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Performance Requirements for Determining Tow-Vehicle Gross Combination Weight Rating and Trailer Weight Rating

RATIONALE

This document is being revised primarily to correct some Table 1 standard trailer weight range descriptions and to clarify test setup, ballast procedures and test requirements in several areas.

FOREWORD

Light truck, minivan, sport utility and crossover vehicles represent a significant portion of the North American vehicle mix, and trailering usage of these vehicles has increased. Heavier duty models, approaching medium duty trucks and often intended for trailering, have become more popular as well. Some passenger cars are also rated to tow trailers. For many vehicles, trailer weight rating may be a major marketing point.

As trailer weight ratings have increased, engine characteristics like horsepower and torque, thermal performance and driveline durability are no longer the only significant factors in determining trailering capability. Combination vehicle dynamics and tow-vehicle hitch/attachment structure have gained in significance.

This document defines procedures and requirements to determine Gross Combination Weight Rating (GCWR) and calculate corresponding Trailer Weight Rating (TWR) for any tow-vehicle. These procedures will establish consistent rating requirements and processes so end users (customers) can reasonably compare similar class models in terms of trailering ability.

1. SCOPE

This document establishes minimum performance criteria at GCWR and calculation methodology to determine tow-vehicle TWR for passenger cars, multipurpose passenger vehicles and trucks. This includes all vehicles up to 13 000 lb GVWR. It is recommended that the performance requirements within be adopted for all vehicles with model year designation 2013 or later.

1.1 Purpose

This document establishes tow-vehicle performance requirements for combination vehicle acceleration, gradeability, understeer, trailer sway response, braking and park brake at GCWR, and tow-vehicle hitch/attachment structure at TWR. In order to minimize test variations, it provides standard test trailer specifications and requirements for use in these tests. It is acknowledged that there are a wide variety of conditions experienced while trailering which cannot be completely addressed within this document and in no way is this document intended to establish or limit manufacturers' designs or instructions to the customer. This document provides simple equations to determine TWR from GCWR in conjunction with other vehicle ratings and defined vehicle weight conditions and dimensions.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J266 Steady-State Directional Control Test Procedures for Passenger Cars and Light Trucks

SAE J684 Trailer Couplings, Hitches, and Safety Chains - Automotive Type

SAE J1491 Vehicle Acceleration Measurement

SAE J2638 Fifth Wheel and Gooseneck Attachment Performance Up to 13 608/kg (30 000/lb) Trailer GVW

SAE J2664 Trailer Sway Response Test Procedure

2.1.2 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 4138 Passenger cars - Steady-state circular driving behaviour - Open-loop test methods

ISO 7401 Road vehicles - Lateral transient response test methods - Open-loop test methods

2.1.3 EEC/ECE Regulations

ECE Regulations available from United Nations Economic Commission for Europe, Palais des Nations, CH-1211, Geneva 10, Switzerland, Tel: 41-0-22-917-12-34, www.unece.org.

EEC Regulations available from Automotive Industry, European Commission, B-1049 Brussels Belgium, Tel: 32-2-299-96-96, www.ec.europa.eu.

92/21/EEC Masses and Dimensions of Motor Vehicles of Category M1, as amended by Directive 95/48/EC

ECE R13H Uniform Provisions Concerning the Approval of Passenger Cars with Regard to Braking

2.1.4 United States Government Federal Safety Standards

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

Motor Vehicle Safety Standard No. 105 Hydraulic and Electric Brake Systems

Motor Vehicle Safety Standard No. 135 Passenger Car Brake Systems

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J134 Brake System Road Test Code—Passenger Car and Light-Duty Truck-Trailer Combinations

SAE J135 Service Brake System Performance Requirements—Passenger Car-Trailer Combinations

SAE J670 Vehicle Dynamics Terminology

2.2.2 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO/TR 4114 Road vehicles - Caravans and light trailers - Static load on ball couplings

ISO 8855 Road vehicles - Vehicle dynamics and road-holding ability - Vocabulary

ISO 9815 Road vehicles - Passenger-car and trailer combinations - Lateral stability test

2.2.3 United States Government Office of the Federal Register Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpoaccess.gov/cfr/retrieve.html.

Title 40 CFR, Section 86.1832-01 Optional Equipment and Air Conditioning for Test Vehicles

Title 49 CFR, Section 393.52 Brake Performance

2.2.4 Other Publications

2.2.4.1 SAE Papers

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

Klein, R., Johnston, D., and Szostak, H., "Effects of Trailer Hookup Practices on Passenger Car Handling and Braking," SAE Technical Paper 780012, 1978

Klein, R.H. and Szostak, H.T., "Determination of Trailer Stability Through Simple Analytical Methods and Test Procedures," SAE Technical Paper 790186, 1979

Klein, R.H. and Szostak, H.T., "Development of Maximum Allowable Hitch Load Boundaries for Trailer Towing," SAE Technical Paper 800157, 1980

2.2.4.2 NHTSA Technical Reports

Available from NHTSA, 1200 New Jersey Avenue, SW, Washington, DC 20590, Tel: 1-888-327-4236, www.nhtsa.gov.

Handling Test Procedures for Passenger Cars Pulling Trailers, Vol. I: Summary Report, Vol. II: Technical Report, Vol. III: Appendices, NHTSA DOT HS-801-935, 936 and 937, June 1976, NTIS: PB-256 071, 072, 073

Development of Car/Trailer Handling and Braking Standards, Vol. I: Executive Summary, Vol. II: Technical Report for Phase I - Rear Wheel Drive Tow Cars, Vol. III: Appendices for Phase I, Vol. IV: Technical Report for Phase II - Front Wheel Drive Tow Cars, NHTSA DOT HS-805 326, 327, 328 and 329, Nov. 1979

Effects of Weight Distributing Hitch Torque on Car-Trailer Directional Control and Braking, NHTSA DOT HS-803 246, 1977

2.2.4.3 American Association of State Highway and Transportation Officials (AASHTO) Publications

Available from AASHTO, 444 North Capitol Street, NW, Suite 249, Washington, DC 20001, Tel: 202-624-5800, www.transportation.org.

A Policy on Geometric Design of Highways and Streets, 4th Edition, 2001
Chapter 3: Elements of Design, Section ‘Grades’, pp 235 - 247
Chapter 8: Freeways, Section ‘General Design Considerations: Grades’, pp 509 - 510

3. DEFINITIONS

3.1 CONVENTIONAL TRAILER

A semi-trailer with a coupling device designed to attach to the rear of the tow-vehicle. This does not include fifth wheel or gooseneck trailers.

3.2 TOW-VEHICLE TRAILERING WEIGHT (TVTW)

3.2.1 Tow-vehicles Under 8500 lb GVWR

TVTW is the weight of the tow-vehicle used for EPA emissions and fuel economy certification including all options in excess of 33% sales penetration plus one 68.0 kg (150 lb) driver and one 68.0 kg (150 lb) front seat passenger, plus the tow-vehicle manufacturer’s available trailering package and/or any required trailering content (if not included in the 33% option penetration weight) plus representative aftermarket trailering equipment as specified in 5.2. In the case where a trailering package is not available from the tow-vehicle manufacturer or it does not include a trailer hitch component, the representative aftermarket trailering equipment as specified in 5.2 shall include a trailer hitch component.

3.2.2 Tow-vehicles at 8500 lb or Greater GVWR

TVTW is base vehicle curb weight plus one 68.0 kg (150 lb) driver and one 68.0 kg (150 lb) front seat passenger plus 45.4 kg (100 lb) of optional equipment split evenly between front and rear axles plus the tow-vehicle manufacturer’s available trailering package and/or any required trailering content and representative aftermarket trailering equipment as specified in 5.2. In the case where a trailering package is not available from the tow-vehicle manufacturer or it does not include a trailer hitch component, the representative aftermarket trailering equipment as specified in 5.2 shall include a trailer hitch component.

3.2.3 Incomplete Tow-vehicles Requiring Final Stage Manufacturer Completion

TVTW is base incomplete vehicle curb weight plus one 68.0 kg (150 lb) driver and one 68.0 kg (150 lb) front seat passenger plus 45.4 kg (100 lb) of optional equipment split evenly between front and rear axles plus 119.1 kg/m (80 lb/ft) for body completion from the rear surface of the cab to the rear end of the frame rail (or rearmost edge of incomplete vehicle structure) plus the tow-vehicle manufacturer's available trailering package and/or any required trailering content and representative aftermarket trailering equipment as specified in 5.2. In the case where a trailering package is not available from the tow-vehicle manufacturer or it does not include a trailer hitch component, the representative aftermarket trailering equipment as specified in 5.2 shall include a trailer hitch component.

3.2.4 Tow-Vehicles Completed by Final Stage Manufacturers

TVTW is that for an incomplete vehicle as defined in 3.2.3 except that the body completion weight shall equal the base weight of the body style of the manufacturer's body completion. The exception to this is that a motorhome body completion shall include 226.8 kg (500 lb) of optional equipment split evenly between front and rear axles plus the base weight of the motorhome completion.

3.3 TRAILER WEIGHT RATING (TWR)

TWR is the rated value for the maximum allowable weight of a loaded trailer for a specific tow-vehicle model and hitch type, as determined by the tow-vehicle manufacturer. A specific tow-vehicle may have multiple TWRs for weight carrying hitch, weight distributing hitch, fifth wheel hitch and/or gooseneck hitch. A tow-vehicle may also have a TWR for an unbraked trailer.

