The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J2264

ISSUED APR95

Issued 1995-04

Submitted for recognition as an American National Standard

CHASSIS DYNAMOMETER SIMULATION OF ROAD LOAD USING COASTDOWN TECHNIQUES

Foreword**—**This Document has not changed other than to put it into the new SAE Technical Standards Board format.

Electric chassis roll dynamometers provide the means for rapid, accurate, automatic adjustment of dynamometer loading to simulate vehicle road load over the entire speed range through which the vehicle is tested. Precise calibration of chassis roll torque measurement, speed instrumentation, and base inertia, together with controls employing valid algorithms, have resulted in accurate dynamometer load coefficient measurements using coastdown techniques without requiring onerous computation and data manipulation by users. Variability of each dynamometer and between dynamometers is low, permitting load coefficients obtained on one dynamometer to be used on other similar dynamometers. To achieve this interchangeability of loading coefficients, operational factors are specified with the objective of keeping test variability at the low levels of the dynamometer.

This procedure has been developed in conjunction with the introduction of the 1.219 m (48 in) diameter single-roll electric dynamometer for vehicle emissions and fuel economy testing. The methodology is generic to any dynamometer capable of carrying out the road load derivation described, regardless of roll size, geometry, or roll surface roughness. However, this procedure is intended to provide a standard of best practice for all vehicle testing requiring accurate road load simulation. Consequently, the 1.219 m roll diameter with smooth roll surface is specified to minimize variability in results of tests done on different dynamometers. This eliminates variability resulting from roll geometry and surface effects on tire energy loss and slip changes occurring during actual test operation, where power transmitted through the vehicle tires is different from the coastdown conditions of the road load derivation.

TABLE OF CONTENTS

1. Scope—This procedure covers two-wheel drive vehicle operation and single-axle electric dynamometer load coefficient adjustment to simulate track road load within the speed range of track testing and the dynamometer inertia and road load simulation capabilities.

1.1 Purpose—To provide a uniform procedure for adjusting an electric chassis roll dynamometer to provide accurate simulation of the resistance which must be overcome by the vehicle powertrain to maintain steady speed on a flat road, as determined by track coastdown tests on that vehicle.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein.

2.1.1 HWFET PUBLICATION—Available from The Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9371.

HWFET, Highway Fuel Economy Test, 40 CFR Part 600, Subpart B and Appendix I

2.1.2 OTHER PUBLICATIONS—Dynamometer manufacturer's operation and calibration manuals

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1263—Road Load Measurement and Dynamometer Simulation Using Coastdown Technique

SAE Paper 780257, "The Influence Of Road Surface Texture On Tire Rolling Resistance," DeRaad, L. W., February 1978

SAE Paper 810166, “The Airflow Field Around An Operating Tire And Its Effect On Tire Power Loss,” Oswald, L. J. et al., February 1981
SAE Paper 900760, “Moments Of Inertia Of Mounted And Unmounted Passenger And Motorcycle Tires,” Metz, L. D. et al., February 1990
SAE Paper 930391, “Large-Roll Chassis Dynamometer with AC Flux-Vector PEU and Friction-Compensated Bearings,” D’Angelo, S. et al., March, 1993
SAE Paper 930392, “Performance Tests of a Large-Roll Chassis Dynamometer with AC Flux-Vector PEU and Friction-Compensated Bearings,” Mears, W. G. et al., March, 1993
SAE Paper 940486, “Simulation of 8.65” Uncoupled Twin-Roll Hydrokinetic Dynamometer Operation on a 48” Single-Roll Electric Dynamometer,” Brownell, C. et al., March 1994

2.2.2 OTHER PUBLICATION—Differential and Integral Calculus, C. E. Love, Macmillan Co., 1948

3. Definitions

3.1 Average Decelerating Force, F_{avg}—The average decelerating force over a coastdown speed interval which would produce the deceleration of the selected inertia (see 3.9) given by the $\frac{\Delta V}{\Delta t}$ value for that speed interval. For example, see Equation 1:

$$\text{Average vehicle-dyno decelerating force for speed interval } \Delta V = (\text{Highway Inertia}) \times \frac{\Delta V}{\Delta t} \qquad \text{(Eq. 1)}$$

3.2 Base Inertia—The rotational inertia of the rotating dynamometer components between the vehicle driving tires and the dynamometer torque-measuring device.

3.3 Coastdown Speed Interval—An upper and lower speed which define a speed interval over which a coastdown time is measured.

3.4 Coastdown Speed Range—The speed range starting at the beginning of the fastest coastdown speed interval and ending at the end of the slowest coastdown speed interval.

3.5 Drivetrain—The rotating components of a vehicle mechanically connected to the driving wheels when the transmission is in neutral. This includes the tires, wheels, brake disks/drums, drive shafts, differential, propeller shaft, transmission output shaft, and some components within the transmission.

3.6 Dynamometer Calibration—The adjustment and verification of the accuracy of dynamometer time, speed, and load instrumentation, base inertia determination, mass simulation, and road load simulation.

3.7 Calibration Verification Coastdown—An unloaded coastdown test which is run to verify the simulation accuracy of the dynamometer. The coastdown load curve calculated from the $\text{Dyno}_{\text{measured}}$ coefficients and the dynamometer Inertia setting is compared to the load curve calculated from the Dyno_{set} coefficient settings and the dynamometer Inertia setting.

3.8 ETW Class (Equivalent Test Weight)—Test mass assigned for a vehicle to represent a group of vehicles.

3.9 Highway Inertia—The inertia setting used, when a vehicle is coasting on the dynamometer, for calculating coastdown times and forces related to $\text{Dyno}_{\text{target}}$ and $\text{Dyno}_{\text{measured}}$ coefficients. The method for determining highway inertia varies depending on the choice of vehicle mass. Two alternatives follow:

3.9.1 CASE 1—Highway inertia equals the vehicle total effective mass, consisting of the vehicle track test mass determined by weight, plus the effective mass of the rotating drivetrain components, as well as the effective mass of the wheels, tires, and other rotating components on the non-driving axle. This case may be used for exact duplication of the on-road mass. For light-duty vehicles, highway inertia can be estimated by multiplying the vehicle track test mass by 1.03. However, vehicles with other than single normal-sized wheels, such as dual-wheel trucks, require specific estimation of the effective mass of the rotating components.

