SAE International™	**SURFACE VEHICLE RECOMMENDED PRACTICE**	**J1263 JAN2009** Issued 1979-06 Revised 2009-01 Superseding J1263 FEB1996

Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques

RATIONALE

This revision updates units and introduces minor procedural refinements and formatting.

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 dry, straight, level road at speeds less than 113 km/h (70 mi/h).

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 mi/h) on a hydrokinetic chassis dynamometer. For application to electric dynamometers, refer to SAE J2263.

2. REFERENCES

2.1 Applicable Publications

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

2.1.1 SAE Publication

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

SAE J1100 Motor Vehicle Dimensions

2.1.2 Federal Regulations

Available from the Superintendent of Documents, U.S. Government Printing Office, Mail Stop: SSOP, Washington, DC 20402-9320.

Code of Federal Regulations, 40 CFR 600, Appendix I

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

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

3. DEFINITIONS

3.1 Test Weight

Is the weight of the vehicle as tested; including driver, operator (if necessary), and all instrumentation.

3.2 Test Mass

Is the mass of the vehicle as tested; including driver, operator (if necessary), and all instrumentation.

3.3 Effective Mass

Is equal to the sum of the test mass and the effective mass of rotating components.

3.4 Effective Mass of Rotating Components

The rotational inertia of driveline and non-drive axle components that rotate with the wheels, expressed as additional "linear mass". For passenger cars without dual drive tires, if the actual effective mass of rotating components is unknown, the effective mass of all rotating components may be estimated as 3.0% of the vehicle test mass.

3.5 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.

4. SYMBOLS

a = Slope of the actual dynamometer horsepower—1/δt curve (kW-s or hp-s)
A = Vehicle frontal area (see 8.6) (m^2 or ft^2)
b = Zero intercept of the actual dynamometer horsepower—1/δ t curve (kW or hp)
C_D = Aerodynamic drag coefficient (dimensionless)
C'_D = Aerodynamic drag coefficient for nonzero yaw (dimensionless) (see 10.2)
C_{DY} = Crosswind aerodynamic drag coefficient (dimensionless)
D = Denominator of expressions to determine a and b from vehicle-dynamometer coastdown data
$\mathbf{D}_{tot}$ = Total drag force (N or lb)
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/[kmh^2] or lb/mph^2) corrected to standard conditions
g = Acceleration of gravity 9.81 m/s^2 or 32.174 ft/s^2
I = Moment of inertia of tire, wheel, and brake rotor or drum kg-m^2 or ft-lb-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 (°C^{-1} or °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_0 = 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_0 = Time (seconds)
$t-t_0$ = Coastdown time interval (seconds)
δt = Vehicle coastdown time on the chassis dynamometer(s)
T = Ambient temperature of test area (K or °R)
T_0 = Standard temperature (20 °C = 293.15 K, 68 °F = 527.67 °R)
V = Vehicle speed (km/h or mi/h)
$\mathbf{V}$ = Vehicle velocity (km/h or mi/h)
V_1, V_0 = Final and initial speeds in the calculation of the coastdown time interval (km/h or mi/h)
v_x = Component of wind parallel to track (km/h or mi/h)
v_y = Component of wind perpendicular to track (km/h or mi/h)
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-dependent coefficient of rolling resistance ([km/h]$^{-2}$ or [mi/h]$^{-2}$)
ρ = Air mass density (kg/m^3 or slugs/ft^3)
Ψ = Aerodynamic yaw angle (radians)

5. PART 1—VEHICLE ROAD LOAD MEASUREMENT

5.1 Instrumentation

All instrumentation must be calibrated.

5.2 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 ±0.1% of total coastdown time interval

2. Resolution 0.1 s

b. Speed:

1. Accuracy ±0.4 km/h (±0.25 mi/h)

2. Resolution ±0.2 km/h (0.1 mi/h)

5.3 Temperature

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

5.4 Atmospheric Pressure

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

5.5 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 mi/h).

5.6 Vehicle Weight

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

5.7 Tire Pressure

Should be measured to an accuracy of ±3 kPa (±0.5 psi).

6. TEST MATERIAL

6.1 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.