3.4 TRAILER ROTATION RADIUS RATIO (RRR)

RRR is the yaw radius of gyration divided by effective tongue length (ETL).

3.5 EFFECTIVE TONGUE LENGTH (ETL)

ETL is the longitudinal distance from the center of the trailer coupler ball socket to the center of the trailer wheel(s).

3.6 FRONT AXLE LOAD RESTORATION (FALR)

FALR is the change in front axle load due to weight distributing hitch application divided by change in front axle load due to addition of trailer tongue weight, expressed in percent.

$$FALR = 100 \times (Wf_{CT\text{-}Vwd} - Wf_{CT\text{-}V}) / (Wf_{UT\text{-}V} - Wf_{CT\text{-}V}) \quad \text{(Eq. 1)}$$

where:

FALR front axle load restoration (%)
$Wf_{UT\text{-}V}$ front axle weight of the uncoupled tow vehicle (N)
$Wf_{CT\text{-}V}$ front axle weight of the coupled tow vehicle without weight distribution (N)
$Wf_{CT\text{-}Vwd}$ front axle weight of the coupled tow vehicle with weight distribution (N)

4. TECHNICAL REQUIREMENTS

This section provides specifications and/or requirements for standard trailers, trailer hitch equipment and combination vehicle connections. It also provides performance requirements for tow-vehicle structure, propulsion system performance and combination vehicle handling and braking. Tow-vehicle GCWR is qualified by conformance to the performance requirements following in this section. Should the tow-vehicle be capable of different GCWR values throughout the various tests in this section, the actual GCWR will be the least of the values attained. The performance requirements of this document are not intended to be used to establish minimum acceptable values for various aspects of trailering. The performance requirements and metrics specified in this document are selected considering carefully controlled specific trailers, combination load conditions and driving maneuvers to provide for objective comparisons of tow-vehicle performance. The full range of acceptable trailer loading conditions, trailer types and driving maneuvers to be experienced by actual customers may produce some lower performance values that remain in the range of acceptability. There is nothing in this document that precludes the use of analytical methods to confirm conformance to requirements. It is presumed that analytical methods, when used, should produce results that are equivalent to physical test results. Physical test results, when available, supersede analytical method results.

4.1 Standard Trailer

This section defines representative ‘standard’ trailers, connections and ballast conditions for test purposes. This is not intended to define ‘worst-case’ trailer loading or specifications, or to establish limits in trailer types that can be towed. The frontal area consideration is required only for propulsion system testing; effective tongue length consideration is required only for dynamics testing. Trailers to be used for dynamics purposes should be equipped with limited optional equipment in order to minimize trailer weight and maximize ballast flexibility. Additional trailer, hitch connection and ballast requirements for testing various performance attributes (propulsion, handling and braking) may be found in those specific sections. The frontal area requirements account for entire trailer frontal silhouette to the ground plane.

4.1.1 Trailer Size/Shape

TABLE 1 - STANDARD TRAILER REQUIREMENTS

	Trailer Type	TWR Requirement	Axle(s)	Maximum Effective Tongue Length	Tire Brand/Size/ Pressure	Minimum Frontal Area
A	Conventional	≤454 kg (1000 lb)	Single	2.1 m (83 in)	Goodyear Marathon Radial ST175/80R13C 345 kPa (50 psi) or Duro Bias ST175/80D13C 345 kPa (50 psi)	1.11 m^2 (12 ft^2)
B	Conventional	≤907 kg (2000 lb)	Single	2.7 m (106 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	1.86 m^2 (20 ft^2)
C	Conventional	≤1588 kg (3500 lb)	Single	2.7 m (106 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	2.79 m^2 (30 ft^2)
D	Conventional	≤2268 kg (5000 lb)	Tandem	4.2 m (165 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	3.72 m^2 (40 ft^2)
E	Conventional	≤3493 kg (7700 lb)	Tandem	4.2 m (165 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	5.11 m^2 (55 ft^2)
F	Conventional	≤4536 kg (10 000 lb)	Tandem	5.0 m (196 in)	Goodyear Marathon Radial ST225/75R15D 540 kPa (65 psi)	5.57 m^2 (60 ft^2)
G	Conventional	≤5897 kg (13 000 lb)	Tandem	5.7 m (224 in)	Goodyear Marathon Radial ST235/80R16D 540 kPa (65 psi)	5.57 m^2 (60 ft^2)
H	Conventional	>5897 kg (13 000 lb)	Tandem/Triple	6.4 m (252 in)	Goodyear G114 Unisteel 215/75R17.5H 865 kPa (125 psi)	5.57 m^2 (60 ft^2)
J	Fifth Wheel or Gooseneck	Commensurate with tow-vehicle TWR	Tandem/Triple	10.7 m (420 in)	Commensurate with trailer Gross Axle Weight Rating (GAWR)	6.97 m^2 (75 ft^2)

With the exception of trailers defined by row ‘A’ above, trailers should all be cargo (‘box’) type with flat, vertical front wall and corner radii no more than 152.4 mm (6 in). Reference Appendix A for trailer exemplars that meet these requirements.

4.1.2 Trailer Chassis

Torsion or leaf spring suspensions are acceptable. Tire size and type shall be as specified by the trailer manufacturer with maximum load capacity consistent with trailer GAWR. Tire load capacities are defined in the Tire and Rim Association Yearbook. Tires should be inflated to maximum sidewall pressure, have a minimum tread depth of 3.97 mm (5/32 in) and be in good condition. Trailer brakes are required at all wheels of trailers with GVWR of 1361 kg (3000 lb) or more.

4.1.3 Trailer Ballast

Unless otherwise specified, all performance tests in this document shall be run with the tow-vehicle/trailer combination ballasted to a minimum of the appropriate GCWR. The trailer ballast should be placed on the floor of the trailer in ‘ballast boxes’ or secured in such a manner that it cannot shift during testing. It should also be equally distributed left and right of the longitudinal centerline of the trailer. Additional information on distribution of ballast between and/or within tow-vehicle and trailer may be found in specific performance requirement sections.

4.2 Tow-vehicle Structural Performance

This section defines tow-vehicle structural performance requirements at maximum TWR as determined (or targeted) as in Section 5. This section should be used to determine any or all of the following TWR limits: weight carrying TWR, weight distributing TWR, fifth wheel TWR and gooseneck TWR.

4.2.1 Tow-vehicle Structural Performance Requirement Summary

The tow-vehicle frame, body sheet metal, trailer hitch or hitch receiver, rear bumper and/or any other structure intended to react trailering loads, shall be capable of meeting the requirements of SAE J684 or SAE J2638 for the specified TWR and hitch type. Table 2 summarizes metrics, requirements and test methods for specific performance attributes.

TABLE 2 - TOW-VEHICLE STRUCTURAL REQUIREMENTS

Performance Attribute	Performance Metric	Requirement	Test Procedure
Tow-vehicle Structural Strength (conventional trailer)	Angular deformation	5 degree permanent deformation in any direction	SAE J684
Tow-vehicle Structural Strength (fifth wheel hitch)	Ability to withstand load	React load for minimum of 5 s	SAE J2638
Tow-vehicle Structural Strength (gooseneck hitch)	Ability to withstand load	React load for minimum of 5 s	SAE J2638
Tow-vehicle Structural Durability (fifth wheel hitch)	Ability to attain loads throughout test	No loss of attachment; react loads throughout test	SAE J2638
Tow-vehicle Structural Durability (gooseneck hitch)	Ability to attain loads throughout test	No loss of attachment; react loads throughout test	SAE J2638

4.2.2 Test Tow-vehicle Structure Selection

The tow-vehicle structure shall be the least capable required to produce the maximum TWR under test. In the case where multiple models (body style, wheelbase, GVWR, etc) or multiple chassis packages within a model share similar structures, it is the responsibility of the tow-vehicle tester to choose the appropriate structure to test to the maximum TWR of the model group.

4.3 Tow-vehicle Propulsion System Performance

This section defines tow-vehicle propulsion system performance requirements at GCWR. This section should be used to determine any or all of the following GCWR limits: conventional trailer GCWR, fifth wheel GCWR and/or gooseneck trailer GCWR.

4.3.1 Propulsion System Performance Requirement Summary

The tow-vehicle propulsion and thermal management systems, in conjunction with appropriate test trailer(s) per 4.1, shall be capable of meeting certain acceleration, launch and gradeability requirements for the specified GCWR. The following table summarizes metrics, requirements and test methods for specific performance attributes.

