CALIFORNIA AIR RESOURCES BOARD

Mobile Source Control Division
Tractor Trailer Greenhouse Gas (TTGHG) Interim Approval Request Form
For
Aero Drag Reduction Technologies

Version 2.2

Date:	Version:	Remarks:
2-14-2019	1.0	Initial Release
4-10-2019	2.0	Convert to a fillable PDF
5-07-2019	2.1	Update some items description on page 48
6-26-2019	2.2	Remove warranty statement requirement and update text field format

Notes

a. The intent of this form is to enable completeness and consistency in providing submissions of requests for approval, as well as facilitating CARB's processing of these requests.

b. The numbering scheme in the Table of Contents is associated with each specific section of the form. Further, the citations indicated in parentheses in front of the items are references to a particular section of either the Code of Federal Regulations or a Society of Automotive Engineers standard.

c. All Code of Federal Regulations cited in this form are referenced in the California Greenhouse Gas Exhaust Emission Standards and Test Procedures for 2014 and subsequent Model Heavy-Duty Vehicles , as incorporated by reference in section 95663(d) title 17, Californian Code of Regulations.

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GENERAL INFORMATION

Manufacturer Code:

Manufacturer Name & Address:

Date of Request:

Name of Aero Device or Package:

Description of Aerodynamic Device			
1.	☐ **Single Device**	☐ **Multiple Devices**	

2. Description of aero device(s), including the physical principles by which it improves fuel efficiency:

3. State if there are restrictions on combining this device/package with other aero devices:

GENERAL INFORMATION

4. Indicate all trailer subcategories that are compatible with device(s). **40 CFR 1037.230**

Full-Aero trailers	Partial-Aero Trailers	Other Trailers
☐ Long Dry Box Vans	☐ Long Dry Box Vans	☐ Non-Aero Trailers
☐ Short Dry Box Vans	☐ Short Dry Box Vans	☐ Non-Box Trailers
☐ Long Refrigerated Box Vans	☐ Long Refrigerated Box Vans	
☐ Short Refrigerated Box Vans	☐ Short Refrigerated Box Vans	

5. This device/package will be offered for sale to other trailer manufacturers? ☐ Yes ☐ No

6. List part numbers for components comprising this device/package:

7. Installation Instructions:

8. Maintenance Instructions:

10. I certify, under penalty of law that the information provided in this document is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

TESTING INFORMATION

Name and address of test facility:

Description of test facility:

Description of standard tractor and its aerodynamic performance level:

Description of tested trailer, both as baseline "A" and with improvements "B":

Summary of test results:

Final adjusted improvement in C_dA, in m^2, to 2 decimal places:

TESTING METHOD

The default method (primary) for measuring ΔC_dA values is the wind-tunnel procedure. If we approve it in advance, you may instead use one of the alternate methods of CFD or Coastdown, consistent with good engineering judgment, which may require that you adjust your test results from the alternate test method to correlate with the primary method. We may require that you use coastdown measurements if we determine that certain technologies are not suited to evaluation with wind-tunnel testing or CFD, such as nonrigid materials whose physical characteristics change in scaled-model testing.

☐ CFD

☐ Coastdown

☐ Wind Tunnel

CFD

The aerodynamic performance data for the device described in this section are based on testing at

…….....

The tests were completed in accordance with methods specified in 40 CFR 1037.532 and SAE J2966 test procedure as detailed below.

Include the following information in your request to determine C_dA values using CFD: **40 CFR 1037.532(g)**	
(g)(1) Name of software:	
(g)(2) Date and version number of the software:	
(g)(3) Name of the company producing the software and the corresponding address, phone number, and website:	

(g)(4) CFD Code: ☐ Navier-Stokes ☐ Lattice-Boltzmann

1:CFD PROTOCOL CHECKLIST

Testing completed using SAE J2966 with the following clarifications and exceptions: **40 CFR 1037.532(a)**

(a)(1) Yaw Angle:	☐ + 4.5°	☐ - 4.5°		
(a)(2) CFD Code:				
(a)(3) Reynolds Number:		**Air Speed:**		
(a)(4) Perform the General On-Road Simulation (not the Wind Tunnel Simulation):			☐ Yes	☐ No
(a)(5) Use a free stream turbulence intensity of 0.0%:			☐ Yes ☐ No	☐ Other
Other:				
(a)(6) Unsteady Time Steps:				
(a)(7) Results provided in C_dA based on air speed of 65 mi/hr:			☐ Yes	☐ No
(a)(8) Submit information as described in paragraph (g) of this section: (see above)			☐ Yes	☐ No

1.1: FORMULA SOLVERS REQUIREMENTS	
1.1.1: Take the following steps for CFD code with a Navier-Stokes formula solver: **40 CFR 1037.532(d)**	
(d)(1) Perform an unstructured analysis using hexahedral and/or polyhedral mesh:	
(d)(1) Surface elements: (Minimum Requirement 6 Million)	
(d)(1) Volume Grid Size: (Minimum Requirement 50 Million)	
(d)(1) Y^+ Value:	
(d)(2) Perform the analysis with Turbulence model and Mesh deformation enabled (if applicable):	
(d)(2) Boundary layer resolution of ±95%. Once the results reach this resolution, demonstrate the convergence by supplying multiple, successive convergence values for the analysis.	
(d)(2) Demonstrate the convergence:	
(d)(2) The turbulence model may use k-epsilon (k-e), shear stress transport k-omega (SST kw), or other commercially accepted methods.	

1.1: FORMULA SOLVERS REQUIREMENTS	
1.1.2: Take the following steps for CFD code with a Lattice-Boltzmann formula solver: **40 CFR 1037.532(e)**	
Perform an unstructured analysis using Cubic volume elements and triangular and/or quadrilateral mesh:	
Surface Grid Size: (Minimum Requirement 50 Million)	
Surface elements: (On High flow gradients and Small geometry features<=6mm near-wall) **(Other areas=>12mm)**	

1.2: SAE J2966 REQUIREMENTS

1.2.1: General On-Road Simulation Requirements:	SAE J2966 Section 4.1
(4.1.1) The simulation model should include all aerodynamically significant physical characteristics of the subject test article.	☐ Yes ☐ No
Simulated trailer model meets all requirements outlined in 40 CFR 1037.501(g)(1) and tractor model meet requirements of 40 CFR 1037.501(h).	
(4.1.2) Deformable parts such as rubber mud flaps, under-hood seals, and recirculation shields are modeled to represent their suitable shape in operating condition.	☐ Yes ☐ No
(4.1.3) Domain Size:	
(4.1.4) Domain Boundary Conditions:	
(4.1.5) Simulation Model:	
(4.1.6) Cooling Fan Model:	
(4.1.7) Numerical Model:	

1.2.2: General Requirements for Solvers:	SAE J2966 Section 5.1
(5.1.1) Minimum Grid and Refinement Regions:	
(5.1.2) All cases were calculated with double precision floating point format:	☐ Yes ☐ No
(5.1.3) Grid Convergence Index and Iteration Error Estimation:	
(5.1.4) All solver parameters remain identical for each design evaluation:	☐ Yes ☐ No
(5.1.5) Run unsteady CFD simulations for at least five convective flow passes (air traveling the distance of the vehicle length) to limit influence of initial conditions.	

1.2.3: Requirements for Navier-Stokes Based Solvers:	SAE J2966 Section 5.2
(5.2.1) Utilized Second Order Discretization:	☐ Yes ☐ No
(5.2.2) Y^+ Value:	
(5.2.3) Boundary Layer Grid:	
(5.2.4, 5.2.5):	
(5.2.6) Residual Convergence:	
(5.2.7) Drag Convergence:	
(5.2.8 - 5.2.12):	

1.2.4: Requirements for Lattice-Boltzmann Based Solvers:	SAE J2966 Section 5.3
(5.3.1) High Flow Gradients and Smaller Geometry Regions:	
(5.3.2) Volume Element	
(5.3.3) Exterior Surface Mesh: (Shape and Size)	

1.2.5: Data Processing and Communication:	SAE J2966 Section 6
(6.1) Representation of test article:	
(6.2) STEP/IGES file formats:	
(6.3) Vehicle geometric model exported to the applicable CFD software package with the highest accuracy possible:	☐ Yes ☐ No

1.2.6: Basic Information about the Simulation:	SAE J2966 Section 6.4
(6.4.1) Vehicle make, model, and year information along with a description of geometry of the test article[1]:	
(6.4.2) Short description of the simulation[2]:	
(6.4.3) Official name/title, date, version number and vendor information of the software product.	
(6.4.4) Type of software code:	
(6.4.5) Description of simulation procedure:	
(6.4.6) Aerodynamic data along with reference values for frontal area and velocity used for normalizing the force data:	

1: Vehicle geometric model in STEP/IGES format has to be submitted with application request.
2: Simulation results in EnSight (.ENS) format has to be submitted with application request.

1.2.7: Certain variables are required to be reported with each simulation:	SAE J2966 Section 6.6
(6.6.1) Average force coefficients (drag, yaw, side, etc.) per case with averaging information (such as number of iterations or simulation time for the averaging calculations.	
(6.6.2) Drag coefficient history plots:	
(6.6.3) Contours, streamlines, vectors, and iso-surfaces for velocity and pressure as required.	
(6.6.4) Report pressure and force coefficient development on vehicle's longitudinal axis. Maximum pressure coefficient for the stagnation region should remain below 1.1.	
(6.6.5) Plot Y+ values on the model surface to confirm grid density and its' applicability on the selected turbulence model.	
(6.6.6) Report maximum turbulence viscosity ration with an iso-surface plot. In general, turbulence viscosity ratio (TVR) values may be above 1000, but they need to remain below 1000 in the free stream.	
(6.6.7) Report maximum velocity in the computational domain. In general, maximum velocity needs to remain below 150 m/s.	

1.2.8: CALCULATIONS, FIGURES AND PLOTS TO BE REPORTED WITH EACH SIMULATION

1.2.8.1: GCI CALCULATION & ITERATION ERROR ESTIMATION

Grid Convergence Index Calculations (based on Celik, B. I., et.al., 2008)			
	Finer Mesh	**Fine Mesh**	**Course Mesh**
Vehicle size (HxWxL) [m^3]			
Number of cells (N)			
Representative mesh height (h) [m]			
Drag Force [N]			
Mesh Refinement Ratio (r)			
Epsilon			
Order of Convergence, P			
Error for P			
Initial Guess for P			
Extrapolated Drag Force (F) [N]			
Approximate Relative Error			
Extrapolated Relative Error			
Grid Convergence Index (GCI)			

Iteration Error Estimation			
Drag Force Over last X Iterations	**Lambda (Principal Eigenvalue)**	**Iteration Error %**	**Uncertainty %**

It is recommended that iteration error should be at least one order of magnitude smaller than the discretization error.	

Note: In order to calculate P using Excel:

1. After entering all the information in blue cells, enter the value in B11 to B9.
2. Go to Data tab (in Excel 2007). Inder "What If Analysis", select "Goal Seek" option.
3. In the Goal Seek Window: Set cell: B10, to Value: 0, by Changing cell: B9, and click OK.

Figure 1— SAE J2966 5.1.3, Grid Convergence Index and Iteration Error Estimation

1.2.8.2: RESIDUAL & DRAG CONVERGENCE PLOTS

Stock Baseline

Testing Device/Package

Figure 2—SAE J2966 5.2.6, Residual Convergence, Stock Baseline and Testing Device/Package

Stock Baseline

Figure 3—SAE J2966 5.2.7, Drag Convergence, Stock Baseline

Testing Device/Package

Figure 4—SAE J2966 5.2.7, Drag Convergence, Testing Device/Package

1.2.8.3: VELOCITY AND PRESSURE VECTORS & ISO-SURFACES PLOTS

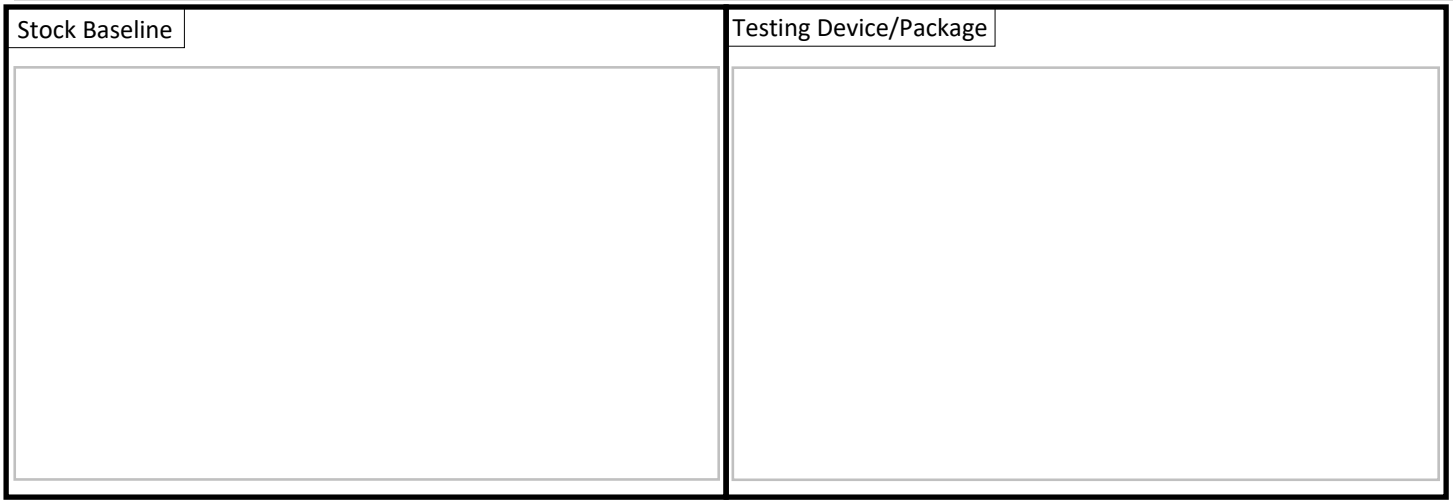


Figure 5—SAE J2966 6.6.3, Reverse Flow Iso-Surface of tractor, side view, Baseline & Testing Device/Package