7. TEST CONDITIONS

7.1 Ambient Temperature

Ambient temperatures shall be between 5 °C and 35 °C (41 to 95 °F). Data obtained at temperatures outside this range cannot be reliably adjusted to standard conditions by Section 10.5.

7.2 Fog

Tests may not be run during foggy conditions.

7.3 Winds

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

7.4 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.)

7.5 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 mi/h) and should include the range of 100 to 40 km/h (60 to 25 mi/h).

8. VEHICLE PREPARATION

8.1 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 3500 km (2175 miles) and should have at least 50% 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 mi/h) 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.

8.2 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 8.5)

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

8.3 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.

8.4 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.

8.5 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 the test is above the test 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).

Date ____
Vehicle No. ____
Odometer Reading ____

VEHICLE DESCRIPTION:
Model Year ____
Make ____
Model ____
Inertia Weight Class ____
Ballast -

Amount	Location
____	____
____	____
____	____
____	____
____	____

Weight Removed ____

Trim Heights –
LF ____ RF ____
LR ____ RR ____

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

EQUIVALENT INERTIA:

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

TIRES:
Size ____
Manufacturer ____
Description ____
Tread Depth >50% yes [ ] no [ ]
Pressures –

	Specified	Actual
LF	____	____
RF	____	____
LR	____	____
RR	____	____

Dynamometer Test Drive Wheel Tire Pressures
Left ____ Right ____

WHEELS:
Size ____
Wheel Covers ____

CHASSIS:

Axle Ratio ____
Transmission Type ____
Brake Type –
Front ____
Rear ____
Toe-in (+=in) ____

FRONTAL AREA DETERMINATION:
Area ____
[ ] Check, if estimated.

Note – Check Brake Drag and Fluid Levels

COMMENTS: ____

AMBIENT CONDITIONS:
Temperature-Start ____ Finish ____ Average ____ (°C, °F)

Wind –
Average Wind ____ (km/h, mi/h)
Direction ____ (deg)
Peak Gusts ____ (km/h, mi/h)
Atmospheric Pressure – Start ____ Finish ____ Average ____ (mm Hg, in Hg)

PREPARATION AREA:

Temperature ____ (°C, °F)

NO RAIN OR FOG – ROADS MUST BE DRY

FIGURE 1 - VEHICLE ROAD TEST DATA SHEET

8.6 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:

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

where:

H101 = Body height (meters [feet]) measured according to SAE J1100
W103 = Body width (meters [feet]) measured according to SAE J1100

8.7 Vehicle Warm-Up

The vehicle must be driven a minimum of 30 min at an average speed of 80 km/h (50 mi/h) immediately prior to the test.

9. COASTDOWN TEST

9.1 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.

9.2 Procedure

The vehicle windows must be closed. At the start of each run, accelerate the vehicle to a speed 8 km/h (5 mi/h) 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.

Vehicle regenerative braking shall be disabled during coastdown testing, minimizing any changes to the mechanical system (see SAE J1634).

9.3 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.

9.4 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 7.3, and averaged. Record the results on the Vehicle Road Test Data Sheet (see Figure 1).

9.5 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).

9.6 Axle Weights

Measure each axle weight as in 9.5 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).

10. 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 mi/h) on a chassis dynamometer.

10.1 Road Load Force

A two-parameter road load force equation is fitted to the V(t) data of Section 9 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 differences 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 mi/h) on a chassis dynamometer.

10.1.1 Additional Applications

For dynamometers with more than one adjustable load parameter, the force-velocity and coastdown time-speed interval equations (Equations 6 and 18) may be used to simulate the vehicle road load in several speed intervals within the experimental data range.

