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(R) ROAD LOAD MEASUREMENT AND DYNAMOMETER SIMULATION USING COASTDOWN TECHNIQUES

Foreword—This procedure was originally designed in the English units system and has been converted to the metric (MKS) system of units. This will explain the somewhat awkward values used in this procedure.

1. Scope—This procedure covers measurement of vehicle road load on a straight, level road at speeds less than 113 km/h (70 mph).

1.1 Purpose—This SAE Recommended Practice provides uniform testing procedures for measuring the road load force on a vehicle as a function of vehicle velocity and for simulation of that road load force at 80 km/h (50 mph) on a chassis dynamometer.

2. References

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.
SAE J1100—Motor Vehicle Dimensions

2.1.2 FEDERAL REGULATIONS—Available from the Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.
Code of Federal Regulations, 40 CFR 600, Appendix A

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

R. A. White and H. H. Korst, "The Determination of Vehicle Drag Contribution from Coast-Down Test," SAE Paper 720099, 1972.

T. P. Yasin, "The Analytical Basis of Automobile Coastdown Testing," SAE Paper 780334, 1978.

B. Dayman, Jr., "Tire Rolling Resistance Measurements from Coast-Down Tests," SAE Paper 760153, 1976.

G. D. Thompson, "Prediction of Dynamometer Power Absorption to Simulate Light Duty Truck Road Load," SAE Paper 770844, 1977.

J. R. Smith, J. C. Tracy, and D. S. Potter, "Tire Rolling Resistance—A Speed Dependent Contribution," SAE Paper 780255, 1978.

B. Dayman, Jr., "Realistic Effects of Winds on the Aerodynamics Resistance of Automobiles," SAE Paper 780337, 1978.

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2.3 Definitions

- 2.3.1 **TEST WEIGHT**—Is the weight of the vehicle as tested; including driver, operator (if necessary), and all instrumentation.
- 2.3.2 **TEST MASS**—Is the mass of the vehicle as tested; including driver, operator (if necessary), and all instrumentation.
- 2.3.3 **EFFECTIVE MASS**—Is equal to the sum of the test mass and the effective inertias of the driven and non-driven axles.
- 2.3.4 **FRONTAL AREA**—Is the area of the orthogonal projection of the vehicle including tires and suspension components onto a plane perpendicular to the longitudinal axis of the vehicle.

2.4 Symbols

- a** = Slope of the actual dynamometer horsepower— $1/\delta$ t curve (kW-s or hp-s).
- A** = Vehicle frontal area (see 6.6) (m^2 or ft^2).
- b** = Zero intercept of the actual dynamometer horsepower— $1/\delta$ t curve (kW or hp).
- C_D** = Aerodynamic drag coefficient (dimensionless).
- C_D'** = Aerodynamic drag coefficient for nonzero yaw (dimensionless) (see 8.2).
- C_{DY}** = Crosswind aerodynamic drag coefficient (dimensionless).
- D** = Denominator of expressions to determine a and b from vehicle-dynamometer coastdown data.
- f_0, f_2** = Coefficients of the zeroth and second order terms (respectively) in the road load force equation, (N or lb and $N/[km/h^2]$ or lb/mph^2).
- f_0', f_2'** = Coefficients of the zeroth and second order terms (respectively) in the road load force equation, (N or lb and $N/[km/h^2]$ or lb/mph^2) corrected to standard conditions.
- g** = Acceleration of gravity $9.80 m/s^2$ or $32.174 ft/s^2$.
- I** = Moment of inertia of tire, wheel, and brake rotor or drum $kg\cdot m^2$ or $ft\cdot lb\cdot s^2$.
- IW** = Inertia weight or equivalent weight of inertia simulation mechanism (N or lb).
- k** = Drag coefficient dependence on yaw angle ψ .
- k_t** = Temperature coefficient of rolling resistance ($^{\circ}C^{-1}$ or $^{\circ}F^{-1}$).
- M** = Vehicle test mass (kg or slugs).
- m_e** = Effective mass of a wheel, tire, and brake assembly (kg or slugs).
- M_{DLC}** = Total equivalent mass of drivetrain components (kg or slugs).
- M_{IW}** = Equivalent mass of dynamometer inertia simulation mechanism (IWC/g) (kg or slugs).
- M_e** = Total effective vehicle mass (kg or slugs).
- N** = Number of data points used in Part 2.
- P_o** = Reference atmospheric pressure 736.6 mm Hg (29.00 in Hg).
- r** = Tire rolling radius (m or ft).
- S** = +1 or -1, depending on vehicle coastdown direction.
- t_o** = Time (seconds).
- $t-t_o$** = Coastdown time interval (seconds).
- δt** = Vehicle coastdown time on the chassis dynamometer(s).
- T** = Ambient temperature of test area (K or $^{\circ}R$).
- T_o** = Standard temperature ($20^{\circ}C = 293.15 K$, $68^{\circ}F = 527.67^{\circ}R$).
- V** = Vehicle speed (km/h or mph).

V_1, V_0	= Final and initial speeds in the calculation of the coastdown time interval (km/h or mph).
V_w	= Wind velocity (km/h or mph).
v_x	= Component of wind parallel to track (km/h or mph).
v_y	= Component of wind perpendicular to track (km/h or mph).
W	= Vehicle test weight (N or lb).
W_w	= Weight of tire, wheel, and brake rotor or drum (N or lb).
μ	= Coefficient of rolling resistance (dimensionless).
μ_0	= Velocity independent coefficient of rolling resistance (dimensionless).
μ'	= Velocity coefficient of rolling resistance ($[(\text{km/h})^{-2}$ or $(\text{mph})^{-2}]$).
ρ	= Air mass density (kg/m^3 or slugs/ft^3).
ψ	= Aerodynamic yaw angle (radians).

3. Part 1—Vehicle Road Load Measurement

3.1 Instrumentation—All instrumentation must be calibrated.

3.2 Speed Time—An instrument to measure vehicle speed as a function of elapsed time is used in this procedure. The device must meet the following specifications:

a. Time:

- (1) Accuracy $\pm 0.1\%$ of total coastdown time interval
- (2) Resolution 0.1 s

b. Speed:

- (1) Accuracy ± 0.4 km/h (± 0.25 mph)
- (2) Resolution ± 0.2 km/h (0.1 mph)

3.3 Temperature—The temperature indicating devices must have a resolution of 2 °F or 1 °C and an accuracy of ± 2 °F or ± 1 °C. The sensing element must be shielded from radiant heat sources.

3.4 Atmospheric Pressure—A barometer with an accuracy of ± 0.7 kPa or ± 0.2 in Hg is necessary.

3.5 Wind—Wind speed and direction during the test should be continuously monitored. Wind measurements should permit the determination of average longitudinal and crosswind components to within ± 1.6 km/h (± 1 mph).

3.6 Vehicle Weight—Vehicle weight should be measured to an accuracy of ± 5 kg (± 10 lb) per axle.

3.7 Tire Pressure—Should be measured to an accuracy of ± 3 kPa (± 0.5 psi).

4. Test Material

4.1 Test Vehicle—The test vehicle should be uniquely described on the Vehicle Road Test Data Sheet (see Figure 1). In particular, any modifications from the normal configuration of the vehicle should be noted.

5. Test Conditions

5.1 Ambient Temperature—Tests may be conducted at ambient temperatures between -1 °C (30 °F) and 32 °C (90 °F). The recommended temperature range is from 5 °C (41 °F) to 32 °C (90 °F). Data obtained at temperatures outside this range cannot be reliably adjusted to standard conditions by 8.5.

5.2 Fog—Tests may not be run during foggy conditions.

5.3 Winds—Tests may not be conducted when wind speeds average more than 16 km/h (10 mph) (or when peak wind speeds are more than 20 km/h [12.3 mph]). The average of the component of the wind velocity perpendicular to the test road may not exceed 8 km/h (5 mph).

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Date _____
 Vehicle No. _____
 Odometer Reading _____

VEHICLE DESCRIPTION:

Model year _____
 Make _____
 Model _____
 Inertia Weight Class _____
 Ballast -
 Amount Location

TIRES:

Size _____
 Make _____
 Tread Depth >75% Yes [] No []
 Pressures -
 Specified Actual
 Front _____
 Rear _____

_____ _____
 _____ _____
 _____ _____

Dynamometer Test Drive Wheel Tire Pressure _____

Weight Removed _____
 Trim Heights -
 LF _____ RF _____
 LR _____ RR _____

WHEELS:

Size _____
 Wheel Covers _____

FINAL WEIGHT (TEST WEIGHT)

Fifth Wheel Down and Off Scale -
 LF _____ RF _____
 Total Front _____
 Fifth Wheel Down and Off Scale -
 LR _____ RR _____
 Total Rear _____
 Total _____

CHASSIS:

Axle Ratio _____
 Transmission Type _____
 Brake Type -
 Front _____
 Rear _____
 Toe-In (+/-in) _____

Fifth Wheel Included -
 LF _____ RF _____
 Total Front _____
 Fifth Wheel Included -
 LR _____ RR _____
 Total Rear _____
 Total _____

FRONTAL AREA DETERMINATION:

Area _____
 [] Check if estimated

NOTE: Check Brake Drag and Fluid Levels

COMMENTS: _____

EQUIVALENT INERTIA:

Front Wheel/Brake/Tire (each) _____
 Rear Wheel/Brake/Tire (each) _____
 Total Non-Driven Axle _____
 Total Drive Line _____
 Total _____
 [] Check if estimated

AMBIENT CONDITIONS:

Temperature-Start _____ Finish _____ Average _____ (°C/°F)

Wind -

Average Wind _____ (km/h/mph) PREPARATION AREA:
 Direction _____ (deg)
 Peak Gusts _____ (km/h/mph) Temperature _____ (°C/°F)

Atmospheric Pressure - Start _____ Finish _____ Average _____ (mm Hg/in Hg)

NO RAIN OR FOG - ROADS MUST BE DRY

FIGURE 1—VEHICLE ROAD TEST DATA SHEET

5.4 Road Conditions—Roads must be dry, clean, smooth, and must not exceed 0.5% grade. In addition, the grade should be constant and the road should be straight since variations in grade or straightness can significantly affect results. (The road surface should be concrete or rolled asphalt (or equivalent) in good condition since rough roads can significantly affect rolling resistance.)

