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National Highway Traffic Safety Administration

PEDESTRIAN AUTOMATIC EMERGENCY BRAKE SYSTEM CONFIRMATION TEST

(WORKING DRAFT)

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16. Abstract

This draft test procedure provides methods and specifications for collecting performance data on Pedestrian Automatic Emergency Braking (PAEB) systems for light vehicles with gross vehicle weight ratings of up to 4,536 kg (10,000 lbs.). Current PAEB technology relies on forward-looking detection capability provided by sensors to actively assist the driver by automatically applying brakes to avoid or mitigate a potential contact between the equipped vehicle and pedestrians. As such, the test procedures described in the document rely on a subject vehicle crossing paths with a pedestrian mannequin.

These test procedures were developed to evaluate the PAEB systems' performance in the two most frequent crash scenarios involving pedestrian in the United States. They include the scenario in which the pedestrian crosses the road in front of the vehicle known as scenario (S1), and the scenario in which the pedestrian walks along side of the road in the path of the vehicle known as scenario (S4).

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PEDESTRIAN AUTOMATIC EMERGENCY BRAKE SYSTEM CONFIRMATION TEST

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GLOSSARY

GVWR	gross vehicle weight rating
IBT	initial brake temperature
IMU	inertial measurement unit
PAEB	pedestrian automatic emergency braking
PTM	pedestrian test mannequin
PV1	parked vehicle 1
PV2	parked vehicle 2
RCS	radar cross section
SAE	Formerly known as the Society of Automotive Engineers, and as SAE International since 2006
SV	subject vehicle
TTC	time-to-collision
WOT	wide open throttle

1.0 PURPOSE AND APPLICATION

This draft test procedure provides methods and specifications for collecting performance data on pedestrian automatic emergency braking systems for light vehicles with gross vehicle weight ratings of up to 4,536 kg (10,000 lbs.). Current PAEB technology relies on forward-looking detection capability provided by sensors to actively assist the driver by automatically applying brakes to avoid or mitigate a potential contact between the equipped vehicle and pedestrians. As such, the test procedures described in the document rely on a subject vehicle crossing paths with a pedestrian mannequin.

2.0 TEST SCENARIOS

These test procedures were developed to evaluate the PAEB systems' performance in the two most frequent crash scenarios involving pedestrian in the United States. They include the scenario in which the pedestrian crosses the road in front of the vehicle known as scenario (S1), and the scenario in which the pedestrian walks along side of the road in the path of the vehicle known as scenario (S4).

S1 is the most frequent pre-crash scenario and S4 has the second highest fatality rate. Vehicles equipped with PAEB systems are evaluated by test scenario and whether the system avoided or mitigated contact with the pedestrian test mannequin. Shown in Figure 2-1 below, is a graphic representation of the two pre-crash scenarios.

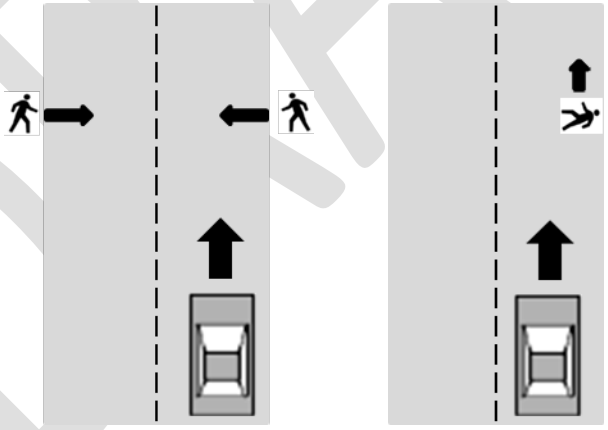


Figure 2-1 – S1 scenario left and S4 scenario right

3.0 DEFINITIONS

Nearside – The side of the vehicle closest to the curb.

Offside – The side of the vehicle closest to the center of the road.

Overlap – Location on the front of the SV where the PTM will make contact if the vehicle's speed is held constant during a test (i.e., the PAEB does not activate). Overlap is expressed in a percentage of the total vehicle width from nearside to the offside (or the reverse if the mannequin's start position is the other side) of the vehicle (0 – 100%).

Pedestrian Automatic Emergency Braking – systems are intended to actively assist the driver by automatically applying brakes to avoid or mitigate potential contact between the equipped vehicle and pedestrian. These safety systems have forward-looking detection capability provided by sensing technologies such as radar, lidar, video cameras, etc.

Test Lane – Road markers are placed on the test surface to provide a visual aid to the driver for controlling the lateral deviation of the SV. Round non-reflective raised pavement markers (Botts dots) are used to create a test lane designed to guide the vehicle to ensure repeatability. Note that the test lane is not a standard lane width since it is used to minimize the lateral deviation of the SV. The test lane width is adapted to the vehicle width plus an additional tolerance.

Vehicle Width – SV width is the distance between two planes parallel to the longitudinal centerline defined by the left and right-side outermost edges of the SV's body. Use of a highly accurate portable coordinate measuring machine is recommended for making the vehicle dimension measurements.

Zero Position – Used as the reference point for calculating trigger timing to begin motion of the PTM. It also serves as an indication of SV-to-PTM contact.

Reveal Time – Reveal time is the time at which the pedestrian is first visible to the vehicle's forward-looking sensors. Obstructions and a sensors field of view can limit the reveal time.

4.0 GENERAL REQUIRMENTS

4.1 Test Track

Unless specified otherwise, the road test surface shall be dry (without visible moisture on the surface), straight, and flat, with a consistent slope between level and one percent. The road surface shall be constructed from asphalt or concrete and shall be free of irregularities, undulations, and/or cracks that could cause unwanted movement of the SV.

Each trial shall be conducted with no other vehicles, obstructions, or stationary objects within one lane width of either side of the SV test lane of travel except when explicitly stated.

4.2 Ambient Conditions

4.2.1 Temperature

The ambient temperature shall be between 45°F (7°C) and 104°F (40°C).

4.2.2 Wind Speed

The wind speed shall be below 24 km/h (15 mph). Gusts may be disregarded, if they do not affect the stability of the mannequin.

4.2.3 Inclement Weather

Tests shall not be performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, and/or ash.

4.2.4 Visibility

The tests shall be conducted during daylight hours with good atmospheric visibility, defined as an absence of fog and the ability to see clearly for at least 5.0 km (3.1 mi). The tests shall not be conducted during very low sun angle conditions (where the sun is oriented 15 degrees or less from horizontal) as camera "washout" or system inoperability may result.

All tests shall be conducted in an area void of overhead signs, bridges, or other significant structures over or near the testing site. Each trial shall be conducted with no vehicles, obstructions, or stationary objects within one lane width of either side of the SV path, unless otherwise specified. Shadows cast by objects other than the SV, test equipment, or the obstructing vehicles shall not be present in the SV lane of travel, or within one lane width of either side of the SV path.