TABLE 3 - TOW-VEHICLE PROPULSION REQUIREMENTS

Performance Attribute	Performance Metric	Requirement	Test Procedure
Level Road Acceleration	0 to 96.6 km/h (0 to 60 mph)	30.0 s (single rear wheel tow-vehicles); 35.0 s (dual rear wheel tow-vehicles)	SAE J1491, modified in 4.3.2 and 4.3.3
Level Road Acceleration	0 to 48.3 km/h (0 to 30 mph) Interval	12.0 s (single rear wheel tow-vehicles); 14.0 s (dual rear wheel tow-vehicles)	SAE J1491, modified in 4.3.2 and 4.3.3
Level Road Acceleration	64.4 to 96.6 km/h (40 to 60 mph) Interval	18.0 s (single rear wheel tow-vehicles); 21.0 s (dual rear wheel tow-vehicles)	SAE J1491, modified in 4.3.2 and 4.3.3
Launch on Grade	12% grade, forward direction	5 launches to 5.0 m (16 ft) in 5 min	92/21/EEC, Annex II, Section 3.3.3, modified in 4.3.2 and 4.3.4
Launch on Grade	12% grade, reverse direction	5 launches to 5.0 m (16 ft) in 5 min	92/21/EEC, Annex II, Section 3.3.3, modified in 4.3.2 and 4.3.4
Highway Gradeability	Minimum speed on grade (Davis Dam)	64.4 km/h (40 mph) (single rear wheel tow-vehicles); 56.3 km/h (35 mph) (dual rear wheel tow-vehicles)	4.3.2 and 4.3.5
Highway Gradeability	Drivetrain system performance	No component failures; no diagnostic codes that alert the operator; no customer warnings	4.3.2 and 4.3.5
Highway Gradeability	Cooling system performance	No component failures; no diagnostic codes that alert the operator to take service or driving action; no customer warnings; no fluid loss	4.3.2 and 4.3.5

4.3.2 Propulsion System Performance Test Vehicle and Ballast Requirements

The following conditions apply to all propulsion system performance tests and supersede any related section(s) in referenced publications.

4.3.2.1 Test Tow-vehicle Selection

The tow-vehicle shall be equipped with the propulsion system or powertrain and driveline (engine, transmission, axle ratio, tire size, etc), and cooling package to produce the GCWR under test. In the case where there is more than one axle ratio and/or tire size available with no change in GCWR, the combination producing the lowest numerical final drive ratio shall be tested. In the case where there is optional cooling content that is not required to attain GCWR, the vehicle should not be equipped with that content. Tow-vehicle chassis content (suspension, steering, brakes, etc.) is immaterial to this section as long as it does not affect propulsion/powertrain selection or final drive ratio. Any vehicle equipped with specific selectable propulsion/powertrain calibration for trailering should be operated per tow-vehicle manufacturer's instructions.

4.3.2.2 Test Trailer Selection

Test trailer should be chosen based upon specifications in 4.1.

4.3.2.3 Combination Ballast and Hitch Connection

The tow-vehicle/trailer combination shall be ballasted to a minimum of GCWR for the model/powertrain/driveline/tire package of the product under test and connected in any manner permissible by the tow-vehicle manufacturer and within the ratings of the associated trailers and trailering equipment used in the test.

4.3.3 Level Road Acceleration

Test per SAE J1491 with the following exceptions:

TABLE 4 - EXCEPTIONS TO SAE J1491

Section	Item	Revision
4.1.c	Engine Speed (Tachometer)	Section optional
4.6	Vehicle Weight	Accuracy is ±10 kg per side
6.1	Table 1 - Standard Ambient Conditions	Replaced with: Ambient temperature ≥10 °C (50 °F) Barometric Pressure ≤102 kPa (30 in Hg) Relative Humidity ≥18%
6.3	Wind Velocity	Average <15 km/h; peak <20 km/h
7.1	Minimum Break-in	Is 805 km (500 miles)
7.2	Vehicle Checklist	Section optional
7.6	Vehicle Warm-up	Section optional
8.1	Test Schedules Summary	64 to 97 km/h test deleted
8.4	Test Procedure 40 to 60	Section deleted
8.5.2	Test Delay Period	Section deleted
8.6	Operation of Accessories	Section optional
9.1.5	Interval 64 to 97 km/h	Section deleted
9.2.2	Charts/Plots	Section optional
9.3	General	Section deleted

4.3.4 Launch on Grade

Position the tow-vehicle and trailer combination so that all tires are on a 12% grade and the combination is at rest. Select an appropriate gear position to proceed in an uphill direction. Begin timing upon initial acceleration and drive uphill at least 5.0 m. Any clutch pedal force (for manual transmission-equipped vehicle) and/or throttle input is permissible. If the test grade is sufficient length, the acceleration may be repeated after completely stopping the combination. If the grade is not sufficient length, return to the base of the grade and repeat the procedure. In either case, stop timing when the fifth run has been completed. This test shall be accomplished in an uphill direction for both forward and reverse movements. If a 12% test grade is not readily available, vehicle load should be adjusted for the available test grade using the following:

$$\text{Adjusted GCW} = \text{GCWR} \times \sin(\operatorname{atan}(0.12))/\sin(\operatorname{atan}(\text{testgrade}/100)), \qquad \text{(Eq. 2)}$$

where test grade is in percent.

For all definition, instrumentation, test material, test condition, vehicle preparation, test procedure and data reduction issues not addressed in this section, refer to SAE J1491 and 4.3.3.

4.3.5 Highway Gradeability

4.3.5.1 General Description

Highway Gradeability Test is accomplished by running Arizona SR 68 (Davis Dam Grade) or simulated dynamic grade in a climatic wind tunnel. The Davis Dam grade is between Bullhead City, Arizona and Golden Valley, Arizona headed east on the east side of the Colorado River. The grade test begins at the intersection of Arizona SR 68 and McCormick Blvd. The posted speed limit changes from 45 mph to 55 mph, and then 65 mph. The test ends at the top of the grade (Union Pass), approximately 18.3 km (11.4 miles) beyond McCormick Blvd.

4.3.5.2 Davis Dam Grade Profile

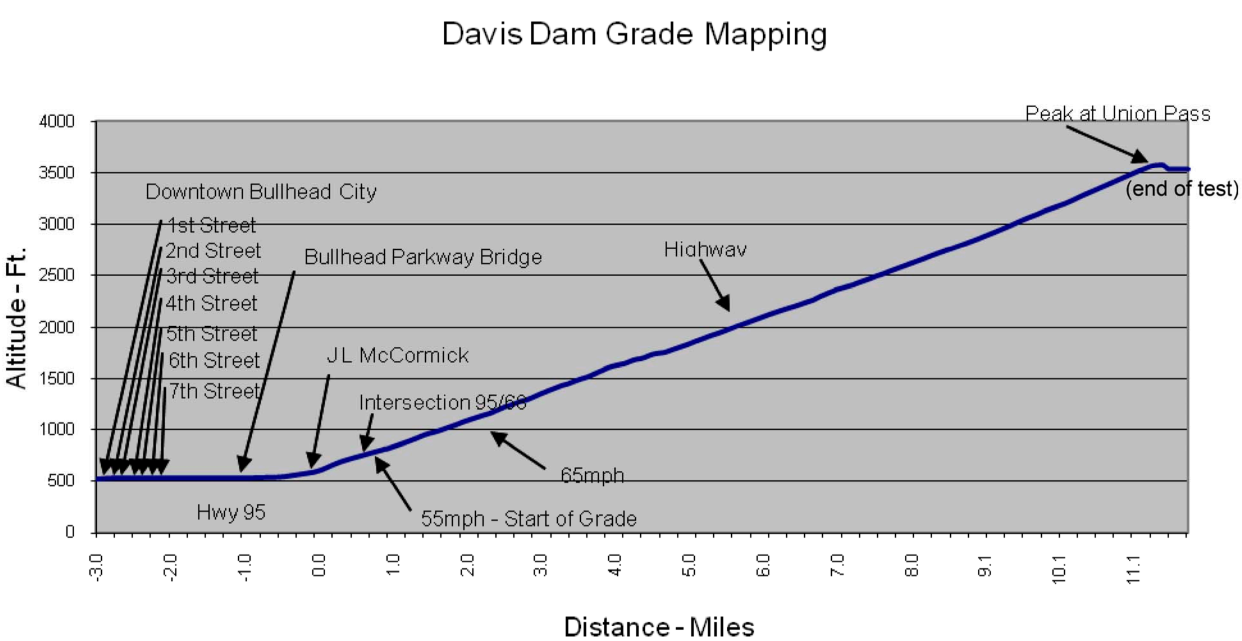

FIGURE 1 - DAVIS DAM ELEVATION BY MILEAGE

The grade profile depicted above represents Davis Dam grade graphically from approach through top of the grade.