5.5 Coastdown Speed Range—The range of speeds over which the vehicle is coasted should be as long as possible considering the length of the straightaway. The speed interval must include 80 km/h (50 mph) and should include the range of 100 to 40 km/h (60 to 25 mph).

6. Vehicle Preparation

6.1 Break-In—The test vehicle should have accumulated a minimum of 500 km (300 miles) prior to testing. The tires should have accumulated a minimum of 160 km (100 miles) and should have at least 75% of the original tread depth remaining. In addition, if a twin roll dynamometer is to be used, the drive axle tires should have a minimum of 1 h at 80 km/h (50 mph) on the dynamometer rolls before conducting the dynamometer road load simulation portion of this procedure. All tire break-in should be performed on the test vehicle or under load conditions similar to those imposed by the test vehicle.

6.2 Vehicle Check-In—The following items should be compared to manufacturer's recommendation and recorded on the Vehicle Road Test Data Sheet (see Figure 1) prior to the test:

- a. Tire type, size, and cold inflation pressure (see 6.5)
- b. Wheel size, conditions, and presence of wheel covers
- c. Brake adjustment
- d. Lubricants in the drivetrain and in the nondriving wheel bearings
- e. Vehicle suspension heights

6.3 Instrumentation—The speed-time measuring device and other necessary equipment must be installed so that they do not hinder vehicle operation or alter the operating characteristics of the vehicle.

6.4 Pretest Weight—The weight of the vehicle prior to testing should be appropriate for the vehicle represented; for example, consideration should be given to the effect of the added weight of the test instrumentation.

6.5 Tire Pressure—Inflate the tires of the test vehicle to the manufacturer's recommended cold inflation pressure, corrected for the temperature difference (if any) between the vehicle tires and the test area. The tire pressure should be increased 1 psi for each 13 °F that the vehicle preparation area temperature is above the test area temperature or 1 kPa for each Celsius degree. Record the actual inflation pressure and preparation area temperature on the Vehicle Road Test Data Sheet (see Figure 1).

6.6 Vehicle Frontal Area—The vehicle frontal area must be known, measured, or estimated and the value recorded on the Vehicle Road Test Data Sheet (see Figure 1). The frontal area may be estimated by the following equation:

$$A = 0.8 (H101) \times (W103) \quad (\text{Eq.1})$$

where:

H101 = Body height (meters [feet]) measured according to SAE J1100

W103 = Body width (meters [feet]) measured according to SAE J1100

6.7 Vehicle Warm-Up—The vehicle must be driven a minimum of 30 min at an average speed of 80 km/h (50 mph) immediately prior to the test.

7. Coastdown Test

7.1 Alternating Directions—A minimum of 10 runs are made in alternating directions. The runs must be paired for the data reduction process in order to reduce error.

7.2 Procedure—The vehicle windows must be closed. At the start of each run, accelerate the vehicle to a speed 8 km/h (5 mph) above the high point of the coastdown speed range, start the recording equipment, and shift into neutral and let the engine idle. The vehicle clutch must be engaged. At a speed less than the lower point of the coastdown speed range, stop the recording equipment, engage the transmission, and prepare for the next run.

7.3 Lane Changes—While coasting, lane changes should be avoided if at all possible. If necessary, they should be done as slowly as possible and over a distance of at least a half kilometer (a quarter mile). If such a gradual change cannot be made, abort the run.

7.4 Data to be Recorded—Record the direction and number of each run (including aborted runs) in such a way that the speed time data can be separated by run number. Record the ambient temperature and atmospheric pressure after the warm-up and after the test. Average the two values to determine the value to be used in the data reduction.

The total wind and either the wind direction or the crosswind component of the total wind must be recorded. The wind quantities should be recorded, screened for gusts exceeding the ambient condition limits in 5.3, and averaged. Record the results on the Vehicle Road Test Data Sheet (see Figure 1).

7.5 Vehicle Test Weight or Mass—After the coastdown run, weigh the vehicle to determine the vehicle test weight or mass. Include the weight of the fifth wheel, driver, and all instrumentation used. Record on the Vehicle Road Test Data Sheet (see Figure 1).

7.6 Axle Weights—Measure each axle weight as in 7.5 except with the fifth wheel (if used) in the operating position and off the scale. Record on the Vehicle Road Test Data Sheet (see Figure 1).

8. Data Reduction—This section prescribes the technique for analyzing a set of coastdown data and the correction factors employed in the determination of the coefficients of the road load force equation. These corrected coefficients are used to calculate the time required to freely decelerate from 88 to 72 km/h (55 to 45 mph) on a chassis dynamometer.

8.1 Road Load Force—A two-parameter road load force equation is fitted to the $V(t)$ data of Section 7 according to the technique of White and Korst (SAE Paper 720099). The coefficients of the road load force equation are determined for each individual $V(t)$ coastdown and are then averaged over all pairs of coastdowns in each data set. Corrections are applied for wind (both parallel and perpendicular to the coastdown path), for the temperature dependence of rolling resistance, and for the density dependence of aerodynamic drag. The corrected coefficients are then used to construct the vehicle force-velocity equation characteristics of the vehicle under standard ambient conditions with no wind. This force is then corrected for inertial difference between the road test configuration and the dynamometer

test configuration and the resultant force is used to calculate the time to coast from 88 to 72 km/h (55 to 45 mph) on a chassis dynamometer (see 8.6).

8.1.1 ADDITIONAL APPLICATIONS—For dynamometers with more than one adjustable load parameter, the force—velocity and coastdown time—speed interval equations (Eqs. 5 and 17) may be used to simulate the vehicle road load in several speed intervals within the experimental data range.

8.2 Solution to Force Equations—The road load force is related to the coastdown deceleration rate by:

$$-M_e \frac{dV}{dt} = \mu W + 1/2\rho C_D A [(V + Sv_x)^2 + V_y^2] \quad (\text{Eq.2})$$

where:

$$\mu = \mu_o(1 + \mu' V^2)$$

The drag coefficient C_D is the sum of the drag coefficient at zero yaw (C_D) and a coefficient k times the square of the sine of the yaw angle.

$$\begin{aligned} C_D' &= C_D + k \sin^2 \psi \\ &= C_D + kv_y^2 / [(V + Sv_x)^2 + v_y^2] \end{aligned} \quad (\text{Eq.3})$$

The road load force can now be expressed as:

$$-M_e \frac{dV}{dt} = \mu_o W (1 + \mu' V^2) + 1/2\rho C_D A (V^2 + v_x^2) + 1/2\rho (C_D + k) A v_y^2 \quad (\text{Eq.4})$$

where:

The term linear in V has been ignored. The error introduced by ignoring this term (and the road grade) is minimized by the averaging process subsequently applied because these terms change sign for each change in coastdown direction.

Collecting terms, (Eq. 4) may be rewritten as:

$$-M_e \frac{dV}{dt} = f_o + f_2 V^2 \quad (\text{Eq.5})$$

where:

$$f_2 = \mu_o \mu' W + 1/2\rho C_D A$$

$$f_o = \mu_o W + (f_2 - \mu_o \mu' W) v_x^2 + 1/2\rho C_{DY} A v_y^2$$

The crosswind aerodynamic drag coefficient C_{DY} is a measure of the response of the vehicle to the crosswind component of the wind at small yaw angles. It may be calculated by:

$$C_{DY} = C_D + k \quad (\text{Eq.6})$$

The integral solution to this equation is:

$$\tau - T_o = \frac{M_e}{\sqrt{f_o f_2}} \left(\tan^{-1} \left(\sqrt{\frac{f_2}{f_o}} V_1 \right) - \tan^{-1} \left(\sqrt{\frac{f_2}{f_o}} V_2 \right) \right) \quad (\text{Eq.7})$$

This is the equation which, after correction of the coefficients determined by the White and Korst technique or equivalent, is used to calculate the coastdown time interval. The units for M_e , f_o , f_2 , V , and V_o must be chosen so that the argument of the inverse tangent function is dimensionless and the resultant coastdown time is in seconds. The individual terms and their corrections are described in the following paragraphs.

8.3 Effective Vehicle Mass—The effective vehicle mass (M_e) is the sum of the final vehicle test mass ($M = W/g$) and the effective mass of the rotating components. The effective mass of the drivetrain components other than the wheels, tires, and brakes may be ignored. For each tire, wheel, and brake rotor or drum, the effective mass, m_e is:

$$m_e = \frac{I}{r^2} \quad (\text{Eq.8})$$

where:

r is the rolling radius of the tire and I is the polar moment of inertia of the assembly. The polar moment of inertia may be measured or may be estimated by circular disk expression:

$$I = \frac{W_w}{g} \frac{r^2}{2} \quad (\text{Eq.9})$$

where:

W_w is the weight of the tire, wheel, and brake rotor or drum. If no measurements are available, the effective inertia of all the rotating components may be estimated as 3.0% of the vehicle test mass.

$$M_e = 1.03 \frac{W}{g} = 1.03M \quad (\text{For use in Eq. 7}) \quad (\text{Eq.10})$$

For chassis dynamometer calculations the equivalent inertia of the driveline components, M_{DLC} is the effective inertia of two tire and wheel assemblies plus the effective inertia of two drive wheel brake rotors or drums. If no measurements are available, M_{DLC} may be estimated as 1.5% of the test mass.

$$M_{DLC} = 0.015 \frac{W}{g} = 0.015M \quad (\text{For use in Eqs. 17 and 18}) \quad (\text{Eq.11})$$

8.4 Data Acceptability Criteria—Experience has shown that the criteria of this section are necessary and sufficient to provide accurate and precise test results. Data which exceed these criteria generally arise from wind gusts or driver inputs, which violate the assumption that the forces on the vehicle are depicted by Eq. 5.

8.4.1 Analyze each individual coastdown $V(t)$ in the set of paired runs obtained in Section 7 by the White and Korst method, or equivalent, to obtain the coefficients f_0 and f_2 . A computer program that performs this task is supplied in Appendix A along with a sample data set (see Figures A1 and A2) and the corresponding output. Using (Eq. 7) of 8.2, compare each individual $V(t)$ trace and its analytical counterpart $V(f_0, f_2, t)$. If the root-mean-square difference (error) exceeds 0.40 km/h (0.25 mph) on any individual run, discard that run and the paired run in the opposite direction. If less than three pairs comply with this criterion, the test run is invalid.

8.4.2 Of the paired runs meeting the criterion of 8.4.1, those which fail to satisfy the following criteria regarding f_0 and f_2 must also be discarded.