4.3 Test Equipment Specifications

4.3.1 Obstruction Vehicles

Two parked vehicles positioned along the nearside of the test lane are used as obstructions. The obstructions block the view of the pedestrian from the vehicle sensors limiting the reveal time (the time that the vehicle's sensors have to process that a pedestrian is approaching the SV lane of travel). Obstruction Vehicle 1 is a dark-colored vehicle positioned closest to the pedestrian path. Its dimensions approximate those of a midsize sedan (i.e., similar to the dimensions of a 2010 Ford Fusion):

A. Vehicle length: ≈4.77 m (15.6 ft)

B. Vehicle width: ≈1.80 m (5.90 ft)

C. Vehicle height: ≈1.44 m (4.72 ft)

Obstruction Vehicle 2 is a dark colored vehicle positioned behind Obstruction Vehicle 1. Its dimensions represent a midsize sport utility vehicle (i.e., similar to the dimensions of a 2003 Toyota 4Runner):

A. Vehicle length: ≈4.72 m (15.4 ft)

B. Vehicle width: ≈1.85 m (6.0 ft)

C. Vehicle height: ≈1.67 m (5.47 ft)

4.3.2 Pedestrian Test Mannequin

All testing described in this document will include the use of a pedestrian test mannequin. Scenarios S1 (a-b-c-e-f-g) and S4 (a-b-c) will test with a mannequin that has the characteristics representative of a 50th percentile adult male. Scenario S1 (d) will test with a mannequin that has the characteristics representative of a 7-year-old child. The adult and child test mannequins are posable with adjustable leg and arm spacing that do not move while testing. Specifically, the test mannequins shall possess the following attributes:

A. Basic body proportions from any angle that represent the adult and child description in section 4.3.2

B. Must include a head, torso, two arms, and two legs.

C. Must be clothed with a black long-sleeved shirt and blue long pants.

D. Posable with adjustable leg and arm spacing that do not move relative to itself while testing (non-articulating).

E. RCS characteristics consistent with the adult and child description in section 4.3.2

F. Remains consistently shaped (e.g., visually, dimensionally, internally, and from a RADAR sensing perspective).

G. Resistant to damage resulting from repeated contact.

H. Inflicts minimal to no damage to the SV, even in the event of multiple collisions.

Note: *The 4activePS pedestrian static developed by 4Active Systems [2] is used as the PTM for collecting performance data on vehicles equipped with PAEB technology. The 4ActivePS pedestrian static mannequins are developed for testing vehicles equipped with PAEB technology. These test mannequins provide a realistic level of fidelity when it is not possible to fully evaluate (e.g. crash imminent situations) the PAEB systems with actual pedestrians.*

4.3.3 Pedestrian Test Target Motion Apparatus Performance Needs

A. Control the speed of the pedestrian test target.

B. Control the position of the pedestrian test target.

C. Accelerate the pedestrian test target to the test speed within the necessary distance.

D. Trigger the motion of the pedestrian test target to achieve the necessary contact point (overlap).

E. Shall perform cross path S1 and in path S4 scenarios.

F. Support the pedestrian test target until contact with the SV.

G. Allow the pedestrian test target to move away from the SV after contact has occurred.

H. Minimal radar-cross-section and minimal optical features (e.g. test vehicle PAEB system should not activate (warn/brake) if test describe in this procedure are conducted without using a pedestrian test target.

Note: *The soft pedestrian target system developed by Anthony Best Dynamics [3] is used for PTM controlled motion and to synchronize events with the SV. The four main components of the SPT are the drive mechanism, belt, platform, and return pully. The SPT can be configured to accommodate PTM motion for the S1 and S4 scenarios.*

5.0 INSTRUMENTATION AND CALIBRATION

5.1 Test Equipment

A. Portable tire pressure gage with an operating pressure of at least 700kPa (100 psi),

graduated increments of 1.0 kPa (0.1 psi) and an accuracy of at least ± 2.0 percent of the applied pressure.

B. Global positioning system comprised of a base station and rover, with post-processing software.

C. Data acquisition system to record the audible alert status, time, GPS data (i.e., SV lateral and longitudinal position, GPS fix type), SV longitudinal speed, SV yaw rate, SV brake pedal application, SV throttle position, SV longitudinal acceleration, PTM longitudinal speed, and PTM longitudinal and lateral position.

D. Signal conditioning shall consist of amplification, anti-alias filtering, and digitizing. Amplifier gains are to be selected to maximize the signal-to-noise ratio of the digitized data.

5.2 Calibration

5.2.1 Test Vehicle Measurements and Preparation

A. The vehicle tires shall be inflated to the recommended cold inflation pressure as specified on the vehicle placard or optional tire inflation pressure label.

B. All non-consumable fluids must be at manufacture suggested levels. Fuel must be maintained at least 75 percent capacity during the testing.

C. The vehicle shall be loaded with one driver and all required equipment during the testing. The vehicle weight should be measured and recorded with the driver and all required equipment included.

D. Vehicle dimensional measurements shall be taken. For purposes of this test procedure, vehicle dimensions shall be represented by a two-dimensional polygon defined by the lateral and longitudinal dimensions relative to the centroid of the vehicle using the standard SAE vehicle coordinate system. The overall vehicle length (longitudinal aspect of the polygon) shall be measured from the foremost point on the front bumper to the rearmost point on the rear bumper. SV width is the distance between two planes parallel to the longitudinal centerline defined by the left- and right-side outermost edges of the SV's body not including the outside rearview mirrors.

E. The lateral, longitudinal, and vertical position of the GPS antenna shall be measured and recorded.

6.0 TEST VEHICLE

6.1 Instrumentation

Each test vehicle shall be equipped with instrumentation and a data acquisition system. Nominal equipment location and weight specifications are presented in Table 6-1.

Table 6-1 - Test Equipment Location and Weights

Equipment Description	Typical Location	Nominal Weight
Data Acquisition System	SV rear cargo area (e.g., trunk)	26 kg (57 lbs.)
Integrated Inertial Measurement Unit and GPS (SV)	Antenna[1] mounted to the roof of the SV. IMU/GPS securely positioned near the center of the vehicle, just behind the front seats. GPS acquisition and ancillary equipment installed/secured in the SV	7 kg (15 lbs.)
Vehicle-to-Apparatus Transmitter (SV) *(wireless communication between the SV and pedestrian motion apparatus)*	Antenna mounted to the roof of the SV. Ancillary equipment secured in the SV rear cargo area.	5 kg (10 lbs.)

[1]Two antennas are necessary if communication with a local base station is used (i.e., to provide real time kinematic correction of GPS position data).

6.1.1 Data Collection

All analog data shall be sampled at 100 Hz. Signal conditioning shall consist of amplification and digitizing. Amplifier gains shall be selected to maximize the signal-to-noise ratio of the digitized data.

6.1.2 Sensor and Sensor Locations

An overview of the sensors used for the tests described in this document is provided in Table 6-2.

Table 6-2 - Recommended Sensor Specifications

Type	Output	Range	Resolution	Accuracy
Longitudinal Speed Sensor	SV longitudinal speed	0.1 – 100 km/h (0.1 - 62 mph)	0.2 km/h (0.1 mph)	+/- 0.25 % of full scale
Rate Sensor	SV yaw rate	+/- 100 deg/s	0.01 deg/s	+/- 0.25 % of
Accelerometer	SV longitudinal deceleration	+/- 2g	0.001g	+/- 0.01 % of
Position Sensor	SV throttle position	0 – 100 % (normalized)	1%	1%
Contact Sensor	SV brake pedal apply	On/Off	NA	NA
Various	Longitudinal position of SV	200 m (650 ft)	5 cm (2 in)	At least 10 cm (3.9 in)
Various	SV lateral position	200 m (650 ft)	5 cm (2 in)	At least 10 cm (3.9 in)
Various	PAEB system warning from SV indicating whether the warning is in operation.	0 – 10V	N/A	Output response < 10 ms
Temperature	Brake lining temperature each wheel.	1200 ^{o}F (649 C)	1 ^{o}F	+/- 10 ^{o}F (5.6 C)
Vehicle Dimensional Measurements	Location of SV GPS antenna; SV centerline (where applicable); front-most SV bumper position; SV width	N/A	1 mm (0.04 in)	1 mm (0.04 in)

6.1.2.1 SV Speed

SV longitudinal vehicle speed shall be measured and recorded for each test. Sensor outputs are to be transmitted not only to the data acquisition system, but also to a dashboard display unit in the SV. This allows the driver to accurately monitor vehicle speed.