3.9.2 CASE 2—Highway inertia equals the ETW class (Equivalent Test Weight) plus the effective mass of the rotating drivetrain components. This case applies to vehicle mass settings dictated by regulations. For light-duty vehicles, highway inertia can be estimated by multiplying the ETW class by 1.015. However, vehicles with other than single normal-sized wheels, such as dual-wheel trucks, require specific estimation of the effective mass of the rotating drivetrain components.

3.10 Inertia—The setting used by the dynamometer to control the vehicle inertia being simulated by the dynamometer. The following are two alternatives, depending on the choice of vehicle mass:

3.10.1 CASE 1—Inertia equals the track test mass determined by weight, plus the effective mass of the wheels, tires, and other rotating components on the non-driving axle. This case may be used for exact duplication of the on-road mass. For light-duty vehicles, inertia can be estimated by multiplying the track test mass by 1.015. However, vehicles with other than single normal-sized wheels on the non-driving axle require specific estimation of the effective mass of the rotating components.

3.10.2 CASE 2—Inertia equals the ETW class (Equivalent Test Weight). This case applies to vehicle mass settings dictated by regulations.

3.11 Instantaneous Force, or Mid-Speed Force—The road load force calculated using A, B, and C road load coefficients and the speed at the midpoint of the speed interval of interest.

3.12 Road Load Coefficients—Several sets of A, B, and C road load force coefficients are used, where road load force at speed V equals $A + BV + CV^2$:

3.12.1 $DYNO_{MEASURED}$, A_m, B_m, AND C_m—Dynamometer coefficients computed from the times measured as the dynamometer-vehicle system coasts through each speed interval. For coastdown calculations with the vehicle on the rolls, highway inertia is used for mass. For unloaded coastdowns, without vehicle, the dynamometer Inertia setting is used.

3.12.2 $DYNO_{SET}$, A_s, B_s, AND C_s—Dynamometer setting coefficients which command the road load simulation done by the dynamometer.

3.12.3 $DYNO_{TARGET}$, A_t, B_t, AND C_t—Dynamometer target coefficients for the vehicle which were developed from track data, corrected to standard conditions, and possibly adjusted to account for differences between vehicle weight as tested on the track and weight represented by an ETW class assigned for dynamometer testing.

3.12.4 $DYNO_{VEHICLE}$, A_v, B_v, AND C_v—Coefficients representing vehicle drivetrain parasitic friction on the dynamometer. These values are obtained from $Dyno_{measured}$ minus $Dyno_{set}$ coefficients.

3.13 Road Load Derivation—The procedure in which the dynamometer conducts coastdown tests with vehicle wheels on the rolls and adjusts its $Dyno_{set}$ coefficients to provide combined vehicle-dynamometer loading from $Dyno_{measured}$ coefficients to match road load represented by $Dyno_{target}$ coefficients.

3.14 Simulation Mode—The dynamometer operating mode where the dynamometer simulates the vehicle inertia and road load commanded by the Inertia and $Dyno_{set}$ coefficients so the vehicle being driven on the dynamometer operates as it would on the road.

3.15 Test Drive Axle Weight—The drive axle weight that applies for the $Dyno_{target}$ road load coefficients.

3.16 Unloaded Coastdown—A dynamometer coastdown run with the vehicle wheels off the roll surface.

4. Symbols

A, B, C	N, N/(km/h), N/(km/h)^2 (lb, lb/mph, lb/mph^2)	Road load coefficients where load = A + BV + CV^2.
F	N (lb)	Force represented by the vehicle friction ($Dyno_{vehicle}$) plus the dynamometer load commanded by the $Dyno_{set}$ coefficients, expressed as tractive force tangential to roll surface.
M	kg (lb)	Highway inertia of vehicle.
Δt	s	Time in seconds to coast from speed V_1 to speed V_2.
V	km/h (mph)	Vehicle tire and dynamometer roll surface speed.
ΔV	km/h (mph)	Coastdown speed interval between speeds V_1 and V_2.

5. Equipment

5.1 Dynamometer

5.1.1 GENERAL REQUIREMENTS—The dynamometer must be able to accelerate the vehicle at approximately 3.6 km/h/s (2.2 mph/s) to a speed 10 km/h (6 mph) above the highest data speed for the coastdown, run a coastdown, calculate and then subtract the $Dyno_{measured}$ load coefficients from the $Dyno_{target}$ values, add their difference to the $Dyno_{set}$ coefficients, and automatically run verification coastdowns, comparing the $Dyno_{measured}$ load curve with the $Dyno_{target}$ curve. The dynamometer must automatically adjust its $Dyno_{set}$ coefficients as required to match, within specified limits, the load curve generated from the $Dyno_{measured}$ coefficients to the curve from the $Dyno_{target}$ coefficients. The method accepts three coastdown $Dyno_{target}$ road load coefficients, A, B, and C where load is determined by A + BV + CV^2. It compensates for errors originating in the assumption that the average decelerating force over a coastdown speed interval is the same as the instantaneous force at the midpoint of the speed interval. This permits flexible selection of speed intervals for timing accuracy without introducing significant coefficient computational errors.

Before starting road load derivation, calibration should be verified using dynamometer manufacturer or laboratory procedures. Also, the rolls must be clean and dry to prevent tire slippage.

5.1.2 SPECIFICATIONS

a. Roll Diameter—1219.2 mm ± 0.3 mm (48.000 in ± 0.010 in)
b. Roll Surface Roughness—< 5 mm peak-peak (200 µin)
c. Speed Resolution and Accuracy—0.01 km/h (0.01 mph)
d. Time Resolution—0.01 s
e. Time Accuracy—0.003%
f. Mass Simulation Accuracy—2 kg (4.4 lb)
g. Torque measuring system requirements in load range required for coastdown operation, expressed as thrust tangential to roll surface:

    1. Accuracy—±10 N (2.2 lb)
    2. Zero Shift—< ±5 N (1.1 lb) over 2 h at constant temperature
    3. Response—< 0.05 s to 90% of value

5.1.3 COASTDOWN LOAD MEASUREMENT REQUIREMENTS

a. Making automatic accelerations at controlled acceleration rate.
b. Initiating, running, and terminating coastdowns using $Dyno_{set}$ coefficients to control road load and the inertia setting to control mass simulation throughout the coastdown.
c. Computing $Dyno_{measured}$ coefficients.
d. Comparing load force curves from $Dyno_{measured}$ versus $Dyno_{target}$ coefficients.
e. Adjusting $Dyno_{set}$ coefficients.
f. Determining $Dyno_{vehicle}$ drivetrain parasitic friction coefficients.
g. Displaying, recording, and reporting results.