- a. The standard deviation of the f_0 's must be less than 11 N (2.5 lb) or 5% of the mean. If this value is exceeded, discard the run and its pair with f_0 farthest from the mean and recompute the standard deviation until compliance is obtained or until the remaining pairs number less than three.
- b. The standard deviation of all the f_2 's must be less than 0.011 N/(km/h)² (0.001 lb/[mile/h]²) or 3% of the mean. If this value is exceeded, discard the run and its pair with f_2 farthest from the mean and recompute the standard deviation until compliance is obtained or until the remaining pairs number less than three. If less than three pairs remain, the test run is invalid. Average f_0 's and f_2 's of all remaining runs to determine an f_0 and f_2 .

8.5 Data Correction—The average f_0 and f_2 values must now be corrected to a standard set of ambient conditions. The standard conditions are:

- a. Temperature—20 °C (68 °F)
- b. Atmospheric pressure—736.6 mm Hg (29.00 in Hg)
- c. Zero wind
- d. The effect of humidity on air density may be ignored

8.5.1 WIND CORRECTIONS TO f_0 —Separate the rolling resistance from wind effects as follows:

$$\mu_0 W = (f_0 - f_2 v_x^2 - 1/2 \rho C_{Dv} A v_y^2) / (1 - \mu' v_x^2) \quad (\text{Eq.12})$$

where:

- ρ = mass density of ambient air.
 μ' = velocity coefficient of rolling resistance.
 C_{DY} = crosswind aerodynamic drag coefficient.
 v_x = component of wind parallel to track.
 v_y = component of wind perpendicular to the track.

Unless specific information about the test vehicle is available, use the following values for the coefficients:

$$\mu' = 19 \times 10^{-6} (\text{km/h})^{-2} (50 \times 10^{-6} (\text{mph})^{-2}) \quad (\text{Eq.13})$$

$$C_{DY} = 0.8181 (\text{m/s})^2 / (\text{km/h})^2 (3.4 (\text{ft/s})^2 / (\text{mph})^2)$$

8.5.2 TEMPERATURE CORRECTION TO f_0 —The temperature dependence of rolling resistance shall be corrected by:

$$f'_0 = \mu_0 W [1 + k_t (T - T_0)] \quad (\text{Eq.14})$$

Unless specific information about the test vehicle is available, use:

$$k_t = 8.6 \times 10^{-3} / ^\circ\text{C} = 4.8 \times 10^{-3} / ^\circ\text{F} \quad (\text{Eq.15})$$

NOTE: Significant changes in sun load may affect rolling resistance and, consequently, contribute to test variations.

8.5.3 WEIGHT CORRECTION—Eq. 14 may be used to correct the test results for small weight differences (less than 50 kg or 100 lb) between the actual vehicle test weight and a desired vehicle test weight (see 7.5).

8.5.4 AIR DENSITY CORRECTION TO f_2 —Adjust the coefficient of the V^2 term to standard ambient conditions ($\rho = 1.1678 \text{ kg/m}^3$ [$\rho = 0.002266 \text{ slugs/ft}^3$]) by the equation:

$$f'_2 = (\rho_0 T / \rho T_0) [f_2 - \mu' (\mu_0 W)] + \mu' f'_0 \quad (\text{Eq.16})$$

where:

- ρ = barometric pressure
 ρ_0 = 736.6 mm Hg (29.00 in)
 T = absolute temperature of ambient air (K or $^\circ\text{R}$)
 T_0 = 293.16 K (527.69 $^\circ\text{R}$).

8.6 Calculation of Coastdown Time

8.6.1 CALCULATION OF 55 TO 45 MPH COASTDOWN TIME—The 55 to 45 mph coastdown time on a chassis dynamometer, which duplicates the force at 50 mph, measured on the road is given by:

$$\delta t = t - t_0 = \frac{1.467 (M_{IW} + M_{DLC})}{\sqrt{f'_0 f'_2}} \left(\tan^{-1} \left(\sqrt{\frac{f'_2}{f'_0}} 55 \right) - \tan^{-1} \left(\sqrt{\frac{f'_2}{f'_0}} 45 \right) \right) \quad (\text{Eq.17})$$

8.6.2 CALCULATION OF 88 TO 72 KM/H COASTDOWN TIME—The 88 to 72 km/h coastdown time on a chassis dynamometer, which duplicates the force at 80 km/h, measured on the road is given by:

$$dt = t - t_0 = \frac{(M_{IW} + M_{DLC})}{3.6\sqrt{f_0 f_2}} \left(\tan^{-1} \left(\sqrt{\frac{f_2}{f_0}} 88 \right) - \tan^{-1} \left(\sqrt{\frac{f_2}{f_0}} 72 \right) \right) \quad (\text{Eq.18})$$

9. **Part 2—Chassis Dynamometer Simulation of Vehicle Road Load**—This portion of the procedure covers the measurement of total load on the vehicle as a function of dynamometer absorber horsepower when the vehicle is mounted on a chassis dynamometer. This procedure is written to determine the total load on the vehicle at 80 km/h (50 mph). It may also be extended to determine the load on the vehicle at other speeds.

10. Definitions

10.1 **Indicated Horsepower**—The indicated horsepower is the load horsepower which is set on the dynamometer and does not include the friction in the dynamometer bearings or inertia simulation mechanism.

10.2 **Actual Horsepower**—The actual horsepower is the load horsepower which includes the friction in the dynamometer bearings and inertia simulation mechanism.

11. Equipment

11.1 **Test Site**—A chassis dynamometer, which has an adjustable power absorber setting capability, is necessary. The dynamometer speed during this test must be measured from the shaft, which drives the power absorber and weights. The dynamometer must be calibrated over a range of horsepower settings and at the inertia weight used in the test.

11.2 **Test Instrumentation**—An instrument that can measure the time to coastdown between two speeds on a chassis dynamometer will be used. The specifications for this instrument are as follows:

a. Speed:

Accuracy— ± 0.040 km/h (± 0.25 mph)

Resolution—0.16 km/h (0.1 mph)

b. Time Base:

Accuracy— $\pm 0.1\%$

Resolution—0.1 s

11.3 **Test Vehicle**—The test vehicle should be the same as the vehicle used during the coastdown tests on the road in Part 1. No differences in the vehicle's transmission, axle, tire size, and construction, or vehicle load on the drive axle can exist between the vehicle used on the road and the vehicle to be tested on the dynamometer. The vehicle must meet the requirements of 6.1, and must not have been operated on the dynamometer or driven during the previous 4 h to provide stabilized tire pressure.

12. Procedure

12.1 Preparation

12.1.1 Preselect the actual dynamometer horsepower values at which the coastdown time will be measured (see Figure 2). A minimum of three values may be chosen using engineering judgment or the horsepower values discussed in 12.1.5, 12.1.6, 12.2.5, and 12.2.7 may be used. Enter the values under A, B, and C on the Dynamometer Test Worksheet (see Figure 3).

12.1.2 For small, twin roll dynamometer, set the drive wheel tire pressures at 310 kPa (45 psi) or lower cold setting. If greater pressures are necessary in order to prolong tire life, or if such pressures are specified by the manufacturer, they may be used and recorded in the Vehicle Test Data Sheet (see Figure

- 1). The tire pressure used for this road load simulation should also be used for any subsequent emission or fuel economy tests. For large roll dynamometers, set the drive wheel tire pressure to the manufacturer's recommended value.
- 12.1.3 Adjust the vehicle total drive wheel weight to the desired drive axle test weight (see 7.6) within ± 7 kg (± 15 lb) as indicated on the Dynamometer Test Worksheet (see Figure 4). The test weight can be adjusted by adding ballast to the trunk or by removing the spare tire and jack.
- 12.1.4 Set the vehicle on the dynamometer and restrain it. The vehicle should be restrained with a horizontal force in such a manner that there is no change in the vertical load on the drive axle. Place the cooling fan in front of the vehicle and record the odometer reading on the Dynamometer Test Worksheet (see Figure 4). Additional fans for cooling tires should not be used unless absolutely necessary to ensure stabilized tire temperature or to prevent tire damage.
- 12.1.5 Select the dynamometer inertia weight requested on the Dynamometer Test Worksheet (see Figure 4). Adjust the 80 km/h (50 mph) actual dynamometer horsepower (warm-up load) to Setting A or the value listed in Table 1 for the selected inertia weight class.
- 12.1.6 Warm the test vehicle and the dynamometer at 80 km/h (50 mph) for 30 min. Near the end of this warm-up period, reset the dynamometer absorber load to the value set in 12.1.5 (Setting A). Record the indicated horsepower on the Dynamometer Test Worksheet (see Figure 3).
- 12.1.7 Alternately, the test vehicle and the dynamometer may be warmed up by driving two Highway Fuel Economy Driving Schedules (Reference, Code of Federal Regulations, 40 CFR 600, Appendix I). Following this warm-up, immediately accelerate the vehicle to a speed of 80 km/h (50 mph), reset the dynamometer absorber load to the value set in 12.1.5 (Setting A), and record the indicated horsepower on the Dynamometer Test Worksheet (see Figure 3).
- 12.1.8 After the warm-up, insure that the speed measurement device is connected to the dynamometer roll, which is coupled to the inertia simulation mechanism.

12.2 Coastdown Time Measurement

- 12.2.1 After the warm-up, accelerate to 105 km/h (65 mph). When the vehicle reaches 105 km/h (65 mph), place the transmission in the NEUTRAL position, engage the clutch, and allow the vehicle to lose speed. Do not touch the brakes or disengage the clutch during the coastdown. If the vehicle speed drops below 65 km/h (40 mph) for more than 1 min during the test, the test is invalid.
- 12.2.2 At a speed less than 72 km/h (45 mph), but not below 64 km/h (40 mph), engage the transmission, accelerate to 55 mph, and decelerate to 80 km/h (50 mph). Allow the indicated absorber load to stabilize at 80 km/h (50 mph).
- 12.2.3 Record the time required to coast from 88 to 72 km/h (55 to 45 mph) and the indicated 80 km/h (50 mph) horsepower on the Dynamometer Test Worksheet (see Figure 3).
- 12.2.4 Repeat 12.2.1 to 12.2.3 until the times from three coastdowns are within ± 0.10 s of each other. If the coastdown times are not consistent, the dynamometer may be malfunctioning. Repeat 12.2.1 to 12.2.3 until consistent times are established or terminate the test.
- 12.2.5 Increase the absorber setting to give an actual dynamometer horsepower setting of 2 hp more than the absorber horsepower listed on the Dynamometer Test Worksheet (Setting B).
- 12.2.6 Repeat 12.2.1 to 12.2.3 until the times from three coastdowns are within ± 0.10 s of each other. If the coastdown times are not consistent, the dynamometer may be malfunctioning. Repeat 12.2.1 to 12.2.3 until consistent times are established or terminate the test.
- 12.2.7 Decrease the absorber setting until the actual dynamometer horsepower setting is approximately 50% of the horsepower listed on the Dynamometer Test Worksheet (Setting C) (see Figure 3). Repeat 12.2.6.

