEADY-STATE	TRANSIENT
Normal	-40°C (-40°F)	121°C (250°F)	open	95% at 38°C (100°F)			Sect. 4.3	no	Sect. 4.5	Sect. 4.4	Figure 12	Tables 2 & 4	Table 3
Extreme	-40°C (-40°F)	141°C (285°F)	open	80% at 66°C (150°F)				no					

TABLE 6

5.2.1 TEMPERATURE—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. Equipment in this area generally relies heavily on convection due to the relatively low thermal conduction characteristics and unpredictable thermal interface between the equipment and the dash panel sheet metal. The rate of change in temperature is therefore set by the thermal mass of the equipment itself, and heat flow due to air movement in its vicinity rather than conduction via the mounting surface. Thermal shock due to the impact of cold mud, slush, etc., is not likely in the upper dash panel location. However, consideration should be given to melted snow and ice leakage from the hood/windshield area.

The majority of investigators have experienced peak temperatures of 121 °C (250 °F), although one data source expects this to be 140 °C (285 °F). Of course, locations on the dash panel 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.

5.2.2 HUMIDITY—This condition is similar to the associated engine condition, with the peak value shown in Table 6. The possibility of snow and ice intrusion, with hot ethylene glycol and water mixtures, due to cooling system failure, should also be considered.

5.2.3 SALT SPRAY—This condition is often a factor, particularly on the lower outboard portions where the dash panel joins the forward floor pan. Driving through salt slush can cause the entrance of salt spray through the radiator. The spray is then delivered to the engine compartment at high velocity by the fan. Spray due to this source is impacted on the dash panel, except for areas shielded by the engine or other underhood components.

5.2.4 IMMERSION—Not generally required.

5.2.5 SAND, DUST, AND GRAVEL—Gravel is not generally a problem, except at the lower dash panel near the transition into the forward floor pan.

5.2.6 OILS AND CHEMICALS—Commonly encountered components (with and without contaminants) are:

Engine oils and additives (hot and cold)
Brake fluid
Gasoline
Ethylene glycol and water (hot and cold)
Water and snow
Waxes
Transmission oil
Windshield washer solvent
Degreasers and cleaning compounds
Detergents
Battery acid
Steam
Freon

