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Marginal notations are not used in this revision to identify changes, with respect to the previous issue, due to the extent of the changes.

14. ABSTRACT
This TOP describes test methods to be utilized for evaluating wheeled and tracked vehicle gradeablility and side slope performance. Included are procedures for calculating the vehicle critical angle, evaluating engine, transmission, brake system, and fuel system performance, and defining vehicle stability and control during grade and side slope testing.

15. SUBJECT TERMS

Gradeability	Critical angle	Tilt table
Braking system	Drawbar pull	Side slope
Towed dynamometer	Percent grade	Sine wave pattern
Fuel system		

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 02-2-610A 20 April 2020
DTIC AD No.:

GRADEABILITY AND SIDE SLOPE PERFORMANCE

*This TOP supersedes TOP 02-2-610, dated 03 December 2009.

1. SCOPE.

a. This Test Operations Procedure (TOP) describes the test methods utilized for assessing wheeled and tracked vehicle performance on longitudinal and side slopes of varying degrees of grade. Included are procedures for assessing engine, transmission, brake system, fuel system performance, and vehicle stability and control during grade and side slope testing.

b. The vehicle capabilities for operating on slopes are of particular interest for military vehicles; which must be capable of operating in any tactical situation without relying on established roadways. The assessment of the gradeability and side slope performance of a vehicle on calibrated grades provides a means for determining the adequacy of the equipment, and provides for an analysis of its tactive effort.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Longitudinal grades and side slopes.	Grades and slopes as described in TOP 01-1-011B[1**]. Representative photos appear as Figures 1 and 2.
Safety vehicle with safety cable.	Vehicle of sufficient weight with a cable of sufficient size and strength to safely restrain the test vehicle in the event tipping, mechanical failure, or if tread slip occurs.
Tilt Table.	A single continuous platform capable of tilting a test vehicle parallel to its longitudinal axis. The platform must remain essentially planar throughout testing.
Level, paved test course.	A straight, level, paved road with a width of not less than 3.7 meters (m), a longitudinal gradient $\leq$ 1%, and a side slope gradient $\leq$ 2%. The length of the roadway should be sufficient to allow the test vehicle with the required towed dynamometer loaded to accelerate to, and maintain, the corresponding stabilized speed.

** Superscript numbers correspond to those in Appendix B, References.

Figure 1. Vehicle on 60 percent Longitudinal Grade.

Figure 2. Vehicle on Side Slopes.

2.2 Instrumentation.

Devices for Measuring	Permissible Measurement Uncertainty (see NOTE a)
Road speed.	1%
Engine speed.	1%
Pressure (vehicle fuel, oil, tire, etc.).	1%
Tilt table angle.	0.2 degrees
Applied drawbar load	1%
Meteorological data:	
Atmospheric pressure.	1%
Ambient temperature.	1 °Celsius (°C)
Humidity.	3%
Wind speed.	5%
Wind direction.	50 milliradian (mrad)

NOTE a: The permissible measurement uncertainty is the two-standard deviation value for normally distributed instrumentation calibration data. Thus 95% of all instrumentation calibration data readings will fall within two standard deviations from the known calibration value.

2.3 Specialized Equipment.

Specialized equipment/instrumentation that may be required for testing are as follows:

a. Towed dynamometer. This is typically an eddy-current power absorber capable of applying a resistive load proportional to the desired longitudinal grade. It is equipped with an on-board load-cell and road speed magnetic pick-up sensor to measure drawbar pull and road speed respectively, for control feedback and data acquisition.

b. Still cameras and/or video cameras to record vehicle-to-surface contact, stability and control problems, and track/wheel slip.

c. When driveline torque and/or steering evaluations are requested as part of this testing, the additional instrumentation required is described in TOP 02-2-806[2] and TOP 02-2-002A[3] respectively.

3. REQUIRED TEST CONDITIONS.

3.1 Preparation for Test.

a. Review all instructional material issued with the test vehicle by the manufacturer, contractor, or government, as well as reports of previous similar tests on the same types of vehicles.

b. Select the applicable test facilities to be used based on the requirements documents and purpose of the test. Review the applicable test procedures listed in the detailed test plan.

c. Prepare data collection sheets to record all pre-test information, conditions of test, test results, observations, and measurements that would be valuable in analysis and assessment.

d. Ensure that all test personnel are familiar with the required technical and operational characteristics of the item and the required test procedures.

