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US Army Aberdeen Test Center (TEDT-AT-ADI)
400 Colleran Road
Aberdeen Proving Ground, MD 21005-5059

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14. ABSTRACT
This TOP describes a procedure for determining the shock and vibration characteristics of self-propelled and towed wheeled and tracked vehicles.

15. SUBJECT TERMS
Field Shock Vibration
Time Waveform Replication (TWR) Shock Response Spectrum (SRS)

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US ARMY DEVELOPMENTAL TEST COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 02-2-808A 15 June 2011
DTIC AD No. ADA544797

FIELD SHOCK AND VIBRATION VEHICLE TESTS

This TOP supersedes TOP 02-2-808, Field Shock and Vibration Tests of Vehicles, 1 October 1981.

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1. SCOPE.

a. This Test Operations Procedure (TOP) describes a procedure for gathering field data that will aid in determining the shock and vibration characteristics of self-propelled and towed wheeled and tracked vehicles. This TOP also discusses the dynamic environment of components, installed equipment, secured cargo, ammunition, and personnel during operation over selected test courses. Instrumentation guidance is provided for recording both the vehicle response characteristics on the road course and the test item response in the vehicle.

b. Vehicle shock and vibration tests are conducted when there is a need to obtain data, which can be used to produce vibration test schedules for control of laboratory vibration test systems or exciters. Field tests are necessary when the vibration schedules for equipment in published test standards (i.e. Military Standard (MIL-STD)-810G[1] and International Test Operations Procedure (ITOP) 01-2-601[2]) are not available, or require tailoring for specific laboratory test requirements. An existing vibration test schedule may not represent the required terrain condition(s). In addition, more detailed vibration response characteristics may be required to represent the structural modes of the test item. The vibration exciters are used to determine if equipment installed in the vehicle will be able to withstand a lifetime of vibration exposure or a defined road terrain condition.

c. Vehicle tests are also conducted to acquire transient waveforms that will be used to develop test references for laboratory shock and vibration tests. In some cases the use of a Time Waveform Replication (TWR) or Shock Response Spectrum (SRS) procedure may better meet the test objective than development of a vibration test schedule(s). Measured data are used to replicate the field conditions. Large vehicle mounted items, such as a shelter, may require field testing on defined test courses to demonstrate performance requirements.

d. Other reasons to conduct shock and vibration testing are to determine the whole-body vibration (also known as ride quality) characteristics of a vehicle, or to be used as input to validate engineering models. Though the general discussion contained in this TOP does apply, for more specific information pertaining to ride quality refer to TOP 01-1-014[3] and International Organization for Standardization (ISO) 2631-1[4].

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Automotive Test Courses	Selected from those listed in TOP 01-1-011[5] to suit test requirements - equivalent courses may be used.

Superscript numbers correspond to those in Appendix B, References.

2.2 Instrumentation.

Transducers	Accelerometers, free or rate gyro scopes, displacement, strain gages, etc. as needed for shock and vibration levels expected. A vehicle speed sensor is also a required transducer.
Signal Conditioning	As appropriate for the transducers selected.
Data Acquisition Equipment	Either on-board or transmitted to a stationary or mobile data acquisition suite.
Audio/Video	Where applicable and practical audio and/or video of the vehicle and driver.

3. REQUIRED TEST CONDITIONS.

3.1 Test Vehicles.

a. Inspect, service, and ensure that the preliminary operational performance checks of the vehicle have been accomplished in accordance with TOP 02-2-505[6].

b. Load the vehicle appropriately. For ammunition vibration schedule development, load the vehicle to 75% of the rated capacity of the vehicle (in accordance with MIL-STD-810G), otherwise load to approximate the intended use of the vehicle. Ensure that all weights are secured to the vehicle in such a way as to prevent the inadvertent movement of the test weights, which may adversely affect the vibration measurements. The center of gravity (CG) of the vehicle should be close to the CG of the in-service condition of the system. Loading of the vehicle should closely replicate the actual end use item and not change the response modes of the vehicle from the in-service condition. Simply welding steel plates to replicate the weight and CG should only be used with caution as that may greatly change the dynamic characteristics of the vehicle.

c. Establish maximum and minimum test speeds for the vehicle in accordance with TOP 02-2-602[7].