5.2.7 MECHANICAL SHOCK AND VIBRATION—Vibration profiles are shown in Figure 12.

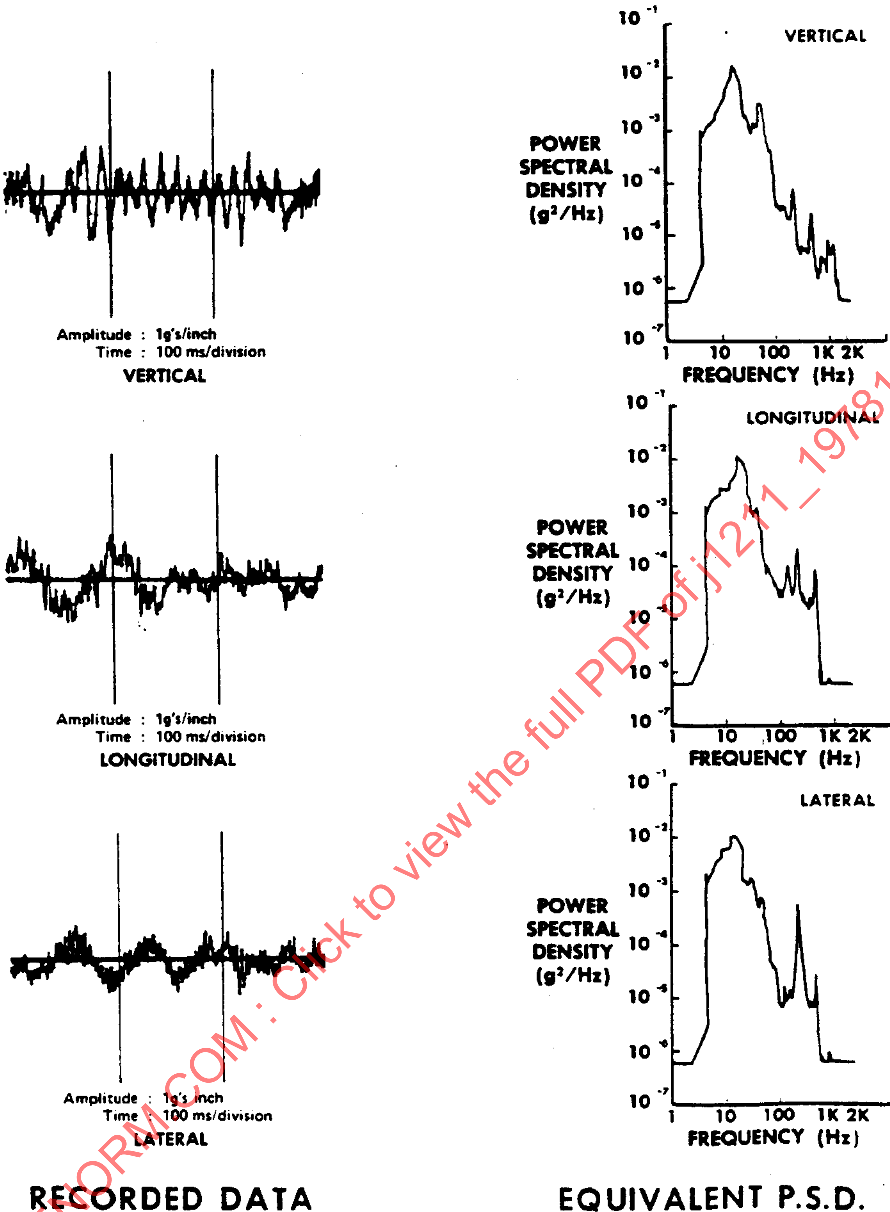
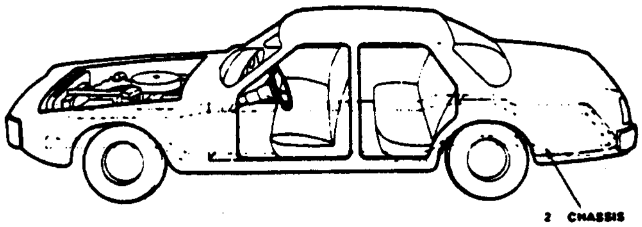


FIGURE 12—PLENUM VIBRATION MEASUREMENTS

5.3 Chassis—Data is summarized in Table 7.

CHASSIS ENVIRONMENTAL EXTREME DATA



	Temperature			Humidity (%RH)			Salt Spray	Immersion	Sand, Dust & Gravel	Oil & Chemical	Mechanical Shock & Vibration	Electrical	
	Low	High	Slew Rate	High	Low	Frost						Steady-State	Transient
Isolated	-40 °C (-40 °F)	85 °C (185 °F)	NA	98% at 38 °C (100 °F)	0	yes							
Near Heat Source	-40 °C (-40 °F)	121 °C (250 °F)	NA	66 °C (150 °F)	0	yes	Sect. 4.3	Sect. 4.4	Sect. 4.5	Sect. 4.4	Figures 13, 14 & 15	Table 2 & 4	Table 3
At Drive Train High Temp Location	-40 °C (-40 °F)	177 °C (350 °F)	NA	80%	0	yes							

TABLE 7

5.3.1 TEMPERATURE—The heat sources encountered in the chassis area include (in rank of decreasing surface temperature):

Source	Peak Temperature
a. Exhaust/catalytic reactor system	649 °C (1200 °F)
b. Brake system/tires and transmission differential drivetrain components	177 °C (350 °F)
c. Engine	121 °C (250 °F)
d. Vehicle ambient peak temperature	85 °C (185 °F)

The practical limitations of equipment components (with the possible exception of sensors) will restrict the designer to locations with the peak temperatures given in c and d above. Again, the designer is urged to check his particular installation for the actual peak temperatures experienced under operating conditions.