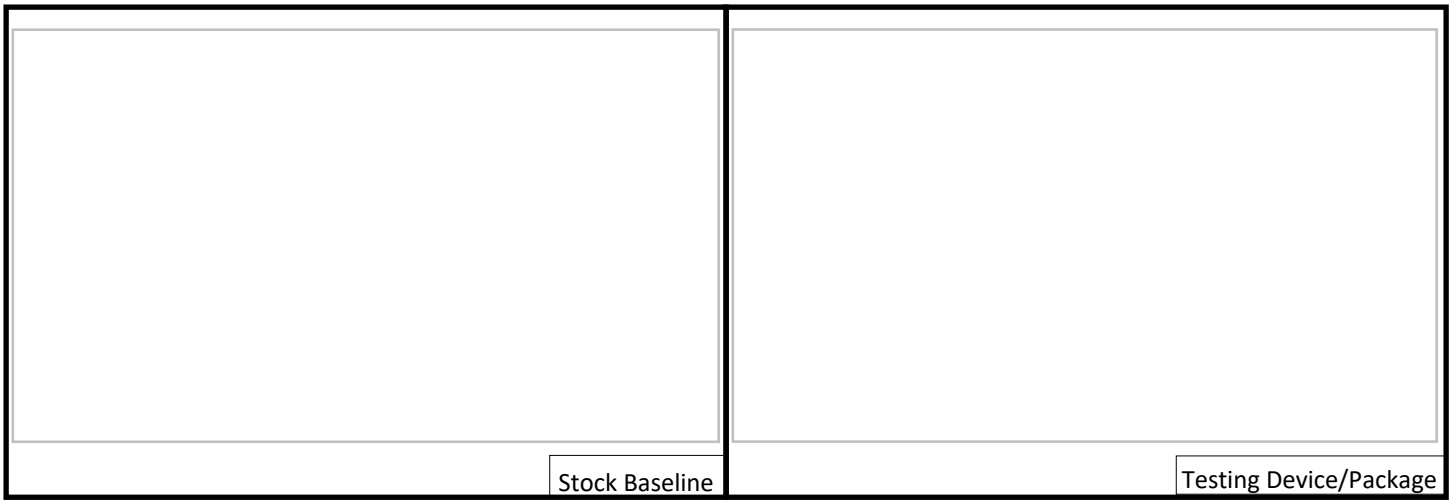


Figure 6—SAE J2966 6.6.3, Reverse Flow Iso-Surfaces of tractor, top down view, Baseline & Testing Device/Package

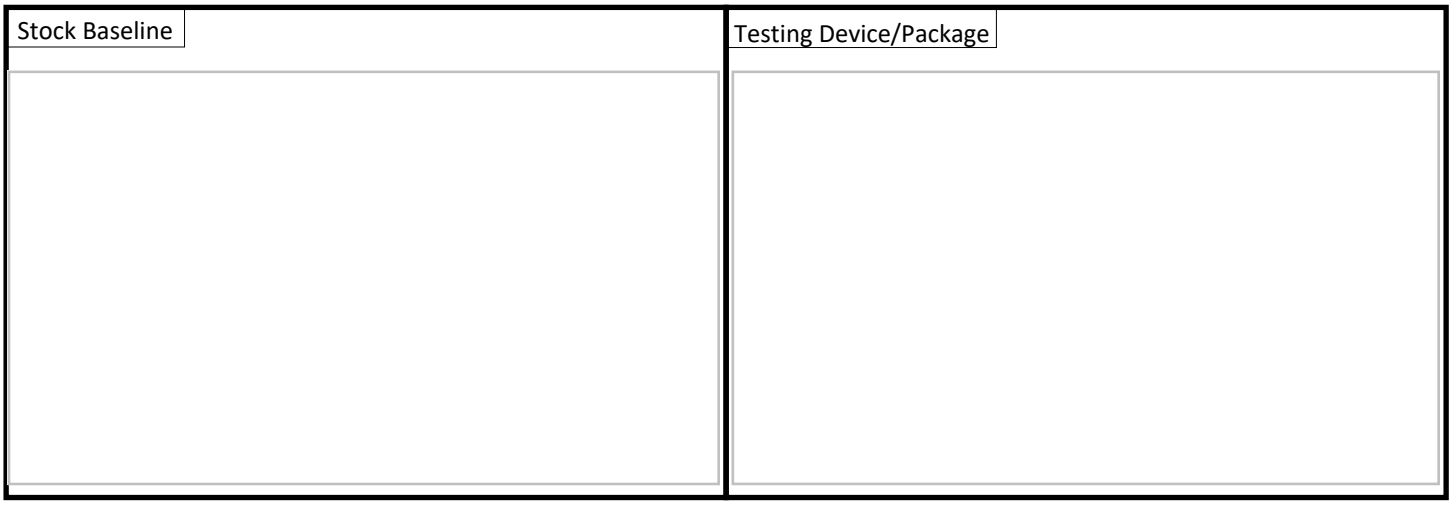


Figure 7—SAE J2966 6.6.3, Reverse Flow Iso-Surfaces of trailer, side view, Baseline & Testing Device/Package

1.2.8.3: VELOCITY AND PRESSURE VECTORS & ISO-SURFACES PLOTS

Stock Baseline	Testing Device/Package

Figure 8—SAE J2966 6.6.3, Reverse Flow Iso-Surfaces of vehicle, side view, Baseline & Testing Device/Package

Stock Baseline	Testing Device/Package

Figure 9—SAE J2966 6.6.3, Reverse Flow Iso-Surfaces of wake region, Baseline & Testing Device/Package

Stock Baseline	Testing Device/Package

Figure 10—SAE J2966 6.6.3, Reverse Flow Iso-Surfaces of wake region, Baseline & Testing Device/Package

1.2.8.3: VELOCITY AND PRESSURE VECTORS & ISO-SURFACES PLOTS

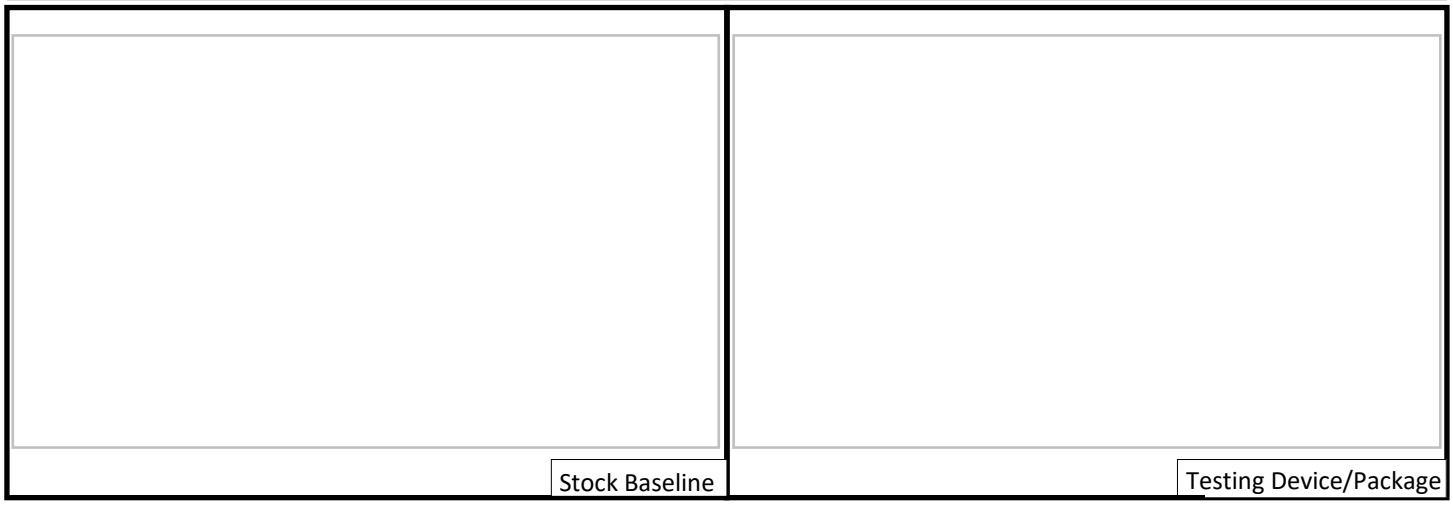


Figure 11—SAE J2966 6.6.3, Reverse Flow Iso-surfaces Baseline & Testing Device/Package

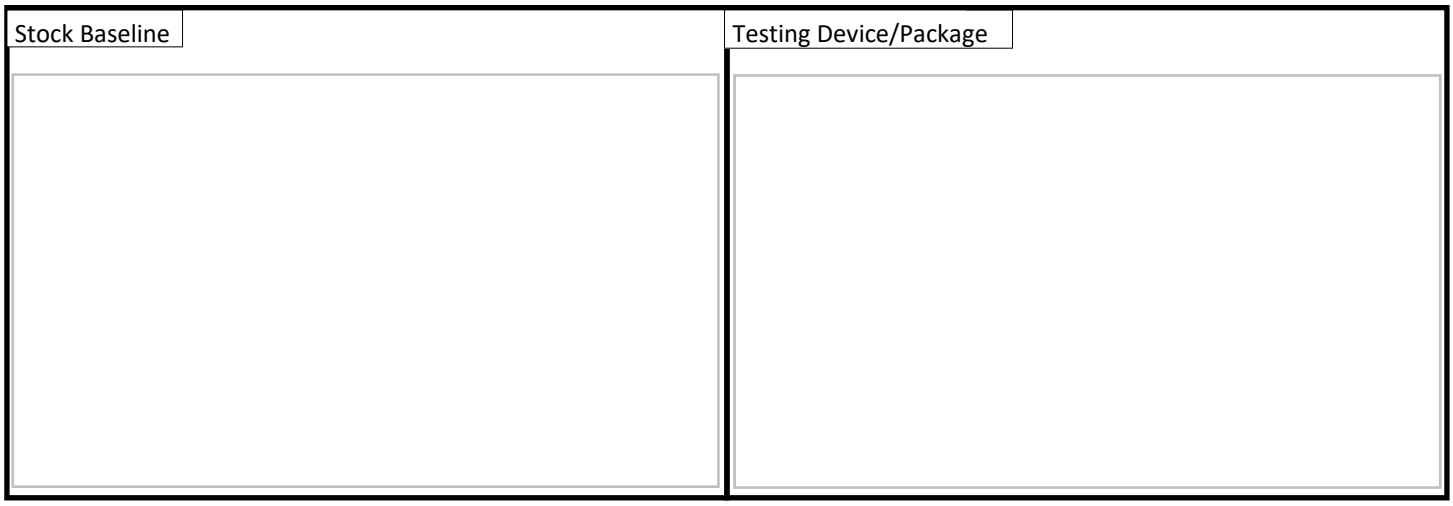


Figure 12—SAE J2966 6.6.3, Reverse Flow Iso-surfaces , Baseline & Testing Device/Package