3.2 Determination of Critical Angle.

3.2.1 General Description.

When negotiating slopes of critical grade, vehicles tend to tip over about some pivot point. In theory, the critical point is reached when the Center of Gravity (CG) of the vehicle is located vertically above its center of rotation (Figure 3). In practice, the actual critical angle is always less than the theoretical value during both static and dynamic operations. Statically, the sagging of suspension members causes the CG to shift toward the center of rotation. Dynamically, this condition is amplified by the torque imposed by the driveline, especially when accelerating.

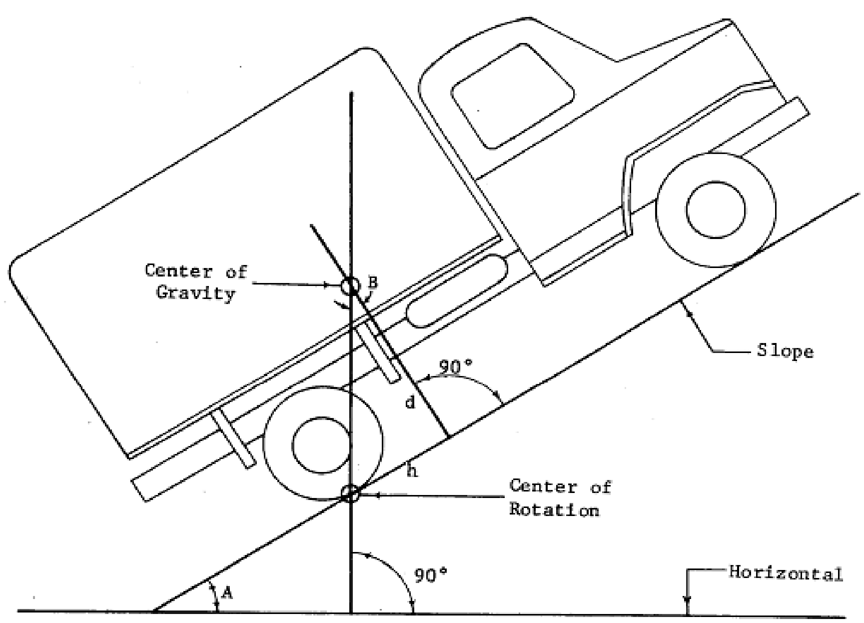

Figure 3. Critical angle for vehicle on longitudinal slope.

3.2.2 Method of Determination.

a. Calculation Method. The theoretical critical angles (tipping angles) are calculated for each direction of operation of the test vehicle before testing, to establish an approximation of the maximum slopes on which the vehicle can safely operate. For these calculations, the vehicle is assumed to be at its designated test weight and the CG position was determined in accordance with TOP 02-2-800[4]. With the vehicle on level ground, the height (d) of the CG above ground and horizontal distance (h) between the CG location and the center of rotation (in this case, the rear wheels) are measured. These measurements are used in the following equations to determine the theoretical values for the critical angle and the critical grade (slope) expressed as a percentage.

$$Critical\ Angle = \tan^{-1}\left({}^{h}/_{d}\right) \qquad (Equation\ 1)$$

$$Critical\ Grade\ (\%) = 100 \times \left({}^{h}/_{d}\right) \qquad (Equation\ 2)$$

(1) At the theoretical critical angle, the CG is directly above the center of rotation.

(2) For the procedure presented above, the critical angle was obtained for a vehicle ascending a longitudinal grade. Critical angles for a vehicle descending a grade and for side slope operations are obtained in a similar manner.

b. Tilt Table Method. Utilizing a tilt table to rotate the test vehicle about its center of rotation, the vehicle critical angles and grades are determined in accordance with the procedures presented in Society of Automotive Engineers (SAE) recommended practice J2180[5].

c. It should be noted that the Calculation Method may provide significantly different results from those obtained during the Tilt Table Method or actual dynamic testing on a longitudinal grade or side slope, depending on the suspension characteristics and control input of the test item. Both the Calculation Method and Tilt Table Method are generally utilized to provide an indicator of the static stability of the test item prior to dynamic testing.

3.3 Test Controls.

a. Prior to testing ensure that:

(1) The vehicle has been prepared and equipped in accordance with standard use and/or guidance provided by the manufacturer, test sponsor, or test plan. Particular attention should be given to the operating configuration of the engine, transmission, brakes, and running gear. Fuel and oil levels shall be adjusted to specified levels.

