



Robot Avoidance Maneuver Test

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This procedure is used to evaluate the obstacle avoidance capability of the test vehicle. Also evaluated is the control of the vehicle when subjected to an open loop drive file similar to an expertly driven path through the Consumer Reports Avoidance Maneuver (CRAM).

1.2 Applicability. This test procedure applies to any two-axle vehicle with pneumatic rubber tires for vehicles < 4545 kg (10 000 lb) gross vehicle weight.

1.3 Remarks. This transient handling test is designed to be run on all types of vehicles to analyze their performance well beyond the linear range of the vehicle. This test was inspired by the CRAM which is used to evaluate vehicles and rate them based on their emergency handling merits. Although this procedure was inspired by this test, it is in no way attempting to duplicate the CRAM test exactly. Instead, it uses similar inputs at a variety of speeds to test a vehicle's ability to react to "expertly" driven avoidance steering functions and will be able to evaluate a vehicle's transient response and control characteristics.

The Robot Avoidance Maneuver (RAM) test consists of a slowly increasing 3rd order steering input followed by sinusoidal inputs with varying amplitudes and dwell segments. Refer to Figure A1 and Table A1 in Appendix A.

This test is different from other vehicle dynamics test in two major ways. First, the vehicle response is analyzed at center of wheelbase as opposed to center of gravity (CG). The spatial nature of the CRAM test that inspired this procedure is the reason for this decision. Second, the vehicles are evaluated at defined road wheel steer angles as opposed to steering wheel angles.

This test is executed at varying entry speeds starting at 65 km/h and increasing in 5 km/h increments up to 95 km/h. Higher or lower speeds may be tested if a special case is to be examined.

Prior to running the RAM Test, a Steer Ratio test (GMW14798) must be run to determine the steering wheel angle input for the RAM test steering drive file. See Table A2 in Appendix A.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM E1136 ASTM E1337-90 FMVSS 126 ISO 9001

2.2 GM Standards/Specifications.

GMW14798 GMW15534

2.3 Additional References.

- Anthony Best Dynamics Ltd., Wiltshire BA15 1AJ, England.
- Oxford Technical Solutions Limited, 77 Heyford Park, Upper Heyford, Oxfordshire, UK.
- United States Department of Transportation/National Highway Traffic Safety Administration (DOT/NHTSA) Report – "NHTSA's Experience with Outriggers Used for Testing Light Vehicles - A Brief Overview", Patrick Boyd, NHTSA-2001-9663-0075.

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3 Resources

3.1 Facilities.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.1.3 The test requires a smooth, flat, dry surface with a high friction coefficient. Unless otherwise specified, the road test surface should produce a peak friction coefficient (PFC) ≥ 0.9 and ≤ 1.0 when measured using an ASTM E1136 standard reference test tire, in accordance with ASTM E1337-90, at a speed of 64.4 km/h (40 mph), without water delivery.

The test surface shall have a consistent slope between level (0%) and 2.5%. Whenever possible, the test shall be conducted with the vehicle traveling up the slope. This ensures that the slope will not cause asymmetries in the measured data when turning both left and right.

3.2 Equipment. Each test vehicle is to be equipped with sensors, a data acquisition system (DAS), programmable steering machine. The Anthony Best Dynamics (ABD) robot steering hardware and software set is required to perform this test.

3.2.1 Sensors and Sensor Locations. Table 1 lists the type of sensors recommended for the Sine with Dwell test procedure. The RAM test uses very similar equipment. A brief description of these sensors is provided in as follows.

3.2.1.1 Steering Angle Encoder. Handwheel position is measured via an angle encoder integral with the programmable steering machine.

3.2.1.2 Vehicle Speed Sensor. Vehicle velocity and side slip can be measured with an optical sensor placed at the front or rear-center of the vehicle. Alternatively, radar based, sonar based, or Global Positioning System (GPS) based sensors may be used. Sensor outputs are transmitted simultaneously to the data acquisition system, the steering machine, and the instrument panel (IP) mounted display. This IP-mounted display allows the driver to accurately monitor vehicle speed.

3.2.1.3 Multi-Axis Inertial Sensor. A multi-axis inertial sensing system is used to measure linear accelerations and the angular rates of roll, pitch and yaw (e.g., Oxford Technical Solutions Limited RT3000 series). The position of the multi-axis inertial sensing system must be accurately measured relative to the total vehicle Center of Gravity (CG) or centroid of the vehicle in the Driver plus Equipment test condition. These data points are required to translate the motion of the vehicle at the measured location to that which occurred at the actual centroid to remove roll, pitch and yaw effects.