1.2.8.3: VELOCITY AND PRESSURE VECTORS & ISO-SURFACES PLOTS

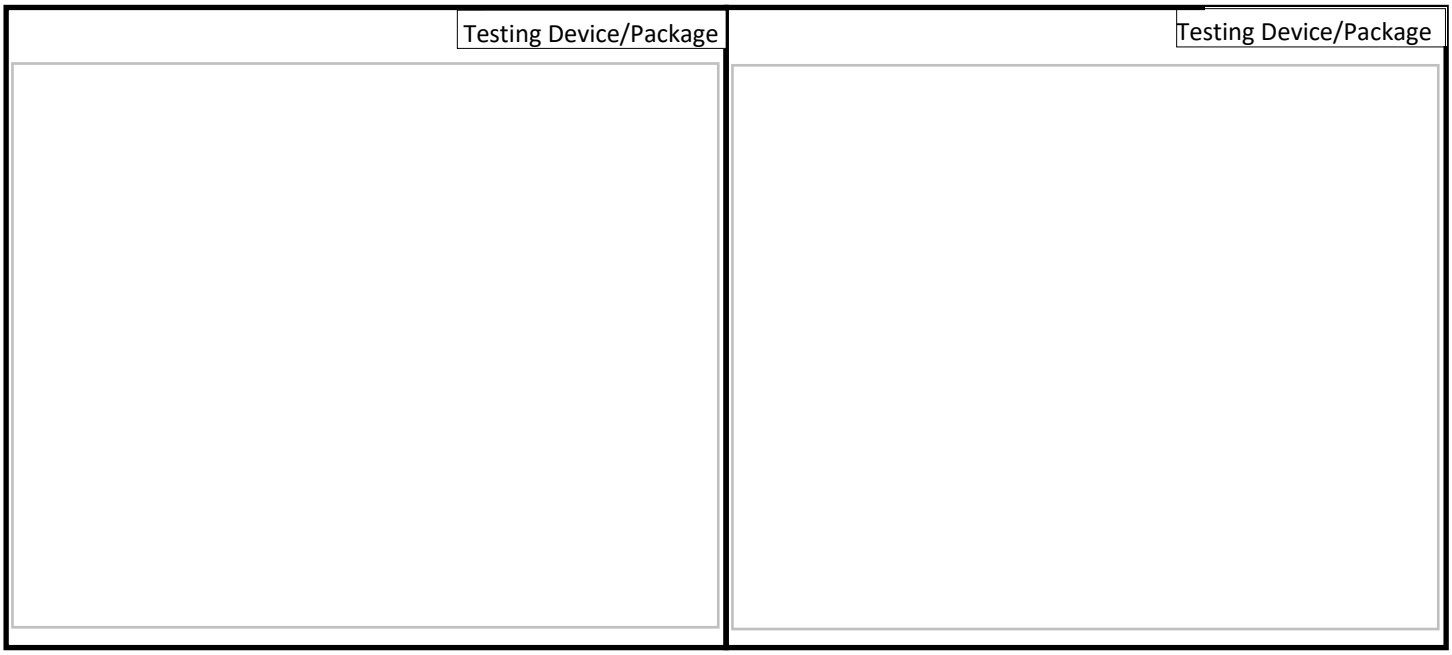


Figure 13—SAE J2966 6.6.3, Vector Slices, Testing Device/Package

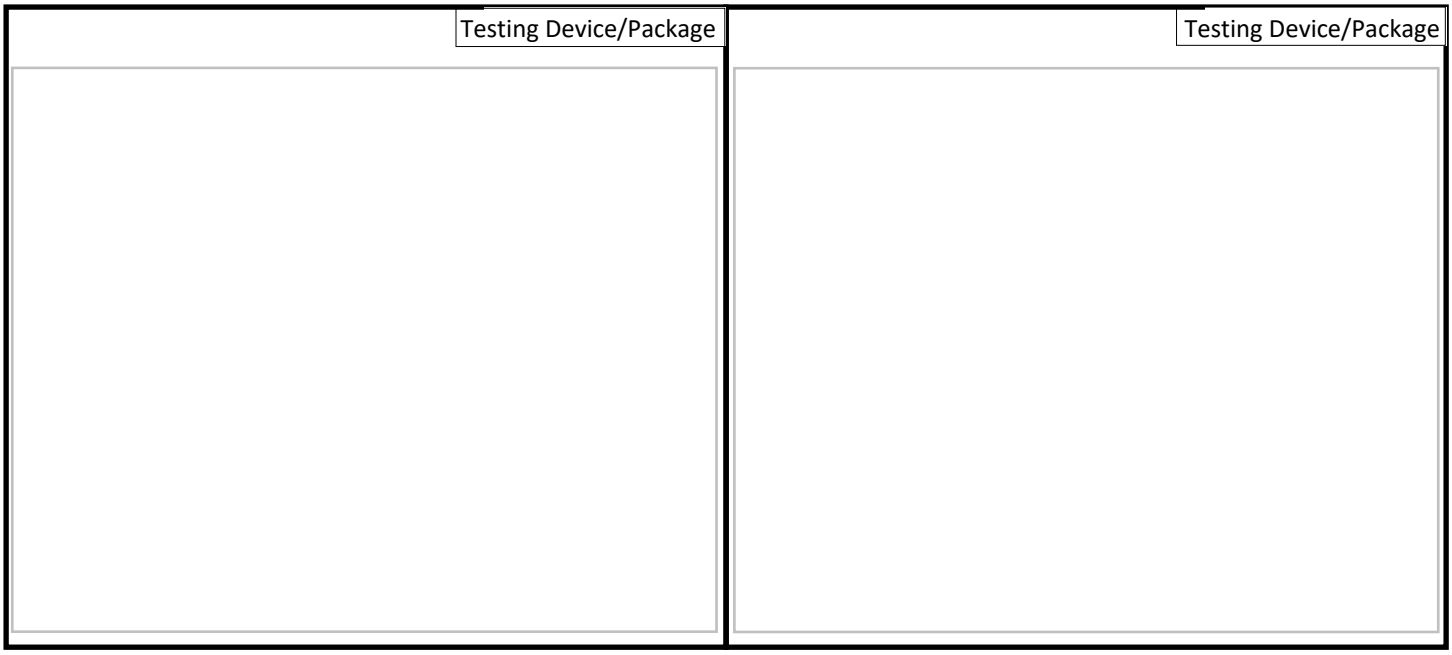


Figure 14—SAE J2966 6.6.3, Vector Slices, Testing Device/Package

1.2.8.3: VELOCITY AND PRESSURE VECTORS & ISO-SURFACES PLOTS

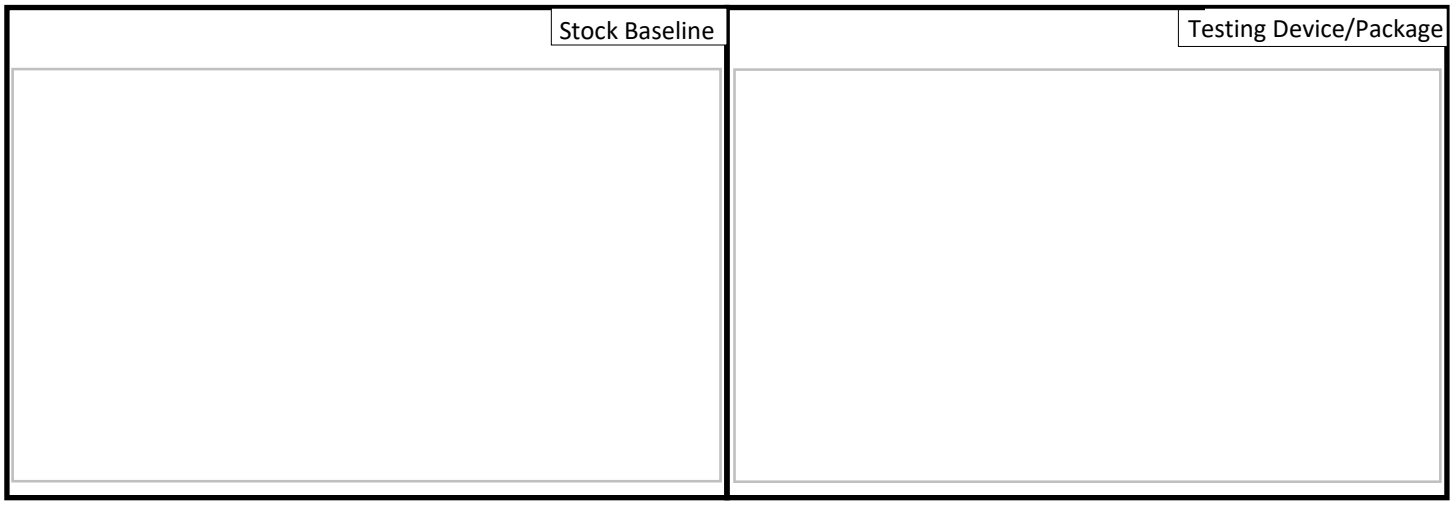


Figure 15—SAE J2966 6.6.3, Velocity Slice of wake region, side view, Baseline & Testing Device/Package

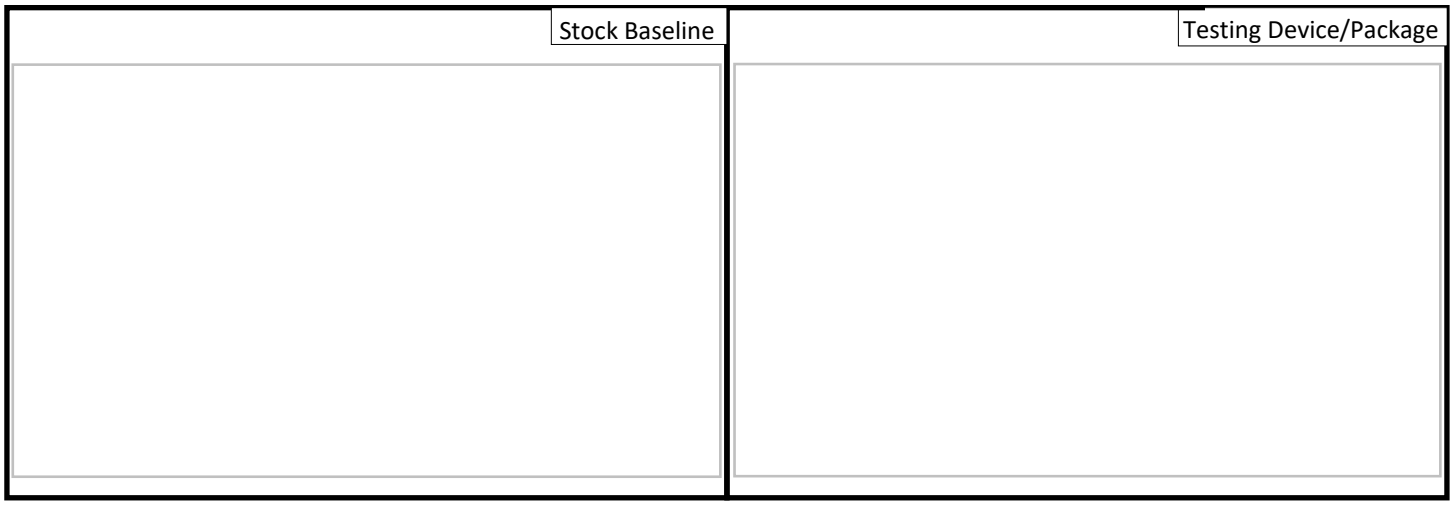


Figure 16—SAE J2966 6.6.3, Velocity Slice of wake region, top down view, Baseline & Testing Device/Package

1.2.8.3: VELOCITY AND PRESSURE VECTORS & ISO-SURFACES PLOTS

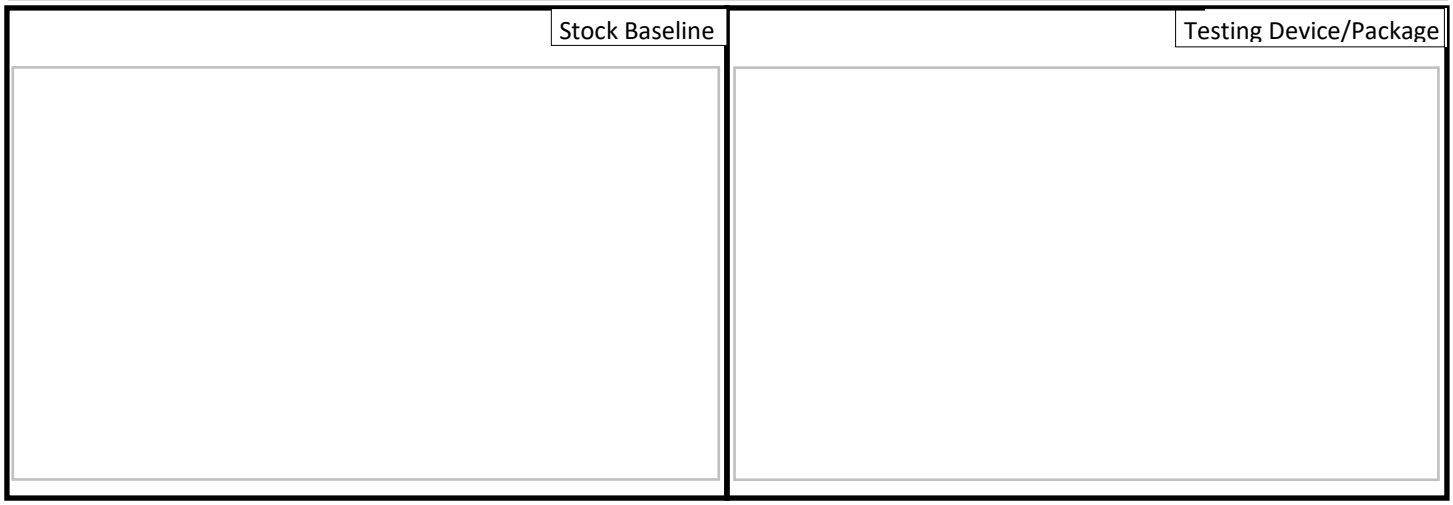


Figure 17—SAE J2966 6.6.3, Velocity Slice of tractor, side view, Baseline & Testing Device/Package

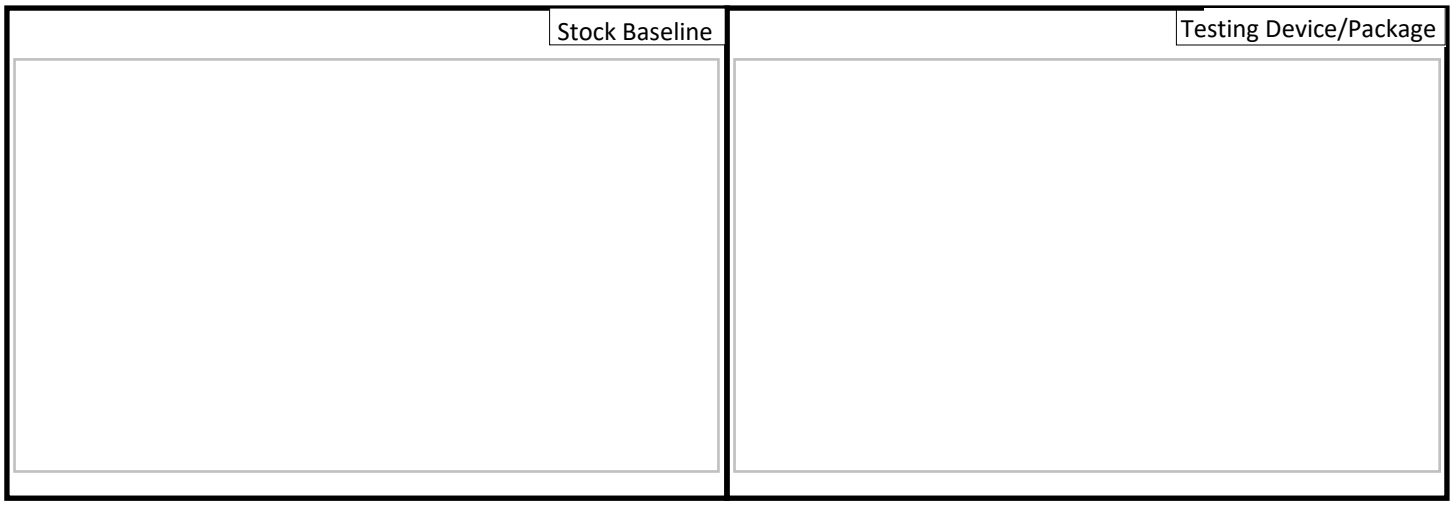


Figure 18—SAE J2966 6.6.3, Velocity Slice of tractor, top down view, Baseline & Testing Device/Package