10.2 Solution to Force Equations

The general form of the equation of motion can be written as:

$$M_e \frac{\partial \mathbf{V}}{\partial t} = \mathbf{D}_{tot} \qquad \text{(Eq. 2)}$$

Noting that drag forces always act in a direction opposite vehicle speed, and breaking the magnitude of drag forces into separate terms, then equation 2 can be written in scalar form as::

$$-M_e \frac{dV}{dt} = \mu W + 1/2\rho C_D' A\left[(V + Sv_x)^2 + v_y{}^2\right] \qquad \text{(Eq. 3)}$$

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.

$$C'_D = C_D + k \sin^2\psi = C_D + kv_y{}^2 / [(V+Sv_x)^2+V_y{}^2] \qquad \text{(Eq. 4)}$$

The road load force magnitude can now be expressed as:

$$-M_e \frac{dV}{dt} = \mu_o W\left(1+\mu' V^2\right) + 1/2\rho C_D A\left(V^2 + v_x^2\right) + 1/2\rho(C_D + k)Av_y^2 \qquad \text{(Eq. 5)}$$

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, Equation 5 may be rewritten as:

$$-M_e \frac{dV}{dt} = f_0 + f_2 V^2 \quad \text{(Eq. 6)}$$

where:

$f_2 = \mu_0\mu' W + 1/2\rho C_D A$
$f_0 = \mu_0 W + (f_2 - \mu_o\mu' W)v_x^2 + 1/2\rho C_{DY} A v_y^2$

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:

$$C_{DY} = C_D + k \quad \text{(Eq. 7)}$$

The integral solution to this equation is:

$$t - t_0 = \frac{M_e}{\sqrt{f_0 f_2}} \left(\tan^{-1}\left(\sqrt{\frac{f_2}{f_0}} V_1 \right) - \tan^{-1}\left(\sqrt{\frac{f_2}{f_0}} V_2 \right) \right) \quad \text{(Eq. 8)}$$

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_0, f_2, V, and V_0 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.

10.3 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:

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

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 a circular disk expression:

$$I = \frac{W_w}{g} \frac{r^2}{2} \quad \text{(Eq. 10)}$$

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.

$$M_e = 1.03\frac{W}{g} = 1.03M \text{ (For use in Equation 8)} \quad \text{(Eq. 11)}$$

Vehicles that employ arrangements other than a normal four tire/wheel configuration require specific estimation of the effective mass of their rotating components.

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.

$$M_{DLC} = 0.015\frac{W}{g} = 0.015M \text{ (For use in Equations 18 and 19)} \quad \text{(Eq. 12)}$$

10.4 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 Equation 6.

10.4.1 Analyze each individual coastdown V(t) in the set of paired runs obtained in Section 9 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 Figure A1 and Figure A2) and the corresponding output. Using Equation 8 of 10.2, 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 mi/h) 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.

10.4.2 Of the paired runs meeting the criterion of 10.4.1, 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 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/[mi/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 of all remaining runs to determine an f_0. Average f_2's of all remaining runs to determine an f_2.

10.5 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

10.5.1 Wind Corrections to F_0

Separate the rolling resistance from wind effects as follows:

$$\mu_0 W = (f_0 - f_2 v_x^2 - 1/2\rho C_{DY} A v_y^2)/(1-\mu' v_x^2) \qquad \text{(Eq. 13)}$$

where:

ρ = mass density of ambient air
μ' = velocity-dependent 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:

$$\mu' = 19\text{x}10^{-6}\ (\text{km/h})^{-2} \qquad [50\text{x}10^{-6}\ (\text{mi/h})^{-2}] \qquad \text{(Eq. 14)}$$

$$C_{DY} = 0.8181(\text{m/s}^2/(\text{km/h})^2 \qquad [3.4(\text{ft/s})^2/(\text{mi/h})^{-2}]$$

10.5.2 Temperature Correction to F_0

The temperature dependence of rolling resistance shall be corrected by:

$$f_0' = \mu_0 W[1 + k_t (T - T_0)] \qquad \text{(Eq. 15)}$$

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

$$k_t = 8.6 \text{ x } 10^{-3}\ /°\text{C} = 4.8 \text{ x } 10^{-3}/°\text{F} \qquad \text{(Eq. 16)}$$

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

10.5.3 Weight Correction

Equation 15 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 9.5).