3.2 Instrumentation.

a. Mount appropriate transducers at various representative locations selected to provide a comprehensive determination of the shock and vibration regimes in the test system during field operation. For isolated systems, measure both the input and the response in each of the three mutually orthogonal axes (vertical, transverse and longitudinal). For example, install accelerometers above and below the isolators utilizing the more rigid members of the system. For wheeled vehicles, install accelerometers on axles, in the cab, and in the cargo area. For tracked vehicles, install accelerometers on the road-wheel arms and on the basic hull structure fore and aft, in the driver compartment, and in the crew compartment. Ammunition storage areas are also of interest and should be instrumented as well.

b. Install accelerometers to measure vibration magnitudes in three orthogonal axes (vertical, transverse, and longitudinal) at the principal areas of contact between the driver's body and the surface supporting it. For seated persons, the measurement should be made on the seat cushion directly beneath the ischial tuberosities to permit the analysis of the whole-body vibration transmitted to the driver. The accelerometers on the seat should be molded into a semi-rigid disk as described in TOP 01-1-014, paragraph 2.1. If necessary, make similar measurements at other passenger and crew positions. If instrumentation is limited, choose a representative set of crew and/or passenger locations.

c. If one of the purposes of the test is to measure the vibration response of particular on-board equipment or vehicle components, install the appropriate transducers on these items and on the vehicle structures that support the items. Vibration measurements on the vehicle structure are needed to describe the input vibration to the specific equipment or component. These input measurements can later be used in the development of laboratory vibration schedules for the specific item under test.

d. Special care needs to be taken in selecting the type of anti-aliasing filter, the filter frequencies, and data sample rates. The filter cut-off frequency should be selected to adequately capture the system response. For random excitations such as those in field vibration testing, a Butterworth filter is often appropriate. Other filter types can also be used if the user understands the characteristics of the filter and these are included in the test report. For an 8-pole Butterworth low-pass filter, a sampling rate of approximately 4 times the filter cut-off frequency is appropriate as a good compromise between time domain peak estimation and frequency domain resolution when the input is essentially stationary. If there is expected to be significant shocks in the data, higher ratios of sample rate to filter cutoff frequency may be required. Lower ratios may be used if the slope of the filter at the cut-off frequency is sharper, and a higher ratio is required if the slope is shallower. Typical values used for a field vibration test are a 500 Hertz (Hz) low-pass filter with a 2000 samples/second digitization rate. Higher values may be required in tracked vehicles. For whole-body vibration analysis the low-pass filter should be set at 100 Hz. The frequency resolution for whole-body vibration should be approximately 0.2 Hz.

3.3 Test Controls.

a. Maintain correct levels of lubricants, hydraulic fluid, coolant, etc., in the test vehicle throughout the test.

b. Maintain appropriate track tension or tire pressure throughout the test in accordance with vehicle specifications of detailed test plan.

c. Ensure that all transducers and data recording equipment are in a current state of calibration, provide acceptable resolution, and have a flat response over the full frequency spectrum of interest.

d. Maintain the severity level of each test course as consistently as possible throughout the test.

e. Observe all safety Standing Operation Procedures (SOPs) throughout test operations.

f. Maintain a constant vehicle speed when recording shock and vibration data.

4. TEST PROCEDURES.

a. Install transducers to the test item and connect them to an on-board signal conditioning and data acquisition system that has the capability of either transmitting the encoded data to a remote data recording station or storing the data on-board. Other methods that insure the proper conditioning and storage of the data are also acceptable and all details of the data acquisition system should be documented in the test report.

b. Operate the test vehicle over the test courses appropriate to the life cycle (further information on life cycle can be found in MIL-STD-810G) of the test item or as specified in a detailed test plan. Speeds should be incremental, starting at a low speed and gradually increasing speed until reaching the maximum test speed. The final speed should be determined from either the maximum speed allowed on the test course, the maximum attainable speed of the vehicle, or a point where the driver or any passenger or crew member would be uncomfortable proceeding to the next speed, or the driver feels that the vehicle would not be controllable or would be in any way unsafe at a higher speed. Speed increments should be at most 2 miles per hour (mph) for tracked vehicles and 2.5 mph for wheeled vehicles. As the maximum safe speed is approached the increment may be smaller. Ensure that an adequate amount of data is collected to enable appropriate statistical confidence. This would require at least 30 averages when computing a Power Spectral Density (PSD). The time required to fill a PSD block to compute a single average is the Fast Fourier Transform (FFT) block size divided by the sample rate.