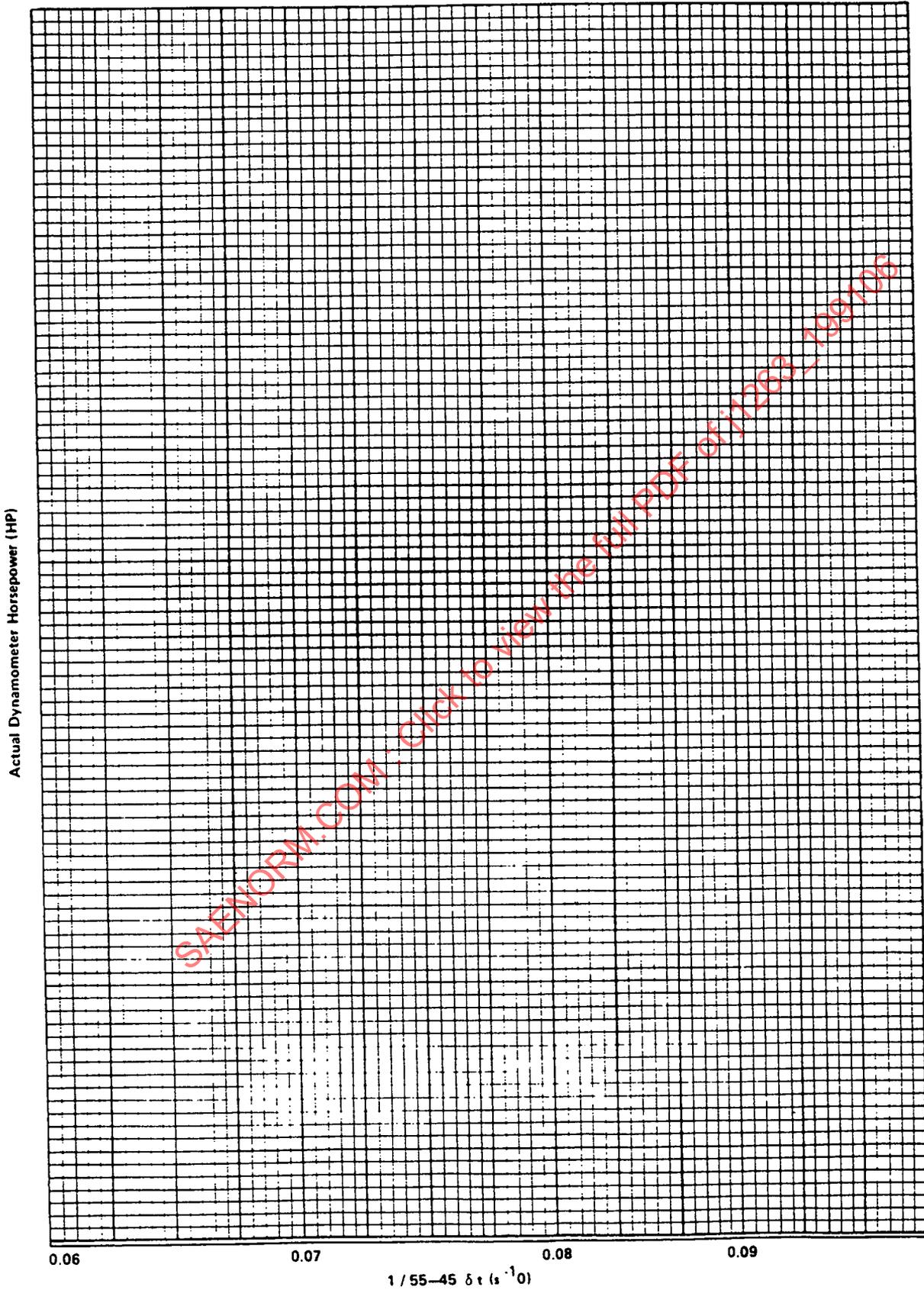


FIGURE 2—ACTUAL DYNAMOMETER HORSEPOWER

TABLE 1—ACTUAL DYNAMOMETER HORSEPOWER (WARM-UP LOAD)

Inertia Weight Class (lb)	Actual hp
≤2000	7.5
2125–2500	8.8
2625–3000	9.9
3125–3500	10.8
3750–4000	11.6
4250–4500	12.4
4750–5000	13.0
5000–5500+	13.6

12.2.8 The intent of the above is to insure that the road coastdown is centrally located within the bracket found by the dynamometer coastdown times.

NOTE: A retest will be necessary if the coastdown time at this lower absorber setting is less than 88 to 72 km/h (55 to 45 mph) coastdown time obtained on the road test procedure. See the Dynamometer Test Worksheet (see Figure 3) for that time, if available.

12.2.9 If more than three values were chosen in 12.1.1, repeat 12.2.1 to 12.2.4 until all data is obtained.

12.2.10 Remove the vehicle from the dynamometer, measure and record the drive axle test weight (with driver) on the Dynamometer Test Worksheet (see Figure 3).

13. Coastdown Time—Actual Horsepower Calculation

13.1 Data Reduction—Fill in the data on the Dynamometer Coastdown Worksheet (see Figure 4). Enter all data points and calculate the inverse of 88 to 72 km/h (55 to 45 mph) coastdown time ($1/\delta t$) for each actual horsepower value. Refer to the dynamometer calibration table and enter the actual horsepower values for each setting. Alternately, if the dynamometer calibration coefficients are available, they should be entered on the Dynamometer Coastdown Worksheet (see Figure 4) along with the indicated horsepower values.

13.1.1 Calculate the best fitting straight line through the data points using the Least Squares method. Use $1/\delta t$ as the independent variable (x), and the actual absorber horsepower as the dependent variable (y).

$$\text{Actual horsepower} = \frac{a}{\delta t} - b \quad (\text{Eq.19})$$

$$D = N \sum (1/\delta t)^2 - (\sum 1/\delta t)^2 \quad (\text{Eq.20})$$

$$a = \frac{[N \sum ((1/\delta t) \times \text{actual hp})] - [\sum (1/\delta t) \sum (\text{actual hp})]}{D} \quad (\text{Eq.21})$$

$$b = \frac{[\sum (1/\delta t) \sum ((1/\delta t) \times \text{actual hp})] - [\sum (1/\delta t) \sum^2 (\text{actual hp})]}{D} \quad (\text{Eq.22})$$

13.1.2 Enter the values for a and b on both the Dynamometer Test Worksheet (see Figure 3) and the Dynamometer Coastdown Worksheet (see Figure 4).

13.1.3 Plot the data on the Dynamometer Coastdown Worksheet (see Figure 4) and draw in the straight line represented by Eq. 19.

13.1.4 Experience has shown that for a properly operating dynamometer if any measured actual horsepower differs from the actual horsepower calculated by Eq. 19 by more than 0.5 hp, the data point is invalid and must be removed and the straight line recalculated using 13.1.1 to 13.2.3. If less than six data points are valid, the test is invalid. This determination is easily made from the $1/\delta t$ versus horsepower graph (see Figure 2) on the Dynamometer Coastdown Worksheet (see Figure 4).

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Vehicle No. _____

DYNAMOMETER TEST WORKSHEET

Vehicle _____ Date _____
 Make Model Year

Tires _____
 Manufacturer Size

Inertia Weight Class _____ Site Number _____

Required Horsepowers:

Warm-up: Actual _____
 Indicated _____

Transmission
 Automatic []
 Manual 3 [] 4 [] 5 []

A. Actual _____
 Indicated _____

Instrument Serial No. _____
 Comments _____

B. Actual _____
 Indicated _____

Test Requested by: _____
 Road Coastdown Time _____ s

C. Actual _____
 Indicated _____

Vehicle Warm-Up: Start Time _____ Finish Time _____

Start Odo. _____ Finish Odo. _____

Test Conditions	55-45 Time	Actual Horsepower
50 mph set		
50 mph check		
Setting A		
Run No. 1		s
Run No. 2		s
Run No. 3		s
Run No. 4		s
Run No. 5		s
Setting B		
Run No. 1		s
Run No. 2		s
Run No. 3		s
Run No. 4		s
Run No. 5		s
Setting C		
Run No. 1		s
Run No. 2		s
Run No. 3		s
Run No. 4		s
Run No. 5		s

Test Results Coefficients— a = _____ b = _____

Operator _____ Finish Odometer _____

Drive Axle Test Weight (after testing) including driver.

Left Wheel _____ Right Wheel _____ Total _____

FIGURE 3—DYNAMOMETER TEST WORKSHEET

DYNAMOMETER COASTDOWN WORKSHEET

Data Point Number	δt	Indicated hp	$1/\delta t$	Actual hp	$(1/\delta t)^2$	$(1/\delta t \times \text{Actual hp})$
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
N =		Σ	$\Sigma 1/\delta t$	Σhp	$\Sigma (1/\delta t)^2$	$\Sigma (1/\delta t \times \text{hp})$

Test Date _____ Site _____

Dynamometer Calibration Coefficients

slope = _____

zero intercept = _____

Actual hp = Slope x indicated hp
+ zero intercept

Actual Horsepower = $\frac{a}{(\delta t)} - b$ (Eq. 10)

Output values:

a = _____

b = _____ (include minus sign)

Vehicle Identifiers:

Car No. _____

Make _____

Model Year _____

FIGURE 4—DYNAMOMETER COASTDOWN WORKSHEET

13.2 Horsepower Determination

- 13.2.1 Determine the 88 to 72 km/h (55 to 45 mph) coastdown time (δt) from the road test data (Part 1). δt must be between data points.
- 13.2.2 Calculate the absorber horsepower for the vehicle using Eq. 19. This is the actual dynamometer horsepower that duplicates the vehicle road load at 80 km/h (50 mph) on a chassis dynamometer. This actual dynamometer horsepower value is applicable to dynamometers with identical roll size, number of rolls, roll spacing, surface finish, and method of restraining the vehicle.
- 13.2.3 When the dynamometer is being adjusted preparatory to operating a test vehicle at the road load determination in Part 2, the load setting should be made with the rolls connected to the power absorption unit running at exactly 80 km/h (50 mph).
- 13.2.4 When adjusting the indicated horsepower on a chassis roll dynamometer to set up the actual horsepower determined by this procedure, operate the dynamometer roll attached to the power absorption unit at the speed used for measuring indicated horsepower under 12.2.3.