10.5.4 Air Density Correction to F_2

Adjust the coefficient of the V^2 term to standard ambient conditions (ρ = 1.1678 kg/m^3 [ρ = 0.002266 slugs/ft^3]) by the equation:

$$f_2' = (p_0 T/pT_0)[f_2 - \mu'(\mu_0 W)] + \mu' f_0' \qquad \text{(Eq. 17)}$$

where:

p = barometric pressure
p_0 = 736.6 mm Hg (29.00 in)
T = absolute temperature of ambient air (K or °R)
T_0 = 293.16 K (527.69 °R)

10.6 Calculation of Coastdown Time

10.6.1 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:

$$\delta t = t - t_0 = \frac{1.467(M_{IW} + M_{DLC})}{\sqrt{f_0' f_2'}}\left(\tan^{-1}\left(\sqrt{\frac{f_2'}{f_0'}}55\right) - \tan^{-1}\left(\sqrt{\frac{f_2'}{f_0'}}45\right)\right) \quad \text{(Eq. 18)}$$

10.6.2 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:

$$\delta t = t - t_0 = \frac{(M_{IW} + M_{DLC})}{3.6\sqrt{f_0' f_2'}}\left(\tan^{-1}\left(\sqrt{\frac{f_2'}{f_0'}}88\right) - \tan^{-1}\left(\sqrt{\frac{f_2'}{f_0'}}72\right)\right) \quad \text{(Eq. 19)}$$

11. 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 mi/h). It may also be extended to determine the load on the vehicle at other speeds.

12. DEFINITIONS

12.1 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.

12.2 Actual Horsepower

The actual horsepower is the load horsepower which includes the friction in the dynamometer bearings and inertia simulation mechanism.

13. EQUIPMENT

13.1 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.

13.2 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:

1. Accuracy—±0.040 km/h (±0.25 mi/h)

2. Resolution—0.16 km/h (0.1 mi/h)

b. Time Base:

1. Accuracy—±0.1%

2. Resolution—0.1 s

13.3 Test Vehicle

The test vehicle should be the identical 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 8.1 and must not have been operated on the dynamometer or driven during the previous 4 h, to provide stabilized tire pressure.

14. PROCEDURE

14.1 Preparation

14.1.1 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 horsepowers discussed in 14.1.5, 14.1.6, 14.2.5, and 14.2.7 may be used. Enter the values under A, B, and C on the Dynamometer Test Worksheet (see Figure 3).

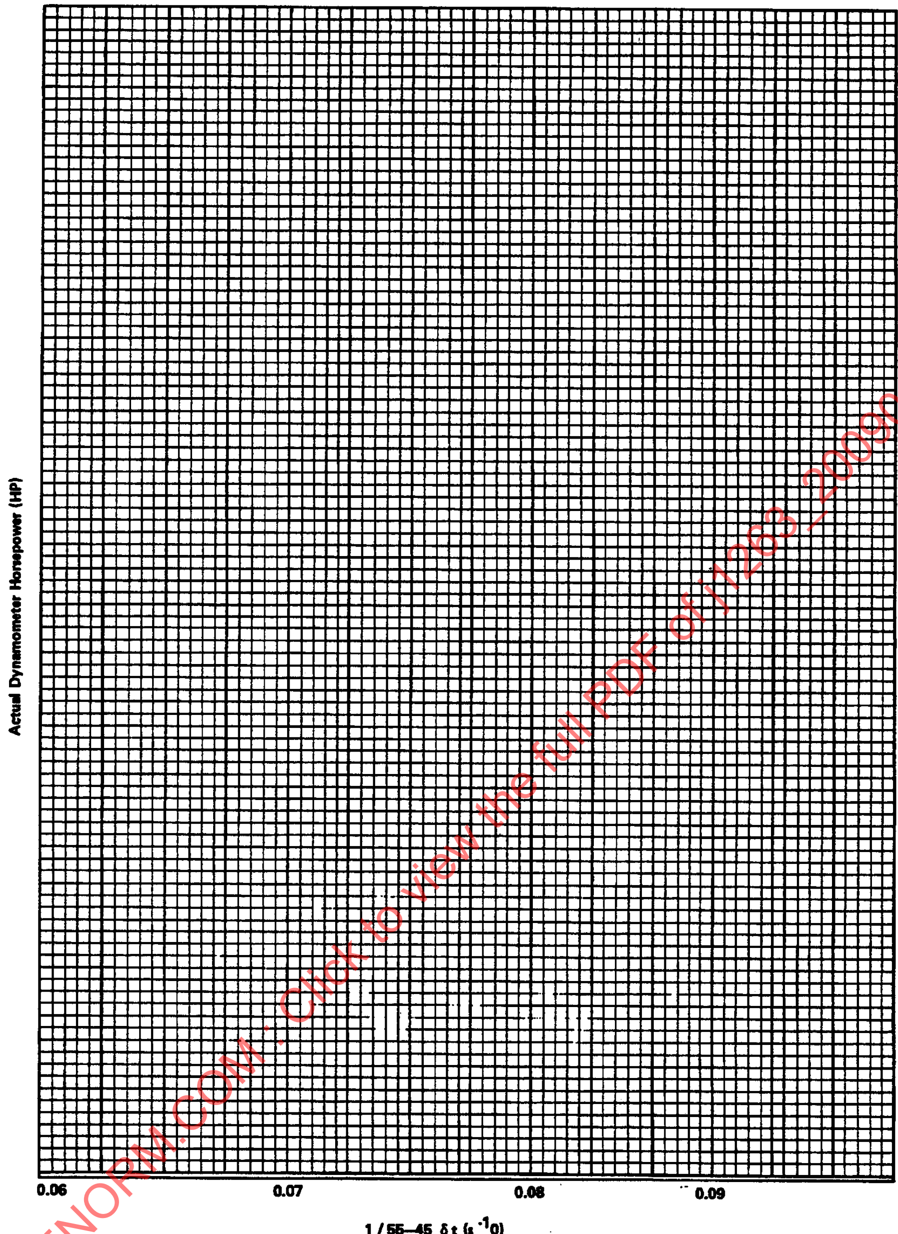
14.1.2 For small, twin roll dynamometer, set the drive wheel tire pressures at 310 kPa (45 psi) or lower cold setting. If greater pressures are necessary in order to prolong tire life, or if such pressures are specified by the manufacturer, they may be used and recorded in the Vehicle Test Data Sheet (see Figure 1). The tire pressure used for this road load simulation should also used for any subsequent emission or fuel economy tests. For large roll dynamometers, set the drive wheel tire pressure to the vehicle manufacturer's recommended value (see 8.5).