6.1.2.2 SV Acceleration

SV longitudinal acceleration shall be measured and recorded for each test.

6.1.2.3 SV Position

SV longitudinal and lateral position shall be measured and recorded for each test.

6.1.2.4 SV Yaw Rate

SV yaw rate shall be measured and recorded for each test.

6.1.2.5 SV Throttle Pedal Position

SV throttle pedal position shall be measured to ensure driver has removed input from the throttle when the SV warning event is recognized. SV throttle pedal position shall be expressed as a percentage of the wide-open throttle pedal position.

6.1.2.6 SV Brake Pedal Apply

SV brake pedal input shall be measured to ensure that the driver did not apply force to the pedal during the test. If the driver does apply force to the brake pedal during tests, the test trial is not valid and shall be repeated.

6.1.2.7 SV PAEB Warning Event

SV PAEB warning shall be measured to ensure the driver has responded by removing input to the throttle pedal. The warning event shall be recorded from a discrete signal and/or other methods that clearly indicate when the warning event has been issued provided there is no damage to the SV.

6.1.2.8 SV Brake Temperature

SV brake temperature shall be measured at each wheel to ensure brake temperature is maintained. Brake temperatures shall be logged and displayed to the SV driver during test conduct.

6.1.2.9 PTM Speed

PTM speed shall be measured and recorded for each test.

6.1.2.10 PTM Position

PTM longitudinal position shall be measured and recorded for each test.

7.0 TEST EXECUTION AND TEST REQUIRMENTS

If the SV is equipped with an automatic transmission, all trials shall be performed in ‘‘Drive.’’ If equipped with a manual transmission, the highest gear capable of sustaining the desired test speed shall be used. Manual transmission clutches are to remain engaged throughout the validity period.

8.0 PRE-TEST CONDITIONING

8.1 SV Brake Burnish

To achieve full brake system capability, and to ensure consistent performance, the procedure defined in section 14.1.2 and section 14.1.3 of NHTSA Laboratory Test Procedure for FMVSS No. 135 Light Vehicle Brake Systems (TP-135-01) [2] shall be used to burnish new SV brake components.

8.2 SV Brake Warm-up and Temperature Maintenance

The initial brake temperature shall be between 149°F (65°C) and 212°F (100°C) at the onset of each test.

A. If the IBT is less than 149°F (65°C), the brakes are heated to the IBT by making one or more brake applications from a speed of 31.1 mph (50 km/h), at a deceleration rate not greater than 0.31g (3 m/s^2).

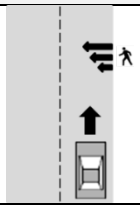
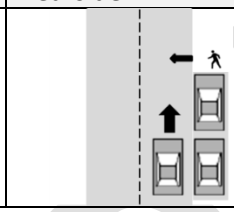
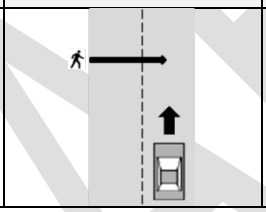
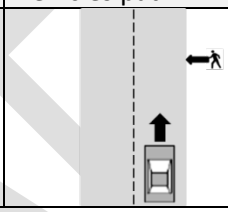
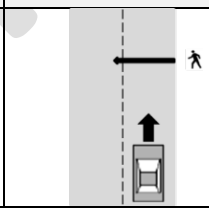
B. If the IBT is greater than 212°F (100°C), the SV shall be driven at speeds up to 62.1 mph (100 km/h) until the IBT specified in this section is reached.

9.0 PEDESTRIAN AUTOMATIC EMERGENCY BRAKING TEST SCENARIOS

9.1 (S1) Crossing Pedestrian

The following test conditions in Table 6-1 for the S1 scenario are suggested to evaluate PAEB system performance.

Table 6-1 Summary of S1 Crossing Scenarios

S1a-b-c	S1d	S1e	S1f	S1g
These tests evaluate the ability of the SV PAEB system to detect and respond to a crossing adult pedestrian walking into the SV path from the nearside.	This test evaluates the ability of the SV PAEB system to detect and respond to a crossing child pedestrian running into the SV path from behind parked vehicles from the nearside	This test evaluates the ability of the SV PAEB system to detect and respond to a crossing adult pedestrian running into the SV path from the offside.	This test evaluates how the SV PAEB system will respond to a crossing adult pedestrian walking from the nearside and stops short of entering the vehicles path.	This test evaluates how the SV PAEB system will respond to a crossing adult pedestrian walking from the nearside and clears the vehicle's path.
				

9.1.1 S1a-b-c-d-f-g Test Course Setup

S1a-b-c-d-f-g Scenario			Drawing illustrates setup but is not to scale
PTM Type	Adult (S1a-b-c-f-g) Child (S1d)		
PTM Location	Nearside		
PTM Action	Crossing SV Path (S1a-b-c-d-g)		
	Not Crossing SV Path (S1f)		
PTM Move Distance	6 m (19 ft)		
PTM Start Distance	3.5 m (11.48 ft)		
PTM Acceleration Distance	0.5 m (1.64 ft)		
Overlap *(Determined from the SV width. Measurement transferred to the location on the PTM route. Minus 25% and 125% do not result in a SV-PTM contact.)*	S1a	25%	
	S1b-d	50%	
	S1c	75%	
	S1f	-25%	
	S1g	125%	
SV Start Distance	182 m (600 ft)		
Lane Width *(Not standard lane width. Adapted to SV width. Lane width should be centered on SV path.)*	SV Width + 40 cm (16 in)		
Lane Length *(Based on 4.0 sec TTC and SV speed = 40 kph (25 mph).)*	44 m (145 ft)		
Obstruction *(S1d only)*	PV1D1	1 m (3.2 ft)	
	PV2D1	1 m (3.2 ft)	
	PVD1	1 m (3.2 ft)	
-	-		