5.1.4 COEFFICIENT RESOLUTION—Number of decimal digits.

A	xxx.xx N or lb
B	x.xxxx N/(km/h) or lb/mph
C	0.xxxxx N/(km/h)^2 or lb/mph^2
Inertia	1 kg or 1 lb

5.1.5 MOTORING CAPABILITY—Sufficient to accelerate dynamometer and vehicle drivetrain to maximum required speed at 3.6 km/h/s ± 0.5 km/h/s (2.2 mph/s ± 0.3 mph/s).

5.1.6 DATA ACQUISITION—Sufficient to record all data required to conduct a complete coastdown road load derivation test.

5.1.7 COMPUTATION—As specified under 6.10 and illustrated in Appendix A.

5.1.8 CALIBRATION VERIFICATION—Calibration is verified by running an unloaded coastdown immediately following the road load coefficient derivation using the final dynamometer settings and coast speed interval schedule from the road load derivation. The maximum load error at any point over the coastdown speed interval may not exceed ±10 N (2.2 lb).

It is also recommended that an unloaded calibration verification coastdown test be run before the road load derivation, using estimated dynamometer settings.

5.2 Restraint System—The dynamometer should be equipped with a centering device which aligns the drive wheels perpendicular to the dynamometer roll axis. After installation, the restraint system should maintain the centered drive wheel position within the following recommended limits throughout the coastdown portions of the road load derivation.

5.2.1 POSITION SIDEWAYS ALONG AXLE CENTERLINE—Within ±10 mm (0.4 in) of the original centered wheel position.

5.2.2 FRONT-REAR POSITION—Within ±25 mm (1 in) of top of roll.

5.2.3 VERTICAL FORCE—The restraint system should be designed to impose no vertical force on the drive wheels. No more than ±5 mm (0.2 in) vertical drive axle suspension static deflection should be caused by restraint installation on the vehicle.

5.3 Air Circulation/Cooling—An air circulation and cooling system is required for engine cooling and maintaining repeatable ambient temperature and airflow conditions around the vehicle drivetrain. It is recommended that the ambient temperature not change more than ±5 °C (9 °F) during the warm-up and road load derivation. Air temperature and flow around the vehicle tires and drivetrain will affect warm-up, and should be within 5 °C (9 °F) of temperature to be used for the vehicle testing which will use the dynamometer setting coefficients obtained in this derivation.

6. Road Load Derivation Procedure

6.1 Summary—The dynamometer is preconditioned to stabilize parasitic friction. A pre-test unloaded coastdown may be run to verify dynamometer calibration. The vehicle test weight is adjusted if necessary, it is soaked to test temperature, and tire pressure is set to the specified value. After installation on the dynamometer, two HWFET cycles are driven to warm up the vehicle tires and drivetrain. Then the automatic road load derivation procedure is run by the dynamometer. The vehicle is removed, and an unloaded coastdown is run to verify dynamometer calibration. The test results from the dynamometer are stored to archive, and reports printed out.

A check-off form summarizing the procedure is provided in Appendix B.

6.2 Recommended Pre-test Calibration Check—To minimize errors in road load derivation results, it is essential that dynamometer calibration is correct. To verify the dynamometer calibration, the following steps are recommended.

6.2.1 DYNAMOMETER PRECONDITIONING—Follow dynamometer manufacturer's recommended practice or laboratory procedure to stabilize the dynamometer parasitic friction.

6.2.2 CALIBRATION VERIFICATION COASTDOWN—Conduct an unloaded coastdown using test coastdown speed intervals with dynamometer inertia and $Dyno_{set}$ coefficients appropriate for the test vehicle. Run one coastdown test. If maximum load error at any point over the test speed range is greater than ±10 N (2.2 lb), recalibrate dynamometer and rerun calibration coastdowns until the maximum error is less than ±10 N. Maximum load error is calculated as the maximum difference, in the coastdown speed range, between the load curves generated from the $Dyno_{set}$ and $Dyno_{measured}$ coefficients.

6.3 Vehicle Preparation

6.3.1 TEST DRIVE AXLE WEIGHT ADJUSTMENT—Vehicle drive axle weight, including driver, is to be within ±20 kg (44 lb) of the specified test drive axle weight. If driver will not be in the vehicle during road load derivation testing, supplementary ballast must be added to maintain the specified test drive axle weight.

6.3.2 TEMPERATURE SOAK—Increase test tire pressure 40 kPa (6 psi) above test pressure. Soak vehicle and test tires at test temperature ±3 °C (5 °F) for at least 4 h.

6.3.3 TIRE PRESSURE ADJUSTMENT—After tires have soaked at least 4 h at test temperature, bleed pressure to test pressure.

6.4 Dynamometer Set-up

6.4.1 ROAD LOAD DERIVATION SETTINGS—Make the following dynamometer settings.

a. $Dyno_{target}$ Coefficients

b. Inertia

c. Highway Inertia

d. Coastdown Speed Intervals—Set up following 10 km/h coastdown speed intervals from 115 to 15 km/h (6.2 mph intervals from 71.5 to 9.3 mph).

   115 to 105 km/h, 105 to 95 km/h, 95 to 85 km/h, 85 to 75 km/h, 75 to 65 km/h, 65 to 55 km/h, 55 to 45 km/h, 45 to 35 km/h, 35 to 25 km/h, 25 to 15 km/h

e. Acceleration Rate Between Coastdowns—Set at 3.6 (km/h)/s (2 mph/s).

f. Maximum Difference Between Measured and Target Force—Set the maximum acceptable force difference between the force versus speed curve derived from the $Dyno_{target}$ coefficients and that from the $Dyno_{measured}$ coefficients. This is the maximum plus or minus difference found anywhere within the coastdown speed range.

Recommended value: ±10 N (2.2 lb). Higher limits may be required for large vehicles.

g. Number of Verification Coasts—Set the required number of additional consecutive coasts required to meet the maximum difference between measured and target force limit specified in 6.4.1.f after one coast falls satisfactorily within that limit.