14.1.3 Adjust the vehicle total drive wheel weight to the desired drive axle test weight within ±7 kg (±15 lb) as indicated on the Dynamometer Test Worksheet (see Figure 3). The test weight can be adjusted by adding ballast to the trunk or by removing the spare tire and jack.

14.1.4 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 3). Additional fans for cooling tires should not be used unless absolutely necessary to ensure stabilized tire temperature or to prevent tire damage.

14.1.5 Select the dynamometer inertia weight requested on the Dynamometer Test Worksheet (see Figure 3). Adjust the 80 km/h (50 mi/h) actual dynamometer horsepower (warm-up load) to Setting A or the value listed in Table 1 for the selected inertia weight class.

14.1.6 Warm the test vehicle and the dynamometer at 80 km/h (50 mi/h) for 30 min. Near the end of this warm-up period, reset the dynamometer absorber load to the value set in 14.1.5 (Setting A). Record the indicated horsepower on the Dynamometer Test Worksheet (see Figure 3).



Vehicle No.____________________

FIGURE 2 - ACTUAL DYNAMOMETER HORSEPOWER

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 ____________

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/δt	Actual hp	$(1/\delta t)^2$	(1/δt x Actual hp)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
N =		Σ				
			Σ1/δt	Σhp	$\Sigma(1/\delta t)^2$	Σ(1/δt x 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.19)

a = ______________

b = ______________ (include minus sign)

Vehicle Identifiers:

Car No. ______________

Make ______________

Model Year ______________

FIGURE 4 - DYNAMOMETER COASTDOWN WORKSHEET

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

14.1.7 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 mi/h), reset the dynamometer absorber load to the value set in 14.1.5 (Setting A), and record the indicated horsepower on the Dynamometer Test Worksheet (see Figure 3).

14.1.8 After the warm-up, ensure that the speed measurement device is connected to the dynamometer roll, which is coupled to the inertia simulation mechanism.

14.2 Coastdown Time Measurement

14.2.1 After the warm-up, accelerate to 105 km/h (65 mi/h). When the vehicle reaches 105 km/h (65 mi/h), 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 mi/h) for more than 1 min during the test, the test is invalid.