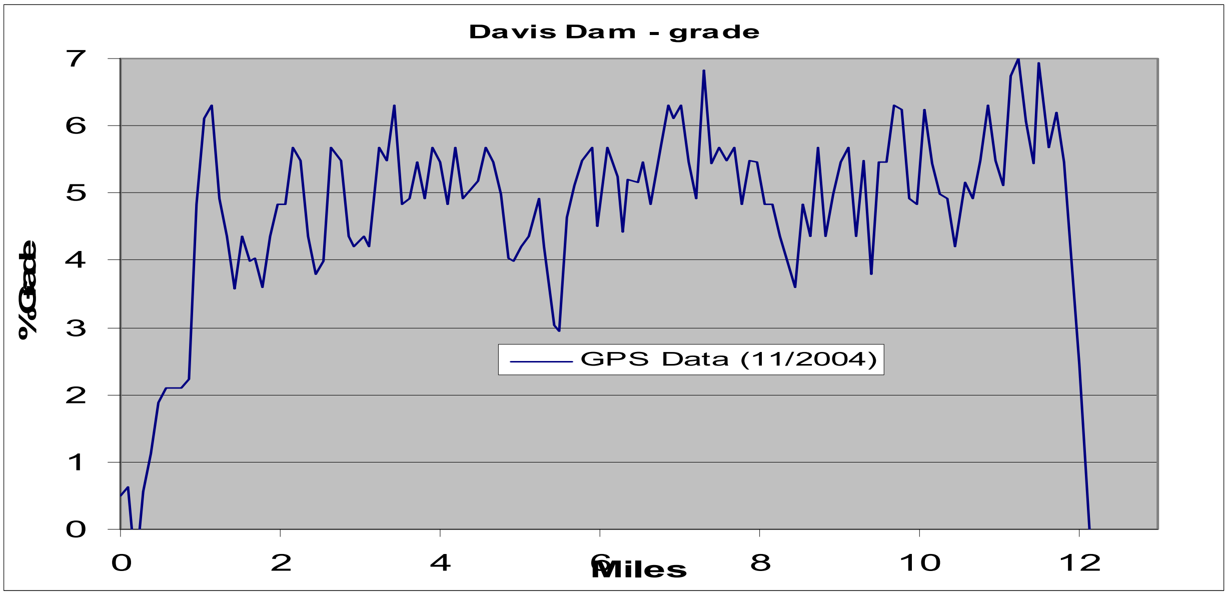

FIGURE 2 - DAVIS DAM % GRADE BY MILEAGE

The actual grade fluctuates as represented in the chart above as recorded from GPS data.

4.3.5.3 Driving Conditions

Minimum allowable ambient temperature is 37.8 °C (100 °F) at the base of the grade. Air conditioning system controls are to be set to maximum cold setting, outside air and full blower setting.

4.3.5.4 Procedure for Automatic Transmission-Equipped Vehicles

Select highest available forward gear position unless otherwise specified by tow-vehicle manufacturer. As the combination begins ascent, accelerate as required to a speed between the minimum speed requirement specified in the Table 3 Performance Attribute of Highway Gradeability for the tow-vehicle under test and the posted 45 mph speed limit. When posted speed limit changes to 55 mph and again to 65 mph, it is the tow-vehicle tester's choice to run at any speed between the minimum speed requirement and the posted speed limit. The minimum speed requirement applies from the Davis Dam turnoff (County Road 68), 1.3 km (0.8 miles) after the start of the test grade as shown in 4.3.5.2 to the end of test run. Note the change to 55 mph posted speed limit occurs 1.4 km (0.9 miles) after the start of the test grade and the 65 mph posted speed limit occurs 3.7 km (2.3 miles) after the start of the test grade.

4.3.5.5 Procedure for Manual Transmission-Equipped Vehicles

Run test in a manner similar to that for automatic transmission-equipped vehicles as detailed in 4.3.5.4. Shift transmission per the tow-vehicle manufacturer's instructions. It is the tow-vehicle tester's choice to run at any speed between the minimum speed requirement and the posted speed limit. Wide open throttle and/or downshifting is permissible should posted speed limit not be sustainable. Wheel spin is not permissible; if tires break loose, reduce throttle pedal force until traction is resumed.

4.3.5.6 Data Logging (Optional)

A data logger capable of (but not limited to) recording diagnostic trouble codes, cabin temperature, vehicle speed, throttle position, and time should be utilized for the Highway Gradeability Test.

4.4 Combination Handling

This section defines combination handling performance requirements at GCWR. This section should be used to determine any or all of the following TWR/GCWR limits: weight carrying, weight distributing and fifth wheel/gooseneck limits.

4.4.1 Combination Handling Performance Requirement Summary

The tow-vehicle, in conjunction with appropriate test trailer(s) per 4.1, shall be capable of meeting certain handling requirements for the specified GCWR. The following table summarizes metrics, requirements and test methods for specific performance attributes.

TABLE 5 - COMBINATION HANDLING REQUIREMENTS

Performance Attribute	Performance Metric	Requirement	Test Procedure
Tow-vehicle Understeer	Understeer at Lateral Acceleration ≤0.3 g at 100% FALR	>0 degree/g	SAE J266, ISO 4138 or ISO 7401, modified in 4.4.2 and 4.4.3
Tow-vehicle Understeer	Understeer at Lateral Acceleration ≤0.4 g at 50% FALR	>0 degree/g	SAE J266, ISO 4138 or ISO 7401, modified in 4.4.2 and 4.4.3
Tow-vehicle Understeer	Understeer at Lateral Acceleration ≤0.4 g for Weight Carrying TWR (0% FALR) & for 5th Wheel and/or Gooseneck TWR	>0 degree/g	SAE J266, ISO 4138 or ISO 7401, modified in 4.4.2 and 4.4.3
Trailer Sway Response	Trailer Sway Damping Ratio	≥0.10 at 100 km/h (62.1 mph)	SAE J2664 as modified in 4.4.2 and 4.4.4

4.4.2 Tow-Vehicle and Trailer Combination Connection

The following conditions apply to all combination handling performance tests and supersede any related section(s) in referenced publications.

4.4.2.1 Test Tow-vehicle Selection

The tow-vehicle shall be equipped with the chassis content (suspension, steering, brakes, tires, etc) to accommodate the GCWR under test. Powertrain selection is immaterial to this section as long as it does not affect required chassis content or provide an advantageous center of gravity location. In the case where multiple models (body style, wheelbase, GVWR, etc) or multiple chassis packages within a model share the same GCWR, it is the responsibility of the tow-vehicle tester to choose the least capable chassis content for the performance being evaluated. Any vehicle equipped with specific selectable dynamic handling or suspension leveling system should be operated per tow-vehicle manufacturer's instructions.

4.4.2.2 Test Trailer Selection

Test trailer should be chosen from the list of exemplar trailers in Appendix A based upon specifications in 4.1. Trailer sway damping performance requirements must be met with the exemplar trailer which has the lowest GVWR that meets or exceeds the TWR being evaluated as well as any exemplar trailer (see Appendix A) with a lower GVWR.

4.4.2.3 Combination Ballast

Tow-vehicle and trailer shall be ballasted to at least the highest GCWR for the product model/chassis package under test. Tow-vehicle understeer and trailer sway damping characteristics may vary based upon ballast distribution among tow-vehicle and trailer axles, so each performance attribute will have its own specific combination ballast requirements (Reference 4.4.3 and 4.4.4). In either case, the trailer is to be ballasted so that trailer tongue weight meets the requirements of 4.4.2.4 or 4.4.2.5 as appropriate. For trailer sway damping tests, the minimum trailer Rotation Radius Ratio (RRR) should be the equivalent of that for evenly distributed ballast on the load floor as described in the following sentences. The ballast is to be evenly distributed in the front and rear halves of the trailer. The ballast is to extend to the extremes of the side walls and from front wall to the centerline of the cargo area with constant density. Likewise, the ballast is to extend to the extremes of the side walls and from rear wall to the centerline of the cargo area with constant, but potentially different density than the front half. The density of the front and rear halves of the cargo area are adjusted to achieve the required trailer tongue weight.

4.4.2.4 Trailer Tongue Weight (Conventional Trailers)

Ballast should be applied to the trailer in a distributed manner such that the trailer tongue weight is 10% of total trailer weight ±0.5%, or ±5 kg (11 lb), whichever is greater, at a nominally level attitude as described in 4.4.2.8. This is intended to provide a nominal longitudinal center of gravity (cg) position of the ballasted trailer that is 10% (of the effective tongue length) forward of the trailer axle(s) centerline.

4.4.2.5 Trailer Tongue/Kingpin Weight (Fifth Wheel or Gooseneck Trailers)

Ballast should be applied to the trailer in a distributed manner such that the trailer tongue weight is 20% of total trailer weight ±1.0%. This provides a nominal longitudinal center of gravity (cg) position of 20% of the effective tongue length forward of the trailer wheel(s) centerline when the trailer is level.

4.4.2.6 Tow-vehicle/Trailer Hitch (Conventional Trailers)

The hitch shall be original equipment, if available, or typical aftermarket, with rating adequate for the weight of the test trailer. Unconventional designs where the trailer does not articulate about the hitch ball are not permitted, unless available as original equipment from the tow-vehicle manufacturer.

4.4.2.7 Tow-vehicle/Trailer Hitch (Fifth Wheel or Gooseneck Trailers)

The hitch shall be original equipment, if available, or typical aftermarket, with rating adequate for the weight of the test trailer. The attachment and location of the hitch (either gooseneck or fifth wheel) articulation point in the pickup should be directly over the rear axle centerline to 51 mm (2 in) forward, or as available as original equipment from the tow-vehicle manufacturer.

4.4.2.8 Hitch Ball Position (Conventional Trailers)

The ball mount and hitch ball installation should be such as to maintain a level trailer attitude within ±1.0 degree from horizontal or within 25 mm of ball height, whichever is greater. A digital inclinometer may be used to measure the angularity of the trailer frame midway between the trailer coupler and the wheel(s) centerline. The trailer frame angle is then added to or subtracted from the ground plane angle to determine the trailer attitude. Alternatively, presuming a continuous section height frame, the height of the trailer frame relative to the ground should be measured at a point near the ball and just behind the rear-most axle, and the pitch angle calculated.

4.4.2.9 Sway Control Devices (Conventional Trailers)

Hitch mounted sway control devices shall not be used while testing.