5.3.2 HUMIDITY—As shown in Table 7.

5.3.3 SALT SPRAY—With the exception of a few shielded locations, all chassis components are subject to heavy salt spray.

5.3.4 IMMERSION—Typical chassis components are subject to immersion.

5.3.5 DUST, SAND AND GRAVEL—All chassis components in line with the wheel track that are not shielded are subject to continuous bombardment during vehicle operation on gravel roads. In nontrack aligned portions of the chassis, some bombardment will be experienced by equipment mounted on forward-facing chassis surfaces. All chassis components are subject to heavy dust and sand environments.

5.3.6 OILS AND CHEMICALS—The chassis is subject to all of the oils and chemicals listed in Section 4.4.

5.3.7 MECHANICAL, SHOCK, AND VIBRATION—Vibration data collected on the frame bumper attachment, frame transmission mount, frame crossmember and wheel backplate with equivalent power spectral density profiles are shown in Figure 13 – 15.

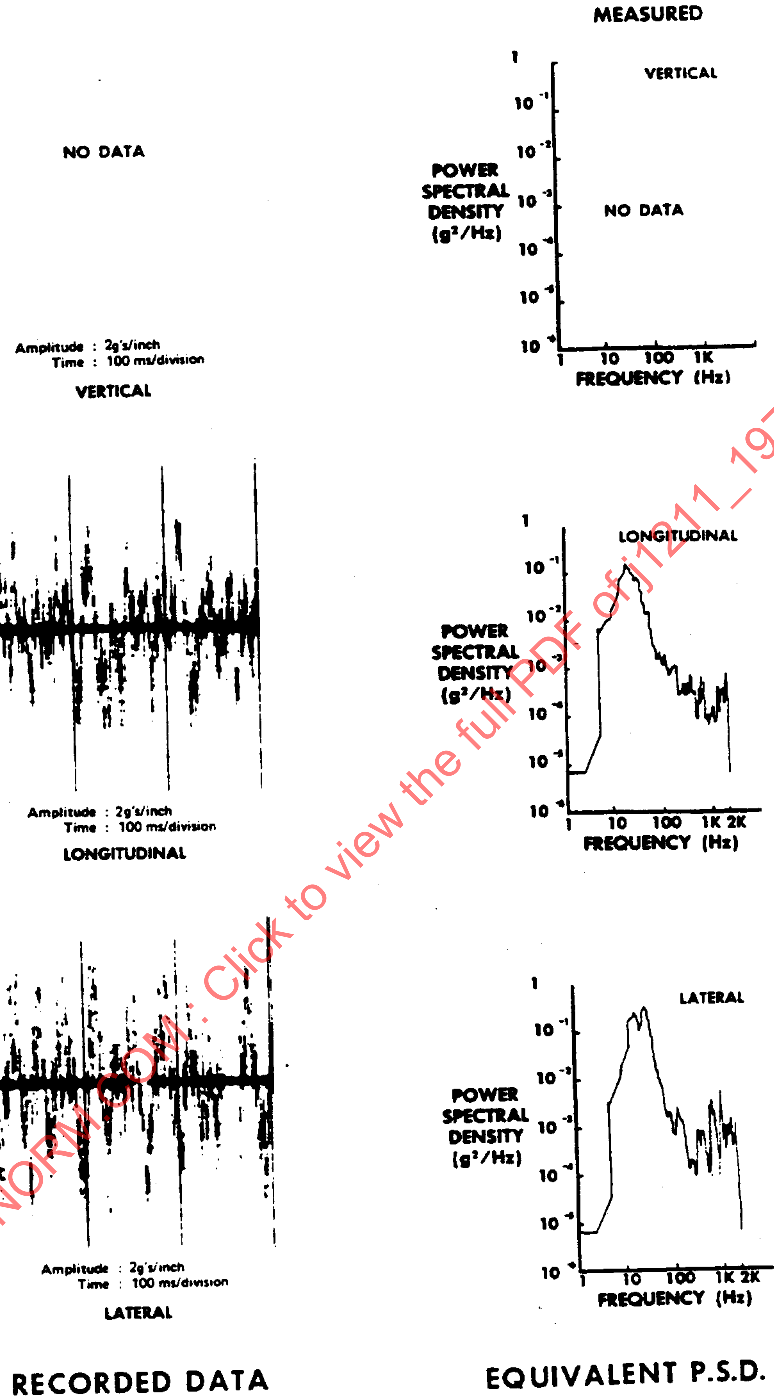


FIGURE 13—FRAME BUMPER ATTACHMENT VIBRATION MEASUREMENTS

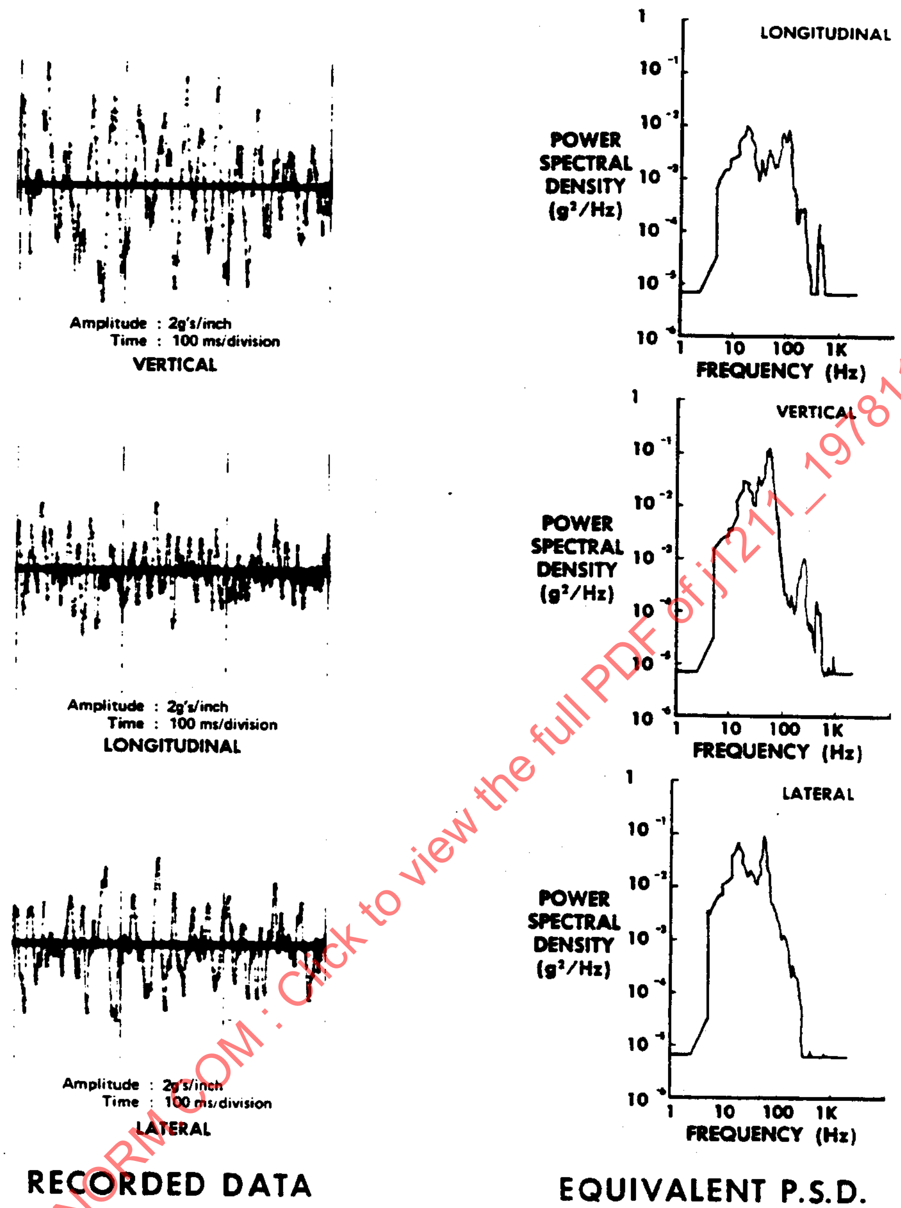


FIGURE 14—FRAME TRANSMISSION MOUNT VIBRATION MEASUREMENTS

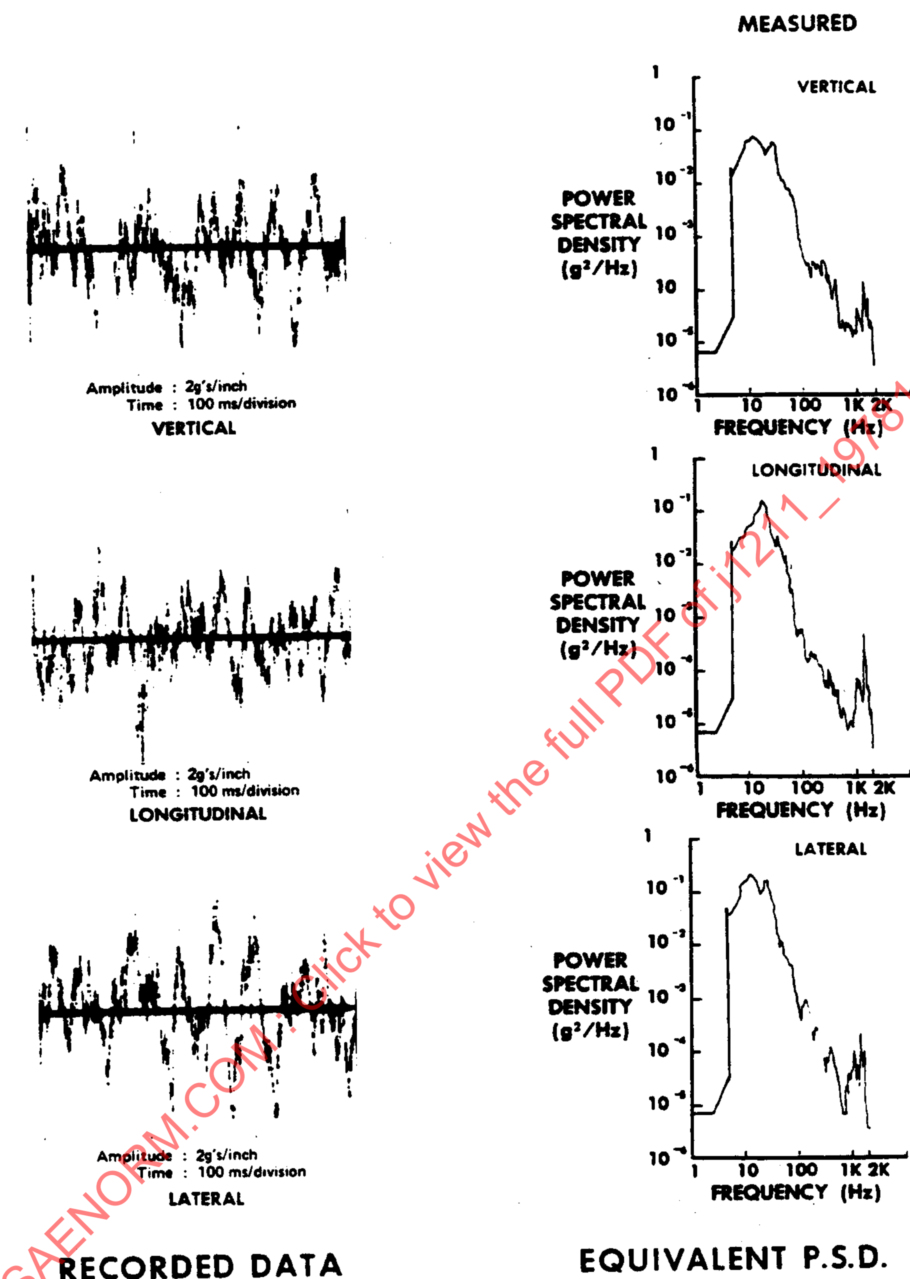


FIGURE 15—FRAME CROSS MEMBER VIBRATION MEASUREMENTS

5.3.8 ELECTRICAL - STEADY STATE (REFER TO 4.10.1 FOR FURTHER INFORMATION)—Three operating conditions are recognized:

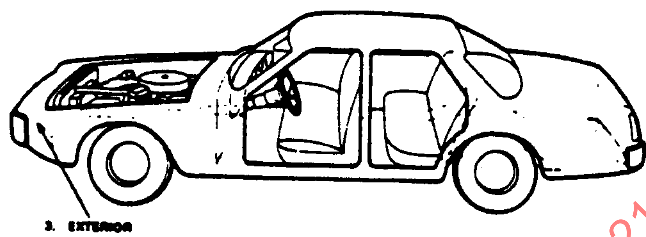
a. Normal starting and running	9 – 16 V (1)
b. Cold starting	4.5 – 6 V
c. Booster battery starting	24 V

1. See paragraph 4.10.1 for a definition of normal voltage.

5.3.9 ELECTRICAL—TRANSIENT—This condition varies, depending upon the electrical distance of the equipment from the battery and the nearness of transient sources (for example, inductive motors, solenoids, the alternator). Typical data is shown in Table 7. (Refer to Section 4.11 for further information.)