14. Notes

- 14.1 **Marginal Indicia**—The (R) is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

PREPARED BY THE SAE LIGHT DUTY VEHICLE PERFORMANCE AND ECONOMY
MEASUREMENTS STANDARDS COMMITTEE

APPENDIX A

A.1 COASTSAE

```

100 * THIS PROGRAM REDUCES COASTDOWN SPEED-TIME DATA AND APPLIES THE APPROPRIATE
110 * CORRECTION FACTORS ACCORDING TO THE SAE RECOMMENDED PRACTICE FOR
120 * ROAD LOAD MEASUREMENT AND DYNAMOMETER SIMULATION USING COASTDOWN TECHNIQUES.
130 *
160 *
170 * THIS PROGRAM USES VELOCITY VS TIME DATA PAIRS TO COMPUTE STATISTICALLY
180 * OPTIMIZED COEFFICIENTS OF THE FORCE-VELOCITY EQUATION. THE FORM OF THE
190 * INPUT DATA IS DESCRIBED BELOW. YOU MUST CREATE A SYSTEM FILE WITH A
200 * UNIQUE NAME TO CONTAIN THE DATA. THIS FILE CONTAINS BASIC VEHICLE AND
210 * ATMOSPHERIC DATA AND THE VELOCITY DATA POINTS. THE FILE MUST BE
220 * ORGANIZED AS FOLLOWS:
230 *
240 *
250 * LINE 1 - A 72 CHARACTER (OR LESS) TITLE WITH DESCRIPTIVE INFO.
260 * LINE 2 - EFFECTIVE WEIGHT,AREA,AIR,TEMP,NUMBER OF RUNS
270 *           AND THE TIME INCREMENT BETWEEN VELOCITY POINTS.
280 * LINE 3 - NO. OF POINTS THIS RUN,V1,V2,V3,V4,.....VN
290 * LINE 4 - NO. OF POINTS NEXT RUN,V1,V2,V3,V4,.....VN
300 * LINE 5 - ETC.
310 * USE COMMAS TO CONTINUE YOUR DATA ON THE NEXT LINE IF NECESSARY.
320 * LINE N-1 - ACTUAL TEST WEIGHT,WIND SPEED,WIND DIRECTION FROM THE NORTH (DEG),
330 *           TEST TRACK SITE(0=TRACK A,1=TRACK B,2=TRACK C,3=TRACK D), AND CDY (OPTIONAL)
331 *           #####
332 *           #                                           #
333 *           # NOTE: As written, Tracks A and D have an angle of 0 #
334 *           # degrees. Track B is at 349 degrees and Track C #
335 *           # is at 329 degrees. This information is needed in #
336 *           # order to resolve the wind into parallel and cross- #
337 *           # wind components. (See lines 4080 to 4150). #
338 *           # Alternately, a user may enter wind in degrees #
339 *           # relative to the track and use Track A (code 0) #
340 *           # as input. #
341 *           #                                           #
342 *           #####
343 * LINE N - DYNAMOMETER TEST WEIGHT AND DRIVELINE INERTIA
350 * LINE N+1 - MODEL YEAR,DIVISION OR MANUFACTURER,MODEL,VEHICLE NUMBER,TRANSMISSION TYPE,
360 *           TIRE SIZE,TIRE MANUFACTURER (3 LETTER CODE),TIRE PRESSURE-FRONT,
370 *           TIRE PRESSURE-REAR,TEST DATE,DRIVER
380 *
390 * THEN SAVE THIS FILE AND TYPE EXE COASTSAE
400 * NOTE THAT YOUR CURRENT TERMINAL FILE REMAINS AS THE FOREGROUND
410 * FILE AND THAT A LIST COMMAND SHOULD SHOW YOU YOUR DATA AND NOT
420 * THE PROGRAM.
430 * THE PROGRAM WILL ASK YOU FOR THE NAME OF YOUR DATA FILE.
440 * SOMETIMES THE PROGRAM HAS TROUBLE BRACKETTING THE ROOTS OF THE
450 * FUNCTION. THIS USUALLY MEANS THAT THE GUESS WAS
460 * EITHER TOO LARGE OR TOO SMALL (OBVIOUSLY)
470 * OR ELSE YOUR DATA IS NOT ACCURATE ENOUGH AT THE LAST TWO
480 * POINTS THAT WERE ENTERED. ADD MORE DATA.
570 *

```

COASTSAE (continued)

```

580 * CHARACTER VARIABLES FOR OUTPUT SHEET
590 *
600 CHARACTER*8 FNAME
610 CHARACTER*4 MODYR
620 CHARACTER*10 DIVISN
630 CHARACTER*10 MODEL
640 CHARACTER*5 VEHNO
650 CHARACTER *2 TRANS
660 CHARACTER*10 TIRE
670 CHARACTER*3 TMFG
680 CHARACTER*8 TDATE,PDATE
690 CHARACTER*8 DRIVER
700 CHARACTER*72 TITLE
710 INTEGER UNIT1,UNIT2
720 COMMON V(150),TAU(150),TIME(150),N
730 COMMON BETA
740 DIMENSION IRUNS(26),CDS(26),RS(26),BS(26),TOS(26)
750 DIMENSION RMSS(26),PAIR(13),PAIRR(13),RSMET(26),BSMET(26),RMSSM(26)
760 INTEGER DELTAT
770 INTEGER TPF,TPR
780 CALL DATE(PDATE)
790 *
800 * PROGRAM STARTUP. ENTER DATA FILE AND DECIDE ON FORM OF
810 * OUTPUT INCLUDING UNITS.
820 *
830 PRINT,"COAST-DOWN TEST DATA REDUCTION PROGRAM: COASTSAE"
840 PRINT
850 PRINT,"LIST THE SOURCE FILE FOR DATA FILE REQUIREMENTS"
870 PRINT
880 PRINT,"ENTER DATA FILE NAME"
890 INPUT'(A8)',FNAME
900 OPEN(1,FNAME)
910 PRINT,"DO YOU WISH INDIVIDUAL RUN SUMMARIES? (2=QUICKRUN, 1=YES, 0=NO)"
920 INPUT'(I1)',NOTYPE
930 PRINT,"IS INPUT IN ENGLISH OR METRIC UNITS (1=METRIC, 0=ENGLISH)"
940 INPUT'(I1)',UNIT1
950 PRINT,"DO YOU WISH ENGLISH OF METRIC OUTPUT (1=METRIC, 0=ENGLISH)"
960 INPUT'(I1)',UNIT2
970 READ(1,'(#.A72)') TITLE
975 PRINT
980 PRINT,TITLE
985 PRINT
990 READ(1,'(#.V)') W,A,T,PRESS,NRUNS,DELTAT
1000 *
1010 * IF INPUT UNITS ARE METRIC, TRANSFORM TO ENGLISH
1020 *
1030 IF(UNIT1.EQ.0) GO TO 851
1040 W = W / 0.4536
1050 A = A / 0.0929
1060 T = 1.8 * T + 32.0

```

COASTSAE (continued)

```

1070 PRESS = PRESS / 25.4
1080 851 CONTINUE
1090 IGAIN=1
1100 IF(DELTA.T.LT.5)IGAIN=6/DELTA.T
1110 IF(NRUNS.LT.2) NOTYPE=1
1120 T=T+459.67
1130 RHO=32.174*.002378*PRESS/29.92*520/T
1140 13 FORMAT(1H,"FOR RUN NUMBER ",I2," SPEED DATA POINTS ARE :")
1150 1 FORMAT(24A4)
1170 DO 1000 J=1,NRUNS
1180 69 CONTINUE
1190 *
1200 *      PARROT BACK THE SPEED-TIME DATA (UNLESS NOTYPE=2)
1210 *
1220 IF(NOTYPE.EQ.1) PRINT11
1230 IF(NOTYPE.NE.2) PRINT 13,J
1240 READ(1,'(#,V)') N,(V(I),I=1,N)
1250 IF(NOTYPE.NE.2) PRINT '(13F6.1)',(V(I),I=1,N)
1260 IF(UNIT1.EQ.0) GO TO 852
1270 DO 853 I=1,N
1280 853 V(I)=V(I)/1.609
1290 852 CONTINUE
1300 *
1310 *      MAKE ALL THE INITIAL GUESSES TO FIT THE DATA.
1320 *      --->NOTE THAT ALL OF THE DATA REDUCTION IS ACTUALLY DONE      <---
1330 *      --->IN ENGLISH UNITS. THIS IS A HOLDOVER FROM AN OLDER PROGRAM.<---
1340 *
1350 V0=V(1)
1360 VOMET=V0*1.609
1370 DO 10 I=1,N
1380 TIME(I)=(I-1)*DELTA.T
1390 10 V(I)=V(I)/V0
1400 TO=(V(N)*IGAIN*DELTA.T/(V(N-IGAIN)-V(N)))+TIME(N)
1410 TL=TO
1420 TR=TO
1430 IF(NOTYPE.EQ.1) PRINT17,TO
1440 17 FORMAT(1H0,"INITIAL APPROXIMATION OF TO",T40,F8.4)
1450 600 TL=TL-2.
1460 TR=TR+5.
1470 *
1480 *      FIT THE DATA FOR THIS RUN
1490 *
1500 CALL YTER8T(TO,DVDT0,TL,TR,.0001,50,IER)
1510 IF(IER-1)50,51,52
1520 51 PRINT,"NO CONVERGENCE"
1530 GO TO 1001
1540 52 IF(TL.GT.TO/2.) GO TO 600
1550 PRINT,"COULD NOT BRACKET ROOT OF TO - CHECK INPUT DATA !!!"
1560 1001 RS(J)=0.
1570 IRUNS(J)=J