Recommended value: 2

h. Maximum Total Number of Coasts—Set the maximum number of consecutive coasts permissible for a valid test.

Recommended value: 15

6.4.2 DYNAMOMETER SETTINGS FOR VEHICLE PRECONDITIONING—If dynamometer settings are available from road load derivation results on similar vehicles, use these settings for the simulation mode set up. If none are available, estimate dynamometer settings from the target coefficients as follows:

$Dyno_{set}$ A_S = 0.5 x Target A
$Dyno_{set}$ B_S = 0.2 x Target B
$Dyno_{set}$ C_S = Target C
Inertia = ETW class, or 1.015 x test weight

6.5 Vehicle Installation On Dynamometer

6.5.1 RESTRAINT AND ALIGNMENT—Install vehicle as outlined in 5.2.

6.5.2 VEHICLE COOLING—Provide vehicle cooling as outlined in 5.3.

6.6 Vehicle Preconditioning—Drive two consecutive HWFET cycles (Reference 2.1.1) with dynamometer operating in simulation mode. Each HWFET is 16.5 km (10.25 miles) long. Total time is 25 min, 28 s.

6.7 Road Load Derivation Runs—Carry out the following sequence:

6.7.1 Place transmission in neutral with engine idling.

6.7.2 Activate any accessories which were operated during track coastdowns, and carry out any operating procedures which may be required for identical engine and transmission operation to that of the track coastdown.

6.7.3 Driver either remains in vehicle or exits in accordance with weight-compensating ballast installation covered in 6.3.1.

6.7.4 Start automatic dynamometer road load derivation sequence within 30 s of completing the vehicle preconditioning.

6.7.5 Allow dynamometer to run through road load derivation sequence without interruption.

6.7.6 At end of road load derivation sequence, shut down vehicle and initiate report printout from the dynamometer.

6.7.7 If maximum difference between measured and target force limit is not met within the allowed number of runs, the testing is void. Further road load derivation testing must be preceeded by a 4-h soak at test temperature, 6.3.3, and preconditioning, 6.6.

6.7.8 Remove any supplemental ballast which was added for driver weight compensation.

6.8 Dynamometer Calibration Verification Coastdown—This procedure verifies the dynamometer calibration.

Within 15 min of completing the road load determination, run a single unloaded coastdown using the speed intervals and final dynamometer settings from the road load determination. The dynamometer calibration is acceptable if the maximum load error at any point over the test speed range is less than ±10 N (2.2 lb). If the error is greater than ±10 N, recalibrate the dynamometer and rerun calibration coastdowns until the maximum error is less than ±10 N. The road load derivation must then be rerun. Maximum load error is calculated as the maximum difference, in the coastdown speed range, between the load curves generated from the $Dyno_{set}$ and $Dyno_{measured}$ coefficients.

6.9 Data Acquisition—The dynamometer automatically measures time to coast through specified speed intervals to give ΔV/Δt for each speed interval. These data are then used to compute load coefficients as described in 6.10 and illustrated in Appendix A.

6.10 Coastdown Computation—Appendix A is included as an illustration of the road load derivation computation results. It contains samples of typical vehicle data and the details of force curve matching and error correction. Other formats that are demonstrated to produce the same results may also be used.

Recommended precision in the computations is at least sixteen bits.

The dynamometer measures speed to 0.01 km/h (or 0.01 mph) accuracy every 10.000 ms during coastdown, and records the time to coast through each speed interval. These coastdown times are used with the highway inertia to compute an "average" decelerating force through each speed interval using $F = M\frac{\Delta V}{\Delta t}$.

The error correction method accounts for the assumption of constant deceleration rate throughout a coastdown interval. This method uses the difference between the instantaneous force at the midpoint of the speed interval computed directly from A, B, and C coefficients, and the force given from $F = M\frac{\Delta V}{\Delta t}$ where the coast time, Δt, is calculated by integration over the coast speed interval using the same A, B, and C coefficients.

The first correction uses the $Dyno_{set}$ coefficients. They are used to calculate a mid-speed force for each speed interval. The same coefficients are used in an integral to compute a coastdown time for each speed interval, which is then used to compute a decelerating force using $F = M\frac{\Delta V}{\Delta t}$. The difference between each pair of these two forces is added to the original “average” decelerating force from the test data to give a partially-corrected "approximate" force. When the coastdown is finished, a quadratic regression is run on the “approximate” force values to give “approximate” A, B, and C coefficients.

The second correction is done by using these "approximate" coefficients to calculate mid-speed forces, and also in the integral to compute coastdown times, which are then used to calculate decelerating forces using $F = M\frac{\Delta V}{\Delta t}$. The differences between the mid-speed forces from these coefficients and mid-speed forces from the integrated coastdown times are added to the original "average" forces from the test data to give "actual" forces. A quadratic regression is then run on the "actual" forces, resulting in the final $Dyno_{measured}$ coefficients. These coefficients are used to generate a curve of "measured" force versus speed which is compared to a similar curve derived from the desired $Dyno_{target}$ coefficients to determine if the "measured" force falls within the specified force difference limit. The speed range for force comparison starts at the top speed of the first coastdown speed interval, and ends at the low speed of the last speed interval.

After the dynamometer has adjusted the $Dyno_{set}$ coefficients to satisfy the criteria for maximum difference between measured and target force, the $Dyno_{vehicle}$ (vehicle drivetrain parasitic friction) coefficients are calculated by subtracting the $Dyno_{set}$ coefficients from the $Dyno_{measured}$ coefficients.

6.10.1 SAMPLE CALCULATIONS—The following description of the coastdown calculations refers to the Figure 1 spreadsheet, "Coastdown Calculations With Error Corrections."

For purposes of illustrating the error correction, only three coastdown speed intervals are used, set at 30 or 35 km/h, to maximize the force calculation errors. The typical $Dyno_{target}$ road load coefficients under TARGET are used to calculate both the Δt targ and Δt data values using the integration method described in 6.10.2. The Δt data values which are used for calculating the $Dyno_{measured}$ coefficients under MEASURED exactly match the Δt targ values from the $Dyno_{target}$ coefficients under TARGET. Thus any errors between the MEASURED and TARGET coefficients and load curves result solely from the error correction calculation method, and not from differences in the values of Δt data and Δt targ.