5.4 Exterior—The exterior consists of all outward and external vehicle surfaces above the chassis. This includes the forward grille area and potential mounting areas just above the bumpers. Data is summarized in Table 8.

EXTERIOR ENVIRONMENTAL DATA



	TEMPERATURE			HUMIDITY (%RH)			SALT SPRAY	IMMERSION	SAND, DUST & GRAVEL	OIL & CHEMICAL	MECHANICAL SHOCK & VIBRATION	ELECTRICAL	
	LOW	HIGH	SLEW RATE	HIGH	LOW	FROST						STEADY-STATE	TRANSIENT
Normal	-40°C (-40°F)	85°C (185°F)	NA	95% at 38°C (100°F)	0	yes	Sect. 4.3	Sect. 4.4	Sect. 4.5	Sect. 4.4	Figure 16 & 17	Table 2 & 4	Table 3

TABLE 8

5.4.1 TEMPERATURE—Since all surfaces are away from internal vehicle heat sources, the temperature is primarily controlled by the climatic ambient conditions. These are discussed in Section 4.1 and shown in Table 8. Thermal shock due to splash or immersion, particularly on the front of the vehicle, should be anticipated.

5.4.2 HUMIDITY—Shown in Table 8.

5.4.3 SALT SPRAY—Most exterior surfaces are subject to heavy salt spray, with the possibility of crystalline salt buildup in some grille areas.

5.4.4 IMMERSION—Equipment mounted approximately below the vehicle axle line are possibly subject to occasional immersion. Components above this line experience splash.

5.4.5 GRAVEL, DUST, AND SAND—Components on the front of the vehicle are subject to bombardment from the vehicle ahead. Sand and dust impinges on all surfaces.

5.4.6 OILS AND CHEMICALS—Environmental chemicals include:

Road tar
Anti-freeze/water mixture
Soaps and detergents
Steam
Salt spray
Washer solvent
Degreasers
Waxes

Water and snow

5.4.7 MECHANICAL SHOCK AND VIBRATION—Data collected at the wheel back plate is shown in Figure 16, and center pillar data is shown in Figure 17.