```

COASTSAE (continued)

```

1580 CDS(J)=0.
1600 RMSS(J)=0.
1610 GO TO 1000
1620 50 CONTINUE
1630 *
1640 *   FROM THE SUBROUTINE OUTPUT CONSTRUCT THE COEFFICIENTS F0 AND F2.
1650 *   THE COEFFICIENTS ARE LABELED R AND B HERE IN THE LISTING, AGAIN
1660 *   AS A HOLDOVER FROM AN OLDER PROGRAM. THE METRIC COEFFICIENTS ARE ALSO CALCULATED.
1670 *
1680 B=ATAN(BETA)
1690 CD=B*W*2.*BETA/(VO*TO*RHO*A*88./60.)
1700 R=W*B*VO*88./(BETA*TO*32.2*60.)
1710 RMET=R*4.448
1720 BCOEFF=RHO*A*CD*88.*88./(60.*60.*2.*32.174)
1730 BMET=BCOEFF*1.7181
1740 CALL SPEEDS(VO,RMS,UNIT1)
1750 RMSMET=RMS*1.609
1760 *
1770 *   IF NOTYPE=1, PRINT OUT ALL THE VARIOUS PARAMETERS IN BOTH SYSTEMS OF UNITS.
1780 *
1790 IF(NOTYPE.EQ.1) PRINT 6,R,RMET
1800 6 FORMAT(" F0 CONSTANT COEFFICIENT:",T40,F8.4," LBS."T60,F8.4," NEWTONS")
1810 IF(NOTYPE.EQ.1) PRINT 7,BCOEFF,BMET
1820 7 FORMAT(" V**2 COEFFICIENT:",T40,F8.4," LBS/MPH**2",T60,F8.4," N/KPH**2")
1830 IF(NOTYPE.EQ.1) PRINT 8,BETA
1840 IF(NOTYPE.EQ.1) PRINT 12,VO,VOMET
1850 12 FORMAT(" INITIAL VELOCITY:",T40,F5.1," MPH",T60,F5.1," KPH")
1860 8 FORMAT(1H0,"PARAMETER BETA",T40,F8.4)
1870 IF(NOTYPE.EQ.1) PRINT 9,TO
1880 9 FORMAT(1H0,"TOTAL COASTDOWN TIME IN SECONDS",T40,F8.4)
1890 IF(NOTYPE.EQ.1) PRINT,RMS,RMSMET
1900 15 FORMAT(" TOTAL RMS ERROR IN VELOCITY FIT:",T40,F8.4," MPH",T60,F8.4," KPH")
1910 BS(J)=BCOEFF
1920 BSMET(J)=BCOEFF*1.7181
1930 IRUNS(J)=J
1940 CDS(J)=CD
1950 RS(J)=R
1960 RSMET(J)=R*4.448
1970 * BETAS(J)=BETA
1980 RMSS(J)=RMS
1990 RMSSM(J)=RMS*1.609
2000 IF(NOTYPE.EQ.1)PRINT 11
2010 11 FORMAT(1H0)
2020 1000 CONTINUE
2030 *
2040 *   READ IN THE REST OF THE DATA AND PARROT IT BACK IN THE APPROPRIATE UNITS.
2050 *   IF CDY IS NOT READ, SET IF EQUAL TO THE STANDARD VALUE.
2052 *
2060 PRINT,"CORRECTION FACTOR DATA INPUTS BEING READ ARE :"
2070 READ(1,'(#,V)') WACT,WO,ALPHA,L1,CDY

```

COASTSAE (continued)

```

2080 IF(UNIT1.EQ.0)GOTO854
2090 PRINT'(T1,"ACTUAL MASS",F8.2," KG",/,T1,"WIND SPEED ",F4.1," KPH",/,
2100 &T1,"WIND DIRECTION ",F6.1," DEGREES FROM NORTH")',WACT,WO,ALPHA
2110 WO=WO/1.609
2120 WACT=WACT/0.4536
2130 854 CONTINUE
2140 PRINT'(T1,"ACTUAL WEIGHT ",F8.2," LBS",
2150 &/,T1,"WIND SPEED ",F3.1," MPH",/,
2160 &T1,"WIND DIRECTION ",F6.1," DEGREES FROM NORTH")',WACT,WO,ALPHA
2170 867 IF(L1.EQ.0)PRINT,"TRACK A"
2180 IF(L1.EQ.1) PRINT,"TRACK B"
2190 IF(L1.EQ.2) PRINT,"TRACK C"
2200 IF(L1.EQ.3) PRINT,"TRACK D"
2210 IF(L1.LT.0.OR.L1.GT.3) PRINT,"TEST TRACK CODE ERROR -- BUT WILL CONTINUE"
2212 PRINT'(T1,"CROSSWIND FACTOR (CDY) = ",F5.3)',CDY
2220 PRINT
2230 PRINT,"DYNAMOMETER PARAMETERS BEING READ ARE : "
2240 READ(1,'(#,V)') XID,XIDLC
2250 IF(UNIT1.EQ.1)DLCMET=XIDLC
2260 IF(UNIT1.EQ.1)XIDLC=XIDLC/0.4536
2270 IF(UNIT1.EQ.0)DLCMET=XIDLC*0.4536
2280 PRINT'(T1,"DYNO INERTIA WEIGHT",F8.2," LBS",/,XID
2290 PRINT'(T1,"DRIVELINE EFFECTIVE INERTIA:",F8.2," LBS",F10.2," KG")',XIDLC,DLCMET
2300 READ(1,'(#,V)') MODYR,DIVISN,MODEL,VEHNO,TRANS,TIRE,TMFG,TPF,TPR,TDATE,DRIVER
2310 PRINT,"....."
2320 IF(NOTYPE.EQ.2)GOTO901
2330 *
2340 *   BEGIN THE PRINTING BY SKIPPING TO THE TOP OF THE NEXT PAGE.
2350 *
2360 PRINT 99
2370 99 FORMAT(IH1)
2380 PRINT,"   COASTDOWN TEST DATA PROCESSING PROGRAM: COASTSAE"
2390 IF(NRUNS.EQ.1)GOTO1003
2400 PRINT
2410 PRINT,"MODEL YEAR _____ TIRE SIZE _____ AXLE RATIO _____"
2420 PRINT'(1H+,11X,A4,21X,A10)',MODYR,TIRE
2430 PRINT,"MAKE (DIVISION) _____ TIRE MAKE _____ TRANS. TYPE _____"
2440 PRINT'(1H+,15X,A10,11X,A3,27X,A2)',DIVISN,TMFG,TRANS
2450 PRINT,"MODEL TYPE _____ TIRE PRESSURE  F ___ R ___ BRAKE TYPE F ___ R ___"
2460 PRINT'(1H+,11X,A10,23X,I3,3X,I3)',MODEL,TPF,TPR
2470 PRINT,"CAR NO. _____ TEST WEIGHT F ___ R ___ AERO DEVICES _____"
2480 PRINT'(1H+,8X,A5)',VEHNO
2490 PRINT,"ODOMETER _____ TRIM HEIGHT LF ___ RF ___ TEST DATE _____"
2500 PRINT'(1H+,64X,A8)',TDATE
2510 PRINT,"VIN _____ LR ___ RR ___ TESTED BY _____"
2520 PRINT'(1H+,64X,A8)',DRIVER
2530 PRINT,"TOE-IN (+=IN) _____ COMMENTS _____"
2540 PRINT
2550 PRINT,TITLE
2560 PRINT