6.10.2 INTEGRATION—The following integration is used to generate dt values throughout the calculations.

$$F = \frac{M}{3.6}\frac{dt}{dt} \quad \text{(Eq. 2)}$$

$$\Delta t = \int dt = \frac{M}{3.6}\int_{V_1}^{V_2}\frac{1}{F}dV = \frac{M}{3.6}\int_{V_1}^{V_2}\frac{1}{A + BV + CV^2}dV \quad \text{(Eq. 3)}$$

where:

A, B, C = Load coefficients; A, N; B, N/(km/h); C, $N/(km/h)^2$
F = Decelerating force produced by the vehicle tire and drivetrain friction and the dynamometer load commanded by the $Dyno_{set}$ coefficients, N
M = Highway inertia of vehicle, kg
Δt = Time in seconds to coast from speed V_1 to speed V_2, km/h

Simpson's approximation is the recommended integration method, using at least twenty segments covering each speed interval. This computation method is described in reference 2.1.2 and many other elementary calculus texts.

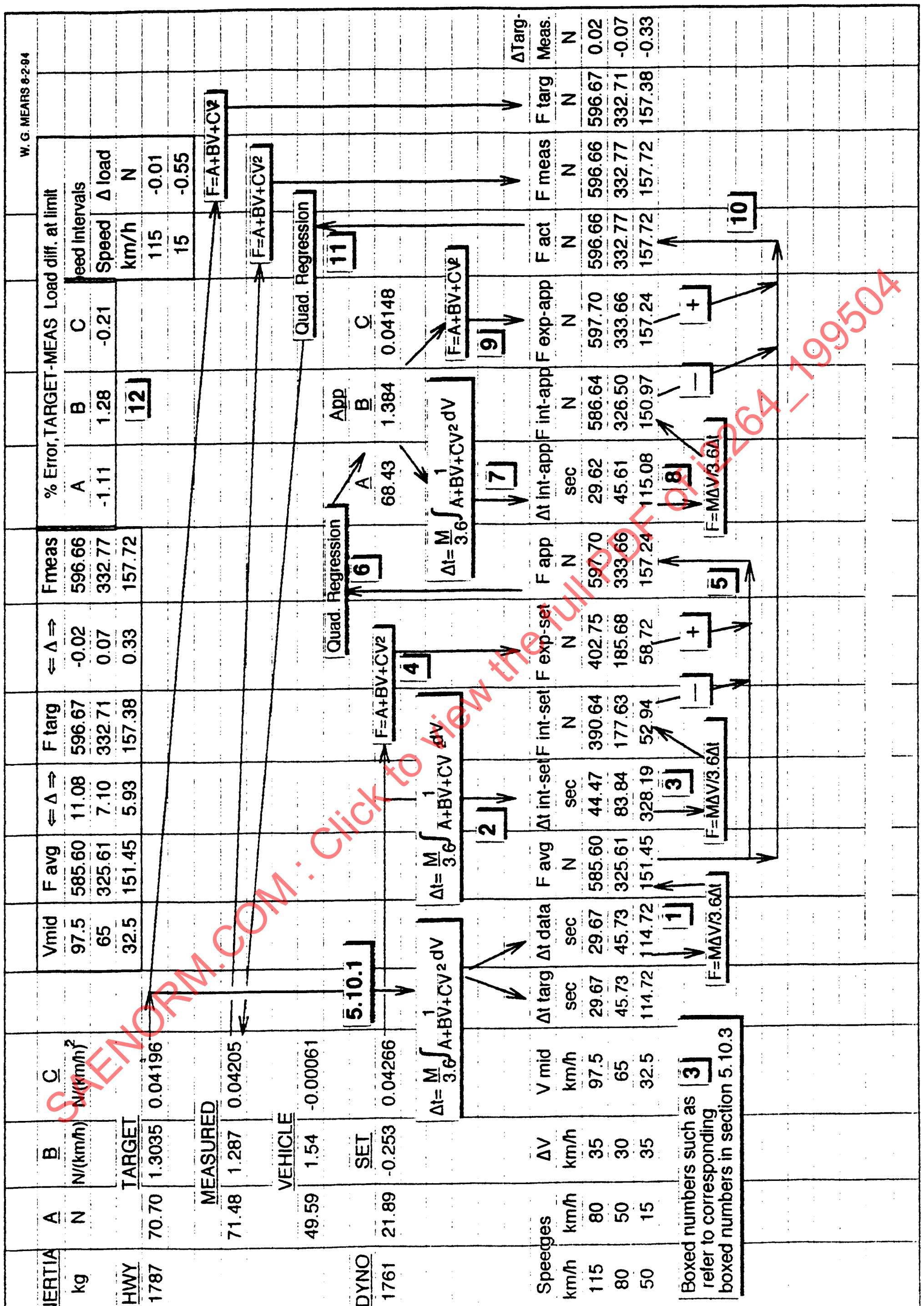

FIGURE 1—COASTDOWN CALCULATIONS WITH ERROR CORRECTIONS

6.10.3 CALCULATION SEQUENCE—The boxed numbers such as [2] correspond to the boxed numbers on Figure 1.

a. [1] Calculate *F avg* from simulated coastdown ΔV/Δt data, ΔV and Δt data columns.

$$F\ avg = \frac{M}{3.6} \times \frac{\Delta V}{\Delta t\ data} \quad \text{(Eq. 4)}$$

b. [2] Calculate Δt int-set for each speed interval using integration and the known dynamometer load coefficients, A SET, B SET, and C SET.

c. [3] Calculate *F int-set* for each speed interval using

$$F = M\frac{\Delta V}{\Delta t} \quad \text{(Eq. 5)}$$

$$F\ int\text{–}set = \frac{M}{3.6} \times \frac{\Delta V}{\Delta t\ int\text{–}set} \quad \text{(Eq. 6)}$$

d. [4] Calculate *F exp-set* for each speed interval using *A SET, B SET*, and *C SET*.

$$F\ exp\text{-}set = A\ SET + B\ SET \times V\ mid + C\ SET \times V\ mid^2 \quad \text{(Eq. 7)}$$

e. [5] Make first correction to *F avg* by adding the difference between *F int-set* and *F exp-set*, which approximates the error between the average force over the speed interval from the $F = M\frac{\Delta V}{\Delta t}$ calculation and the exact value of F at the mid-speed. This produces *F app*.