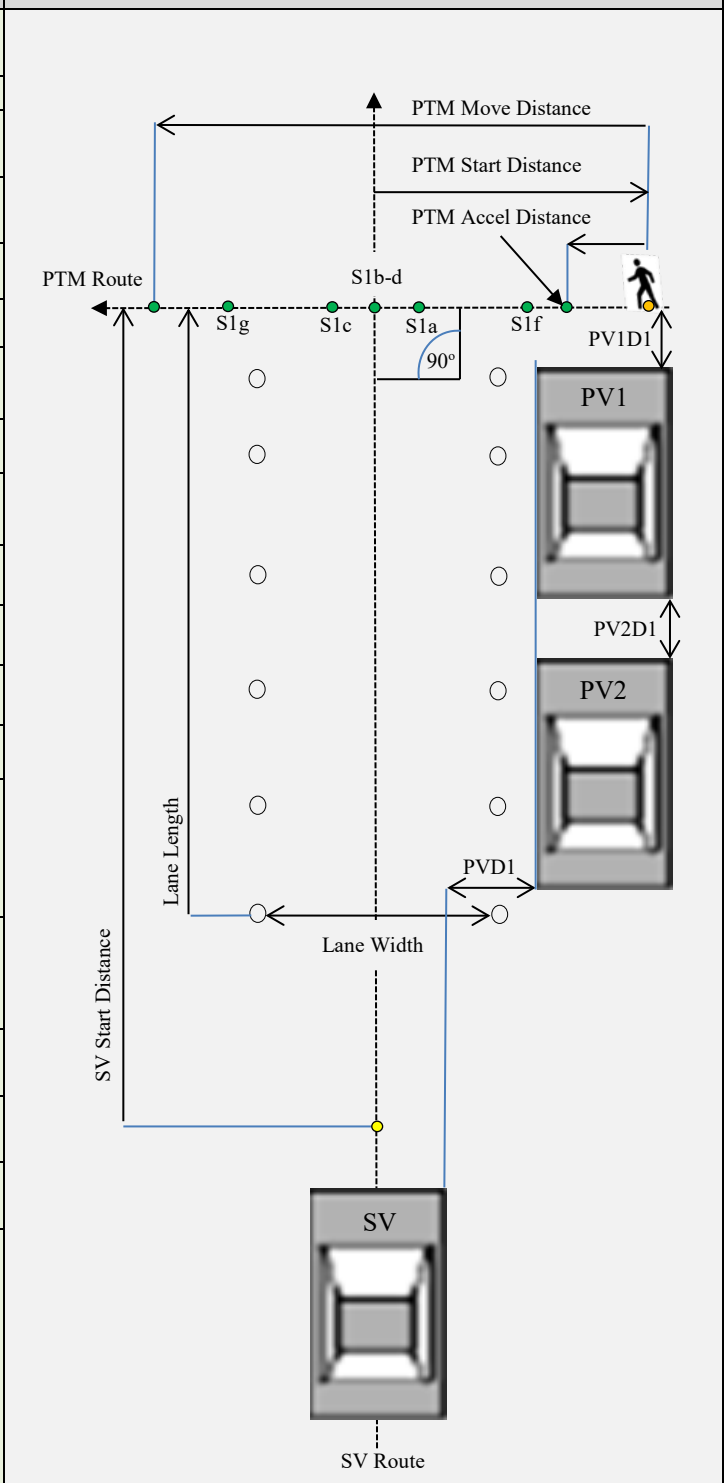


Figure 9-1 S1a-b-c-d-f-g Test Course Setup

9.1.2 S1e Test Course Setup

S1e Scenario			Drawing illustrates setup but is not to scale
PTM Type	Adult		
PTM Location	Offside		
PTM Action	Crossing SV Path		
PTM Move Distance	9 m (29.5 ft)		
PTM Start Distance	5.5 m (18 ft)		
PTM Acceleration Distance	1.0 m (3.2 ft)		
Overlap *(Determined from the SV width. Measurement transferred to the location on the PTM route.)*	S1e	50%	
SV Start Distance	182 m (600 ft)		
Lane Width *(Not standard lane width. Adapted to SV width. Lane width should be centered on SV path.)*	SV Width + 40 cm (16 in)		
Lane Length *(Based on 4.0 sec TTC and SV speed = 40 kph (25 mph).)*	44 m (145 ft)		
Obstruction *(S1d only)*	PV1D1	--	
	PV2D1	--	
	PVD1	--	
--	--		

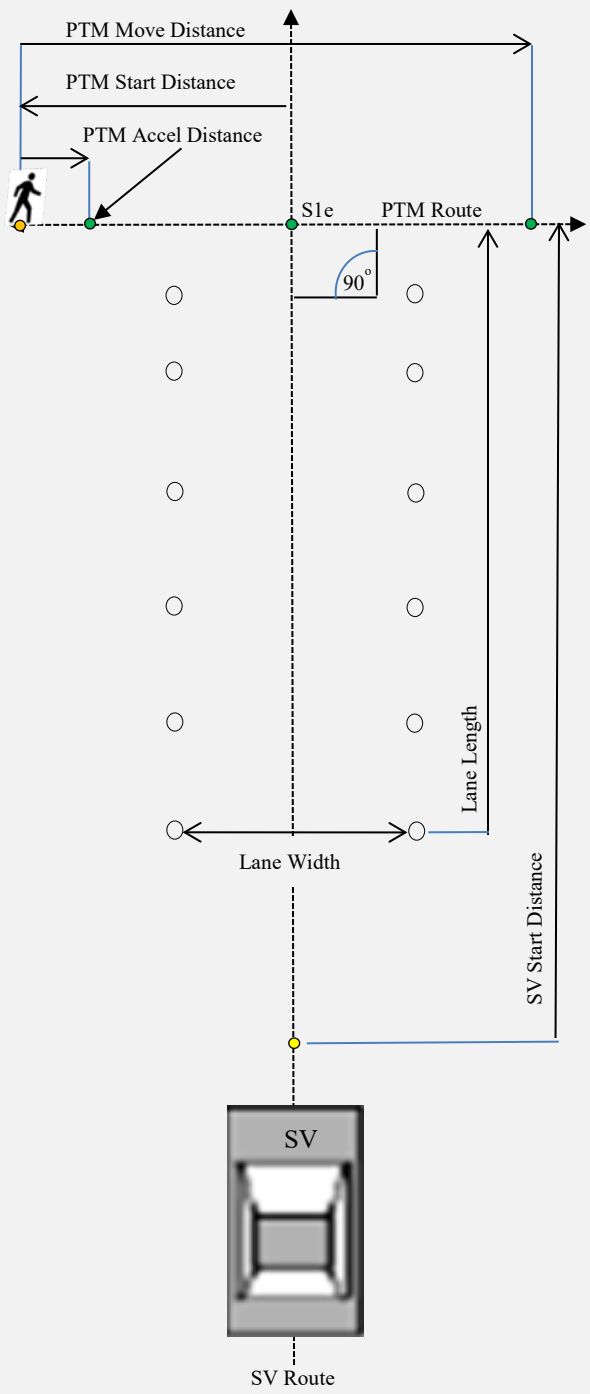


Figure 9-2 S1a-b-c-d-f-g Test Course Setup

9.1.3 Pedestrian Test Mannequin Placement and Movement

For tests S1a-b-c-d-f-g, the PTM is positioned 3.5 m (11.5 ft) from the SV centerline on the nearside and its orientation is also perpendicular to the SV centerline. For tests S1e the PTM is positioned 5.5 m (18.0 ft) from the SV centerline on the offside and its orientation is also perpendicular to the SV centerline.

Trigger timing for the S1 tests assumes that the SV will approach the crossing PTM at a constant speed with no PAEB system intervention. Trigger timing for the

- S1a test is set up so that the PTM will contact the front of the SV at 25 percent of the SV width.

- S1b-d-e is set up so that the PTM will contact the front of the SV at 50 percent of the SV width which is also the center of the SV.

- S1c test is set up so that the PTM will contact on the front of the SV at 75 percent of the SV width.

- S1f is set up so that the PTM will contact the front of the SV at 50 percent of the SV width, but the PTM forward motion is stopped at -25 percent of the SV width. Meaning the PMT will not enter the direct path of the SV.