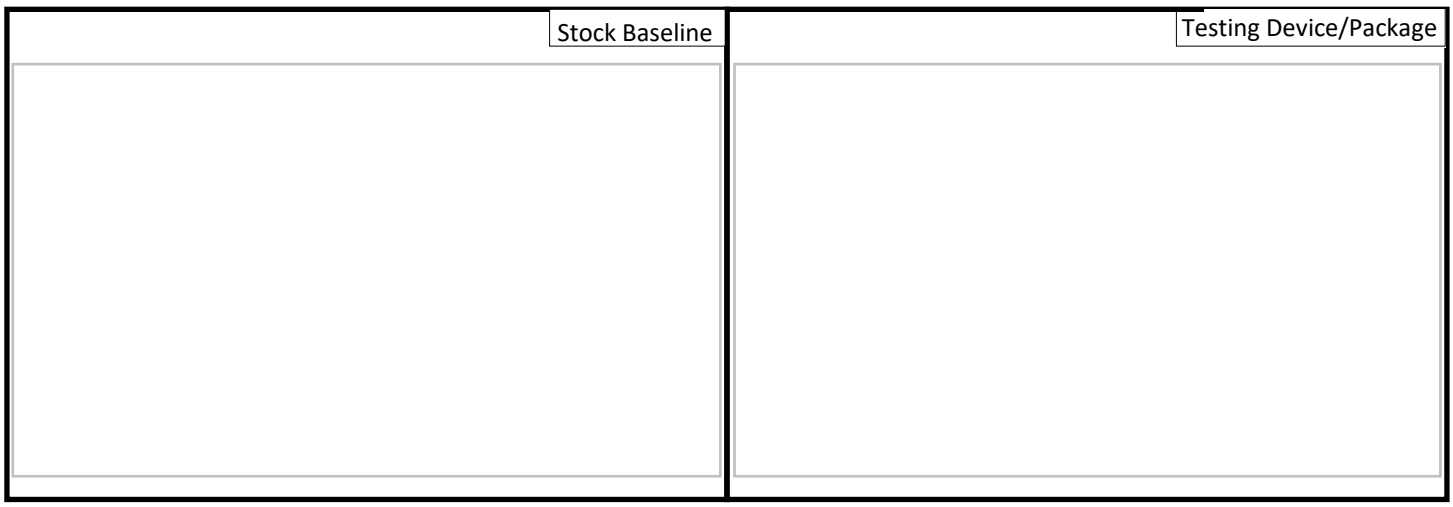


Figure 19—SAE J2966 6.6.3, Velocity Slice of tractor, underside, Baseline & Testing Device/Package

1.2.8.3: VELOCITY AND PRESSURE VECTORS & ISO-SURFACES PLOTS

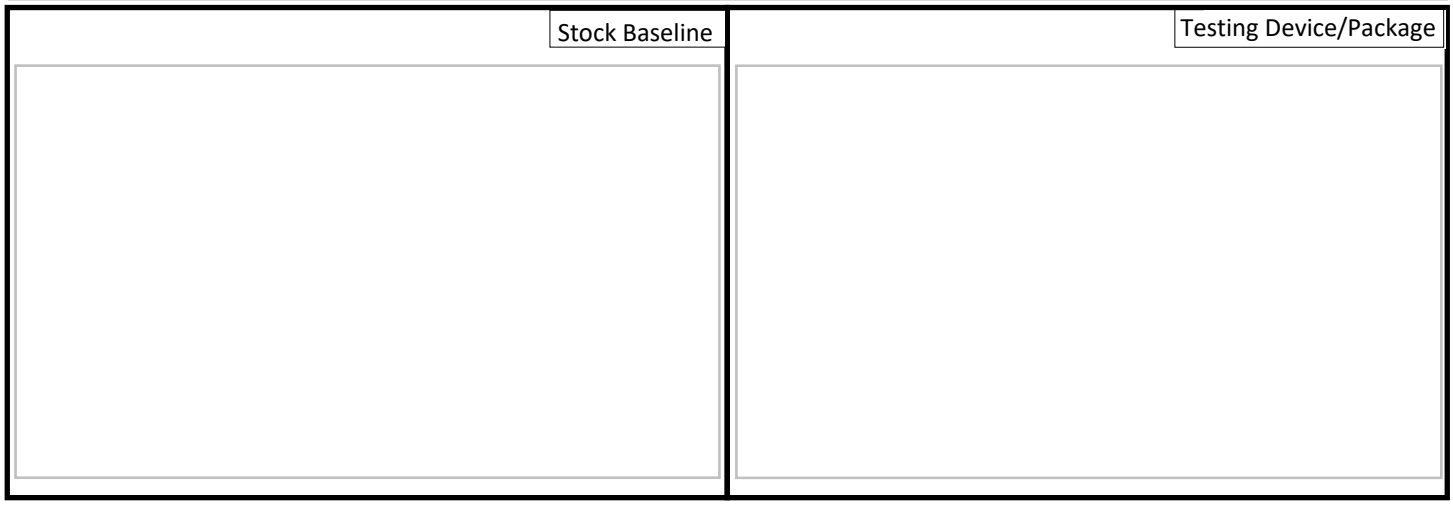


Figure 20—SAE J2966 6.6.3, Velocity Slice of vehicle, side view, Baseline & Testing Device/Package

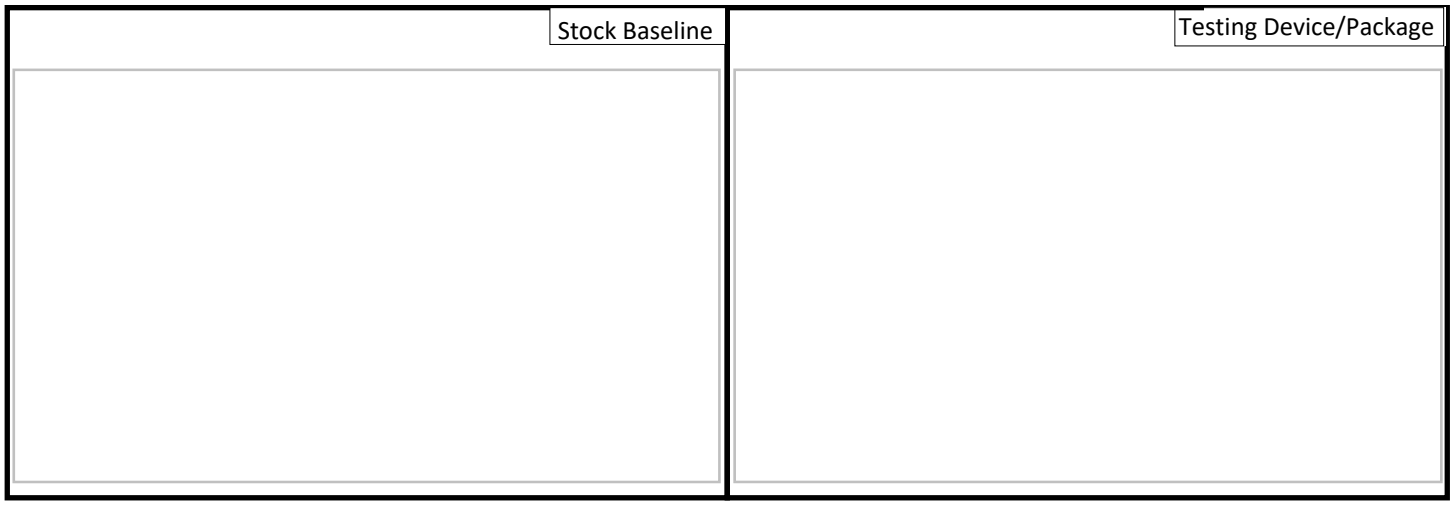


Figure 21—SAE J2966 6.6.3, Velocity Slice of vehicle, top down view, Baseline & Testing Device/Package

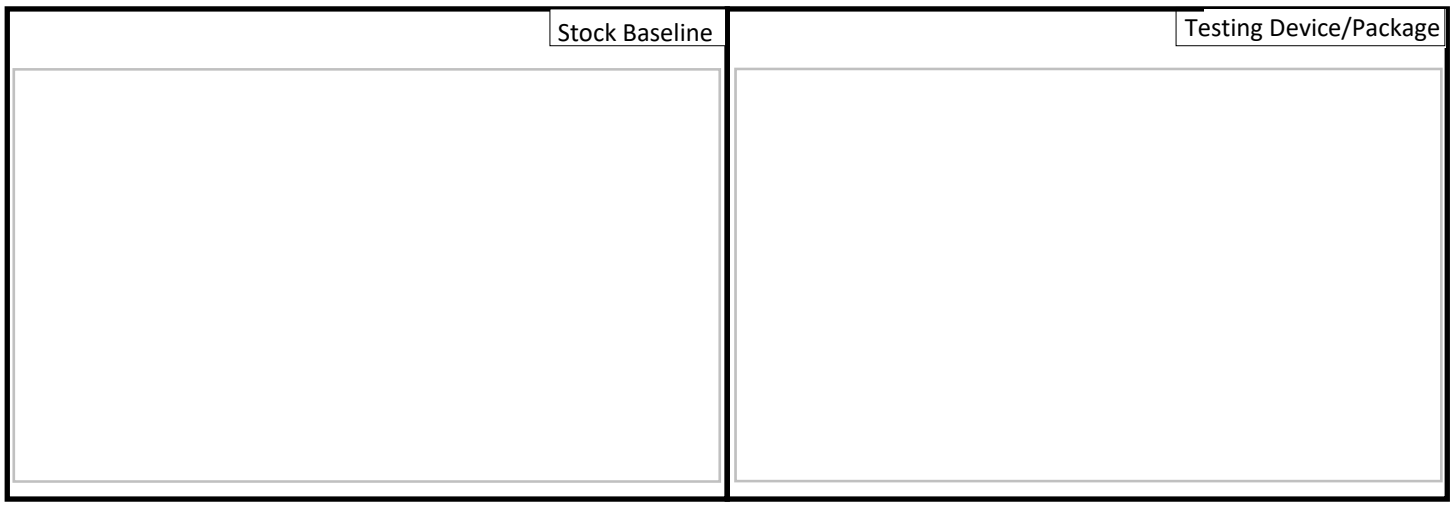


Figure 22—SAE J2966 6.6.3, Velocity Slice of vehicle,underside, Baseline & Testing Device/Package

1.2.8.3: VELOCITY AND PRESSURE VECTORS & ISO-SURFACES PLOTS

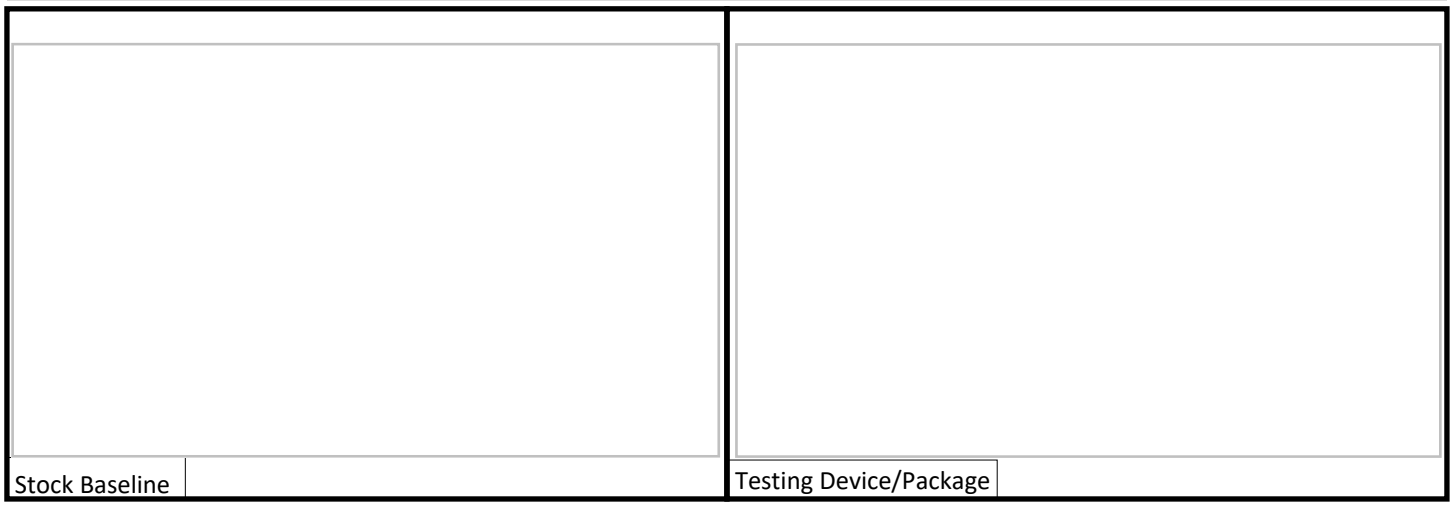


Figure 23—SAE J2966 6.6.3, Velocity Slice, complementary-1, Baseline & Testing Device/Package

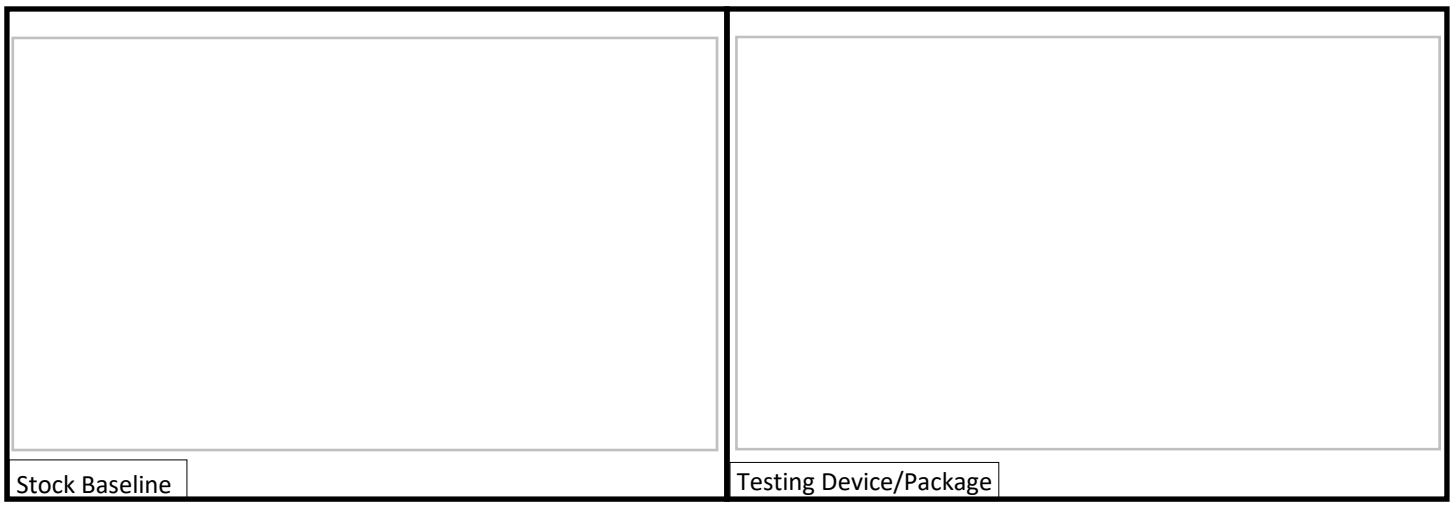


Figure 24—SAE J2966 6.6.3, Velocity Slice, complementary-2,Baseline & Testing Device/Package