3.2.1.4 Roll Angle Sensor. This channel is not required if the acquired lateral acceleration data is already roll compensated (i.e., when using the RT3000 Series sensor). Height sensors may be used to collect left and right side vertical displacements for the purpose of calculating vehicle roll angle during post processing using trigonometry.

3.2.1.5 Brake Pedal Force/Actuation Switch (Optional). This transducer is used to document if the driver did not provide any braking intervention during the test maneuver as specified by the test procedure.

3.2.1.6 GPS Radio Receiver or 2nd GPS Antenna (Preferred). If available at the test facility or with the RT System; utilizing the 2-antenna setup or communicating with a base station to improve GPS positional accuracy through radio communication will improve the consistency and quality of test data.

3.2.2 Data Acquisition System. The following channel assignments are shown to demonstrate the typical acquisition parameters.

- Speed
- Side Slip Angle
- Roll Rate
- Yaw Rate
- Lateral Acceleration
- Longitudinal Acceleration

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- Vertical Acceleration
- Steering Wheel Angle
- Lateral Velocity
- Forward Velocity
- Heading Angle
- (Optional) Steering Wheel Torque
- Roll Angle or Left Trim (roll height)
- (Optional) Right Trim (roll height)
- (Optional) Brake Pedal Force/Actuation

See 3.5 and 4.1.1 for more information about the data acquisition method.

3.2.3 Steering Machine. A programmable steering machine is used to generate handwheel steering inputs for all test maneuvers. The steering machine shall be capable of supplying steering torques between 40 N·m to 60 N·m (29.5 lbf·ft to 44.3 lbf·ft). The steering machine must be able to apply these torques when operating with steering wheel velocities up to 1200°/s (degree per second) and be able to move each vehicle's steering system through its full range. The steering machine should initiate steering programs at a preset road speed, and have the convenience of changing the steering program during test sessions.

3.2.4 (Optional) Outriggers. The RAM test is not designed to evaluate roll stability of the vehicle and outriggers may be used if the tester feels they should be. The addition of outriggers will lower the quality of the data collected. Safety outriggers may be installed on test vehicles whose T/2h (track width divided by twice the center of gravity height) is < 1.3 during all test maneuvers. It is recommended to use outriggers machined from 6Al-4V titanium I-beams. "Lightweight" outriggers are used for vehicles with baseline weights under 1588 kg (3500 lb) in a baseline condition (as delivered); "standard" outriggers are used for vehicles with baseline weights 1588 kg (3500 lb) and up. Information on this titanium outrigger system is documented in United States Department of Transportation/National Highway Traffic Safety Administration (DOT/NHTSA) Report – "NHTSA's Experience With Outriggers Used for Testing Light Vehicles - A Brief Overview", Patrick Boyd, NHTSA-2001-9663-0075.

3.3 Test Vehicle/Test Piece. This test procedure applies to any two-axle vehicle with pneumatic rubber tires that is under study for nonlinear handling stability and responsiveness characteristics by General Motors.

3.4 Test Time.

Calendar time:	2 days to 4 days
Test hours:	2 h to 3 h
Coordination hours:	3 h to 5 h

3.5 Test Required Information.

3.5.1 Typical Sensors and Instrumentation. See Table 1.

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Table 1: Typical Sensors and Instrumentation

Type	Typical Sensors Used by GM	Output	Range	Resolution	Accuracy
Multi-Axis Inertial Sensing System	Bei Motion Pak 160-260-181	Longitudinal/Lateral/Vertical Acceleration, Roll/Yaw/Pitch Rate	Acceleration: ± 2 g, Angular Rate: ± 100 deg/s	Acceleration: ≤ 10 μ g, Angular Rate: ≤ 0.004 deg/s	Acceleration: $\leq 0.05\%$ of full range, Angular Rate: $\leq 0.05\%$ of full range
Multi-Axis Inertial Sensing System	Oxford Systems RT3200	Longitudinal/Lateral/Vertical Acceleration, Roll/Yaw/Pitch Rate, Roll/Pitch/Heading Angle, Position, Speed, Sideslip	Acceleration: ± 10 g, Angular Rate: ± 100 deg/s	Acceleration: ≤ 10 μ g, Angular Rate: ≤ 0.004 deg/s	Acceleration: $\leq 0.05\%$ of full range, Angular Rate: $\leq 0.05\%$ of full range
Steering Machine Angle Encoder	ATI / Heitz Sprint 3	Handwheel angle, Torque, Steering Command Flag, Signal Feedback Flag	± 800 deg	0.25 deg	± 0.25 deg
Steering Machine Angle Encoder	Anthony Best Dynamics SR60	Handwheel angle, Torque, Steering Command Flag, Signal Feedback Flag	lock - to - lock	0.0075 deg	0.2 deg
Height measurement System (Roll Angle)	Massa M-5000/200 Smart Sensor Kit	height above ground	125-600 mm	0.25 mm	$\pm 0.25\%$ of full scale (~1.5 mm)
Speed Sensor	Corsys Datron 11316 Correvit S-400	Vehicle Speed, Distance, Sideslip Angle	0.2 - 200 km/h	0.015 km/h	$\pm 0.25\%$ of full scale (~0.5 km/h)