$$F\ app = F\ avg + F\ exp\text{-}set - F\ int\text{-}set \quad \text{(Eq. 8)}$$

f. [6] Run a quadratic regression on the *F app* and *V mid* values to give A app, B app, and C app.

g. [7] Calculate *Δt int-app* for each speed interval using integration and the approximate load coefficients, *A app, B app,* and *C app*.

h. [8] Calculate *F int-app* for each speed interval using $F = M\frac{\Delta V}{\Delta t}$

$$F\ int\text{–}app = \frac{M}{3.6} \times \frac{\Delta V}{\Delta t\ int\text{–}app} \quad \text{(Eq. 9)}$$

i. [9] Calculate *F exp-app* for each speed interval using *A app, B app*, and *C app*.

$$F\ exp\text{-}app = A\ app + B\ app \times V\ mid + C\ app \times V\ mid^2 \quad \text{(Eq. 10)}$$

j. [10] Make second correction to *F avg* by adding the difference between *F int-app* and *F exp-app*, which closely approximates the error between the average force over the speed interval from the $F = M\frac{\Delta V}{\Delta t}$ calculation and the exact value of F at the mid-speed. This produces *F act*.

$$F\ act = F\ avg + F\ exp\text{-}app - F\ int\text{-}app \quad \text{(Eq. 11)}$$

k. [11] Run a quadratic regression on the *F act* and *V mid* values to give *A MEAS, B MEAS*, and *C MEAS*. These are the final values for the overall road load coefficients of the vehicle and dynamometer system.

6.10.4 EVALUATION OF ERROR CORRECTION—The following section shows the amount of error correction produced by the calculation methods described. It is not part of the normal dynamometer road load derivation calculations.

a. [12] Determine % error between the original *A TARGET, B TARGET*, and *C TARGET* coefficients and the final resulting *A MEAS, B MEAS*, and *C MEAS* coefficients, which should be equal if all errors were perfectly corrected.

Figure 1 shows how the usual method of calculating coastdown force using $F = M\frac{\Delta V}{\Delta t}$ which gives the *F avg* values, produces an 11.08 N force error at 97.5 km/h *V mid*, compared to the *F targ* value. This error is reduced to the 0.02 N difference between *F meas* and *F targ* by the error-correcting computation method.

6.10.5 ERROR CORRECTION WITH 10 km/h COASTDOWN SPEED INTERVALS—A second spreadsheet, Figure 2, is included to show how computation errors are virtually eliminated by the error-correcting computation method when 10 km/h speed intervals are used. In this case the error between the *F avg* and *F targ* values of 0.93 N at 110 km/h *V mid* is reduced to a zero difference between *F meas* and *F targ*.

6.11 Road Load Derivation Report—Sample reports of road load derivation test results are included in Appendix A, Sample Reports and Calculations. Other formats which include the required information may be used.

6.12 Forms

6.12.1 ROAD LOAD DERIVATION PREPARATION AND VEHICLE DATA—(See Figure 3.)

6.12.2 ROAD LOAD DERIVATION—Examples of road load derivation report forms are shown as Figures A1 and A2 in Appendix A, Sample Reports and Calculations. Other formats which include the required information may be used.

7. Notes

7.1 Key Words—Chassis roll, Coastdown, Dynamometer, Road load, Road load derivation, Road simulation, Simulation, Vehicle testing

7.2 Conversion Factors

7.2.1 DISTANCE

1 m = 39.3701 in = 3.2808 ft
1 km = 0.62137 mi = 3280.8 ft
1 inch = 25.40 mm = 2.540 cm = 0.0254 m = 1/12 ft
1 mile = 1609.3 m = 1.6093 km = 5280 ft

7.2.2 SPEED

1 km/h = 0.62137 mph = 0.27778 m/s = 0.91134 ft/s
1 mph = 1.6093 km/h = 0.44704 m/s = 1.4667 ft/s

7.2.3 ACCELERATION

1 (km/h)/s = 0.62137 mph/s = 0.27778 m/s^2 = 0.91134 ft/s^2
1 mph/s = 1.6093 (km/h)/s = 0.44704 m/s^2 = 1.4667 ft/s^2

INERTIA	A	B	C
kg	N	N/(km/h)	N/(km/h)^2
HWY		TARGET	
1787	70.70	1.3035	0.04196
		MEASURED	
	70.71	1.3034	0.04196
		VEHICLE	
	48.82	1.5566	-0.00070
DYNO		SET	
1761	21.89	-0.2531	0.04266

Vmid	F avg	⇐ Δ ⇒	F targ	⇐ Δ ⇒	Fmeas
110	720.87	0.93	721.80	0.00	721.80
70	366.73	0.82	367.55	0.00	367.55
20	113.25	0.30	113.55	0.00	113.56

% Error,TARGET-MEAS		
A	B	C
-0.01	0.01	0.00

Load diff. at limit of speed intervals	
Speed km/h	Δ load N
115	0.00
85	0.01

Set to = TARGET

App		
A	B	C
70.42	1.314	0.04189

Speed	ranges	ΔV	V mid	Δt targ	Δt data	F avg	Δt int-set	F int-set	F exp-set	F app	Δt int-app	F int-app	F exp-app	F act	F MEAS	F TARGET	DIFF
km/h	km/h	km/h	km/h	sec	sec	N	sec	N	N	N	sec	N	N	N	N	N	N
115	105	10	110	6.89	6.89	720.87	9.75	509.23	510.23	721.88	6.89	720.91	721.85	721.80	721.80	721.80	0.00
105	95	10	100	8.01	8.01	619.74	11.76	422.19	423.18	620.73	8.01	619.82	620.74	620.65	620.65	620.65	0.00
95	85	10	90	9.42	9.42	527.00	14.44	343.68	344.66	527.98	9.42	527.12	528.00	527.89	527.89	527.89	0.00
85	75	10	80	11.21	11.21	442.67	18.14	273.71	274.67	443.62	11.21	442.79	443.65	443.52	443.52	443.52	0.00
75	65	10	70	13.54	13.54	366.73	23.38	212.28	213.21	367.65	13.53	366.86	367.67	367.55	367.55	367.55	0.00
65	55	10	60	16.59	16.59	299.20	31.14	159.41	160.28	300.07	16.58	299.31	300.08	299.97	299.97	299.97	0.00
55	45	10	50	20.68	20.68	240.08	43.13	115.08	115.89	240.88	20.67	240.16	240.85	240.78	240.78	240.78	0.00
45	35	10	40	26.21	26.21	189.37	62.56	79.34	80.02	190.06	26.21	189.41	190.01	189.98	189.98	189.98	0.00
35	25	10	30	33.75	33.75	147.10	95.07	52.21	52.69	147.58	33.75	147.07	147.55	147.57	147.57	147.57	0.00
25	15	10	20	43.83	43.83	113.25	147.13	33.74	33.89	113.41	43.87	113.16	113.46	113.56	113.56	113.55	0.00
			115												775.52	775.52	0.00
			15												99.70	99.69	-0.01