- S1g test is set up so that the PTM will clear the direct path of the SV. For calculating trigger timing for PTM motion 125 percent of the SV width is used.

The start position of the PTM from the SV centerline for all S1 test conditions remains the same regardless of trigger timing adjustments for the different SV contact locations (overlaps).

9.1.4 SV Zero Position

1. The SV and PTM shall be centered on the SV centerline with the PTM facing the direction specified for each test scenario.

2. The front-most location of the SV shall be positioned such that it just contacts the PTM. This is the “zero position.” The zero position does not change based on different overlap test conditions. The arms of the PTM are not to be considered contact points.

3. The zero position shall be documented both prior to and immediately after conduct of a test series.

9.1.5 SV Approach to a Crossing Pedestrian (S1)

For each test trial to be valid, the following criteria should be met.

A. The PTM shall be secured to the apparatus for motion such that its position relative to the apparatus remains constant.

B. The PTM is at the start position distance on the PTM route from the SV route and shall not move until the triggering criteria for motion are met.

    1. PTM start position nearside: 3.5 m (11.5 ft)

    2. PTM start position offside: 5.5 m (18.0 ft)

C. When triggered, the PTM shall accelerate to the test speed in the required distance and hold that test speed until PTM is clear of the SV path, stops short of entering the SV path, or a contact event by the SV.

    1. PTM speed = 5 km/h (3.1 mph) = acceleration distance 0.5 m (1.64 ft)

    2. PTM speed = 8 km/h (4.9 mph) = acceleration distance 1.0 m (3.28 ft)

D. While the PTM is in motion, the PTM route should remain perpendicular to the SV Route. Lateral deviations induced by wind, equipment, or surface conditions should be monitored.

9.1.5.1 SV Approach

For an individual test trial to be valid, the following must hold true throughout the test:

A. The SV driver seatbelt must be latched.

B. SV Driver shall cycle ignition.

C. The SV shall be driven at the nominal speed specified for each test.

    1. SV: 16 km/h (10 mph)

    2. SV: 40 km/h (25 mph)

D. Test begins when the longitudinal Time-to-Collision (TTC) of the SV = 4.0 seconds.

1. When the SV speed is 16 and 40 km/h, TTC = 4.0 seconds will occur at the following distance.

    i. SV 16 km/h (10 mph): TTC = 4.0 seconds occurs at 17.7 m (58 ft)
    ii. SV 40 km/h (25 mph): TTC = 4.0 seconds occurs at 44.4 m (145.6 ft)

2. The driver shall use the least amount of steering input necessary to maintain SV position in the center of the test lane. The test lane is a guide for the driver to control the lateral deviation of the SV. If it is observed that the SV tires crossed the boundary of the test lane on either side the test should be repeated. The test lane is the width of the SV plus 40 cm (16 in).

3. The yaw rate of the SV must not exceed ± 1.0 deg/s.

4. The SV driver shall modulate the throttle, using smooth inputs, to maintain a constant SV speed.

5. The SV driver shall not apply any force to the brake pedal unless the PTM is contacted or the front of the SV has crossed the route of the PTM.

E. The instant the SV PAEB warning event is presented (visual, haptic, or audible) the SV throttle shall be fully released (within 500 msec). If no SV warning event is presented by the SV PAEB system, the SV driver shall modulate the throttle to maintain a constant speed until either the onset of PAEB or, if the SV's PAEB does not activate, the end of the test occurs (i.e., contact with the PTM occurs).

9.1.5.2 Validity Period

A. The valid test interval begins when the longitudinal TTC of the SV = 4.0 seconds, as defined in section 9.1.5.1C1.

B. Test ends when any of the following occurs for scenario S1a-b-c-d-e:

1. The SV contacts the PTM; or
2. The SV stops (PAEB) before contacting the PTM; or
3. The PTM clears the direct path of the SV.

C. Test ends when the following occurs for scenario S1f-g:

1. The front of the SV crosses the route of the PTM (i.e., the front most location of the SV front bumper crosses the zero position described in section 9.1.4).

9.1.5.3 End-of-Test Instructions

A. After the test is complete, the SV driver shall manually apply force to the brake pedal, bring the vehicle to a stop (if necessary), and place the transmission in park (automatic transmission) or neutral (manual transmission).

B. The test trial is complete.

9.1.5.4 Number of Test Trials

Perform the number of test trials shown in Table 9-1.

Table 9-1 - Number of Test Trials for PAEB Scenario S1

Scenario	SV Speed	PTM Speed	Number of Test Trials
S1a	16 km/h	5 km/h	7 trials
	40 km/h	5 km/h	7 trials
S1b	16 km/h	5 km/h	7 trials
	40 km/h	5 km/h	7 trials
S1c	16 km/h	5 km/h	7 trials
	40 km/h	5 km/h	7 trials
S1d	16 km/h	5 km/h	7 trials
	40 km/h	5 km/h	7 trials
S1e	40 km/h	8 km/h	7 trials
S1f	40 km/h	5 km/h	7 trials
S1g	40 km/h	5 km/h	7 trials

9.1.5.5 Speed Reduction

The magnitude of the SV speed reduction attributable to PAEB intervention is calculated in one of two ways, depending on whether a test trial concludes with the SV colliding with the PTM. For scenario S1a-b-c-d-e:

A. If the SV contacts the PTM during a test trial, the PAEB speed reduction is calculated by subtracting the SV speed at the time of contact (i.e., when longitudinal range becomes zero) from the average SV speed calculated from TTC = 4.0 seconds.
B. If the SV does not contact the PTM during a test trial (i.e., PAEB intervention prevents the crash), the SV speed at the time of SV and PTM contact is taken to be zero. The speed reduction is therefore equal to the SV speed at TTC = 4.0 seconds.

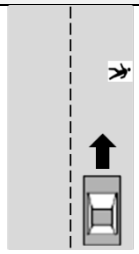
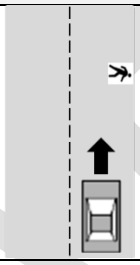
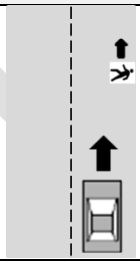
9.1.5.6 Deceleration

A. SV decelerations within the validity period described in section 9.1.5.2C shall be documented for each test trial performed for the S1f-g scenario.

9.2 (S4) Pedestrian Walking Along/Against Traffic

The following test conditions in Table 9-2 for the S4 scenario are suggested to evaluate PAEB system performance.

Table 9-2 Summary of S4 in-Path Scenarios

S4a	S4b	S4c
SV encounters an adult pedestrian standing in front of the vehicle on the nearside of the road facing away from the vehicle.	SV encounters an adult pedestrian standing in front of the vehicle on the nearside of the road facing towards the vehicle.	SV encounters an adult pedestrian walking in front of the vehicle on the nearside of the road away from the vehicle.
		