(2) The vehicle is payloaded in accordance with the test plan and the payload is secured in a safe and proper manner.

(3) The vehicle has received the proper break-in operation.

(4) Vehicle tires or track pads are in good serviceable condition and track tension is adjusted in accordance with applicable technical manuals.

(5) Tire pressure and suspension setting are adjusted in accordance with manufacturer, test sponsor, or test plan guidance for slope operations.

(6) Prior to longitudinal and side slope operations, the tire and wheel at the bead interface should be marked to allow a visual check of bead slip and possible loss of traction during testing.

b. All safety procedures shall be observed in accordance with the test center's applicable Safety Operating Procedure (SOP). In particular, safety cables, used in conjunction with a properly sized anchor vehicle, are attached to unproven test vehicles when negotiating longitudinal slopes greater than 40 percent. For side slope testing when the grade is within ten percent less than the tipping angle measured during tilt table testing, operations are conducted either with safety cables and an upslope anchor vehicle, or with an appropriately sized and positioned downslope vehicle to prevent vehicle rollover. Operation without a safety restraint may be permitted only after previous testing of a "like" vehicle (similar total weight, CG, and dimensions) has demonstrated that the vehicle can safely negotiate the specified slope.

3.4 Restrictions.

Tests are not conducted at night or during inclement weather. Test course safety and operational procedures will be carefully followed.

4. TEST PROCEDURES.

4.1 Longitudinal Grade Performance.

Usually, military specifications require that tactical and combat vehicles be able to negotiate a 60-percent grade in both forward and reverse gears and have adequate braking capability to hold the vehicle stationary on this grade. Generally, all military vehicles are required to demonstrate gradeability on designated grades at specified speeds without stalling, upsetting, losing traction, or overheating the engine. These procedures will allow the determination of those capabilities.

4.1.1 Braking System Grade Holding Ability.

The vehicle's service and parking brake systems, each independent of the other, should be capable of holding the vehicle stationary on the maximum longitudinal slope gradients over which the vehicle is required to operate.

a. The vehicle is positioned on dry, paved, longitudinal slopes in both ascending and descending vehicle orientations. In both cases, the vehicle is driven onto the slopes from the base using forward or reverse gears as appropriate.

b. In accordance with the recommended guidance, the service and parking brake systems are engaged separately to assure their individual capability to hold the vehicle stationary. The test sequence should, as a minimum, be as follows:

(1) Select the proper driveline setting (e.g., locked transfer case) prior to operating the vehicle onto the slope, based on guidance from the manufacturer, test sponsor, or test plan.

(2) Position the test vehicle on the designated grade.

(3) Apply the service brake.

(4) Place the transmission in neutral.

(5) If testing the service brake, wait a minimum of two minutes.

(6) If testing the parking brake, perform the following:

(a) Apply the parking brake and slowly release the service brake.

(b) Turn off the engine and wait a minimum of two minutes.

(7) Observe wheel or track movement, and note any inability of the brakes to adequately hold the vehicle or prime mover/trailer combination on the slope.

c. When testing a trailer or semi-trailer, a safe disconnect (mechanical, electrical, pneumatic, and hydraulics connections) from the prime mover must be maintained.

4.1.2 Vehicle Engine and Transmission Performance.

The vehicle's engine and transmission system should be capable of negotiating the maximum longitudinal slope gradients over which the vehicle is required to operate.

a. The vehicle is operated on dry, paved, longitudinal slopes in both ascending and descending vehicle orientations. In most cases, the vehicle is driven onto the slopes from the base using forward or reverse gears as appropriate.

b. The test sequence should, as a minimum, be as follows:

(1) Position the vehicle at the base of longitudinal slope with the selected gradient in the ascending or descending vehicle orientation, as appropriate.

(2) Select the proper driveline setting (e.g., locked transfer case) prior to operating the vehicle onto the slope, based on guidance from the manufacturer, test sponsor, or test plan.

(3) Operate the vehicle up the specified longitudinal slope.

(4) The vehicle is brought to rest on the slope by applying the service brake, the transmission is set to neutral, parking brake is applied, and the service brake is released. If the parking brake cannot hold the vehicle on the slope, the service brake is re-applied.

(5) Idle the vehicle engine for two minutes.

(6) Shut down the engine for two minutes.