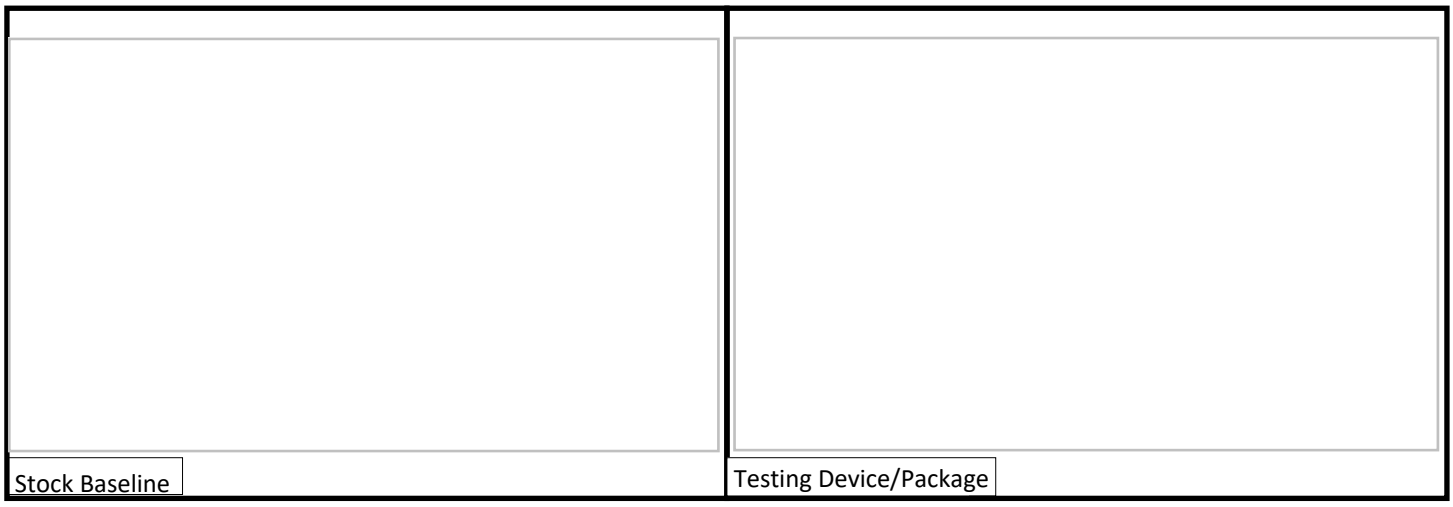


Figure 25—SAE J2966 6.6.3, Velocity Slice, complementary-3, Baseline & Testing Device/Package

1.2.8.3: VELOCITY AND PRESSURE VECTORS & ISO-SURFACES PLOTS

Stock Baseline	Testing Device/Package

Figure 26—SAE J2966 6.6.3, Velocity Slice, complementary-4, Baseline & Testing Device/Package

1.2.8.4: PRESSURE AND FORCE COEFFICIENT PLOTS

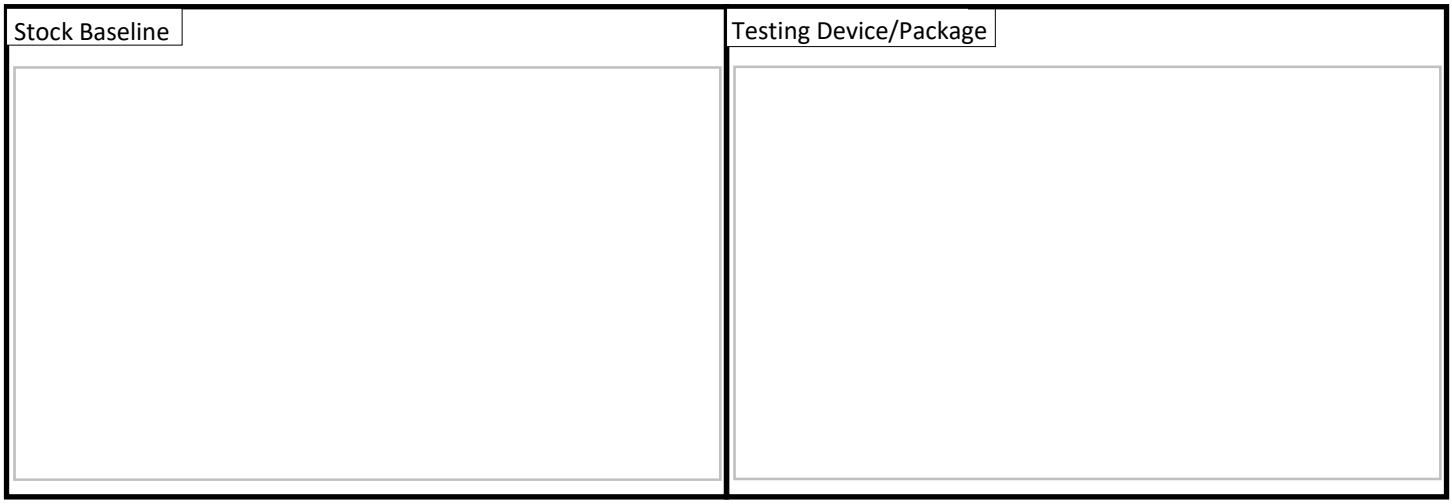


Figure 27—SAE J2966 6.6.3, CP of trailer, back side, Baseline & Testing Device/Package

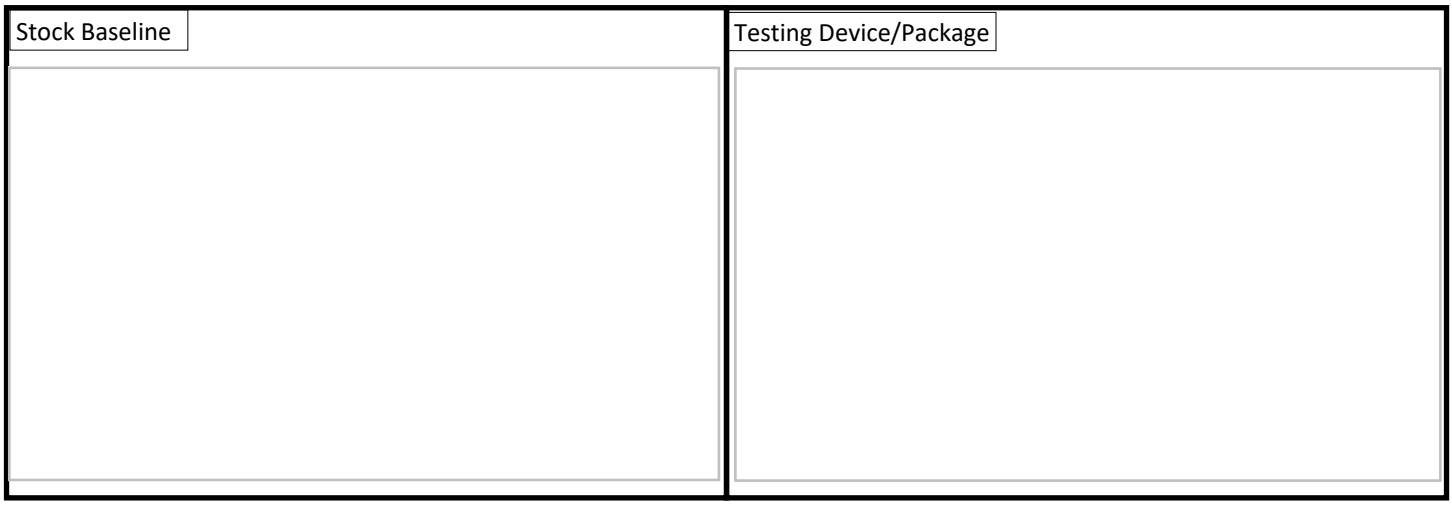


Figure 28—SAE J2966 6.6.4, CP of vehicle, right side, Baseline & Testing Device/Package

1.2.8.4: PRESSURE AND FORCE COEFFICIENT PLOTS

Stock Baseline	Testing Device/Package

Figure 29—SAE J2966 6.6.4, CP of vehicle, left side, Baseline & Testing Device/Package

Stock Baseline	Testing Device/Package

Figure 30—SAE J2966 6.6.4, CP of vehicle, top side, Baseline & Testing Device/Package

Stock Baseline	Testing Device/Package

Figure 31—SAE J2966 6.6.4, CP of vehicle, underside, Baseline & Testing Device/Package