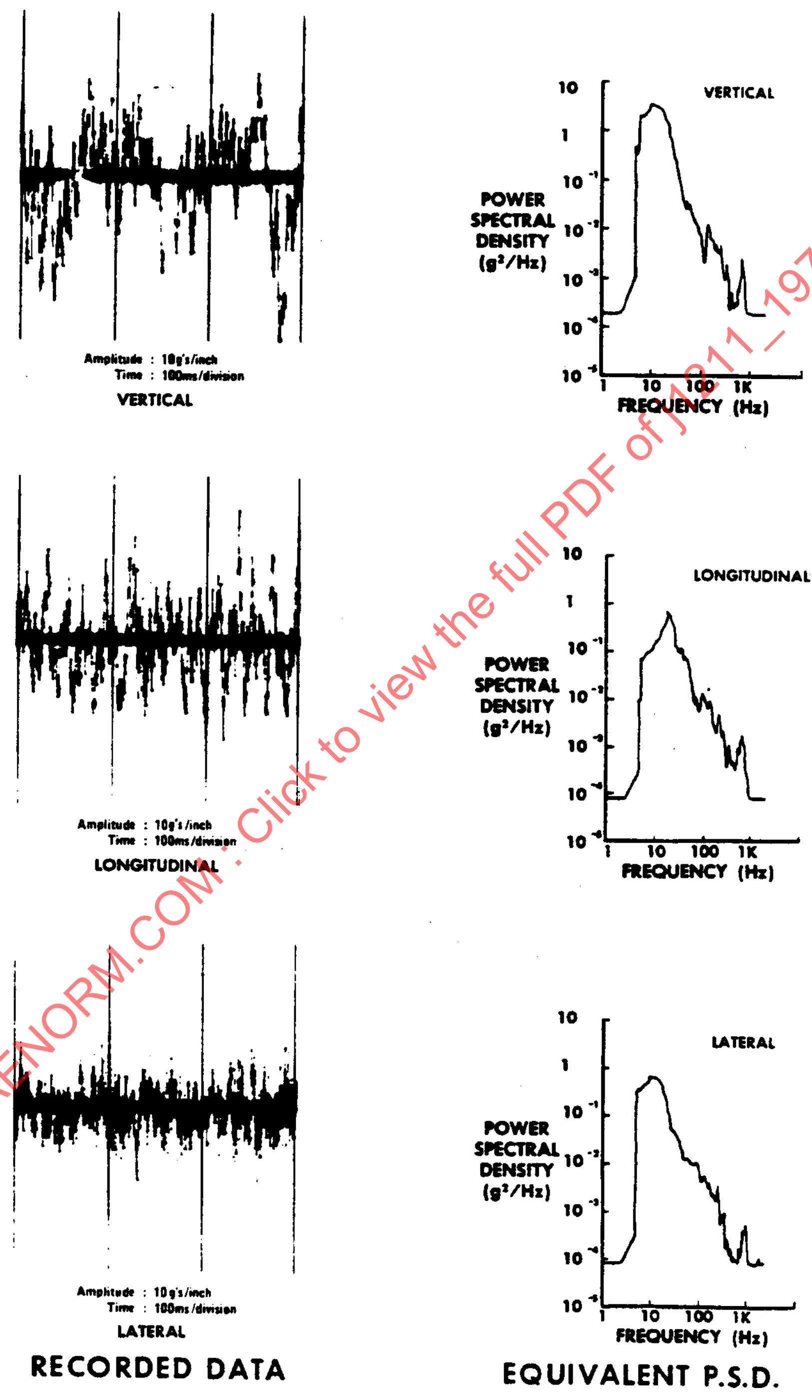


FIGURE 16—WHEEL BACK PLATE VIBRATION MEASUREMENTS