FIGURE 2—COASTDOWN WITH 10 km/h SPEED INTERVALS

SAE J2264
DYNAMOMETER ROAD LOAD DERIVATION
PREPARATION AND VEHICLE DATA

Date_______________________Done by__________________________Test lab_______________________
Vehicle year, make, model_____________________________Body style____________________________
VIN____Odometer______________________________
Front/rear drive_________________ Transmission____________________Axle ratio___________________
Engine_________________________Frontal area___________________ Drag coef.__________________
Inertia of: Drivetrain_________________________ Non-drive tires & wheels_________________________
Track test weight________________Drive axle test weight_________________ETW class_________________
Drive axle tire pressure_______________ Tire brand, size, type______________________________________
Accessories used during track coastdown____

<u>Dynamometer setup</u>
Dynamometer Identification____
Type of restraint____
Cooling fan type ______________________________________
Drive axle weight________________ Supplemental ballast for driver weight compensation __________________
Test cell temperature_________ Soak temperature_________ Measured tire pressure_____________________
Inertia setting____________Highway Inertia setting ____________
$\text{Dyno}_{\text{target}}$ coefficients: A_t ____________________ B_t _______________________ C_t ______________________
Preconditioning Dyno_{set} coefficients: A_s _______________ B_s ____________________ C_s ______________________
Limit of measured-target load curve difference ________________
Number of verification coasts________________________Maximum number of coasts______________________

<u>Results</u>
Dyno_{set} coefficients: A_s ____________________ B_s _____________________ C_s ________________________
$\text{Dyno}_{\text{vehicle}}$ coefficients: A_v ___________________ B_v _____________________ C_v ________________________

<u>**Attach road load derivation reports from dynamometer**</u>

<u>Comments</u>
____
____
____

FIGURE 3—DYNAMOMETER LOAD DERIVATION PREPARATION AND VEHICLE DATA

7.2.4 MASS

1 lb = 0.4536 kg
1 kg = 2.2046 lb

7.2.5 FORCE

1N = 0.224809 lb = 0.029974 HP at 50 mph
1 lb = 4.4482 N = 0.13333 HP at 50 mph

7.2.6 TORQUE

1 N·m = 0.73756 lb·ft = 8.8507 lb·in
1 lb·ft = 1.3558 N·m = 12 lb·in

7.2.7 PRESSURE

1 kPa = 0.145037 psi = 0.3196 in Hg = 0.01 bar
1 lb/in^2 = 6.89476 kPa = 2.2036 in Hg = 0.06895 bar

7.2.8 ENERGY

1 N·m = 0.73756 ft·lb = 1 J = 1 W·s
1 ft·lb = 1.3358 N·M = 1.3558 J

7.2.9 POWER

1 kW = 1.34102 hp = 3600 N·km/h
1 hp = 2684 N·km/h = 0.7457 kW = 375 lb·mph = 550 lb·ft/s

7.2.10 STANDARD GRAVITATIONAL ACCELERATION

1 g = 35.303 (km/h)/s = 9.80665 m/s^2 = 21.937 mph/s = 32.174 ft/s^2

7.2.11 ROAD LOAD COEFFICIENTS

a. A coeffficient, 1N = 0.22481 lb = 0.029974 A coef. HP at 50 mph
b. " " 1lb = 4.4482 N = 0.13333 A coef. HP at 50 mph
c. B " 1 N/(km/h) = 0.3618 lb/mph = 3.6 N/(m/s) = 2.412 B coef. HP at 50 mph
d. " " 1 lb/mph = 2.764 N/(km/h) = 9.9503 N/(m/s) = 6.6667 B coef. HP at 50 mph
e. C " 1 $N/(km/h)^2$ = 0.5823 lb/mph^2 = 12.957 $N/(m/s)^2$ = 194.07 C coef. HP at 50 mph
f. " " 1 lb/mph^2 = 1.7176 $N/(km/h)^2$ = 22.255 $N/(m/s)^2$ = 333.33 C coef. HP at 50 mph

PREPARED BY THE SAE J1263 REVISION TASK FORCE OF THE SAE LIGHT DUTY VEHICLE PERFORMANCE AND ECONOMY MEASUREMENTS STANDARDS COMMITTEE

APPENDIX A

SAMPLE REPORTS AND CALCULATIONS

A.1 Scope—Appendix A covers samples of road load derivation reports generated by the dynamometer.

A.2 Reference

A.2.1 Related Publications

A.2.1.1 Horiba 48-in Dynamometer Operating Manual

A.3 Sample Dynamometer Reports

A.3.1 Road Load Derivation Display—Figure A1 is a printout of the summarized coastdown road load derivation results which is displayed on the dynamometer video monitor. The following describes the information on this report:

a. BRAKE, COVER, CRADLE, DIRECTION, LOSS RECORD, COMMENT. etc.—Dynamometer status information.

b. DIFF LIMIT—The specified maximum acceptable force difference between the force versus speed curve derived from the TARGET A, B, and C coefficients and that from the computed MEASURED coefficients, found anywhere between the top speed of the first coastdown speed interval and the bottom speed of the last coastdown speed interval. When this value is exceeded, the dynamometer automatically adjusts the dyno setting coefficients for the next coastdown.

c. DYNO MEASURED—These are the $Dyno_{measured}$ coefficients computed from the times measured as the vehicle coasts through each speed interval.