1.2.8.4: PRESSURE AND FORCE COEFFICIENT PLOTS

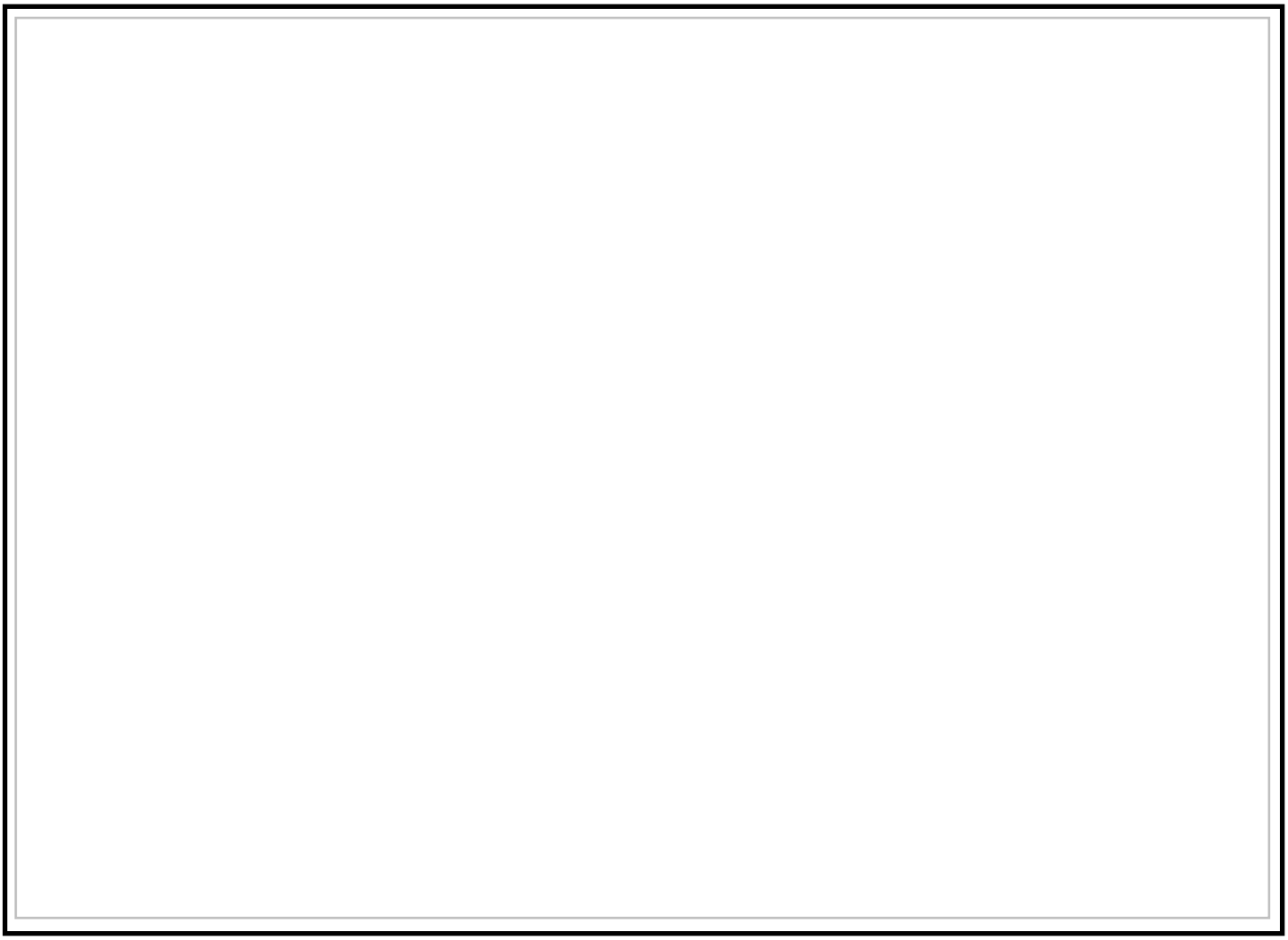


Figure 32—SAE J2966 6.6.4, Delta Cd break down by component of vehicle

1.2.8.5: Y+ PLOTS

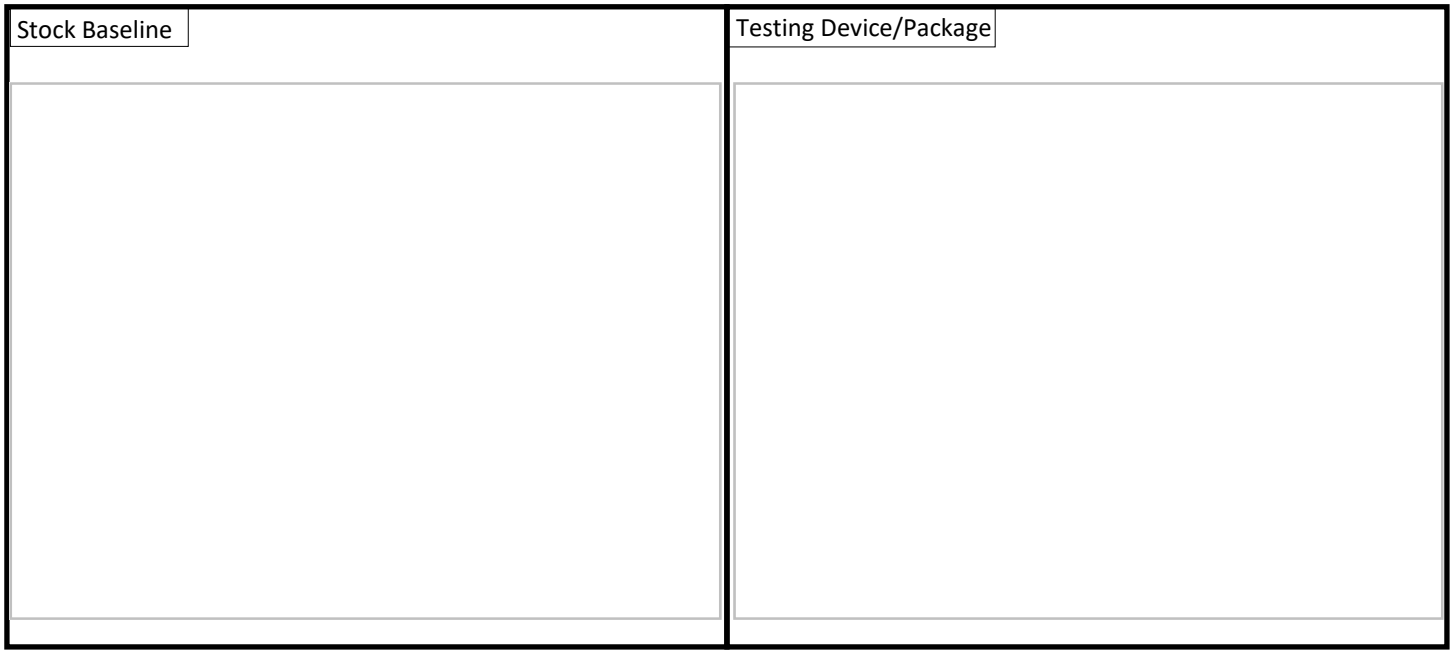


Figure 33—SAE J2966 6.6.5, Y+ of vehicle, frontside, Baseline & Testing Device/Package

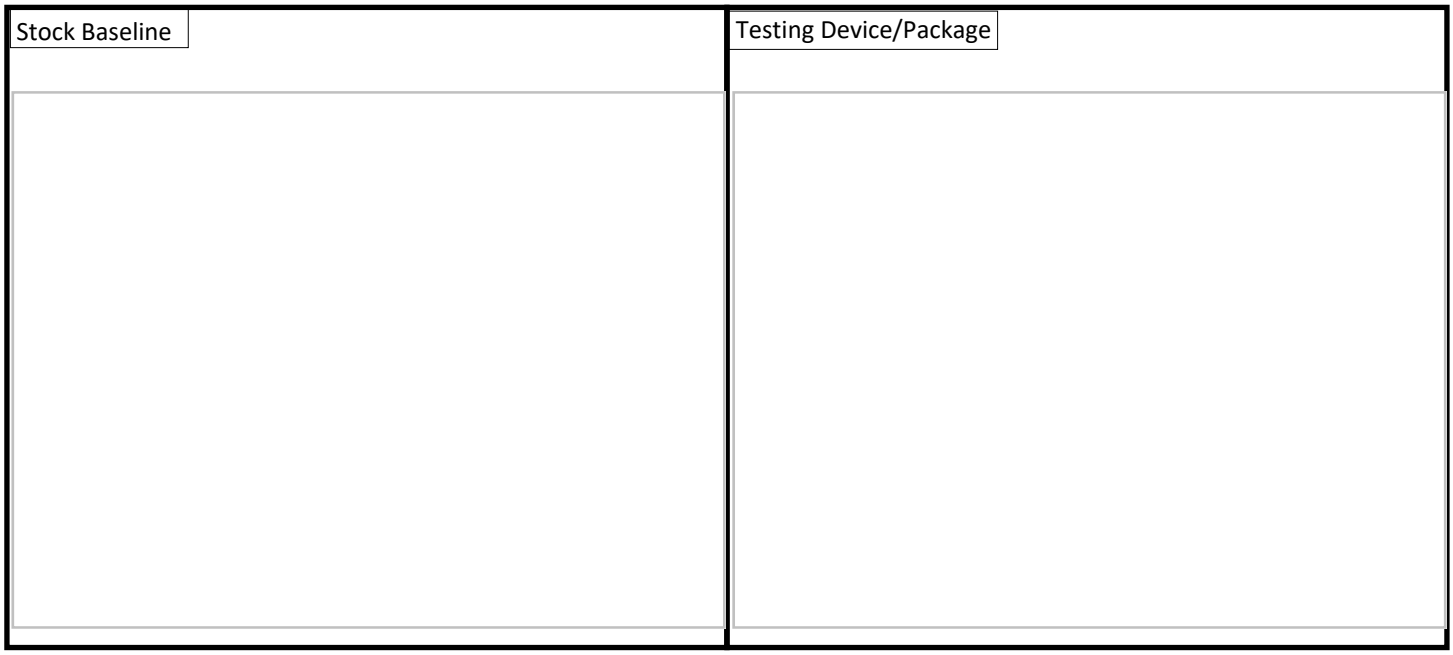


Figure 34—SAE J2966 6.6.5, Y+ of vehicle, underside, Baseline & Testing Device/Package

1.2.8.5: Y+ PLOTS

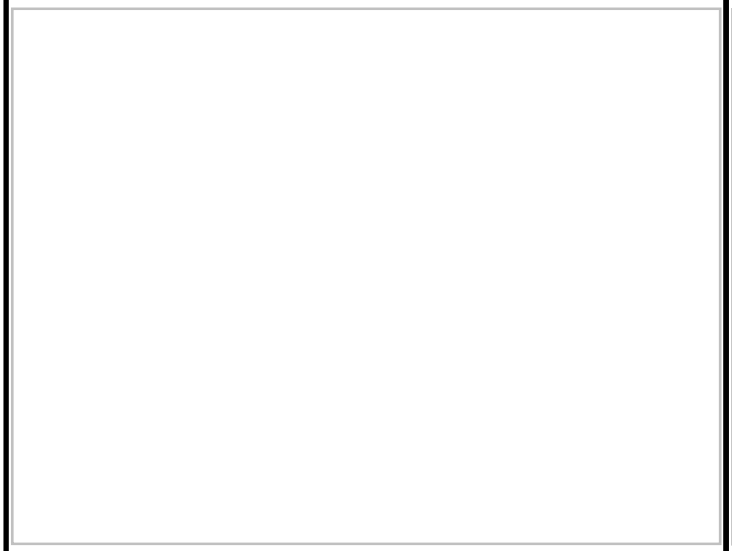
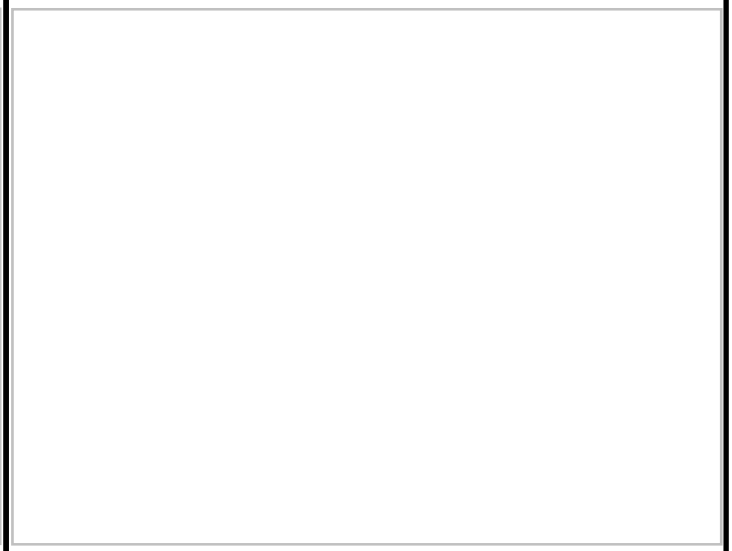
Stock Baseline	Testing Device/Package
	

Figure 35—SAE J2966 6.6.5, Y+ of vehicle, backside, Baseline & Testing Device/Package

1.2.8.6: TVR ISO-SURFACE PLOTS

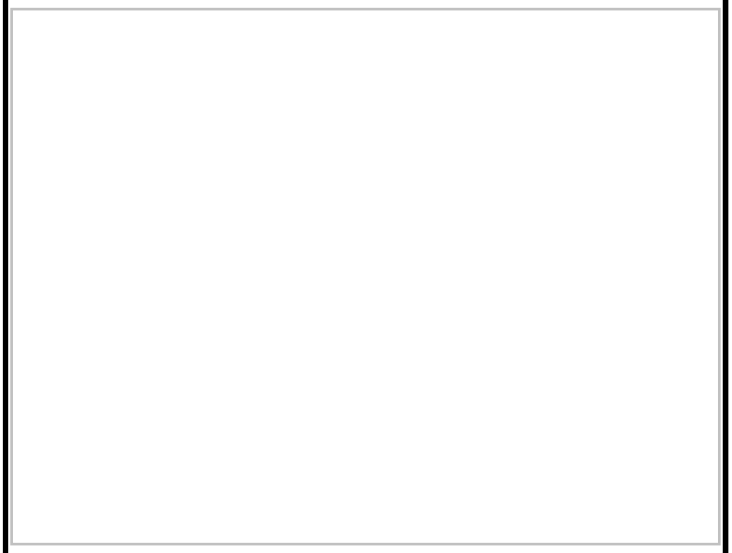
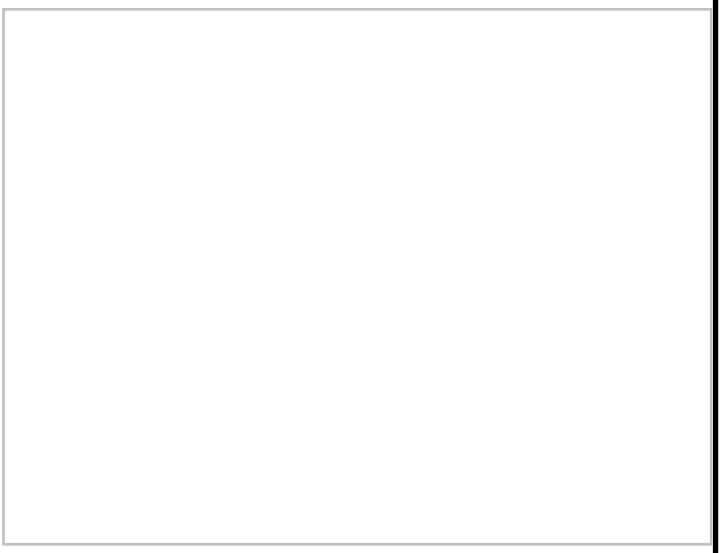
Stock Baseline	Testing Device/Package
	
TVR = 250	**TVR = 250**

FIGURE 36—SAE J2966 6.6.6, ISO-SURFACE OF TVR, BASELINE & TESTING DEVICE/PACKAGE

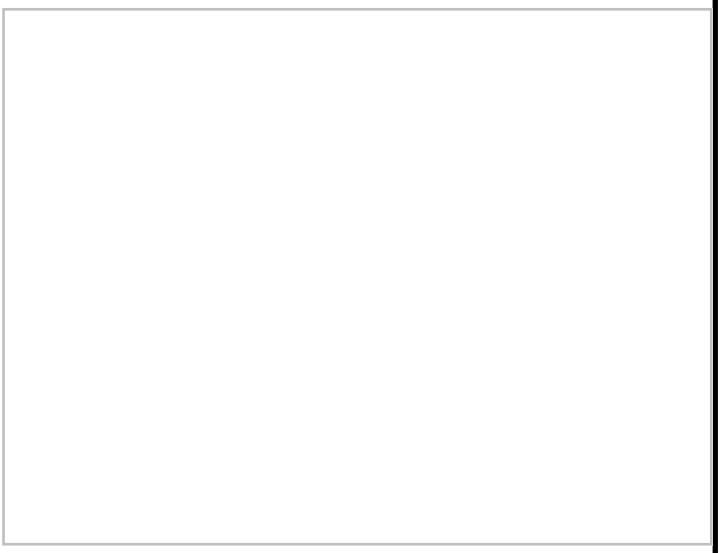
Stock Baseline	Testing Device/Package
	
TVR = 500	**TVR = 500**

FIGURE 37—SAE J2966 6.6.6, ISO-SURFACE OF TVR, BASELINE & TESTING DEVICE/PACKAGE

1.2.8.6: TVR ISO-SURFACE PLOTS

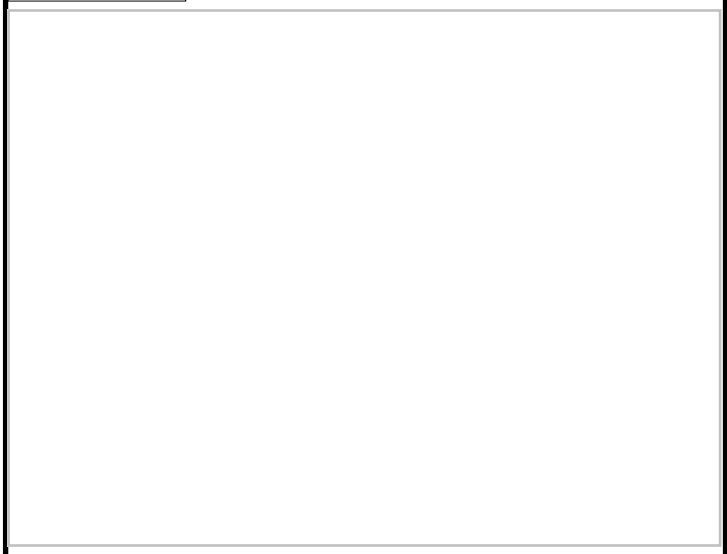
Stock Baseline	Testing Device/Package
	
TVR = 1000	**TVR = 1000**

FIGURE 38—SAE J2966 6.6.6, ISO-SURFACE OF TVR, BASELINE & TESTING DEVICE/PACKAGE

COASTDOWN

The aerodynamic performance data for the device described in this section are based on testing at

…….....