3.5.2 Additional Channels. Additional channels may be used as required.

3.5.3 Sample Rate. All data is to be sampled at 100 Hz. Signal conditioning consists of amplification, anti-alias filtering, and digitizing. Amplifier gains are selected to maximize the signal to noise ratio of the digitized data. Filtering is performed with a two-pole, low-pass Butterworth filter with a 25 Hz cut-off frequency.

3.6 Personnel/Skills. Operator must be qualified and documented as capable to run this test as required by ISO 9001.

4 Procedure

4.1 Preparation.

4.1.1 Installation.

4.1.1.1 For all vehicles that are tested using outriggers, remove and store the front and rear bumpers and/or fascias.

Outrigger mounting brackets must be fabricated for both the front and rear locations. Each mounting bracket must attach to the vehicle frame or structure, preferably at the existing bumper mounting location. Additionally, the mounting brackets must allow the attachment of the Outrigger Adapter Interface (the National Highway Traffic Safety Administration (NHTSA) universal adapter interface is 425 mm (16.75 in) from ground to centerline). The outrigger adapter interface may follow a standardized design. However, the mounting brackets required to attach the adapter interface to the vehicle will be unique to each family of vehicles.

For vehicles > 1588 kg (3500 lb) curb weight, the standard outriggers should be installed and adjusted such that the skid pads are 406 mm (16 in) above level ground in the front and rear. This height may be adjusted as necessary during the test.

The lightweight outriggers, used for vehicles < 1588 kg (3500 lb) at a curb condition, should be installed and adjusted such that the skid pads are 305 mm (12 in) above level ground in the front and rear and adjusted as necessary during the test.

4.1.1.2 The data acquisition module must be fastened securely to the vehicle interior to prevent it from being dislodged in the event of loss of vehicle control or vehicle tip up.

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4.1.1.3 The external speed sensor (if required) should be mounted at the longitudinal vehicle centerline at the front of the vehicle. If the sensor cannot be mounted at the precise center, the magnitude and direction of offset from center should be documented and reported to the appropriate test engineer.

4.1.1.4 The multi-axis inertial sensor must be installed and securely mounted at or near the total vehicle center of gravity (centroid or CG), with the location recorded on the Test Vehicle Description (TVD) sheet, or RAM Test Vehicle Description sheet, (or similar). Refer to Appendix B, Data Sheets B1, B2, and B3 for a sample TVD sheet and a RAM Test Vehicle Description sheet. The CG of a vehicle is typically located in the area between the front driver and passenger seats. Interior components such as the center console may need to be removed in order to mount the multi-axis inertial sensor in a suitable location.

4.1.1.5 Roll height sensors (if required) must be securely mounted to the vehicle.

4.1.1.6 It is preferable to remove the steering wheel and air bag in order to install the steering machine. The steering machine command module should be securely mounted for easy driver access, typically near the rear view mirror. The steering machine electronics box should be secured to the passenger seat, or alternatively, in a position convenient to the driver while as close as possible to the vehicle CG.

4.1.2 Vehicle Preparation.

4.1.2.1 It is expected that the vehicle provided for RAM testing be in excellent mechanical condition. For safety reasons, the vehicle should be thoroughly inspected and any chassis components should be replaced as necessary.

4.1.2.2 The vehicle total interior load of 168 kg (370 lb) is comprised of the test driver, approximately 59 kg (130 lb) of test equipment (automated steering machine, data acquisition system and the power supply for the steering machine), and ballast as required by differences in the weight of test drivers and test equipment. Where required, ballast shall be placed on the floor behind the passenger front seat or if necessary in the front passenger foot well area.

This test can also be run to examine nonlinear handling performance at other load conditions.

4.1.2.3 All equipment and ballast inside the passenger compartment of the vehicle must be secured in place. All loose equipment should be removed from the passenger compartment, including tools, extra transducers, and personal belongings.

4.1.2.4 The vehicle suspension should be aligned to nominal specifications.

4.1.2.5 With the fuel tank full, the vehicle test weights should be determined and recorded in the TVD.

4.1.2.6 Check engine oil and fill to capacity if necessary.

4.1.2.7 Check wheel lug nut torques, tire pressures, and state of tire wear at the start of each test and regularly during testing in order to identify any deviations from nominal.