9.2.1 S4a-b Test Course Setup

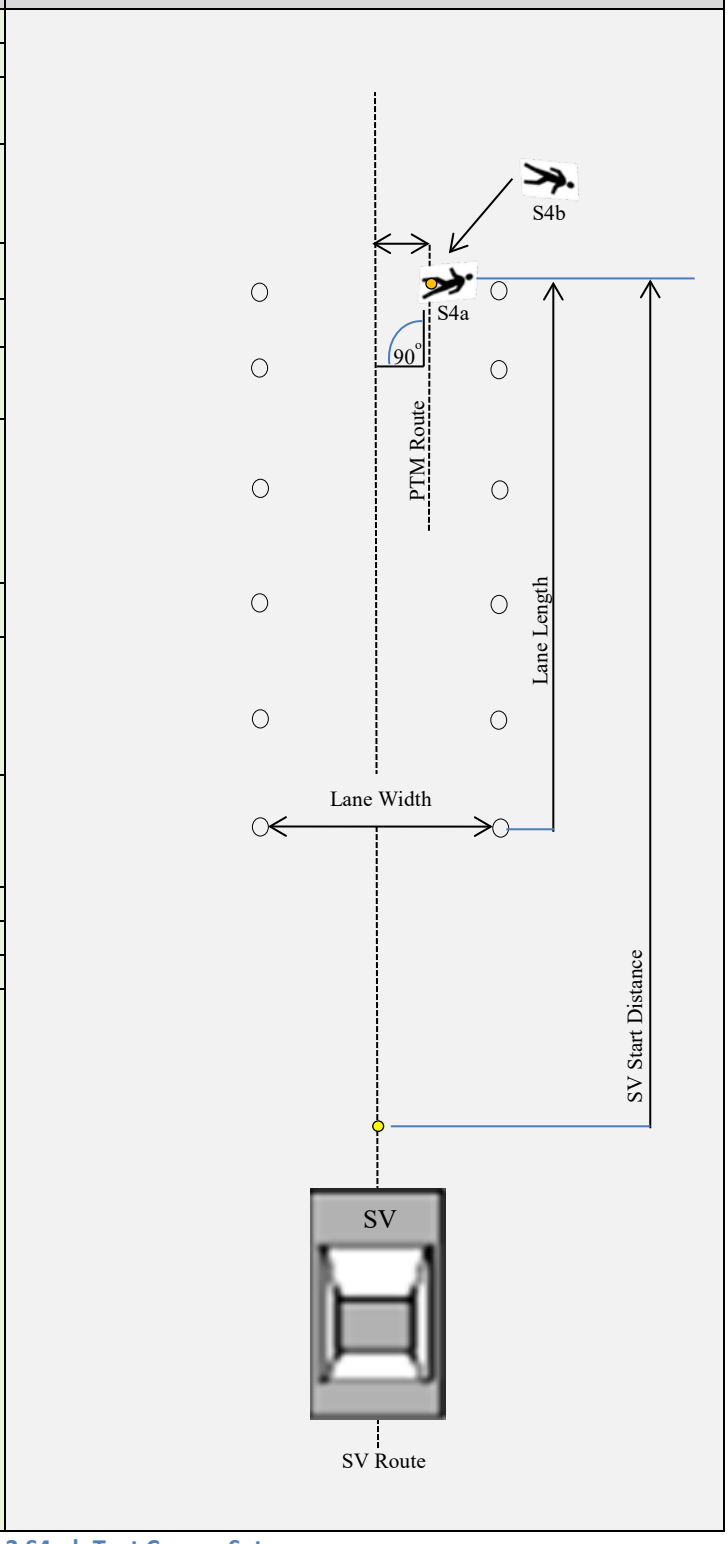
S4a-b Scenario			Drawing illustrates setup but is not to scale
PTM Type	Adult		
PTM Location	Nearside In-Path		
PTM Action	S4a	Stationary Facing Away	
	S4b	Stationary Facing Towards	
PTM Move Distance	Na		
PTM Start Distance	Na		
PTM Acceleration Distance	Na		
Overlap *(Determined from the SV width. Measurement transferred to the location on the PTM route.)*	25%		
SV Start Distance	182 m (600 ft)		
Lane Width *(Not standard lane width. Adapted to SV width. Lane width should be centered on SV path.)*	SV Width + 40 cm (16 in)		
Lane Length *(Based on 4.0 sec TTC and SV speed = 40 kph (25 mph).)*	44 m (145 ft)		
Obstruction *(S1d only)*	PV1D1	Na	
	PV2D1	Na	
	PVD1	Na	
-	-		

Figure 9-3 S4a-b Test Course Setup

9.2.2 S4c Test Course Setup

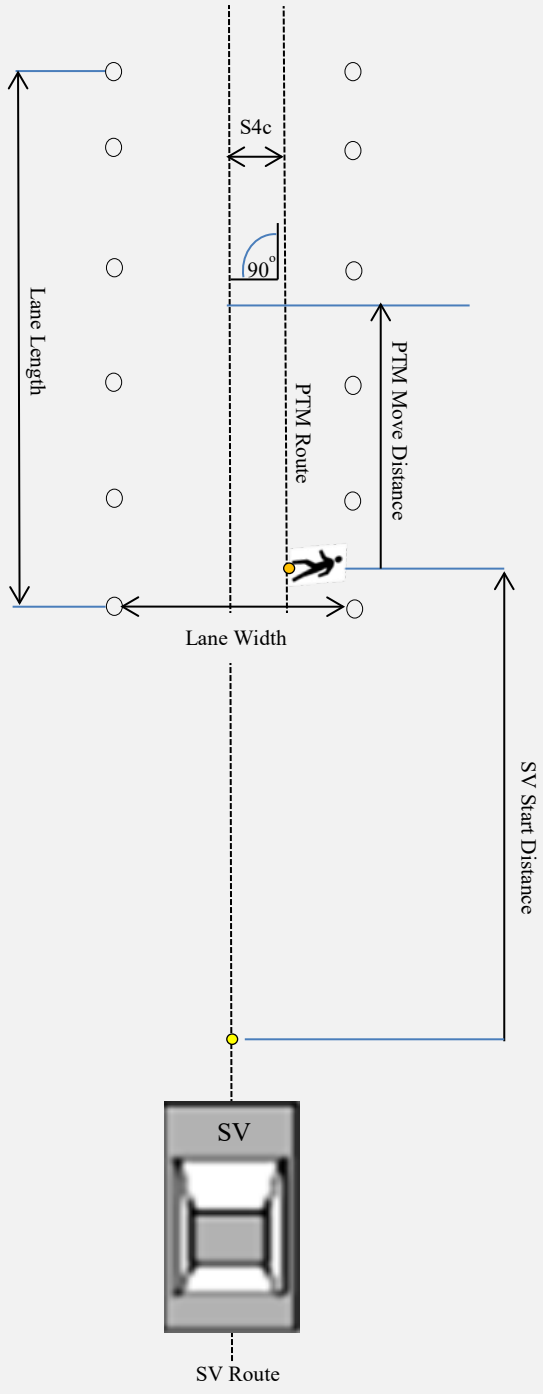
S4c Scenario			Drawing illustrates setup but is not to scale
PTM Type	Adult		
PTM Location	Nearside In Path		
PTM Action	Moving Away		
PTM Move Distance	17 m (55 ft)		
PTM Start Distance	Na		
PTM Acceleration Distance	1 m (3.28 ft)		
Overlap *(Determined from the SV width. Measurement transferred to the location on the PTM route.)*	25%		
SV Start Distance	182 m (600 ft)		
Lane Width *(Not standard lane width. Adapted to SV width. Lane width should be centered on SV path.)*	SV Width + 40 cm (16 in)		
Lane Length *(Based on 4.0 sec TTC and SV speed = 40 kph (25 mph).)*	44 m (145 ft)		
Obstruction *(S1d only)*	PV1D1	Na	
	PV2D1	Na	
	PVD1	Na	
-	-		

Figure 9-4 S4c Test Course Setup

9.2.3 PTM Placement and Movement

For tests S4a – S4c the PTM is positioned in the direct path of the SV at a 25 percent overlap on the nearside. The orientation of the PTM is either facing toward or away from the SV and is either stationary or moving for the duration of the tests.