The tests were completed in accordance with methods specified in 40 CFR 1037.528 and SAE J2263 and SAE J1263 test procedures as detailed below.

Include the following information in your request to determine C_dA values using Coastdown:	**40 CFR 1037.528(j)**
(j)(1) Name and location of test facility:	
(j)(1) Background and history of test facility:	
(j)(1) Equipment and capability of test facility:	
(j)(1) Track and facility elevation:	
(j)(1) Grade and size/length of the track:	
(j)(2) Test Conditions for each test result: **(Environmental Conditions)** **Date&time, Wind speed and direction, ambient temperature and humidity**	
(j)(2) Test conditions for each test result: **(Performance Conditions)** **Vehicle speed, driving distance**	
(j)(2) Vehicle Specifications: **Manufacturer name, test vehicle/model type, model year, applicable family, tire type and rolling resistance, weight of tractor-trailer (as tested), and driver identifier**	
(j)(3) Average C_dA and yaw angle results and all the individual run results: **(Including voided or invalid runs)**	

2: COASTDOWN PROTOCOL CHECKLIST	
2.1: Take the following steps to determine C_dA values for a trailer, perform coastdown testing with a tractor-trailer combination using a standard tractor:	**40 CFR 1037.528(b)**
(b)(1) Required instrumentation install for specific measurements:	☐ Yes ☐ No
(b)(2) Brake drag or other condition that prevents the wheels from rotating freely:	☐ Yes ☐ No
(b)(2) Parking Brake applied between inspection and the end of the measurements:	☐ Yes ☐ No
(b)(3) Tires mounted on steel rims installed in a dual configuration (Except for steer tires):	☐ Yes ☐ No
(b)(3)(i) Smart Way-Verified or have a coefficient of rolling resistance at or below 5.1kg/metric ton:	☐ Yes ☐ No
(b)(3)(ii) Accumulated at least 2,000 miles but have no less than 50 percent of their original tread depth:	☐ Yes ☐ No
(b)(3)(iii) Not be retreads or have any apparent signs of chunking or uneven wear:	☐ Yes ☐ No
(b)(3)(iv) Size 295/75R22.5 or 275/80R22.5:	☐ Yes ☐ No
(b)(3)(v) Inflated to the proper tire pressure as specified in Sections 6.6 and 8.1 percent of SAE J2263:	☐ Yes ☐ No
(b)(3)(vi) Same tire model for a give axle:	☐ Yes ☐ No
(b)(4) Wheel alignment for both the tractor and the trailer is within the manufacturer's specifications:	☐ Yes ☐ No
2.2: The test condition specifications described in Sections 7.1 through 7.4 of SAE J1263 apply, with the following exceptions and additional provisions[3]:	**40 CFR 1037.528(c)**
(c)(1) Winds exceeded 6.0 mi/hr:	☐ Yes ☐ No
(c)(2) Average of the component of the wind speed parallel to the road exceeded 6.0 mi/hr:	☐ Yes ☐ No
(c)(3) Road grade is greater than 0.02% over the length of the test surface[4]:	☐ Yes ☐ No
(c)(4) Road grade exceeded 0.5% for limited portions of the test surface[5]:	☐ Yes ☐ No
(c)(5) Road surface temperature is at or below 50°C:	☐ Yes ☐ No

3: You must answer these questions for each specific run.
4: If the answer is "YES", you must determine elevation as a function of distance along the length of the test surface and incorporate this into the analysis.
5: If the answer is "YES", The Test report is acceptable as long as it does not affect coastdown results, consistent with good engineering judgment.

2: COASTDOWN PROTOCOL CHECKLIST		
2.3: Measure speed values while the vehicle coasts down through a high-speed range from 70 to 60 mi/hr, and through a low-speed range from 20 to 10 mi/hr with the additional provisions:		**40 CFR 1037.528(d)**
(d) Disabled any vehicle speed limiters that prevent travel above 72 mi/hr:		☐ Yes ☐ No
(d) Vehicle speed measured at a minimum recording frequency of 10 Hz, in conjunction with time-of-day:		☐ Yes ☐ No
(d) Vehicle speed measurement method:	☐ Complete Coastdown runs	☐ Split Coastdown runs
2.3.1: COMPLETE COASTDOWN RUNS		**40 CFR 1037.528(d)(1)**
(d)(1) Operate the vehicle at a top speed above 72.0 mi/hr and allow the vehicle to coast down to 8.0 mi/hr or lower:		☐ Yes ☐ No
(d)(1) Collect data for the high-speed range over a test segment vehicle to that includes speeds from 72.0 down to 58.0 mi/hr:		☐ Yes ☐ No
(d)(1) Collect data for the low-speed range over a test segment vehicle to that includes speeds from 22.0 down to 8.0 mi/hr:		☐ Yes ☐ No
2.3.2: SPLIT COASTDOWN RUNS[6]		**40 CFR 1037.528(d)(2)**
(d)(2) Collect data during a high-speed coastdown while the vehicle coasts through a test segment that includes speeds from 72.0 mi/hr down to 58.0 mi/hr:		☐ Yes ☐ No
(d)(2) Collect data during a low-speed coastdown while the vehicle coasts through a test segment that includes speeds from 22.0 mi/hr down to 8.0 mi/hr:		☐ Yes ☐ No
(d)(2) Perform one high-speed coastdown segment or two consecutive high-speed coastdown segments in one direction, followed by the same number of low-speed coastdown segments in the same direction, and then perform that same number of measurements in the opposite direction:		☐ Yes ☐ No

6: You may not split runs as described in Section 9.3.1 of SAE J2263 except as allowed under this section.

2: COASTDOWN PROTOCOL CHECKLIST	
2.4: Measure wind speed, wind direction, air temperature, and air pressure at a recording frequency of 10 Hz, in conjunction with time-of-day data. Use at least one stationary electro-mechanical anemometer and suitable data loggers meeting SAE J1263 specifications, subject to the following additional specifications for the anemometer placed along the test surface:	**40 CFR 1037.528(e)**
(e)(1) Coastdown measurement within 24 hours after completing zero-wind and zero-angle calibration:	☐ Yes ☐ No
(e)(2) Place the anemometer at least 50 feet from the nearest tree and at least 25 feet from the nearest bush (or equivalent features):	☐ Yes ☐ No
(e)(2) Position the anemometer adjacent to the test surface, near the midpoint of the length of the track, between 2.5 and 3.0 body widths from the expected location of the test vehicle's centerline as it passes the anemometer:	☐ Yes ☐ No
(e)(2) Record the location of the anemometer along the test track, to the nearest 10 feet:	☐ Yes ☐ No
(e)(3) Mount the anemometer at a height that is within 6 inches of half the test vehicle's body height:	☐ Yes ☐ No
(e)(4) The height of vegetation surrounding the anemometer may not exceed 10% of the anemometer's mounted height, within a radius equal to the anemometer's mounted height:	☐ Yes ☐ No
2.5: Measure air speed and relative wind direction (yaw angle) onboard the vehicle at a minimum recording frequency of 10 Hz, in conjunction with time-of-day data, using an anemometer and suitable data loggers that meet the requirements of Sections 5.4 of SAE J2263:	**40 CFR 1037.528(f)**
(f) The yaw angle measured to a resolution and accuracy of ±0.5°:	☐ Yes ☐ No
(f) Mount the anemometer such that it measures air speed at 1.5 meters above the top of the leading edge of the trailer:*	☐ Yes ☐ No

2.6: SAE J2263 REQUIREMENTS	
2.6.1: Instrumentation Requirements:	**SAE J2263 Section 5**
(5.1) All instrumentation calibrated:	☐ Yes ☐ No
(5.2) Time measured to an accuracy of ±0.001 s:	☐ Yes ☐ No
(5.2) Time recorded to a resolution of 0.01 s:	☐ Yes ☐ No
(5.3) Vehicle speed measured to an accuracy of 0.1mi/h:	☐ Yes ☐ No
(5.3) Vehicle speed recorded to a resolution of 0.1mi/h:	☐ Yes ☐ No
(5.4) Relative wind speed measured to an accuracy of 0.6mph:	☐ Yes ☐ No
(5.4) Relative wind speed recorded to a resolution of 0.6mi/h:	☐ Yes ☐ No
(5.4) Calibration of the anemometer included corrections for vehicle "blockage."	☐ Yes ☐ No
(5.5) Relative wind direction (Yaw) measured to an accuracy of 3 degrees:	☐ Yes ☐ No
(5.5) Relative wind direction (Yaw) recorded to a resolution of 1 degree:	☐ Yes ☐ No
(5.5) Dead band of the instrument not exceeded 10 degrees:	☐ Yes ☐ No
(5.5) Dead band of the instrument directed toward the rear of the vehicle:	☐ Yes ☐ No
(5.5) Calibration of the instrument included corrections for vehicle "blockage."	☐ Yes ☐ No
(5.6) Ambient Temperature measured to an accuracy of 1.8°F:	☐ Yes ☐ No
(5.6) Ambient Temperature recorded to a resolution of 1.8°F:	☐ Yes ☐ No
(5.6) True Air Temperature (shielded from the sun and	☐ Yes ☐ No
(5.6) Ambient Temperature measured in a location such that it is not influenced by the vehicle:	☐ Yes ☐ No
(5.7) Atmospheric pressure measured to an accuracy of 0.1 in-hg:	☐ Yes ☐ No
(5.7) Atmospheric pressure recorded to a resolution of 0.1 in-hg:	☐ Yes ☐ No
(5.7) Track side pressure readings:	☐ Yes ☐ No
(5.8) Tire Pressure measured to an accuracy of 1psi:	☐ Yes ☐ No
(5.9) Vehicle (and axle) mass measured to an accuracy of ±22 lb., if vehicles over 8818 lb. the accuracy requirement is ±44 lb. :	☐ Yes ☐ No

2.6: SAE J2263 REQUIREMENTS	
2.6.2: Vehicle Preparation:	**SAE J2263 Section 6**
(6.1) Vehicle road service mileage prior to testing:	
(6.1) Tires road service mileage prior to testing:	
(6.2)(a) Vehicle description including make, model year, body style, VIN, engine and transmission type:	
(6.2)(b) Tire size, manufacturer, tire performance code (TPC), DOT identification number for each tire and the amount of thread on each tire:	
(6.2)(c) Aerodynamic drag coefficient:	
(6.2)(d) Frontal area:	
(6.2)(e) Vehicle ride heights measured using the procedure specified by the manufacturer:	
(6.2)(f) Manufacturer's minimum recommended tire inflation pressure:	
(6.2)(g) Wheel bearing and brake drag for abnormal conditions:	
(6.2)(h) Vehicle alignment to manufacturer's mean specification:	☐ Yes ☐ No
(6.2)(h) Recorded values for vehicle alignment:	
(6.3) fluid level corrected to manufacturer's specifications:	☐ Yes ☐ No
(6.4) Instrumentation installed on the vehicle in such a manner as to minimize effects on the operating characteristics of the vehicle:	☐ Yes ☐ No
(6.5) The vehicle fuel tank filled. For multiple fuel tanks, only main (largest) tank filled:	☐ Yes ☐ No
(6.6) The vehicle tires inflated to the vehicle manufacturer's minimum recommended inflation pressure, adjusted for changes in temperature between the tire soak area temperature at the time of inflation and the test track ambient temperature:	☐ Yes ☐ No
(6.6) The tire pressure set and recorded prior to moving the vehicle:	☐ Yes ☐ No
(6.6.1) The test was run immediately after vehicle preparation:	☐ Yes ☐ No

2.6: SAE J2263 REQUIREMENTS	
2.6.3: Test Conditions:	**SAE J2263 Section 7**
(7.1) Ambient Temperature between 41 to 95°F:	☐ Yes ☐ No
(7.2) Average wind speed not exceeded 21.7 mi/h:	Section 2.2 (c)(1) requirement
(7.2) Wind gusts not exceeded 31.3 mi/h:	Section 2.9 (7.3) requirement
(7.2) Average cross winds not exceeded 9.3 mi/h:	☐ Yes ☐ No
(7.3) Tests done during fog or precipitation conditions:	☐ Yes ☐ No
(7.4) Test road was dry, clean, straight, smooth, hard surfaced, no excessive crown and a constant grade of no more than 0.5%:	☐ Yes ☐ No Section 2.2 (c)(4) requirement can be applied
2.6.4: Pretest Operations:	**SAE J2263 Section 8**
(8.1) If not adjusted for the track ambient temperature, the vehicle tire pressures bled down to the manufacturer's minimum recommend tire pressure:	☐ Yes ☐ No
(8.2) The vehicle weighed to verify that it has been adjusted to the correct total mass and individual axle loads:	☐ Yes ☐ No
(8.3) Vehicle and tires preconditioned for a minimum of 30 min total operation at 49.7 mi/h:	☐ Yes ☐ No
2.6.5: Coastdown test:	**SAE J2263 Section 9**
(9.1) Vehicle windows and vents closed:	☐ Yes ☐ No
(9.1) Headlights turned on:	☐ Yes ☐ No
(9.1) If needed, air conditioning in the re-circulation mode and its use recorded.	☐ Yes ☐ No
(9.2) A minimum of 10 runs in alternating directions; 5 runs in each direction:	☐ Yes ☐ No
(9.3) Test began immediately following preconditioning:	☐ Yes ☐ No
(9.3) Vehicle speed of 77.7mi/h or higher at the star of each run:	☐ Yes ☐ No
(9.3) Data recorded in a stabilized required speed conditions:	☐ Yes ☐ No
(9.3) Time between runs minimized to reduce the effect of changes in tire and lubricant temperatures:	☐ Yes ☐ No
(9.3.1) The track length is sufficient for the entire speed range:	☐ Yes ☐ No
(9.3.1) Split run option applied:	☐ Yes ☐ No
(9.4) Lane Changes avoided:	☐ Yes ☐ No
(9.5) Vehicles moving in the same direction as the test vehicle:	☐ Yes ☐ No
(9.5) Any vehicles came within 0.12 mil either leading or trailing test vehicle:	☐ Yes ☐ No