(7) Attempt to restart the engine.

(8) If the engine restarts, apply the service brake and engage the transmission with the appropriate gear selection.

(9) Increase the throttle and gradually release the service brake to determine the vehicle's ability to continue ascending the grade.

c. When applicable, auxiliary engines are also checked for idling and restart capability.

d. Observe and record any instance of wheel slip, mechanical failure, inability of the engine and/or driveline to ascend the grade, fluid overflow (oil, fuel, water, etc.), change in fuel and oil pressures, and tire-to-wheel bead slip.

e. When requested, for vehicles with torque-converter transmissions, the engine speed at vehicle stall is observed with the vehicle ascending slopes of maximum grade. This can be an indication of whether the engine is delivering appropriate torque and horsepower.

4.1.3 Longitudinal Slope Speed.

a. On the steeper grades, the maximum sustained speed of the test vehicle is determined by accelerating the vehicle from a standing start on the grade. A number of trials may be required to determine the optimum speed/gear combination for maximum performance.

b. On slopes of lesser grade that lack sufficient length, the vehicle's maximum sustained speeds are obtained by making running approaches to the designated slope at predetermined speeds. Once on the slope maximum throttle is applied. During subsequent runs, the slopes are approached at a speed equal to the maximum speed attained during the previous run. This process is repeated until the maximum sustained speed is reached.

c. If the desired gradient is not available, vehicle slope performance can be calculated utilizing its drawbar pull performance. By referencing its drawbar pull curves, both the vehicle's gradeability at a given speed and its maximum speed at a given gradient may be determined. The formulas for making these determinations are:

$$\sin\theta = {}^{P}/_{W} \qquad (Equation\ 3)$$

$$Percent\ Grade = \tan\theta \times 100 \qquad (Equation\ 4)$$

where
θ = Angle of grade.
P = Drawbar pull value.
W = Vehicle test weight.

d. Alternative methods for measuring the maximum sustained speed required by a vehicle to negotiate slopes of lesser grade (usually 5 percent or less), where a longer grade is needed, are as follow:

(1) Using a towed dynamometer (paragraph 2.3.a), a resistive load is applied equal to the force imposed by the designated grade as the vehicle is operated at full throttle on a level, paved test course. If the test item involves a prime mover with trailer, the additional rolling resistance associated with the driveline and wind resistance of the trailer must be accounted for in the resistive loading. Typically, four data runs, two in each direction, are averaged to obtain the maximum sustained speed in the optimum transmission gear for the specified grade.

(2) In the absence of a dynamometer, the maximum sustained vehicle speeds required to ascend grades less than 5 percent can be determined through the use of appropriate sections of public highways. The highway must be surveyed to assure the designated section corresponds to the desired grade. When operating on public highways care must be taken to adhere to all local, state, and federal laws. Also, additional safety precautions should be considered, when appropriate, to include the use of escort vehicles to provide warning to local traffic.

4.2 <u>Side Slope Performance</u>.

Military vehicles are tested to determine their capability for negotiating side slopes of varying grade, as required in the applicable specifications.

a. Maneuver the vehicle onto the designated slope with the right or left side facing upslope. Idle the engine for two minutes, shut down the engine for two minutes, and then attempt to restart the engine. If the engine restart is successful, proceed to the next step. The same procedure is followed for any auxiliary engines equipped on the vehicle.

b. Drive the vehicle forward in a sinusoidal steering pattern the length of the designated side slope at a minimal speed ($\leq$ 8 kilometer per hour (km/hr)) to evaluate dynamic stability, steering control, and tracking (reference TOP 02-2-002A). The wavelength of the sine wave steering path is determined by Equation 5, unless other guidance is provided in the test plan.

$$Wavelength = 2 \times (Overall\ vehicle\ length + 15m\ (50\ feet)) \qquad (Equation\ 5)$$

Notes: The overall vehicle length for this application is measured at 0.5 m from the ground.

Traffic cones are used to define the sine wave pattern along the longitudinal length of the test course. The cones may need to be offset laterally in an alternating pattern if the side slope is not wide enough relative to the width of the vehicle to ensure the vehicle wheels or tracks remain on the test surface during the maneuver.

c. Repeat steps a and b with the other side of the vehicle facing upslope.

d. During slope operations, any fluid overflow (oil, fuel, water, etc.) and change in fuel and oil pressures are observed and reported, as well as fuel flowing from a high-side tank to a low-side tank.

e. Any observations of tire bead unseating from the wheel or misguiding of track will be reported.