4.4.2.10 Weight Distributing Hitch

When used, a weight distributing hitch should consist of one or two spring bars with a chain at the trailer end. No other mechanisms shall be used to increase friction or articulation stiffness.

4.4.3 Tow-vehicle Understeer Specific Ballast Conditions

Ideally, the tow-vehicle/trailer combination should be ballasted such that the tow-vehicle simultaneously attains GCWR, GVWR and Rear GAWR. If testing with a weight distributing hitch, ballast distribution shall occur prior to applying the weight distributing hitch torque. The weight distributing hitch shall be adjusted to provide FALR levels within ±10% of target FALR (e.g. from 40% to 60% for a 50% FALR target) as specified in 4.4.1. Refer to Appendices B and C for procedure. There may be tow-vehicles that cannot attain GCWR, GVWR and Rear GAWR simultaneously with tongue weight at 10% (conventional trailer) or kingpin weight at 20% (fifth wheel or gooseneck trailer) of loaded test trailer weight; in this case, priority in meeting these values should be: 1) GCWR, 2) RGAWR and 3) GVWR. Again, refer to Appendices B and C for details.

4.4.4 Trailer Sway Damping Specific Ballast Conditions

Tow-vehicle should be ballasted to simulate TVTW and the trailer test weight should be tow-vehicle TWR as determined by the TWR calculations in Section 5. By definition, this will produce a combination weight equal to GCWR. If a weight distributing hitch is recommended by the tow-vehicle manufacturer for the GCWR/TWR under test, _it should be adjusted per tow-vehicle manufacturer's instructions or to 50% FALR if no particular value is specified. Refer to Appendices B and C for procedure.

4.5 Combination Braking

This section defines combination braking performance requirements at GCWR. This section should be used to determine any or all of the following TWR/GCWR limits: maximum unbraked trailer limit, conventional braked trailer limit and fifth wheel/gooseneck braked trailer limit.

4.5.1 Combination Braking Performance Requirement Summary

The tow-vehicle brake system, in conjunction with appropriate test trailer(s) per 4.1, shall be capable of meeting certain braking requirements for the specified GCWR. The following table summarizes metrics, requirements and test methods for specific performance attributes. The purpose of 4.5 is to determine the suitability of the tow-vehicle brake system in conjunction with a trailer. Tests are to be run without the use of trailer brakes.

TABLE 6 - COMBINATION BRAKING REQUIREMENTS

Performance Attribute	Performance Metric	Requirement	Test Procedure
Combination Stability	Deviation within lane	Remain within 3.5 m (11.5 ft) lane throughout stop	FMVSS 105, Sec 7.5(b) or FMVSS 135, Sec 7.5, modified in 4.5.2 and 4.5.4
Combination Stopping Distance	Stopping distance, 32.2 to 0 km/h (20 to 0 mph) for TWR ≤1361 kg (3000 lb)	≤10.7 m (35 ft) except; ≤13.7 m (45 ft) at any TWR above the tow-vehicle's unbraked TWR	FMVSS 105 or 135, modified in 4.5.2 through 4.5.4
Combination Stopping Distance	Stopping distance, 32.2 to 0 km/h (20 to 0 mph) for TWR >1361 kg (3000 lb)	≤24.4 m, (80 ft)	FMVSS 105 or 135, modified in 4.5.2 through 4.5.4
Park Brake Performance	Hold on grade	12% grade (upward and downward) at GCWR	ECE R13H, Annex 3, Section 2.3, modified in 4.5.2 and 4.5.5

4.5.2 Tow-Vehicle and Trailer Combination Connection

4.5.2.1 Ballast Requirements at GCWR

The conditions noted in 4.4.2 and associated subsections should also apply to all combination braking performance tests at GCWR, except that only the ballast condition used for trailer sway damping (4.4.4) is required.

4.5.2.2 Ballast Requirements at Unbraked TWR

The conditions noted in 4.5.2.1 and associated subsections should also apply to all combination braking performance tests at unbraked TWR, except that the tow-vehicle/trailer combination should be ballasted such that the combination simultaneously attains GVWR, Rear GAWR and unbraked TWR.

4.5.3 Trailer Brakes

Due to variation in trailer brake system design, performance, actuation and adjustment, the following tests are to be run without the use of trailer brakes. It is the tow-vehicle tester's responsibility to prevent trailer brake actuation during these tests.

4.5.4 Straight Line Braking Performance

The tow-vehicle is to be tested at GCWR (reference 4.5.2.1) and at unbraked TWR (reference 4.5.2.2). Perform stopping distance evaluations in a manner similar to FMVSS 105, Section 7.5(b) or FMVSS 135, Section 7.5, as appropriate for the tow-vehicle GVWR. Evaluations need only be conducted at the speed indicated in 4.5.1 and there is no pedal force requirement. The tow-vehicle brakes may be burnished prior to test (reference FMVSS 105, Section 7.4 or FMVSS 135, Section 7.1). For any definitions, equipment requirements, general test conditions, road test procedures and performance requirements not specified elsewhere in this document, refer to portions of FMVSS 105 or FMVSS 135 as appropriate.

4.5.5 Park Brake Performance

The tow-vehicle is to be tested at GCWR (reference 4.5.2.1). Perform evaluation per ECE R13H, Annex 3, Section 2.3, except delete Sections 2.3.1, 2.3.3, 2.3.4 and 2.3.6 so there is no apply force requirement. For any definitions, equipment requirements, general test conditions, road test procedures and performance requirements not specified elsewhere in this document or ECE R13H, refer to parking brake portions of FMVSS 105, Section 7.7, or FMVSS 135, Section 7.12, as appropriate. If a 12% test grade is not readily available, vehicle load should be adjusted for the available test grade using the following:

$$\text{Adjusted GCW} = \text{GCWR} \times \sin(\operatorname{atan}(0.12))/\sin(\operatorname{atan}(\text{testgrade}/100)), \quad \text{(Eq. 3)}$$

where test grade is in percent.

5. TWR CALCULATION METHODOLOGY

This section provides the methodology and basic equations to calculate TWR from GCWR and TVTW.

5.1 GCWR Considerations

Performance requirements in 4.3 through 4.5 are defined with the combination generally ballasted to GCWR, even though there may be variations in ballast distribution between tow-vehicle and trailer. There may also be specific test conditions where the combination is ballasted to a value less than maximum GCWR (e.g., unbraked TWR limit testing or weight carrying TWR testing). Section 4.2 determines TWR structural limitations. Specific tow-vehicle TWR is to be calculated from the lowest GCWR value determined through testing to performance requirements in 4.3, 4.4, and 4.5 and also cannot exceed the value determined in 4.2.

5.2 Defined Tow-vehicle Trailering Weight

Tow-vehicle Trailering Weight (TVTW) is defined in 3.2. The representative aftermarket trailering equipment discussed in the TVTW definition is indicated below:

5.2.1 Tow-vehicle Without Available Original Equipment (OE) Hitch Receiver

In the case where a trailering package is not available from the tow-vehicle manufacturer or it does not include a trailer hitch component, the representative aftermarket trailer hitch component mass specified below shall be used.

TABLE 7 - AFTERMARKET HITCH RECEIVER WEIGHT

Target TWR	TWR Type	Hitch Receiver Weight	Longitudinal Application Point on Tow-vehicle Centerline
≤907 kg (2000 lb)	Conventional	9.1 kg (20 lb)	Rear edge of frame or BIW structure
≤1588 kg (3500 lb)	Conventional	13.6 kg (30 lb)	Rear edge of frame or BIW structure
≤2268 kg (5000 lb)	Conventional	18.1 kg (40 lb)	Rear edge of frame or BIW structure
≤5443 kg (12 000 lb)	Conventional	22.7 kg (50 lb)	Rear edge of frame or BIW structure
>5443 kg (12 000 lb)	Conventional	31.8 kg (70 lb)	Rear edge of frame or BIW structure
≤6804 kg (15 000 lb)	Fifth Wheel	68.0 kg (150 lb)	Rear axle centerline
>6804 kg (15 000 lb)	Fifth Wheel	113.4 kg (250 lb)	Rear axle centerline
Any	Gooseneck	54.4 kg (120 lb)	Rear axle centerline

5.2.2 Additional Aftermarket Trailering Equipment

Additional trailering equipment such as drawbar, ball mount, hitch ball, weight distributing bars and sway control devices may be required or recommended by tow-vehicle manufacturers. The representative aftermarket trailering equipment mass specified below shall be used.