```

COASTSAE (continued)

```

2570 PRINT 20,
2580 20 FORMAT(1H ,T12,"SUMMARY OF RESULTS FOR UNCORRECTED INDIVIDUAL RUNS")
2590 PRINT,"          ROAD LOAD FORCE = F0 + F2*(V**2)"
2600 62 CONTINUE
2610 PRINT 22,
2620 22 FORMAT(1H0,T1,"RUN",T9,"F2 COEFFICIENT",T28,"F0 COEFFICIENT",
2630 &T48,"R.M.S. ERROR")
2640 *
2650 *      PRINT OUT F0, F2 AND RMS ERROR FOR EACH RUN
2660 *
2670 IF(UNIT2.EQ.0)PRINT 23
2680 IF(UNIT2.EQ.1)PRINT 855
2690 855 FORMAT(1H ,T10," N/KPH**2",T28,"CONSTANT ( N )",
2700 &T48,"VELOCITY FIT(KPH)")
2710 23 FORMAT(1H ,T10,"LBS/MPH**2",T28,"CONSTANT (LBS.)",
2720 &T48,"VELOCITY FIT(MPH)")
2730 901 CONTINUE
2740 DO 25 I=1,NRUNS
2750 IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT 26,IRUNS(I),BS(I),RS(I),RMSS(I)
2760 IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT 26,IRUNS(I),BSMET(I),RSMET(I),RMSSM(I)
2770 26 FORMAT(1H ,T1,I2,T12,F6.4,T31,F6.1,T49,F7.4,T66,F6.3)
2780 IF(UNIT2.EQ.0)GOTO856
2790 *
2800 *      IF THE RMS ERROR IS EXCESSIVE, FLAG IT.
2810 *
2820 IF(RMSSM(I).GT.0.40)PRINT'("+",T56,"<---EXCESSIVE")'
2830 IF(RMSSM(I).GT.0.40)RS(I)=0.0
2840 IF(RMSSM(I).GT.0.40)EXCESS=1.0
2850 GOTO25
2860 856 CONTINUE
2870 IF(RMSS(I).GT.0.25)PRINT'("+",T56,"<---EXCESSIVE")'
2880 IF(RMSS(I).GT.0.25)RS(I)=0
2890 IF(RMSS(I).GT.0.25)EXCESS=1.
2900 25 CONTINUE
2910 24 PRINT
2920 J=1
2930 *
2940 *      AVERAGE THE COEFFICIENTS, LEAVING OUT THE RUNS WITH EXCESSIVE RMS.
2950 *
2960 DO 96 I=1,NRUNS,2
2970 IF(RS(I).EQ.0.OR.RS(I+1).EQ.0)GOTO96
2980 J=J+2
2990 IRUNS(J)=IRUNS(I)
3000 IRUNS(J+1)=IRUNS(I+1)
3010 BS(J)=BS(I)
3020 BS(J+1)=BS(I+1)
3030 RMSS(J)=RMSS(I)
3040 RMSS(J+1)=RMSS(I+1)
3050 RS(J)=RS(I)
3060 RS(J+1)=RS(I+1)

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COASTSAE (continued)

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3070 CDS(J)=CDS(I)
3080 CDS(J+1)=CDS(I+1)
3090 96 CONTINUE
3100 NPAIRS=(J+1)/2
3110 NRUNS=NPAIRS*2
3120 IF(NPAIRS.LT.3)PRINT,"  INSUFFICIENT DATA REMAINING FOR VALID STATISTICAL PROCESSING"
3130 IF(NPAIRS.LT.3)PRINT'(1H ,///,"**** DATA NOT BOUNDED BY CONSTRAINTS ON INTERNAL CONSISTANCY ****",///)'
3150 IF(NPAIRS.LE.0)GOTO63
3160 IF(LIST.EQ.0)GOTO66
3170 IF(NOTYPE.NE.2)PRINT22,
3180 IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT23,
3190 IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT855,
3200 DO 67 I=1,NRUNS
3210 IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT26,IRUNS(I),BS(I),RS(I),RMSS(I)
3220 67 IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT26,IRUNS(I),BSMET(I),RSMET(I),RMSSM(I)
3230 66 CONTINUE
3240 DO 30 I=1,NPAIRS
3250 PAIRR(I)=(RS(2*I-1)+RS(2*I))/2.
3260 30 PAIR(I)=(BS(2*I-1)+BS(2*I))/2.
3270 CDMEAN=0.
3280 RMEAN=0.
3290 DO 31 I=1,NPAIRS
3300 RMEAN=RMEAN+PAIRR(I)
3310 31 CDMEAN=CDMEAN+PAIR(I)
3320 RMEAN=RMEAN/NPAIRS
3330 CDMEAN=CDMEAN/NPAIRS
3340 SDR=0.
3350 SDCD=0.
3360 DO 32 I=1,NPAIRS
3370 SDR=SDR+(PAIRR(I)-RMEAN)**2
3380 32 SDCD=SDCD+(PAIR(I)-CDMEAN)**2
3390 SDR=SQRT(SDR/NPAIRS)
3400 SDRMET=SDR*4.448
3410 RMET=RMEAN*4.448
3420 PERCR=SDR/RMEAN
3430 SDCD=SQRT(SDCD/NPAIRS)
3440 IF(NOTYPE.NE.2)PRINT58,NPAIRS
3450 58 FORMAT(1H ,T20,"SUMMARY OF RESULTS FOR ",I1," PAIRED RUNS")
3460 IF(EXCESS.EQ.1.0.AND.UNIT2.EQ.0)PRINT,"RUNS WITH EXCESSIVE ERROR (>.25 MPH) WERE DELETED"
3470 IF(EXCESS.EQ.1.0.AND.UNIT2.EQ.1)PRINT,"RUNS WITH EXCESSIVE ERROR (>.40 KPH) WERE DELETED"
3480 PRINT
3490 BMEAN=CDMEAN
3500 BMET=CDMEAN*1.7181
3510 BSD=SDCD
3520 BSDMET=SDCD*1.7181
3530 PERCB=BSDMET/BMET
3540 *
3550 * CHECK THAT THE S.D. OF F0 AND F2 ARE WITHIN LIMITS. IF NOT, THROW OUT
3560 * THE RUN AND ITS PAIR FURTHEST FROM THE MEAN AND RE-COMPUTE.
3570 *

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COASTSAE (continued)

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3580 IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT48,BMEAN,BSD
3590 IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT857,BMET,BSDMET
3600 IF(UNIT2.EQ.0)GOTO858
3610 IF(BSDMET.GE.0.011.OR.PERC.B.GE.0.03)PRINT3
3620 IF(BSDMET.GE.0.011.OR.PERC.B.GE.0.03)DELETE=1.0
3630 GOTO859
3640 858 CONTINUE
3650 IF(BSD.GE.0.001.OR.PERC.B.GE.0.03)PRINT3
3660 IF(BSD.GE.0.001.OR.PERC.B.GE.0.03)DELETE=1.0
3670 3 FORMAT(1H+,T66,"<---EXCESSIVE")
3680 48 FORMAT(1H,"OBSERVED F2 COEFFICIENT (LBS/MPH**2)",T40,F7.4,T60,F6.4)
3690 857 FORMAT(1H,"OBSERVED F2 COEFFICIENT ( N/KPH**2)",T40,F7.4,T60,F6.4)
3700 859 CONTINUE
3710 IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT,"OBSERVED F0 CONSTANT (LBS)"
3720 IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT41,RMEAN,SDR
3730 IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT,"OBSERVED F0 CONSTANT (N)"
3740 IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT860,RMET,SDRMET
3750 860 FORMAT(1H+,T33,"MEAN",T40,F7.1,T50,"STD. DEV.",T60,F6.1)
3760 IF(UNIT2.EQ.0)GOTO861
3770 IF(SDRMET.GE.11..OR.PERC.R.GE.0.05)PRINT3
3780 IF(SDRMET.GE.11..OR.PERC.R.GE.0.05)DELETE=2.0
3790 GOTO200
3800 861 CONTINUE
3810 IF(SDR.GE.2.5.OR.PERC.R.GE.0.05)PRINT3
3820 IF(SDR.GE.2.5.OR.PERC.R.GE.0.05)DELETE=2.0
3830 41 FORMAT(1H+,T33,"MEAN",T40,F7.1,T50,"STD. DEV.",T60,F6.1)
3840 200 CONTINUE
3850 IF(DELETE.EQ.0.)GOTO61
3860 TEMP=0.
3870 NGRUN=0
3880 ERROR=0.
3890 DO 60 I=1,NPAIRS
3900 TEMP=ABS(RMEAN-PAIRR(I))
3910 IF(TEMP.GT.ERROR)NGRUN=I
3920 60 IF(TEMP.GT.ERROR)ERROR=TEMP
3930 NGRUN=NGRUN*2
3940 RS(NGRUN)=0.
3950 IF(NOTYPE.NE.2)PRINT
3960 PRINT,"          SUMMARY OF REMAINING UNCORRECTED RUNS"
3970 PRINT,"          WITH WORST ERROR RUN PAIRS DELETED"
3980 DELETE=0.
3990 LIST=1
4000 EXCESS=0.
4010 GOTO24
4020 61 CONTINUE
4030 *
4040 *   CORRECTION FACTOR APPLICATION
4050 *
4060 RHO=RHO/32.174
4070 *

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COASTSAE (continued)

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4080 * RESOLVE WIND INTO PARALLEL AND PERPENDICULAR COMPONENTS. TRACK ANGLES ARE:
4090 * TRACKS A AND D = 0 DEGREES, TRACK B = 349 DEGREES, TRACK C = 329 DEGREES.
4100 *
4110 X=W0*SIN((ALPHA+11*L1)/57.2958)
4120 IF(L1.EQ.2)X=W0*SIN((ALPHA+31)/57.2958)
4130 IF(L1.EQ.3)X=W0*SIN(ALPHA/57.2958)
4133 VX2=W0*W0-X*X
4135 IF(VX2.LT.0.0)VX2=0.0
4140 VX=SQRT(VX2)
4150 VY=X
4160 *
4170 * APPLY CORRECTION FACTORS TO F0 FOR PARALLEL WIND (VX), CROSSWIND (VY)
4180 * CDY IS THE CROSSWIND DRAG COEFFICIENT WHICH CAN BE EITHER THE DEFAULT VALUE
4190 * OF 3.40 OR THE USER MAY INPUT HIS OR HER OWN IN THE DATA (LINE 130).
4200 *
4210 IF(CDY.EQ.0.0)CDY=3.40
4220 F0=(RMEAN-BMEAN*VX*VX-0.5*RHO*A*CDY*VY*VY)/(1-0.00005*VX*VX)
4230 *
4240 * APPLY THE TEMPERATURE CORRECTION TO F0
4250 *
4260 TERM1=F0*(1.0+0.0048*(T-527.67))
4270 *
4280 * CONSTRUCT THE AIR DENSITY CORRECTION FACTOR (CF) AND APPLY IF TO F2.
4290 *
4300 CF=29.00*T/PRESS/527.67
4310 *
4320 * APPLY THE AIR DENSITY CORRECTION ONLY TO THAT PART OF F2 WHICH IS DUE
4330 * TO AIR RESISTANCE. SUBTRACT OFF THE TIRE CONTRIBUTION. APPLY THE
4340 * CORRECTION FACTOR AND THEN ADD BACK IN THE CORRECTED TIRE CONTRIBUTION.
4350 *
4360 TERM2=CF*(BMEAN-(0.00005*F0))+0.00005*TERM1
4370 *
4380 * CONVERT THE RESULTS TO METRIC UNITS IF NECESSARY.
4390 *
4400 IF(UNIT2.EQ.1)TERM1=TERM1*4.448
4410 IF(UNIT2.EQ.1)TERM2=TERM2*1.7181
4420 IF(NOTYPE.NE.2)PRINT
4430 IF(NOTYPE.NE.2)PRINT,"CORRECTION TO REFERENCE CONDITIONS OF"
4440 IF(NOTYPE.NE.2)PRINT," 29.00 IN HG. (736.6 MM HG.)"
4450 IF(NOTYPE.NE.2)PRINT," WIND = 0.0 MPH"
4460 IF(NOTYPE.NE.2)PRINT," AIR TEMPERATURE = 68 DEG F. (20 DEG C.)"
4465 PRINT
4470 PRINT,"TOTAL CORRECTED ROAD LOAD FORCE IS GIVEN BY : "
4480 PRINT
4490 PRINT'(T10,"F = ",T14,F5.1,T20,"+ ",T22,F5.4,T28,"* V**2")',TERM1,TERM2
4500 PRINT
4510 *
4520 * CONSTRUCT THE VARIOUS USEFUL OUTPUT VALUES AND PRINT THEM OUT.
4530 *
4540 F=TERM1+TERM2*50.0*50.0

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COASTSAE (continued)

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4550 IF(UNIT2.EQ.1)F=TERM1+TERM2*80.0*80.0
4570 IF(UNIT2.EQ.0)PRINT('" ROAD LOAD AT 50 MPH =",F6.1," LBS (CORRECTED)"')',F
4580 IF(UNIT2.EQ.1)PRINT('" ROAD LOAD AT 80 KPH +",F6.1," N (CORRECTED)"')',F
4590 TRLHP=F*50.*88./60./550.
4600 TRLKW=T*0.02222
4610 IF(UNIT2.EQ.0)PRINT'(T1,"TOTAL ROAD LOAD H.P. = ",F6.2)',TRLHP
4620 IF(UNIT2.EQ.1)PRINT'(T1,"TOTAL ROAD LOAD POWER = ",F6.2," KW")')',TRLKW
4630 PRINT
4640 F2X=TERM2*50.*50.
4650 IF(UNIT2.EQ.1)F2X=TERM2*80.*80.
4660 IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT'(T1,"F2 X 2500 = ",F6.2,".....F2 UNROUNDED")',F2X
4670 IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT'(T1,"F2 X 6400 = ",F6.2," N...F2 UNROUNDED")',F2X
4690 IF(UNIT2.EQ.0)GOTO862
4700 CLARK1=SQRT(TERM2/TERM1)*88.
4710 CLARK2=SQRT(TERM2/TERM1)*72.
4720 DT=(XID+XIDLCL)*0.4536/(SQRT(TERM1*TERM2))*(ATAN(CLARK1)-ATAN(CLARK2))*5.0/18.0
4725 PRINT
4740 PRINT'(T1,"CALCULATED 88-72 KPH DYNO COASTDOWN TIME = ",F6.2," SEC")',DT
4750 GOTO863
4760 862 CLARK1=SQRT(TERM2/TERM1)*55.0
4770 CLARK2=SQRT(TERM2/TERM1)*45.0
4780 DT=(XID+XIDLCL)/32.174/(SQRT(TERM1*TERM2))*(ATAN(CLARK1)-ATAN(CLARK2))*1.466667
4785 PRINT
4790 PRINT'(T1,"CALCULATED 55-45 MPH DYNO COASTDOWN TIME = ",F6.2," SEC")',DT
4800 863 CONTINUE
4810 T=T-459.67
4820 63 CONTINUE
4830 PRINT,
4850 IF(NPAIRS.LT.3)PRINT,"*** HOWEVER INSUFFICIENT DATA ARE PRESENT FOR THESE TO BE ACCEPTABLE VALUES ***"
4870 PRINT," INPUT DATA : "
4880 WKG=W*0.4536
4890 WACTKG=WACT*0.4536
4900 AM3=A*0.0929
4910 TMET=(T-32.0)/1.8
4920 PBAR=PRESS*25.4
4930 WOKPH=WO*1.609
4940 *
4950 * PRINT OUT THE INPUT DATA, BUT IN THE OUTPUT UNIT SYSTEM.
4960 *
4970 IF(UNIT2.EQ.1)PRINT 864,WKG,WACTKG,AM3,TMET,PBAR,WOKPH,ALPHA
4980 864 FORMAT(T1,"EFFECTIVE WEIGHT (KG)",T30,F8.2,T43,"ACTUAL WEIGHT (KG)",T67,F8.2./,
5000 &T1,"FRONTAL AREA (M**2)",T30,F8.3,T43,"AIR TEMPERATURE (DEG C)",T67,F8.1./,
5010 &T1,"ATM. PRESSURE (MM HG)",T30,F8.0,T43,"WIND SPEED (KPH)",T67,F8.1./,
5020 &T1,"WIND DIRECTION FROM NORTH (DEG)",T30,F8.1)
5030 IF(UNIT2.EQ.0)PRINT 46,W,WACT,A,T,PRESS,WO,ALPHA
5040 46 FORMAT(T1,"EFFECTIVE WEIGHT (LBS)",T30,F8.2,T43,"ACTUAL WEIGHT (LBS)",T67,F8.2./,
5060 &T1,"FRONTAL AREA (SQ. FT.)",T30,F8.2,T43,"AIR TEMPERATURE (DEG F)",T67,F8.0./,
5070 &T1,"ATM. PRESSURE (IN.HG.)",T30,F8.2,T43,"WIND SPEED (MPH)",T67,F8.1./,
5080 &T1,"WIND DIRECTION FROM NORTH (DEG)",T33,F5.1)
5090 IF(L1.EQ.0)PRINT'(1H+,T43,"TRACK A")'

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COASTSAE (continued)

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5100 IF(L1.EQ.1)PRINT'(1H+,T43,"TRACK B")'
5110 IF(L1.EQ.2)PRINT'(1H+,T43,"TRACK C")'
5120 IF(L1.EQ.3)PRINT'(1H+,T43,"TRACK D")'
5130 IF(L1.GT.3)PRINT,"UNKOWN TEST SITE"
5140 PRINT'(T1,"DYNAMOMETER INERTIA WEIGHT",T30,F6.0," LBS.",T43,"CROSSWIND FACTOR (CDY)",T70,F5.3)',XID,CDY
5150 IF(UNIT2.EQ.0)PRINT'(T1,"DRIVELINE INERTIA WEIGHT",T30,F8.2)',XIDLC
5160 IF(UNIT2.EQ.1)PRINT'(T1,"DRIVELINE EFFECTIVE INERTIA (KG)",T30,F8.2)',DLCMET
5170 PRINT'(T1,"PROCESSING DATE",T30,A8,T43,"DATA FILE NAME",T67,A8)',PDATE,FNAME
5190 PRINT
5200 PRINT
5210 1003 CONTINUE
5220 CLOSE(1)
5230 PRINT11
5240 PRINT11
5250 PRINT11
5260 84 STOP
5270 END
5280 *
5290 *   SUBROUTINE YTER8T(X,F,XL1,EPS,IEND,IER)
5300 *
5310 SUBROUTINE YTER8T(X,F,XL1,XRI,EPS,IEND,IER)
5320 IER=0
5330 XL=XL1
5340 XR=XRI
5350 X=XL
5360 TOL=X
5370 CALL VALU8T(TOL,F)
5380 IF(F)1,16,1
5390 1 FL=F
5400 X=XR
5410 TOL=X
5420 CALL VALU8T(TOL,F)
5430 IF(F)2,16,2
5440 2 FR=F
5450 IF(SIGN(1.,FL)+SIGN(1.,FR)) 25,3,25
5460 3 I=0
5470 TOLF=100.*EPS
5480 4 I=I+1
5490 DO 13 K=1,IEND
5500 X=.5*(XL+XR)
5510 TOL=X
5520 CALL VALU8T(TOL,F)
5530 IF(F) 5,16,5
5540 5 IF(SIGN(1.,F)+SIGN(1.,FR))7,6,7
5550 6 TOL=XL
5560 XL=XR
5570 XR=TOL
5580 TOL=FL
5590 FL=FR
5600 FR=TOL

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COASTSAE (continued)