4.1.2.8 Before the start of testing, use a diagnostic scan tool to extract and clear any diagnostic codes from the Electronic Stability Control (ESC) system.

4.1.2.9 The use of ESC in the default mode is the standard condition for the RAM test. Testing with ESC disabled is also a requirement. If any other modes are to be evaluated, it should be discussed with the requesting and test engineers.

4.1.3 Telltale Bulb Check. With the vehicle stationary and the ignition locking system in the "Lock" or "Off" position, activate the ignition locking system to the "On" ("Run") position or, where applicable, the appropriate position for the lamp check. The ESC malfunction telltale must be activated as a check of lamp function, as specified in FMVSS 126 S5.3.4, and if equipped, the "ESC Off" telltale must also be activated as a check of lamp function, as specified in FMVSS 126 S5.5.6. The telltale bulb check is not required for a telltale shown in a common space as specified in FMVSS 126 S5.3.6 and FMVSS 126 S5.5.8.

4.1.4 "ESC Off" Control Check. For vehicles equipped with an "ESC Off" control, with the vehicle stationary and the ignition locking system in the "Lock" or "Off" position, activate the ignition locking system to the "On" ("Run") position. Activate the "ESC Off" control and verify that the "ESC Off" telltale is illuminated, as specified in FMVSS 126 S5.5.4. Turn the ignition locking system to the "Lock" or "Off" position. Again, activate the ignition locking system to the "On" ("Run") position and verify that the "ESC Off" telltale has extinguished indicating that the ESC system has been reactivated as specified in FMVSS 126 S5.4.1.

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4.1.5 (Optional) Brake Conditioning. If new brake pads/rotors are utilized, condition the vehicle brakes as follows.

4.1.5.1 Ten stops are performed from a speed of 56 km/h (35 mph), with an average deceleration of approximately 0.5G.

4.1.5.2 Immediately following the series of 56 km/h (35 mph) stops, three additional stops are performed from 72 km/h (45 mph).

4.1.5.3 When executing the stops in 4.1.5.2, sufficient force is applied to the brake pedal to activate the vehicle's antilock brake system (ABS) for a majority of each braking event.

4.1.5.4 Following completion of the final stop in 4.1.5.2, the vehicle is driven at a speed of 72 km/h (45 mph) for 5 minutes to cool the brakes.

4.1.6 Tire Preparation.

4.1.6.1 Tire pressures should be set to the requesting engineer's recommended cold pressure for each tire, unless otherwise stated on the test request.

4.1.6.2 Tires used in the RAM test must be in excellent condition. It is not required that they be new, but should indicate typical performance for a vehicle to be evaluated with under 8047 km (5000 mi) of normal tire wear.

4.1.7 (Optional) Tire Conditioning. If new tires are utilized, condition the tires using the following procedure to wear away mold sheen and achieve operating temperature immediately before beginning Constantly Increasing Steer or Sine with Dwell test runs.

4.1.7.1 The test vehicle is driven around a circle 30 m (100 ft) in diameter at a speed that produces a lateral acceleration of approximately 0.5G to 0.6G for three clockwise laps followed by three counterclockwise laps.

4.1.7.2 Using a sinusoidal steering pattern at a frequency of 1 Hz, a peak steering wheel angle amplitude corresponding to a peak lateral acceleration of 0.5G to 0.6G, and a vehicle speed of 56 km/h (35 mph), the vehicle is driven through four passes performing 10 cycles of sinusoidal steering during each pass.

4.1.7.3 The steering wheel angle amplitude of the final cycle of the final pass is twice that of the other cycles. The maximum time permitted between all laps and passes is 5 minutes

The steering machine can be programmed to execute the sinusoidal inputs.

There should be only a minimal delay between the completion of the tire break-in and the start of a test series to allow for the collection of a static data file, steering machine and data acquisition system adjustment, and final driver briefing.

4.1.8 Operator Precautions.

4.1.8.1 A helmet (optional) and seat belts must be worn during all testing. Lock all doors and close all windows prior to testing.

4.1.8.2 The test operator (driver) must inform any others at the test site of their presence using the appropriate site-specific communications protocol.

4.2 Conditions.

4.2.1 Environmental Conditions. The test is run on dry, clean asphalt surfaces that are clear from debris.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

The test is generally conducted with automatic transmissions in drive. Manual transmissions are run in the highest gear capable of sustaining the desired test speed. The clutch is not disengaged during the test maneuver.

4.3 Instructions.

4.3.1 Test Series Overview. For each test vehicle, testing may be performed according to the following general plan:

- a. Installation of new tires.
- b. Telltale bulb check.
- c. "ESC Off" switch check.
- d. Brake conditioning.
- e. Tire conditioning.
- f. RAM test procedure.

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