2.7: SAE J1263 REQUIREMENTS	
2.7.1: Test Conditions:	**SAE 1263 Section 7**
(7.1) Ambient Temperature between 41 to 95°F:	☐ Yes ☐ No
(7.2) Tests done during foggy conditions:	☐ Yes ☐ No
(7.3) Average wind speed not exceeded 10.0 mi/h:*	Section 2.2 (c)(1) requirement
(7.3) Peak wind speed not exceeded 12.3 mi/h:	☐ Yes ☐ No
(7.3) Average of the component of the wind velocity perpendicular to the test road not exceeded 5.0 mi/hr:	☐ Yes ☐ No
(7.4) Test road was dry, clean, straight, smooth, and concrete or rolled asphalt in good condition and a constant grade of no more than 0.5%:*	☐ Yes ☐ No Section 2.2 (c)(4) requirement can be applied

TEST TRACTOR CHARACTRISTICS:

TEST TRAILER CHARACTRISTICS:

TESTED DEVICE/PACKAGE CHARACTRISTICS:

2.9: Instrumentation Specifications and Set up: **40 CFR 1037.528(e)**

INSTRUMENTATION AND DATA ACQUISITION:

CALIBRATION:

SET UP:

VEHICLE CONDITIONS:

TEST CONDITIONS:

TRACK CONDITIONS:

2.12: Measured Data Points: 40 CFR 1037.528(e)(f)

RUN#	Date and time								
Recording Frequency (Data Point)	Avg. Wind Speed (mph)	Max. Wind Speed (mph)	Avg. Wind Speed Parallel to the Road (mph)	Avg. Wind Speed Perpendicular to the Road (mph)	Wind Direction	Yaw Angle (degree)	Air Temperature (°F)	Air Pressure (in-hg)	Vehicle Speed (mph)

Baseline

RUN#	Date and time								
Recording Frequency (Data Point)	Avg. Wind Speed (mph)	Max. Wind Speed (mph)	Avg. Wind Speed Parallel to the Road (mph)	Avg. Wind Speed Perpendicular to the Road (mph)	Wind Direction	Yaw Angle (degree)	Air Temperature (°F)	Air Pressure (in-hg)	Vehicle Speed (mph)

Aerodynamic Device

2.13: Measured Data Filter and Correction Calculations: **40 CFR 1037.528(g)**

INCORPORATE THE DISCUSSION AND CALCULATION OF FILTERING AND CORRECTING MEASURED DATA:

INCLUDING ALL CALCULATIONS REQUIRED BY SECTION (g) OF 40 CFR 1037.528.

2.14: Average C_dA Calculations: **40 CFR 1037.528(h)**

INCORPORATE THE DISCUSSION AND CALCULATION OF EFFECTIVE YAW ANGLE, ψ_{eff} AND $C_dA_{effective\text{-}yaw\text{-}coastdown}$:

INCLUDING ALL CALCULATIONS REQUIRED BY SECTION (h) OF 40 CFR 1037.528.

2.15: Tabulated Test Results:

40 CFR 1037.528(h)

Baseline-High Speed Segment											
RUN#	$\overline{v}^2_{air,hi}$ (m^2/s^2)	$\overline{v}^2_{air,lo,pair}$ (m^2/s^2)	F_{hi} (N)	$F_{lo,pair}$ (N)	ΔF_{spin} (N)	ΔF_{TRR} (N)	$\overline{T}$ (K)	$\overline{P}_{act}$ (Pa)	C_dA (m^2)	ψ (degree)	ψ_{med} (degree)

Aero Device-High Speed Segment											
RUN#	$\overline{v}^2_{air,hi}$ (m^2/s^2)	$\overline{v}^2_{air,lo,pair}$ (m^2/s^2)	F_{hi} (N)	$F_{lo,pair}$ (N)	ΔF_{spin} (N)	ΔF_{TRR} (N)	$\overline{T}$ (K)	$\overline{P}_{act}$ (Pa)	C_dA (m^2)	ψ (degree)	ψ_{med} (degree)

Baseline		Aero Device		
Ψ_{eff} (degree)	C_dA effective-yaw-coastdown (m^2)	Ψ_{eff} (degree)	C_dA effective-yaw-coastdown (m^2)	Delta C_dA (m^2)

2.16: Photos of Baseline Article:

2.17: Photos of Tested Article (Device/Package):

Wind-Tunnel	
The aerodynamic performance data for the device described in this section are based on testing at …….....	
The tests were completed in accordance with methods specified in 40 CFR 1037.530 and SAE J1252 test procedure as detailed below.	
Include the following information in your request to determine C_dA values using Wind-Tunnel:	**40 CFR 1037.530(d)**
(d)(1) Name and location of test facility:	
(d)(2) Background and history of wind-tunnel:	
(d)(3) The wind-tunnel's layout (with diagram), type, and construction (structural and material):	
(d)(4) The wind-tunnel's design details:	
(d)(5) The wind-tunnel's flow quality:	
(d)(6) The wind-tunnel's test/working section information:	
(d)(7) The wind-tunnel's fan section description:	
(d)(8) The wind-tunnel's data acquisition and control:	
(d)(9) The wind-tunnel's moving ground plane or rolling road:	
(d)(10) Facility correction factors and purpose:	

3: WIND-TUNNEL PROTOCOL CHECKLIST		
Testing completed using SAE J1252 with the following exceptions and additional provisions:		**40 CFR 1037.530(a)**
Wind-Tunnel Recognized by the Subsonic Aerodynamic Testing Association:	☐ Yes ☐ No	
Wind-tunnel meets §1037.530 Specifications[7]:	☐ Yes ☐ No	
(a)(1) Overall Vehicle Reynolds Number ($Re^{\#}_{w}$):		
(a)(3) Wind-tunnel Scale:	☐ 1/8 ☐ 30% ☐ Other ( )	
(a)(3) Scaled model is sufficient to simulate airflow through the radiator inlet grill:	☐ Yes ☐ No	
(a)(3) Scaled model is sufficient to simulate airflow across an engine geometry that represents engines commonly used in the test vehicle:	☐ Yes ☐ No	
Open-throat wind-tunnel must also meet the specifications of SAE J2071:		**40 CFR 1037.530(b)**
(b) Open-throat wind-tunnel:	☐ Yes ☐ No	
Determine C_dA values for certifying trailers:		**40 CFR 1037.530(c)**
(c) Use a standard tractor:	☐ Yes ☐ No	
(c) Use a moving/rolling floor:	☐ Yes ☐ No	
(c) Measure the drag area at +4.5° and -4.5° yaw angles	☐ Yes ☐ No	
(c) Calculate the average of drag area at +4.5° and -4.5° yaw angles	☐ Yes ☐ No	

7: If the answer is "NO", you may ask CARB to approve it as an alternate method under §1037.526(d).

3.1: Data reporting requirements:	SAE J1252 Section 9.1.13
(9.1.13)(a) Test section dimensions:	
(9.1.13)(b) Ground simulation type:	
(9.1.13)(c) Ground simulation location and dimensions:	
(9.1.13)(d) Empty facility boundary layer velocity profile at model front bumper or center:	
(9.1.13)(e) Model location on ground plane/belt:	
(9.1.13)(f) Distance of model from collector:	
(9.1.13)(g) Distance of model from nozzle:	
(9.1.13)(h) Model dimensions:	
(9.1.13)(i) Type of test section:	
(9.1.13)(j) Type of support:	
(9.1.13)(k) Blockage: frontal area/test section cross sectional area	
(9.1.13)(l) Facility instrument source bias values:	
(9.1.13)(m) Photographs of all tested model configurations:	
(9.1.13)(n) Photographs of all model installed in wind tunnel:	
(9.1.13)(o) Description of baseline model and modifications:	
(9.1.13)(p) Description of engine cooling flow simulation:	
(9.1.13)(q) Description of blockage correction used (if any):	
(9.1.13)(r) Scale of model:	
(9.1.13)(s) Results of Reynolds number test (velocity sweep):	
(9.1.13)(t) Results of cooling drag increment (if tested is conducted):	
(9.1.13)(u) Force measurement system specifications:	
(9.1.13)(v) Signal conditioning and data acquisition system specification:	
(9.1.13)(w) Sample rate/duration/filtering:	
(9.1.13)(x) Wind averaged drag coefficient for each configuration tested should be presented in tabular form. The road vehicle averaged wind speed (V_W) chosen and the chosen road vehicle (V_T) should be reported:	
(9.1.13)(y) Yaw-drag coefficient polar plots should be presented for each tested configuration. A discussion of corrections applied should list all assumptions and relevant parameters.	
(9.1.13)(z) Uncertainty estimates should be reported using a 95% confidence interval. The report should specify the mean value of a measured response +/- the uncertainty U. The method and configurations used for uncertainty calculations should be documented.	

TEST TRUCK CHARACTRISTICS:

TEST TRAILER CHARACTRISTICS:

TESTED DEVICE/PACKAGE CHARACTRISTICS:

3.3: Test Facility: **40 CFR 1037.530(d)(2)**

HISTORY & BACKGROUND:

3.4: Wind Tunnel Layout: **40 CFR 1037.530(d)(3)**

3.5: Wind Tunnel Design Details: **40 CFR 1037.530(d)(4)**

TYPE:

CONSTRUCTION:

CORNER TURNING VANES:

AIR SETTLING:

MESH SCREEN SPECIFICATION:

AIR STRAIGHTENING:

TUNNEL VOLUME:

SURFACE AREA:

AVERAGE DUCT AREA:

CIRCUIT LENGTH:

TEMPERATURE CONTROL:

3.6: Wind Tunnel Flow Quality: **40 CFR 1037.530(d)(5)**

AIR FLOW QUALITY:

MINIMUM AIRFLOW VELOCITY:

FLOW UNIFORMITY:

ANGULARITY/STABILITY:

STATIC PRESSURE VARIATION:

TURBULENCE INTENSITY (PERCENT TURBULENCE:

TEST DURATION FLOW QUALITY:

3.7: Test/Working Section Information: **40 CFR 1037.530(d)(6)**

TYPE:

LENGTH:

CONTRACTION RATIO:

MAXIMUM AIR VELOCITY:

MAXIMUM DYNAMIC PRESSURE:

NOZZLE WIDTH:

NOZZLE HEIGHT:

PLENUM DIMENSIONS:

PLENUM NET VOLUME:

MAXIMUM MODEL SCALE:

MAXIMUM MODEL HEIGHT
ABOVE ROAD:

MODEL SUPPORT:

PRIMARY BOUNDARY-LAYER SLOT:

BOUNDARY-LAYER ELIMINATION:

3.8: Fan Section Description: **40 CFR 1037.530(d)(7)**

FAN TYPE:

FAN DIAMETER:

FAN POWER:

MAXIMUM ROTATIONAL SPEED:

MAXIMUM TIP SPEED:

FAN SUPPORT:

FAN MECHANICAL DRIVE:

FAN SECTION TOTAL WEIGHT:

3.9: Data Acquisition and Control: **40 CFR 1037.530(d)(8)**

DATA ACQUISITION TYPE:

MOTOR CONTROL:

TUNNEL CONTROL:

MODEL BALANCE:

MODEL PRESSURE MEASUREMENT:

WHEEL DRAG BALANCES:

WING/BODY PANEL BALANCES:

MODEL EXHAUST SIMULATION:

3.10: Moving Ground Plane (Rolling Road): 40 CFR 1037.530(d)(9)

CONSTRUCTION AND MATERIAL:

YAW TABLE AND RANGE:

MOVING GROUND LENGTH:

MOVING GROUND WIDTH:

BELT TYPE:

MAXIMUM BELT SPEED:

BELT SUCTION:

PLATEN INSTRUMENTATION:

TEMPERATURE CONTROL:

STEERING:

3.11: Photos of Baseline Article:

SAE J1252 Section 9.1.13 (n)

3.12: Photos of Tested Article (Device/Package): SAE J1252 Section 9.1.13 (m)

3.13: Tabulated Test Results: **SAE J1252 Section 9.1.13 (x)**

THE ROAD VEHICLE AVERAGE WIND SPEED (V_W) CHOSEN AND THE CHOSEN ROAD VEHICLE SPEED (V_T) SHOULD BE REPORTED:

RUN#	DESCRIPTION	YAW AOA	C_D	C_DA [m^2]
		0		
		1		
		3		
		4.5		
		6		
		9		
		0		
		-1		
		-3		
		-4.5		
		-6		
		-9		
		0		
		Avg.		

Baseline Run before Aerodynamic Device Run

RUN#	DESCRIPTION	YAW AOA	C_D	C_DA [m^2]
		0		
		4.5		
		0		
		-4.5		
		0		
		Avg.		
			ΔC_DA	
			ΔC_D	

Aerodynamic Device Run

RUN#	DESCRIPTION	YAW AOA	C_D	C_DA [m^2]
		0		
		4.5		
		0		
		-4.5		
		0		
		Avg.		
			ΔC_DA	
			ΔC_D	

Baseline Run after Aerodynamic Device Run

CONFIGURATION	C_DA [m^2]	ΔC_DA [m^2]
BASELINE		
DEVICE/PACKAGE		

Final ΔC_DA Results

3.14: Yaw-Drag Coefficient Polar Plots: **SAE J1252 Section 9.1.13 (y)**

INCORPORATE THE DISCUSSION OF CORRECTIONS APPLIED
INCLUDING THE LIST OF ALL ASSUMPTIONS AND RELEVANT

3.15: Uncertainty Requirements and Calculations: **SAE J1252 Section 9.1.13 (z)**

THE MEHOD AND CONFIGURATIONS USED FOR UNCERTAINTY CALCULATIONS SHOULD BE DOCUMENTED:

3.16: Data Reduction: **40 CFR 1037.530(d)(10)**

INCORPORATE THE DISCUSSION OF FACILITY CORRECTION FACTORS AND PURPOSE:

APPENDIX A: TECHNICAL DRAWINGS

APPENDIX B: INSTALLATION INSTRUCTIONS

APPENDIX C: MAINTENANCE INSTRUCTIONS