```
5610 7 TOL=F-FL
5620 A=F*TOL
5630 A=A+A
5640 IF(A-FR*(FR-FL))8,9,9
5650 8 IF(I-IEND)17,17,9
5660 9 XR=X
5670 FR=F
5680 TOL=EPS
5690 A=ABS(XR)
5700 IF(A-1.)11,11,10
5710 10 TOL=TOL*A
5720 11 IF(ABS(XR-XL)-TOL)12,12,13
5730 12 IF(ABS(FR-FL)-TOLF)14,14,13
5740 13 CONTINUE
5750 IER=1
5760 14 IF(ABS(FR)-ABS(FL))16,16,15
5770 15 X=XL
5780 F=FL
5790 16 RETURN
5800 17 A=FR-F
5810 DX=(X-XL)*FL*(1.+F*(A-TOL)/(A*(FR-FL)))/TOL
5820 XM=X
5830 FM=F
5840 X=XL-DX
5850 TOL=X
5860 CALL VALU8T(TOL,F)
5870 IF(F)18,16,18
5880 18 TOL=EPS
5890 A=ABS(X)
5900 IF(A-1.) 20,20,19
5910 19 TOL=TOL*A
5920 20 IF(ABS(DX)-TOL)21,21,22
5930 21 IF(ABS(F)-TOLF)16,16,22
5940 22 IF(SIGN(1.,F)+SIGN(1.,FL)) 24,23,24
5950 23 XR=X
5960 FR=F
5970 GO TO 4
5980 24 XL=X
5990 FL=F
6000 XR=XM
6010 FR=FM
6020 GO TO 4
6030 25 IER=2
6040 RETURN
6050 END
6060 *
6070 *   SUBROUTINE VALU8T(TO,DVDT0)
6080 *
6090 SUBROUTINE VALU8T (TO,DVDT0)
6100 COMMON V(150),TAU(150),TIME(150),N
```

COASTSAE (continued)

```

6110 COMMON BETA
6120 DO 10 I=1,N
6130 10 TAU(I)=TIME(I)/T0
6140 BL=.5
6150 BR=5.
6160 CALL YTER8B(ABETA,DVDB,BL,BR,.0001,50,IER)
6170 IF (IER-1)50,51,52
6180 50 BETA=ABETA
6190 SIGMA1=0.
6200 SIGMA2=0
6210 DO 20 I=1,N
6220 A=1.-TAU(I)
6230 B=ATAN(BETA)
6240 C=A*B
6250 SIGMA1=SIGMA1+V(I)*TIME(I)/COS(C)**2.
6260 20 SIGMA2=SIGMA2+TIME(I)*SIN(C)/(BETA*COS(C)**3)
6270 DVDT0=SIGMA1-SIGMA2
6280 RETURN
6290 51 PRINT," NO ROOT IN GIVEN RANGE OF BETA "
6300 RETURN
6310 52 PRINT," COULD NOT BRACKET THE ROOT OF BETA BETWEEN ",BL,BR
6320 RETURN
6330 END
6340 *
6350 *   SUBROUTINE YTER8B(X,F,XLI,XRI,EPS,IEND,IER)
6360 *
6370 SUBROUTINE YTER8B(X,F,XLI,XRI,EPS,IEND,IER)
6380 IER=0
6390 XL=XLI
6400 XR=XRI
6410 X=XL
6420 TOL=X
6430 CALL VALU8B(TOL,F)
6440 IF(F)1,16,1
6450 1 FL=F
6460 X=XR
6470 TOL=X
6480 CALL VALU8B(TOL,F)
6490 IF(F)2,16,2
6500 2 FR=F
6510 IF(SIGN(1.,FL)+SIGN(1.,FR)) 25,3,25
6520 3 I=0
6530 TOLF=100.*EPS
6540 4 I=I+1
6550 DO 13 K=1,IEND
6560 X=.5*(XL+XR)
6570 TOL=X
6580 CALL VALU8B(TOL,F)
6590 IF(F) 5,16,5
6600 5 IF(SIGN(1.,F)+SIGN(1.,FR))7,6,7

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