4.3 Other Performance Factors.

During longitudinal grade and side slope testing, the following observations are made as appropriate, to determine the effect of grades and slopes on other performance factors:

a. The ability of the driver to remain in an adequate position to control the vehicle (i.e., steer, apply brakes, visibility).

b. The security of payloads (reference TOP 02-2-537[6]).

c. The security of Basic Issue Items (BII) (reference TOP 02-2-802[7]).

d. Adequacy of vehicle design to accommodate the angles of approach, departure, and breakover required for grade negotiation.

5. DATA REQUIRED.

5.1 Longitudinal Grade Performance.

5.1.1 Braking System Grade Holding Ability.

a. Percent grade.

b. Vehicle position (ascending/descending).

c. Distance vehicle moved, if at all (note wheel/track roll or slide).

d. Test duration.

e. Brake control force, if required.

f. Brake temperatures, if required.

g. Vehicle test configuration (payload, weight, tire pressures, drivetrain setting (e.g., locked axles, locked transfer case, fluid levels).

h. Comments on vehicle behavior.

5.1.2 Engine and Transmission Performance.

a. Calculated critical angle/grade, if required.

b. Percent grade and direction of travel.

c. Vehicle test configuration (payload, weight, tire pressures, fuel and oil levels, drivetrain setting (e.g., locked axles, locked transfer case), etc).

d. Observations of engine idle and restart capabilities and ability of vehicle to continue slope climb.

e. Location and approximate amount of any fluid overflow.

f. Observations of adequacy of vehicle steering and stability.

g. Engine speed.

h. Fuel and oil pressures.

i. Observations of tire-to-wheel bead slip.

j. Engine accessories operating mode.

5.1.3 Longitudinal Slope Speed.

a. Percent grade.

b. Vehicle test configuration (payload, weight, tire pressures, fuel and oil levels, drivetrain setting (e.g., locked axles, locked transfer case), etc.).

c. Road and engine speeds, and gear range of each test run.

d. Calculated and actual drawbar loading supplied by the towed dynamometer.

e. Fuel and oil pressures when requested.

5.2 Side Slope Performance.

a. Vehicle critical angle/slope determined during tilt table testing.

b. Percent slope and direction of travel.

c. Vehicle test configuration (payload, weight, CG location, fuel and oil levels, drivetrain setting (e.g., locked axles, locked transfer case), etc.).

d. Road speed.

e. Engine speed.

f. Fuel and oil pressures.

g. Steering and stability observations.

h. Engine starting ability.

i. Observations of tire bead unseating or track misguide.

j. Location and approximate amount of any fluid overflow.

k. Engine accessories operating mode.

6. PRESENTATION OF DATA.

a. At a minimum, the following results will be presented in a tabular format and compared to the criteria and, when requested, the results of other test vehicles.

(1) Vehicle critical angle/slope for each direction tested.

(2) Maximum grade holding ability for each brake system tested and vehicle direction.

(3) Maximum road and engine speeds and gear range of the vehicle for each longitudinal grade tested.

(4) Engine idle and restart and vehicle climbing capabilities for each grade tested.

(5) Engine idle and restart capabilities and steering and stability observations for each side slope tested.

(6) Drivetrain setting during testing.

b. Examples of typical tables utilized for data presentation are presented in Figures 4, 5, and 6.

TABLE X.X-X. LONGITUDINAL GRADE RESULTS, VEHICLE XXX AT GVW

Percent Grade	Vehicle Orientation	Ability to Climb Grade	Brake Holding Ability		Engine Restart	Ability to Continue Climb
			Service	Parking		
30	Ascending	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
	Descending	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
40	Ascending	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
	Descending	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
50	Ascending	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
	Descending	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
60	Ascending	Satisfactory	Satisfactory	Unsatisfactory[a]	Satisfactory[c,d]	Satisfactory
	Descending	Satisfactory	Unsatisfactory[b]	Unsatisfactory[a]	Satisfactory[c,d]	Satisfactory

[a] Braked wheels rolled down grade when service brakes were slowly released with parking brake applied.
[b] Braked wheels rolled down grade with transmission in neutral and service brake pedal applied.
[c] Engine shutdown/restart was conducted with service brakes applied.
[d] After restart, “Engine Oil Low” light illuminated along with audible warning. Oil level was checked and considered satisfactory on level ground.