TABLE 8 - AFTERMARKET HITCH EQUIPMENT WEIGHT

Target TWR	Hitch Type	Part(s)	Weight	Longitudinal Application Point on Tow-vehicle Centerline
≤907 kg (2000 lb)	Weight Carrying	Drawbar, hitch ball and attachments	2.3 kg (5 lb)	76 mm (3 in) rear of bumper/fascia edge or 216 mm (8.5 in) rear of OE pin hole
≤1588 kg (3500 lb)	Weight Carrying	Drawbar, hitch ball and attachments	4.5 kg (10 lb)	76 mm (3 in) rear of bumper/fascia edge or 216 mm (8.5 in) rear of OE pin hole
≤2268 kg (5000 lb)	Weight Carrying	Drawbar, hitch ball and attachments	4.5 kg (10 lb)	76 mm (3 in) rear of bumper/fascia edge or 216 mm (8.5 in) rear of OE pin hole
≤2268 kg (5000 lb)	Weight Distributing	Ball mount, hitch ball and attachments, weight distribution bars	24.9 kg (55 lb)	102 mm (4 in) rear of bumper/fascia edge or 225 mm (8.88 in) rear of OE pin hole
≤5443 kg (12 000 lb)	Weight Carrying	Drawbar, hitch ball and attachments	6.8 kg (15 lb)	76 mm (3 in) rear of bumper/fascia edge or 216 mm (8.5 in) rear of OE pin hole
≤5443 kg (12 000 lb)	Weight Distributing	Ball mount, hitch ball and attachments, weight distribution bars	29.5 kg (65 lb)	102 mm (4 in) rear of bumper/fascia edge or 225 mm (8.88 in) rear of OE pin hole
>5443 kg (12 000 lb)	Weight Carrying	Drawbar, hitch ball and attachments	9.1 kg (20 lb)	76 mm (3 in) rear of bumper/fascia edge or 216 mm (8.5 in) rear of OE pin hole
>5443 kg (12 000 lb)	Weight Distributing	Ball mount, hitch ball and attachments, weight distribution bars	34.0 kg (75 lb)	152 mm (6 in) rear of bumper/fascia edge or 276 mm (10.88 in) rear of OE pin hole
Any where tow-vehicle manufacturer requires sway control device	Weight Carrying or Weight Distributing	Sway control device	11.3 kg (25 lb)	254 mm (10 in) rear of trailer connection point per 5.5

5.3 Basic TWR Calculation

$$TWR = GCWR - TVTW \quad \text{(Eq. 4)}$$

5.4 GVWR/Rear GAWR and Tongue Weight/Kingpin Weight Considerations

The tow-vehicle shall be able to accommodate appropriate trailer tongue and/or kingpin weight to attain a particular TWR without exceeding Rear GAWR and/or GVWR. Required minimum conventional trailer tongue weight shall be 10% of TWR and required minimum fifth wheel or gooseneck trailer kingpin weight shall be 20% of TWR. For purposes of this standard, fifth wheel or gooseneck trailer kingpin weight shall be applied directly over rear axle centerline unless a fixed-ball hitch is available from the tow-vehicle original equipment manufacturer (OEM) in which case it shall be at the OEM position. Conventional trailer tongue weight shall be applied at a longitudinal connection point as indicated in 5.5.

5.5 Trailer Connection Point (Conventional Trailer)

Conventional trailer tongue weight requirement shall be applied at a specified point along the longitudinal centerline of the vehicle as indicated in Table 9:

TABLE 9 - TRAILER CONNECTION POINT LOCATION

Hitch Type	Connection Point (with OE Trailer Hitch Receiver)	Connection Point (w/o OE Trailer Hitch Receiver)
Weight Carrying (Step Bumper)	Center of step bumper hitch ball hole	N/A
Weight Carrying	267 mm (10.5 in) rear of receiver pin hole	127 mm (5 in) rear of bumper/fascia edge
Weight Distributing ≤5443 kg(12 000 lb)	302 mm (11.88 in) rear of receiver pin hole	178 mm (7 in) rear of bumper/fascia edge
Weight Distributing >5443 kg (12 000 lb)	403 mm (15.88 in) rear of receiver pin hole	279 mm (11 in) rear of bumper/fascia edge

5.6 Complete TWR Calculation

Resultant TWR shall be no greater than the least of:

TABLE 10 - TWR CALCULATIONS

Trailer Type	GCWR Constrained	GVWR Constrained	Rear GAWR (RGAWR) Constrained
Fifth Wheel or Gooseneck Trailer	GCWR - TVTW	(GVWR - TVTW) x 5	(RGAWR – TVTW rear axle load) x 5
Conventional Trailer	GCWR - TVTW	(GVWR - TVTW) x 10	(RGAWR - TVTW rear axle load) x 10/((WB + CPOH)/WB)

where:

WB is wheelbase
CPOH is connection point overhang, measured from rear axle centerline to connection point position
No allowance is to be made for weight distribution effects

6. TOW-VEHICLE GCWR AND TWR DOCUMENTATION

Trailer Weight Ratings (TWRs) and Gross Combination Weight Ratings (GCWRs) may be important marketing attributes for some tow-vehicle models. For any model or group of models rated per all the applicable requirements of this document, tow-vehicle manufacturers may make the following claim in any publication: “This(These) model(s) meet(s) or exceed(s) the tow-vehicle trailering requirements of SAE International per SAE J2807”.

7. NOTES

7.1 Marginal Indicia

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY THE SAE TOW VEHICLE TRAILER RATING COMMITTEE

APPENDIX A

TRAILER EXEMPLARS - WELLS CARGO TRAILERS

TABLE A1 - WELLS CARGO EXEMPLAR TRAILERS - PROPULSION TEST USAGE

	Model	GVWR	Axle(s)	Effective Tongue Length*	Tire Brand/Size/ Pressure	Frontal Area
A	MPT461	498 kg (1100 lb)	Single	2.0 m (80 in)	Goodyear Marathon Radial ST175/80R13C 345 kPa (50 psi)	1.39 m^2 (15 ft^2)
B	MW6	997 kg (2200 lb)	Single	2.0 m (80 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	2.22 m^2 (23 ft^2)
C	SW8	1746 kg (3850 lb)	Single	2.6 m (102 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	2.90 m^2 (31 ft^2)
D	TW162	3492 kg (7700 lb)	Tandem	4.1 m (162 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	3.73 m^2 (40 ft^2)
E	EW1622W	3492 kg (7700 lb)	Tandem	4.1 m (162 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	5.65 m^2 (60 ft^2)
F/G/H	EW2025 EW2427	5987 kg (13 200 lb) 7983 kg (17 600 lb)	Tandem	4.9 m (191 in) 5.6 m (220 in)	Goodyear Marathon Radial ST235/80R16D 540 kPa (65 psi) Goodyear G114 Unisteel 215/75R17.5H 865 kPa (125 psi)	5.81 m^2 (63 ft^2)
J	CVG3225W + 2' HT CVG3227W + 2' HT	6667 kg (14 700 lb) 9072 kg (20 000 lb)	Tandem	9.6 m (379 in)	Goodyear Marathon Radial ST235/80R16D 540 kPa (65 psi) Goodyear G114 Unisteel 215/75R17.5H 865 kPa (125 psi)	7.33 m^2 (78 ft^2)

*Effective tongue length requirements do not apply to propulsion testing.

TABLE A2 - WELLS CARGO EXEMPLAR TRAILERS - DYNAMICS TEST USAGE

	Model	GVWR	Axle(s)	Effective Tongue Length	Tire Brand/Size/ Pressure	Frontal Area*
A	TC461-FB	454 kg (1000 lb)	Single	2.0 m (80 in)	Duro Bias ST175/80D13C 345 kPa (50 psi)	N/A—Flatbed
B/C	SW8	1746 kg (3850 lb)	Single	2.6 m (102 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	2.90 m^2 (31 ft^2)
D/E	TW162	3492 kg (7700 lb)	Tandem	4.1 m (162 in)	Goodyear Marathon Radial ST205/75R15C 345 kPa (50 psi)	3.73 m^2 (40 ft^2)
F	EW2024	4536 kg (10 000 lb)	Tandem	4.9 m (191 in)	Goodyear Marathon Radial ST225/75R15D 540 kPa (65 psi)	5.79 m^2 (62 ft^2)
G	EW2425	5987 kg (13 200 lb)	Tandem	5.6 m (220 in)	Goodyear Marathon Radial ST235/80R16D 540 kPa (65 psi)	5.81 m^2 (63 ft^2)
H	EW2427	7983 kg (17 600 lb)	Tandem	5.6 m (220 in)	Goodyear G114 Unisteel 215/75R17.5H 865 kPa (125 psi)	5.81 m^2 (63 ft^2)
J	CVG3225W + 2' HT CVG3227W + 2' HT	6667 kg (14 700 lb) 9072 kg (20 000 lb)	Tandem	9.6 m (379 in)	Goodyear Marathon Radial ST235/80R16D 540 kPa (65 psi) Goodyear G114 Unisteel 215/75R17.5H 865 kPa (125 psi)	7.33 m^2 (78 ft^2)

*Frontal area requirements do not apply to dynamics testing.

As noted in 4.1, trailers to be used for dynamics purposes should be equipped with limited optional equipment in order to minimize trailer weight and maximize ballast flexibility. However, the following options may be useful for test purposes:

36 in wide curbside entry door with cam lock
12 V power jack ram hoist with above floor or recessed battery assembly including: 100 amp hour deep cycle battery, vented battery box, and 6-circuit fuse panel
18 in high aluminum tread plate front stone guard with wrapped corners
5000 lb non-swivel type D-ring tie-off, floor mounted, with steel backing plate

APPENDIX B

TOW-VEHICLE - TRAILER WEIGHT CARRYING COUPLING SETUP GUIDELINES

In the case where weight distributing hitch is not required to attain GCWR and/or TWR, or if a tow-vehicle has a different TWR with weight carrying hitch versus weight distributing hitch, follow steps 1 through 8 below. When weight distributing hitch is required, follow instructions in Appendix C.