d. DYNO SETTING—These are the $Dyno_{set}$ coefficients, the load commands to the dynamometer load control. They are set automatically during the Road Load Derivation. On the first coastdown they are estimated from the $Dyno_{target}$ settings so the first coastdown will run for about the same time as subsequent coastdowns. In this case the $Dyno_{set}$ coefficients have been estimated from the target settings as follows:

   $Dyno_{set}$ A = 0.5 x Target A
   $Dyno_{set}$ B = 0.2 x Target B
   $Dyno_{set}$ C = Target C

   On the second and all additional coastdowns, if the DIFF LIMIT has been exceeded on the previous coastdown, the DYNO SETTING coefficients are automatically set by subtracting the MEASURED coefficients of the previous coastdown from the TARGET coefficients and adding the differences to their respective DYNO SETTING coefficients.

e. HIGH SPEED—The top speed of the first coast speed interval.

f. HWY INERTIA—The keyed-in highway inertia value used in coastdown computations when a vehicle is on the rolls. This includes the inertia simulated by the dynamometer plus the inertia of the drivetrain components which are rotating on the dynamometer, and thus are releasing kinetic energy during the coastdown.

14:04:16 **ROAD LOAD DERIVATION** 05-JAN-94

RUN	DYNO SETTING A N	DYNO SETTING B N/KM/H	DYNO SETTING C N/KM/H2	DYNO MEASURED A N	DYNO MEASURED B N/KM/H	DYNO MEASURED C N/KM/H2	MAXIMUM DIFF N
1	35.35	0.2607	0.04196	97.99	1.6713	0.04148	63.1 *
2	8.06	-0.1071	0.04244	61.50	1.4774	0.04154	6.7
3	8.06	-0.1071	0.04244	58.40	1.4864	0.04151	9.7
4	8.06	-0.1071	0.04244	57.71	1.4566	0.04175	10.7 *
5	21.05	-0.2603	0.04266	71.03	1.2903	0.04208	0.3
6	21.05	-0.2603	0.04266	69.85	1.2964	0.04196	1.7
7	21.05	-0.2603	0.04266	70.57	1.2617	0.04220	1.9

TARGET: A = 70.70 N; B = 1.3035 N/KM/H; C = 0.04196 N/KM/H2

SET: A = 21.05 N; B = -0.2603 N/KM/H; C = 0.04266 N/KM/H2

VEH: A = 49.44 N; B = 1.5430 N/KM/H; C = -.00057 N/KM/H2

CLASS = 010594
F4= BRAKE = ON
F5= COVER = OFF
F6= CRADLE = DOWN
SITE = EPA 5

INERTIA = 1761 KG
HWY INERTIA = 1787 KG
DIRECTION = FWD
LOSS REC = 119
COMMENT =

DIFF LIMIT = 10.00 N
HIGH SPEED = 115.00 KM/H
LOW SPEED = 15.00 KM/H

FIGURE A1—ROAD LOAD DERIVATION DISPLAY

g. INERTIA—The keyed-in inertia setting which commands the vehicle inertia simulated by the dynamometer. This is the mass of the vehicle plus the rotational inertia of the tires and wheels which are not rotating on the dynamometer. When an inertia weight class is specified for the vehicle, this is used for the INERTIA setting.

h. LOW SPEED—The bottom speed of the last speed interval.

i. MAXIMUM DIFF—The maximum force difference found between the force versus speed curves generated by the DYNO MEASURED coefficients and by the TARGET settings. This comparison is made between the top speed of the first coastdown speed interval and the bottom speed of the last coastdown speed interval.

j. SET—The final $Dyno_{set}$ load coefficient settings which satisfied the DIFF LIMIT criteria for the required number of coastdowns.

k. TARGET—These are the $Dyno_{target}$ coefficients derived from the track coastdown measurement on the test vehicle, and keyed into the dynamometer control. They are the coefficients for the dynamometer- vehicle system which the dynamometer tries to match with the coefficients measured on the dynamometer during the series of coastdowns comprising the road load derivation.

l. VEH—These are the $Dyno_{vehicle}$ coefficients representing the vehicle drivetrain friction, determined from the average of the $Dyno_{measured}$ coefficients for the final series of coastdowns which satisfied the DIFF LIMIT criteria.

$$\text{VEH (A, B, and C) = DYNO MEASURED (A, B, and C) – SET (A, B, and C)} \quad \text{(Eq. A1)}$$

A.3.1.1 TYPICAL MEASURED-TARGET COASTDOWN COMPARISON—Figure A2 is a printout of results from one of the coastdowns where the dynamometer is comparing the combined vehicle-dynamometer loading against the target road load.

The following describes the information on this report:

a. DIFFERENCE LIMIT—Same as DIFF LIMIT in FIGURE A1.

b. FORCE ACTUAL—The road load force, with error correction, at the midpoint of the SPEED RANGE, resulting from computation based on the TIME ACTUAL.

c. FORCE TARGET—The road load force at the midpoint of the SPEED INTERVAL calculated from TARGET coefficients.

d. INERTIA—Same as in Figure A1.

e. MAXIMUM DIFFERENCE, etc.—Same as MAXIMUM DIFF in Figure A1.

f. MEASURED—Same as DYNO MEASURED in Figure A1.

g. POWER ACTUAL—The road load power, with error correction, based on the road load force at the midpoint of the SPEED RANGE, resulting from computation based on the TIME ACTUAL.

When power is listed on the dynamometer reports, it is calculated from the corresponding force and mid-range speed:

$$kW = F\frac{V_{mid}}{3600} \quad \text{(Eq. A2)}$$

where:

F = Road load force, N
V_{mid} = Mid-speed of coastdown speed interval, km/h

h. POWER TARGET—The road load power at the midpoint of the SPEED INTERVAL calculated from TARGET coefficients.

i. SET—Same as DYNO SETTING in Figure A1.

j. SPEED RANGE—The top and bottom speed of each interval over which the coastdown is timed. This is the same as "Coastdown speed interval" under 3.3.

k. TARGET—Same as TARGET in Figure A1.

l. TIME ACTUAL—The coastdown time actually measured for the SPEED RANGE.

m. TIME TARGET—The theoretical coastdown time for the accompanying SPEED RANGE, based on integration of the TARGET coefficients.