c. For the health and safety of the driver, and any passengers or crew, terminate testing operations when any of the passengers or crew believes that it is unsafe or will cause harm to the vehicle or crew. Ride quality parameters should be monitored throughout the testing and any absorbed power exceeding 15 Watts[3] in the vertical axis should also be cause to terminate testing operations.

d. To ensure that accurate and valid data are being collected periodic validity checks should be completed during the data acquisition process. These checks should include but are not limited to the following:

(1) Wild points (single point excursions).

(2) Full scale excursions (exceeding the range of measurement).

(3) Direct current (DC) shifts of the data (change in the average over time).

(4) Noisy data.

(5) Inactive channels.

(6) One sided data.

e. If, based on the checks outlined above, the data are determined to be invalid then the source of the error needs to be identified and corrected. After making the necessary fixes the affected test runs need to repeated and then checked for validity.

5. DATA REQUIRED.

a. Test date.

b. Vehicle identification, serial number, and date of manufacture.

c. Courses traversed.

d. Test course description to include root mean square (rms) roughness.

e. Measured speeds over each test course and speed measuring instrumentation identification.

f. Transducer recording system identification and description including but not limited to: the sample rate, amplitude resolution, and frequency resolution.

g. Photographs and narrative descriptions of transducer locations for structural, cargo, or personnel-position measurements.

h. Record of shock and vibration data.

i. Calibration information for transducers and signal conditioning equipment as applicable.

j. Tire pressure/track tension as applicable. If the vehicle is equipped with a Central Tire Inflation System (CTIS) record the CTIS setting as well as the nominal pressure it represents.

k. Description of the suspension system where applicable. If the vehicle has an active suspension, record any available parameters to describe it.

l. Detailed description of the vehicle load to include, but not be limited to:

(1) Overall weight.

(2) Payload composition.

(3) Weight distribution.

(4) Method(s) of payload securement.

m. Damage or impaired operation of vehicle components as a result of traveling over the test courses.

n. Ambient conditions including basic meteorological information and time of day.

6. PRESENTATION OF DATA.

a. Using appropriate data-processing equipment, reduce the recorded test data into a format that provides the proper information to meet the objective of the test. Such formats include, but are not limited to: amplitude distribution, power spectral density, coherence, transfer functions, ride quality analysis including absorbed power, and ISO 2631 analysis and shock response spectra for shock data.

b. Present data collected from personnel positions and present it in accordance with TOP 01-1-014.

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APPENDIX A. ACRONYMS.

CG	center of gravity
CTIS	Central Tire Inflation System
DC	direct current
FFT	Fast Fourier Transform
Hz	Hertz
ISO	International Organization for Standardization
ITOP	International Test Operations Procedure
MIL-STD	Military Standard
PSD	power spectral density
rms	root mean square
SOP	Standing Operating Procedure
SRS	shock response system
TOP	Test Operations Procedure
TWR	Time Waveform Replication

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APPENDIX B. REFERENCES.

1. MIL-STD-810G, Department of Defense Test Method Standard; Environmental Engineering Considerations and Laboratory Tests, 31 October 2008.

2. ITOP 01-2-601, Laboratory Vibration Schedules, 19 February 2009.

3. TOP 01-1-014 (with Change 1), Ride Dynamics, 30 October 2007.

4. ISO 2631-1, Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-Body Vibration - Part 1: General Requirements, 1 May 1997.

5. TOP 01-1-011 Vehicle Test Facilities at Aberdeen Proving Ground, 6 July 1981.

6. TOP 02-2-505, Inspection and Preliminary Operation of Vehicles, 4 February 1987.

7. TOP 02-2-602 (with Change 1), Acceleration; Maximum and Minimum Speeds, 28 January 1981.

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Test Management Directorate (CSTE-TM), US Army Test and Evaluation Command, 314 Longs Corner Road, Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: US Army Aberdeen Test Center (TEDT-AT-ADI), 400 Colleran Road, Aberdeen Proving Ground, MD 21005-5059. Additional copies can be requested through the following website: http://itops.dtc.army.mil/RequestForDocuments.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.