1. The TWR Evaluation Axle Load equations in Appendix D can be used to estimate the uncoupled tow-vehicle front and rear axle loads, and trailer total and coupling loads for this test condition. Tow-vehicle wheelbase, rear axle to coupling distance, GVWR, rear GAWR, and coupling load (10% of total trailer weight for conventional coupling; 20% for fifth wheel or gooseneck) are needed for these calculations.

2. Set tow-vehicle and trailer tire pressures to their respective manufacturers' specifications. Exemplar trailer tires pressures are listed in Appendix A. Measure tow-vehicle wheel loads, wheel cutout trims, front bumper height, and coupling height at TVTW and record on the Test Trailer Description (TTD) sheets in Appendix E.

3. Ballast the tow-vehicle to GVWR minus the required coupling load using recommended axle loads determined in step 1. It may be necessary to place all ballast beyond TVTW in the cargo area to achieve the desired axle loads. To the extent possible, distribute ballast equivalent to one 68 kg (150 lb) passenger per bucket seat and two passengers per bench seat loading from front to rear and then distribute cargo in the cargo area until the recommended tow-vehicle axle loads are reached. It may be necessary to place all ballast, including passenger ballast, beyond TVTW in the cargo area to achieve the desired axle loads.

   If it appears that rear GAWR is not achievable without exceeding GVWR with the ballast concentrated as far rearward in the tow-vehicle as possible, proceed with the vehicle at GVWR (minus the coupling load) and the rear axle load as great as possible. Conversely, if it appears that it is not possible to achieve GVWR without exceeding rear GAWR, distribute ballast as described in the previous paragraph until the axle load necessary to achieve rear GAWR (when coupled) is reached and proceed with a total tow-vehicle load that is less than GVWR.

4. Ballast the trailer until the coupling load plus trailer wheel loads equal TWR for a weight carrying coupling. If a flat and level surface extends ahead of and behind the scales that can simultaneously support the tow-vehicle and trailer axles, the trailer weight can be measured with the trailer coupled to the tow-vehicle. With the tow-vehicle on the scales (as ballasted in step 3), measure the difference between the total coupled and uncoupled tow-vehicle weights to determine the coupling load. Then position the trailer on the scales to measure the trailer wheel loads. Add or remove ballast until the prescribed total trailer weight is achieved. The trailer ballast should be distributed as prescribed in 4.4.

5. With the trailer coupled to the tow-vehicle, reposition the trailer ballast until total tow-vehicle weight results in the required coupling load within the guidelines specified in 4.4.2. The trailer should be level as specified in 4.4.2.

6. Measure coupling load at the coupled height to record it and confirm that it is at the required load as specified in 4.4.2. If there is a discrepancy in load, it may be necessary to confirm the scale accuracy and/or repeat step 5. This discrepancy may also result from a multiple-axle trailer and the tow-vehicle not being in the same plane when the tow-vehicle weight is measured in step 5.

   If a multi-axle trailer is used, it will be necessary to account for hysteresis in coupling load that results with coupling height change. Coupling height and load shall be measured for at least one cycle of height change. Hysteresis will likely increase with the magnitude of the cycle up to some magnitude of height change. The magnitude of the cycle shall, therefore, be at least this large with the mid-point of the cycle being the coupling height at which the handling tests are conducted. The coupling load is determined as the average of the maximum and minimum coupling loads at this coupling height that are defined by the hysteresis loop.

7. Measure the coupled tow-vehicle wheel loads, wheel cutout and front bumper heights, and ball height, and trailer wheel loads. Then measure uncoupled tow-vehicle wheel loads (including all ballast), trim heights, and ball height and complete the TTD sheet before testing.

8. Typical TWR for Weight Carrying Coupling test condition descriptions include:

   Preferred test condition -
   'GVWR/Rear GAWR/nnnn lb Trailer, 10% Coupling Load' ('20%' for fifth wheel or gooseneck)

   When ballast is as far rearward in the tow-vehicle as possible does not achieve rear GAWR without exceeding GVWR -
   'GVWR/Ballast Max Rearward/nnnn lb Trailer, 10% Coupling Load' ('20%' for fifth wheel or gooseneck)

   When any additional ballast in the tow-vehicle results in rear GAWR being exceeded without achieving GVWR -
   'Rear GAWR/nnnn lb Trailer, 10% Coupling Load' ('20%' for fifth wheel or gooseneck)

APPENDIX C

TOW-VEHICLE - TRAILER WEIGHT DISTRIBUTING COUPLING SETUP GUIDELINES

1. The TWR Evaluation Axle Load equations in Appendix D can be used to calculate the uncoupled tow-vehicle front and rear axle loads, and trailer total and coupling loads for this test condition. Tow-vehicle wheelbase, rear axle to coupling distance, GVWR, rear GAWR, and required coupling load are needed for these calculations. Regardless of test condition, it is desired to achieve the equivalent of rear GAWR when calculated with the coupling load in place, but not including the effect of the weight distributing moment.

2. Set tow-vehicle and trailer tire pressures to their respective manufacturers' specifications. Exemplar trailer tires pressures are listed in Appendix A. Measure tow-vehicle wheel loads, wheel cutout trims, front bumper height, and coupling height at TVTW and record on the Test Trailer Description (TTD) sheet in Appendix E.

3. TWR/GCWR Test Condition: Load to GCWR with the trailer at TWR and the tow-vehicle at TVTW.

   GVWR/GCWR Test Condition: Load to GCWR with the tow-vehicle ballasted to GVWR minus the coupling load and the balance of the ballast in the trailer as determined in step 1.

   It may be necessary to place all tow-vehicle ballast, including passenger ballast, beyond TVTW in the cargo area to achieve the required axle loads. To the extent possible, distribute ballast equivalent to one passenger per bucket seat and two passengers per bench seat loading from front to rear and then distribute cargo in the cargo area until TWR Evaluation axle loads are reached.

   With ballast as far rearward in the tow-vehicle as possible, rear GAWR may not be achieved without exceeding GVWR. In that case, proceed with the vehicle at GVWR with ballast concentrated as far rearward in the vehicle as practicable and the rear axle load less than GAWR. Conversely, it may not be possible to achieve GVWR without exceeding rear GAWR. In that case, distribute ballast as described in the previous paragraph until rear GAWR is reached and proceed with a total tow-vehicle load less than GVWR.

4. Measure the uncoupled, but ballasted, tow-vehicle wheel cutout trims, front bumper height, and coupling height and record on the TTD sheet.

5. Distribute trailer load to achieve the required coupling load with the coupling at the height required for a level trailer as defined in 4.4.2.

6. Couple the trailer to the tow-vehicle and adjust weight distributing spring bars to achieve a coupled front axle load as close as possible to the required FALR (see 3.6) and a level trailer within the specifications provided in 4.4.2 and 4.4.3.

7. Repeat step 5 for coupling height position found in step 6.

8. Repeat steps 5 and 6 until the front axle load as specified in 4.4.2 is achieved and required coupling load is achieved at the same coupling height that results when coupled and the weight distributing spring bars are engaged.

   If a multi-axle trailer is used, it will be necessary to account for hysteresis in coupling load that results with coupling height change. Coupling height and load shall be measured for at least one cycle of height change. Hysteresis will likely increase with the magnitude of the cycle up to some magnitude of height change. The magnitude of the cycle shall therefore be at least this large with the mid-point of the cycle being the coupling height at which the handling tests are conducted. The coupling load is determined as the average of the maximum and minimum coupling loads at this coupling height that are defined by the hysteresis loop.

9. With weight distributing spring bars engaged, measure the coupled tow-vehicle wheel loads, wheel cutout and front bumper heights, and ball height, and trailer wheel loads and record on the TTD sheet. Complete the TTD sheet before testing. Note the location of all tow-vehicle and trailer ballast.

10. Typical GCWR test condition descriptions for test headers include:

    Preferred TWR/GCWR test condition -
    'Rear GAWR/TWR/GCWR, 10% Coupling Load w/ Weight Distributing Hitch'

    TWR/GCWR test condition when ballast as far rearward in the tow-vehicle does not achieve rear GAWR without exceeding GVWR -
    'Ballast Max Rearward/TWR/GCWR, 10% Coupling Load w/ Weight Distributing Hitch'

    Preferred GVWR/GCWR test condition –
    'GVWR/Rear GAWR/ GCWR, 10% Coupling Load w/ Weight Distributing Hitch'

    GVWR/GCWR test condition when ballast as far rearward in the tow-vehicle does not achieve rear GAWR without exceeding GVWR -
    'GVWR/Ballast Max Rearward/GCWR, 10% Coupling Load w/ Weight Distributing Hitch'

    When any additional ballast in the tow-vehicle results in GVWR being exceeded -
    'Rear GAWR/GCWR, 10% Coupling Load w/ Weight Distributing Hitch'