No trigger time is needed for S4a and S4b. The PTM remains stationary for the duration of the test. Trigger timing for the S4c test is set up so that the PTM will be moving and reach steady state speed for a TTC of 7 seconds before SV-to-PTM contact would occur if there was no PAEB system intervention.

9.2.4 SV Zero Position

1. The SV shall be centered on the SV route at the start of the test lane. The PTM is located on the PTM route which is parallel to the SV route inside the test lane located on the nearside. The SV overlap is 25 percent of the SV width which is the distance between the SV route and the PTM route. The PTM shall face the direction specified for each test scenario.

2. The SV shall be positioned such that it just contacts the PTM. This is the “zero position.” The arms of the PTM are not to be considered contact points.

3. The zero position shall be documented prior to, and immediately after, conduct of a test series.

9.2.5 SV Approach to a PTM in the SV Forward Path

For each test trial to be valid, the following criteria should be met.

A. The PTM shall be secured to the apparatus for motion such that its position relative to the apparatus remains constant.

B. The PTM is at the start position distance on the PTM route and shall not move until the triggering criteria (only S4c) for motion are met.

C. When triggered (only S4c), the PTM shall accelerate to the test speed in the required distance and hold that test speed until a contact event or the SV speed is reduced to zero and no contact has occurred.

    1. PTM speed = 5 km/h (3.1 mph) = acceleration distance 1.0 m (3.28 ft)

D. While the PTM is in motion (only S4c), the PTM route should remain parallel to the SV

route. Lateral deviations induced by wind, equipment, or surface conditions should be monitored.

9.2.5.1 SV Approach

For an individual test trial to be valid, the following must hold true throughout the test:

A. The SV driver seatbelt must be latched.

B. SV Driver shall cycle ignition.

C. The SV shall be driven at the nominal speed specified for each test.

1. SV: 16 km/h (10 mph)

2. SV: 40 km/h (25 mph)

D. For scenario S4c only, mannequin motion begins when the longitudinal TTC of the SV = 7.0 seconds.

- TTC = 7.0 seconds occurs at 77.7 m (255 ft) at SV 40 km/h (25 mph)

E. Test begins when the longitudinal TTC of the SV = 4.0 seconds.

- TTC = 4.0 seconds occurs at 17.7 m (58.0 ft) at SV 16 km/h (10 mph)
- TTC = 4.0 seconds occurs at 44.4 m (145.7 ft) at SV 40 km/h (25 mph)

1. When the SV speed is 16 and 40 km/h, TTC = 4.0 seconds will occur at the following distance.

   i. SV 16 km/h (10 mph): TTC = 4.0 seconds occurs at 17.7 m (58 ft)
   ii. SV 40 km/h (25 mph): TTC = 4.0 seconds occurs at 44.4 m (145.6 ft)

2. The driver shall use the least amount of steering input necessary to maintain SV position in the center of the test lane. The test lane is a guide for the driver to control the lateral deviation of the SV. If it is observed that the SV tires crossed the boundary of the test lane on either side the test should be repeated. The test lane is the width of the SV plus 42 cm (16.5 in).

3. The yaw rate of the SV must not exceed ± 1.0 deg/s.

4. The SV driver shall modulate the throttle, using smooth inputs, to maintain a constant SV speed.

5. The SV driver shall not apply any force to the brake pedal unless the PTM is contacted or the SV has come to a complete stop (speed = 0) because the PAEB system has activated and prevented PTM contact.

F. The instant the SV PAEB warning event is presented (visual, haptic, or audible) the SV throttle shall be fully released. If no SV warning event is presented by the SV PAEB system, the SV driver shall modulate the throttle to maintain a constant speed until either the onset of PAEB or, if the SV's PAEB does not activate, the end of the test occurs (i.e., contact with the PTM occurs).

9.2.5.2 Validity Period

A. The valid test interval begins when the longitudinal TTC of the SV = 4.0 seconds, as defined in section 9.2.5.1D.

B. Test ends when any of the following occurs:

1. Test Scenario S4a-b

i. The SV comes in contact with the PTM; or
ii. The SV comes to a stop before making contact with the PTM.

2. Test Scenario S4c

i. The SV comes in contact with the PTM; or
ii. 1 second after the velocity of the SV becomes less than or equal to that of the pedestrian target.

9.2.5.3 End-of-Test Instructions

A. After the tests is complete, the SV driver shall manually apply force to the brake pedal, bring the vehicle to a stop (if necessary), and place the transmission in park (automatic transmission) or neutral (manual transmission).

B. The test trial is complete.

9.2.5.4 Number of Test Trials

Perform the number of test trials shown in Table 9-3.

Table 9-3 - Number of Test Trials for PAEB Scenario S4

Scenario	SV Speed	PTM Speed	Number of Test Trials
S4a	16 km/h	Stationary	7 trials
	40 km/h	Stationary	7 trials
S4b	16 km/h	Stationary	7 trials
	40 km/h	Stationary	7 trials
S4c	40 km/h	5 km/h	7 trials

9.2.5.5 Speed Reduction

The magnitude of the SV speed reduction attributable to PAEB intervention is calculated in one of two ways, depending on whether a test trial concludes with the SV colliding with the PTM.

A. If the SV contacts the PTM during a test trial the PAEB speed reduction is calculated by subtracting the SV speed at the time of contact (i.e., when longitudinal range becomes zero) from the average SV speed calculated from TTC = 4.0 seconds.

B. If the SV does not contact the PTM during a test trial:

    1. Tests S4a-b

        i. If the SV does not contact the PTM during a test trial (i.e., PAEB intervention prevents the crash), the SV speed at the time of SV and PTM contact is taken to be zero. The speed reduction is therefore equal to the SV speed at TTC = 4.0 seconds.

    2. Test Scenario S4c

        i. The PAEB speed reduction is calculated by subtracting the SV speed at the minimum longitudinal SV-to-PTM range during the validity period specified in section 16.5.3.2A from the SV speed at TTC = 4.0 seconds.