Figure 4. Longitudinal grade performance data presentation.

TABLE X.X-X. SPEED ON GRADE RESULTS, VEHICLE XXX AT GVW

Percent Grade	Maximum Sustained Road Speed		Engine Speed, (revolutions per minute (rpm))	Transmission Gear	Range
	kilometers per hour	miles per hour			
2[a]	78.5	48.8	2575	5L	High
3[a]	63.9	39.7	2650	4L	High
5[b]	49.4	30.7	2700	3L	High
10	31.4	19.5	2390	5L	Low
20	17.7	11.0	2490	3L	Low
30	12.9	8.0	2390	2L	Low
40	7.9	4.9	2700	1L	Low
50	7.9	4.9	2640	1L	Low
60	4.0	2.5	1930	1C	Low

[a] Testing was conducted on level ground with a towing dynamometer to simulate grade.
[b] Results were calculated from drawbar pull data.

Figure 5. Longitudinal grade sustained speed data presentation.

TABLE X.X-X. SIDE SLOPE PERFORMANCE, VEHICLE XXX AT GVW

Percent Slope	Direction	Left Side Upslope		Right Side Upslope	
		Shutdown/restart	Sine Wave	Shutdown/restart	Sine Wave
20	Forward	Satisfactory	Satisfactory	Satisfactory	Satisfactory
	Reverse	Satisfactory	Satisfactory	Satisfactory	Satisfactory
30	Forward	Satisfactory	Satisfactory	Satisfactory	Satisfactory
	Reverse	Satisfactory	Satisfactory	Satisfactory	Satisfactory
40	Forward	Satisfactory	Satisfactory	Satisfactory	Unsatisfactory[a]
	Reverse	Satisfactory	Satisfactory	Satisfactory	Unsatisfactory[a]

[a] During the performance of the sine wave steering maneuver, the upslope wheels on the rear axle exhibited limited traction.

Figure 6. Side slope performance data presentation.

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APPENDIX A. ABBREVIATIONS.

BII	Basic Issue Items
°C	degrees Celsius
CG	Center of Gravity
km/hr	kilometers per hour
m	meter
mrad	milliradian
rpm	revolutions per minute
SAE	Society of Automotive Engineers
SOP	Safety Operating Procedure
TOP	Test Operations Procedure

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APPENDIX B. REFERENCES.

1. TOP 01-1-011B, Vehicle Test Facilities at Aberdeen Test Center and Yuma Test Center, 12 December 2017.

2. TOP 02-2-806, Power Train Torque Measurement, 30 December 1994.

3. TOP 02-2-002A, Steering and Cornering Behavior, 25 September 2019.

4. TOP 02-2-800, Center of Gravity, 26 September 2006.

5. SAE Procedure J2180, A Tilt Table Procedure for Measuring the Static Rollover Threshold for Heavy Trucks, May 2011.

6. TOP 02-2-537, Cargo Loading Adaptability, 15 April 1971.

7. TOP 02-2-802, Stowage, 9 January 1979.

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APPENDIX C. APPROVAL AUTHORITY.

CSTE-CI 20 April 2020

MEMORANDUM FOR

Commander, U.S. Army Operational Test Command
Director, U.S. Army Evaluation Center
Commanders, ATEC Test Centers
Technical Directors, ATEC Test Centers

SUBJECT: Test Operations Procedure 02-2-610A, Gradeability and Side Slope Performance, Approved for Publication

1. Test Operations Procedure (TOP) 02-2-610A, Gradeability and Side Slope Performance, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency.

2. Scope of the document. This TOP describes the test methods utilized for assessing wheeled and tracked vehicle performance on longitudinal and side slopes of varying degrees of grade. Included are procedures for assessing engine, transmission, brake system, fuel system performance, and vehicle stability and control during grade and side slope testing.

3. This document is approved for publication and has been posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

4. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-CI), 6617 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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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: Policy and Standardization Division (CSTE-CI-P), U.S. Army Test and Evaluation Command, 6617 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: Automotive Instrumentation Division (TEDT-AT-AD-I), US Army Aberdeen Test Center, 6943 Colleran Road, Aberdeen Proving Ground, MD 21005. Additional copies can be requested through the following website: https://www.atec.army.mil/publications/documents.html, 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.