APPENDIX D

TRAILER WEIGHT RATING EVALUATION LOAD EQUATIONS

GCW	gross combination weight (tow vehicle and trailer)
$Wt_{UT\text{-}V}$	total weight of uncoupled tow vehicle
$Wf_{UT\text{-}V}$	front axle weight of the uncoupled tow vehicle
$Wr_{UT\text{-}V}$	rear axle weight of the uncoupled tow vehicle
$Wf_{CT\text{-}V}$	front axle weight of the coupled tow vehicle without weight distribution
$Wr_{CT\text{-}V}$	rear axle weight of the coupled tow vehicle without weight distribution
Wt_{UTrlr}	total weight of the uncoupled trailer
Wa_{UTrlr}	trailer axle(s) weight of the uncoupled trailer
PctWTongue	tongue weight as percent of total uncoupled trailer weight
WTongue	tongue weight
L	tow vehicle wheelbase
e	rear axle to ball (positive is behind the rear axle)

NOTE: $Wt_{UT\text{-}V}$ = TVTW and Wt_{UTrlr} = TWR for some specific cases, e.g., TWR/GCWR)

$Wr_{CT\text{-}V}$ = Tow Vehicle Rear GAWR

$WTongue = Wt_{UTrlr} * PctWTongue / 100$

$Wr_{UT\text{-}V} = ((Wr_{CT\text{-}V} * L) - (WTongue * (L + e))) / L$

$Wf_{UT\text{-}V} = GCW - Wt_{UTrlr} - Wr_{UT\text{-}V}$

$Wt_{UT\text{-}V} = Wf_{UT\text{-}V} + Wr_{UT\text{-}V}$

$Wa_{UTrlr} = Wt_{UTrlr} - WTongue$

$Wf_{CT\text{-}V} = GCW - Wr_{CT\text{-}V} - Wa_{UTrl}r$

APPENDIX E

TEST TRAILER DESCRIPTION SHEET

V12JA06.1

Engineer: ______ Config. 1 # ______ Req./Vol. # ______
Technician: ______ Config. 2 # ______

TRAILER

Year: ______
Make: ______
Model Number: ______
Model Name: ______
Trailer Number: ______

Type
☐ Utility
☐ Travel
☐ Flat-Bed
☐ Boat
☐ Other

TV Rear Axle to Coupling: ______ mm
Coupling to Axle 1: ______ mm
Axle 1 to Axle 2 *: ______ mm
Axle 2 to Axle 3 *: ______ mm
Axle 1 Track: ______ mm
Axle 2 Track *: ______ mm
Axle 3 Track *: ______ mm
TV Wheelbase: ______ mm

Curb Weight (kg)

L1:	______	R1:	______
L2 *:	______	R2 *:	______
L3 *:	______	R3 *:	______
Coupling:	______	Total:	______

Design Load Data Units: ☐ kg ☐ lb.
GVW Rating: ______
Axle 1 GAWR: ______
Axle 2 GAWR *: ______
Axle 3 GAWR *: ______

LOAD CONDITIONS

Weight Units: ☐ kg ☐ lb.

Config. 1 **Tow Vehicle:** ☐ D+E ☐ GVWR (w/Trlr) ☐ RGAWR (w/Trailer) **Trailer:** ☐ GCWR ☐ TV Max. Trailer Rating ☐ Other: ______
Config. 2 **Tow Vehicle:** ☐ D+E ☐ GVWR (w/Trlr) ☐ RGAWR (w/Trailer) **Trailer:** ☐ GCWR ☐ TV Max. Trailer Rating ☐ Other: ______

		Uncoupled Weights				Coupled Weights (w/Equalization)**			
Config. 1	**Trailer:**	L1:	______	R1:	______	L1:	______	R1:	______
		L2 *:	______	R2 *:	______	L2 *:	______	R2 *:	______
		L3 *:	______	R3 *:	______	L3 *:	______	R3 *:	______
		Coupling:	______	Total:	______			Total:	______
	Tow Vehicle:	LF:	______	RF:	______	LF:	______	RF:	______
		LR:	______	RR:	______	LR:	______	RR:	______
				Total:	______			Total:	______
Config. 2	**Trailer:**	L1:	______	R1:	______	L1:	______	R1:	______
		L2 *:	______	R2 *:	______	L2 *:	______	R2 *:	______
		L3 *:	______	R3 *:	______	L3 *:	______	R3 *:	______
		Coupling:	______	Total:	______			Total:	______
	Tow Vehicle:	LF:	______	RF:	______	LF:	______	RF:	______
		LR:	______	RR:	______	LR:	______	RR:	______
				Total:	______			Total:	______

LEVEL TRAILER COUPLING HEIGHT (mm)

Configuration 1 Coupling: ______ **Configuration 2** Coupling: ______

TOW VEHICLE TRIMS (mm)

D+E LF: ______ RF: ______ Fr. Bumper: ______
LR: ______ RR: ______ Coupling: ______

	Uncoupled Trims				Coupled Trims (w/Equalization)**			
Configuration 1	LF:	______	RF:	______	LF:	______	RF:	______
	LR:	______	RR:	______	LR:	______	RR:	______
	Fr. Bumper:	______	Coupling:	______	Fr. Bumper:	______	Coupling:	______
Configuration 2	LF:	______	RF:	______	LF:	______	RF:	______
	LR:	______	RR:	______	LR:	______	RR:	______
	Fr. Bumper:	______	Coupling:	______	Fr. Bumper:	______	Coupling:	______

*** Multiple axle information only.**
**** Measure with trailer and tow vehicle coupled. Engage load distributing mechanism if required by configuration.**

FIGURE E1 - TEST TRAILER DESCRIPTION

TEST TRAILER DESCRIPTION SHEET

V12JA06.1

COUPLING

Configuration 1

Type: ☐ Ball ☐ Pintle ☐ Fifth Wheel ☐ Gooseneck Ball
☐ Other: ____________
Ball Size: ☐ 3 inch ☐ 2 5/16 inch ☐ 2 inch ☐ 1 7/8 inch
☐ Other: ____________
Auxiliary Damping: ☐ Flat Bar Slider ☐ Hydraulic Damper ☐ Dual Cam ☐ Other: ____________
Load Distributing: ☐ None ☐ Spring Bars ☐ Other: ____________
Coupling Lube: ☐ None ☐ Other (Describe): ____________

Configuration 2

Type: ☐ Ball ☐ Pintle ☐ Fifth Wheel ☐ Gooseneck Ball
☐ Other: ____________
Ball Size: ☐ 3 inch ☐ 2 5/16 inch ☐ 2 inch ☐ 1 7/8 inch
☐ Other: ____________
Auxiliary Damping: ☐ Flat Bar Slider ☐ Hydraulic Damper ☐ Dual Cam ☐ Other: ____________
Load Distributing: ☐ None ☐ Spring Bars ☐ Other: ____________
Coupling Lube: ☐ None ☐ Other (Describe): ____________

BRAKES

Axles w/ Brakes: ☐ None ☐ Axle 1 ☐ Axle 2 * ☐ Axle 3 *
Control: ☐ No brakes ☐ Electronic ☐ Surge ☐ Other: ____________
Actuation: ☐ Hydraulic ☐ Electric ☐ Cable ☐ Other: ____________
Type: ☐ Disc ☐ Drum **Features:** ☐ Antilock ☐ Other: ____________
Comments: ____________

SUSPENSION

Suspension Type	Axle 1	Axle 2 *	Axle 3 *
Solid Leaf	☐	☐	☐
Walking Beam Leaf	☐	☐	☐
Rubber Torsion	☐	☐	☐
Other	☐	☐	☐

Describe: ____________

Track Bar	Axle 1	Axle 2 *	Axle 3 *
Yes	☐	☐	☐

Stabilizer Bar	Axle 1	Axle 2 *	Axle 3 *
Yes	☐	☐	☐

Spring Type	Axle 1	Axle 2 *	Axle 3 *
Coil	☐	☐	☐
Leaf	☐	☐	☐
Torsion Bar/Coil	☐	☐	☐
Air	☐	☐	☐
Hydraulic	☐	☐	☐

Spring Material	Axle 1	Axle 2 *	Axle 3 *
Steel	☐	☐	☐
Composite/Fiberglass	☐	☐	☐
Rubber	☐	☐	☐

Damper Type	Axle 1	Axle 2 *	Axle 3 *
None	☐	☐	☐
Hydraulic	☐	☐	☐
Other: ____________	☐	☐	☐

TIRES

Size: ____________ **Pressure:** ____________ ☐ psi ☐ kpa **Temp:** ☐ Cold ☐ Hot

Brand: ☐ GDY ☐ MIC ☐ BRI ☐ DUN ☐ UNI ☐ Titan ☐ Cooper ☐ Towmaster
☐ FIR ☐ YOK ☐ PIR ☐ GEN ☐ BFG ☐ TOY ☐ CON ☐ Other: ____________
Model: ____________ **Const #:** ____________
Load Range: ____________ (For LT/ST Tires) ☐ Dual Wheels
Tire Type: ☐ Radial ☐ Belted Bias ☐ Bias ☐ Other: ____________
Tread Type: ☐ HWY ☐ ALS ☐ AL2 ☐ AL3 ☐ M+S (OOR) ☐ M+S (AT)
Depth: ☐ New (<100mi) ☐ Lt Wear (<1000mi) ☐ Mod (>1000mi) ☐ Near TWI

TEST EQUIPMENT

Articulation Transducer Type: ☐ Rotary Digital Encoder ☐ String Potentiometers ☐ RVDT
Coupler Load Transducer: ☐ Multi-Axial Force & Moment **Other:** ____________

FIGURE E1 - TEST TRAILER DESCRIPTION (CONTINUED)