10.0 REFERENCES

[1] National Highway Traffic Safety Administration. (2005, December 2). Laboratory Test Procedure or FMVSS 135, Light Vehicle Brake Systems (Test No. TP-135-01). Washington, DC: Author. Available at https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/tp-135-01.pdf

[2] 4activeSystems GmbH. (n.a.). 4activePS pedestrian static (Web page). Traboch, Austria: Author. Available at www.4activesystems.at/en/products/dummies/4activeps.html

[3] Anthony Best Dynamics Ltd. (2017, November 2). Soft Pedestrian Target, SP-6030 (Web page, Issue No. 7). Wiltshire, England: Author. Available at www.abdynamics.com/resources/files/SP6030-issue-7-pedestrian-target.pdf

11.0 DATA SHEETS

TEST AND VEHICLE PARAMETER DATA

General Vehicle Information	
NHTSA Vehicle No.	Test Date
Vehicle Make/Model/Body Style and Trim Level	
In-Vehicle PAEB Setting (If applicable)	

General Test Facility Information	
Facility Designation (e.g., “Skid Pad Lane #4”)	Test Surface (e.g., asphalt, concrete)
Surface Condition	

Pretest Conditions			
Time	Ambient Temperature (°C)	Wind Speed (km/h)	Wind Direction
Test Vehicle-to-Pedestrian Distance During Static Cal, Measured (mm)		Test Vehicle-to-Pedestrian Distance During Static Cal, Displayed (mm)	

Post-test Conditions			
Time	Ambient Temperature (°C)	Wind Speed (km/h)	Wind Direction
Test Vehicle-to-Pedestrian Distance During Static Cal, Measured (mm)		Test Vehicle-to-Pedestrian Distance During Static Cal, Displayed (mm)	

TEST VEHICLE

Driver Seatbelt Buckled?	Front Passenger Seatbelt Buckled?
Airbags Disabled?	
Method To Disable Airbag(s)?	
Airbag Squibs Installed?	Airbag Squib Resistance (ohms)
Fuels checked	Tires Checked

PEDESTRIAN TEST MANNEQUIN AND MOTION APPARATUS

Adult Pedestrian Test Mannequin	Manufactured by:
	Dummy Serial Number:
	Dummy Model Number or Version:
	Calibration Date:
Child Pedestrian Test Mannequin	Manufactured by:
	Dummy Serial Number:
	Dummy Model Number or Version:
	Calibration Date:
Pedestrian Test Target Motion Apparatus	Manufactured by:
	Dummy Serial Number:
	Software Configuration Number or Version:
	Calibration Date:

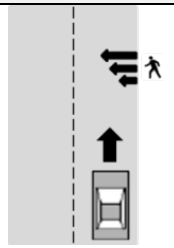
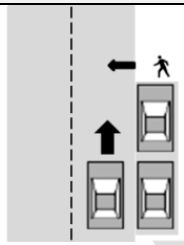
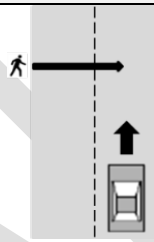
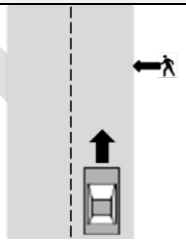
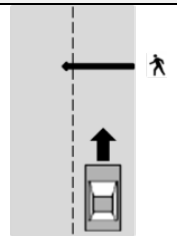
S1/S4 PAEB Speed Reduction Summary Table

PAEB Speed Reduction Summary. If no SV-to-PTM contact occurred, enter "NC".														
Trial #	Test Condition													
	SV: 16 km/h (10 mph)				SV: 40 km/h (25 mph)						SV: 16 km/h (10 mph)		SV: 40 km/h (25 mph)	
	PTM: 5 km/h (3.1 mph)				PTM: 5 km/h (3.1 mph)				PTM: 8 km/h (4.9 mph)	PTM: 5 km/h (3.1 mph)	PTM: 0 km/h			
	S1a	S1b	S1c	S1d	S1a	S1b	S1c	S1d	S1e	S4c	S4a	S4b	S4a	S4b
1														
2														
3														
4														
5														
6														
7														

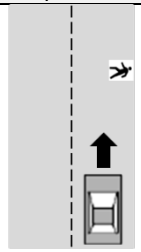
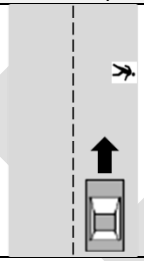
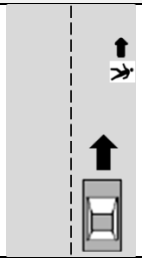
S1f-g Peak Deceleration Summary Table

Trial #	Peak Deceleration (m/s/s)	
	Test Condition	
	S1f	S1g
	SV: 40 km/h (25 mph) Ped: 5 km/h (3.1 mph)	SV: 40 km/h (25 mph) Ped: 5 km/h (3.1 mph)
1		
2		
3		
4		
5		
6		
7		

S1 Scenario Summary

Scenario	**S1a-b-c**	**S1d**	**S1e**	**S1f**	**S1g**
Test description	Crossing adult pedestrian walking from the nearside 25/50/75 % overlap.	Crossing child pedestrian running from behind parked vehicles from the nearside 50 % overlap.	Crossing adult pedestrian running from the offside 50 % overlap.	Crossing adult pedestrian walking from the nearside and stops short of entering the vehicles path.	Crossing adult pedestrian walking from the nearside and clears the vehicles path.
Test diagram					
SV approach speed	16/40 km/h +/- 1.0 (10/25 mph)	16/40 km/h +/- 1.0 (10/25 mph)	40 km/h +/- 1.0 (25 mph)	40 km/h +/- 1.0 (25 mph)	40 km/h +/- 1.0 (25 mph)
SV tests lane	SV Width + 40 cm (16 in)	SV Width + 40 cm (16 in)	SV Width + 40 cm (16 in)	SV Width + 40 cm (16 in)	SV Width + 40 cm (16 in)
PTM route relative to the SV route	Perpendicular	Perpendicular	Perpendicular	Perpendicular	Perpendicular
PTM start distance	3.5 m +/- 2.54 cm (11.4 ft)	3.5 m +/- 2.54 cm (11.4 ft)	5.5 m +/- 2.54 cm (18.04 ft)	3.5 m +/- 2.54 cm (11.4 ft)	3.5 m +/- 2.54 cm (11.4 ft)
PTM speed	5.0 km/h +/- 0.4 (3.1 mph)	5.0 km/h +/- 0.4 (3.1 mph)	8.0 km/h +/- 0.4 (4.9 mph)	5.0 km/h +/- 0.4 (3.1 mph)	5.0 km/h +/- 0.4 (3.1)
PTM acceleration distance	0.5 m (1.64 ft)	0.5 m (1.64 ft)	1.0 m (3.28 ft)	0.5 m (1.64 ft)	0.5 m (1.64 ft)
Validity period TTC = 4.0 sec	17.7 m (58 ft) at SV 16 km/h (10 mph) 44.4 m (145.6 ft) at SV 40 km/h (25 mph)				

S4 Scenario Summary Matrix

Scenario	**S4a**	**S4b**	**S4c**
Test description	SV encounters an adult pedestrian standing in front of the vehicle on the nearside of the road facing away from the vehicle 25 % overlap.	SV encounters an adult pedestrian standing in front of the vehicle on the nearside of the road facing towards the vehicle 25 % overlap.	SV encounters an adult pedestrian walking in front of the vehicle on the nearside of the road away from the vehicle 25 % overlap.
Test diagram			
SV approach speed	16/40 km/h +/- 1.0 (10/25 mph)	16/40 km/h +/- 1.0 (10/25 mph)	40 km/h +/- 1.0 (25 mph)
SV test lane	SV Width + 40 cm (16 in)	SV Width + 40 cm (16 in)	SV Width + 40 cm (16 in)
PTM start distance	Parallel	Parallel	Parallel
PTM speed	Stationary	Stationary	5.0 km/h +/- 0.4 (3.1 mph)
Trigger time (PTM motion)	NA	NA	TTC = 7.0 sec 77.7 m (255 ft) at SV 40 km/h (25 mph)
Validity period TTC = 4.0 sec	17.7 m (58 ft) at SV 16 km/h (10 mph) 44.4 m (145.7 ft) at SV 40 km/h (25 mph)		