14.2.2 At a speed less than 72 km/h (45 mi/h), but not below 64 km/h (40 mi/h), engage the transmission, accelerate to 55 mi/h, and decelerate to 80 km/h (50 mi/h). Allow the indicated absorber load to stabilize at 80 km/h (50 mi/h).

14.2.3 Record the time required to coast from 88 to 72 km/h (55 to 45 mi/h) and the indicated 80 km/h (50 mi/h) horsepower on the Dynamometer Test Worksheet (see Figure 3).

14.2.4 Repeat 14.2.1 to 14.2.3 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 14.2.1 to 14.2.3 until consistent times are established or terminate the test.

14.2.5 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).

14.2.6 Repeat 14.2.1 to 14.2.3 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 14.2.1 to 14.2.3 until consistent times are established or terminate the test.

14.2.7 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 14.2.6.

14.2.8 The intent of the previous is to ensure 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 mi/h) coastdown time obtained on the road test procedure. See the Dynamometer Test Worksheet Figure 3 for that time, if available.

14.2.9 If more than three values were chosen in 14.1.1, repeat 14.2.1 to 14.2.4 until all data is obtained.

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

15. COASTDOWN TIME—ACTUAL HORSEPOWER CALCULATION

15.1 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 mi/h) 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.

15.1.1 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).

$$\text{Actual Horsepower} = \frac{a}{\delta t} - b \quad \text{(Eq. 20)}$$

$$D = N\Sigma(1/\delta t)^2 - (\Sigma 1/\delta t)^2 \quad \text{(Eq. 21)}$$

$$a = \frac{[N\Sigma((1/\delta t)\times \text{actual hp})] - [\Sigma(1/\delta t)\Sigma(\text{actual hp})]}{D} \quad \text{(Eq. 22)}$$

$$b = \frac{[\Sigma(1/\delta t)\Sigma((1/\delta t)\times \text{actual hp})] - [\Sigma(1/\delta t)^2_{\Sigma}(\text{actual hp})]}{D} \quad \text{(Eq. 23)}$$

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

15.1.3 Plot the data found on the Dynamometer Coastdown Worksheet (see Figure 4) and draw in the straight line represented by Equation 20.

15.1.4 Experience has shown that for a properly operating dynamometer if any measured actual horsepower differs from the actual horsepower calculated by Equation 20 by more than 0.5 hp, the data point is invalid and must be removed and the straight line recalculated using 15.1.1 to 15.2.3. 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).

15.2 Horsepower Determination

15.2.1 Determine the 88 to 72 km/h (55 to 45 mi/h) coastdown time (δt) from the road test data (Part 1). δt must be between data points.

15.2.2 Calculate the absorber horsepower for the vehicle using Equation 20. This is the actual dynamometer horsepower that duplicates the vehicle road load at 80 km/h (50 mi/h) 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.

15.2.3 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 mi/h).

15.2.4 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 14.2.3.

16. NOTES

16.1 Marginal Indicia

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

PREPARED BY THE SAE LIGHT-DUTY VEHICLE PERFORMANCE MEASUREMENT 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 BRACKETING 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 *
```

```
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),T0S(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 OR 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
```

```
1070  PRESS = PRESS / 25.4
1080  851 CONTINUE
1090  IGAIN=1
1100  IF(DELTAT.LT.5)IGAIN=6/DELTAT
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  D0 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  D0 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  V0MET=V0*1.609
1370  D0 10 I=1,N
1380  TIME(I)=(I-1)*DELTAT
1390  10 V(I)=V(I)/V0
1400  T0=(V(N)*IGAIN*DELTAT/(V(N-IGAIN)-V(N)))+TIME(N)
1410  TL=T0
1420  TR=T0
1430  IF(NOTYPE.EQ.1) PRINT17,T0
1440  17 FORMAT(1HO,"INITIAL APPROXIMATION OF T0",T40,F8.4)
1450  600 TL=TL-2.
1460  TR=TR+5.
1470  *
1480  *        FIT THE DATA FOR THIS RUN
1490  *
1500  CALL YTER8T(T0,DVDTO,TL,TR,.001,50,IER)
1510  IF(IER-1)50,51,52
1520  51 PRINT,"NO CONVERGENCE"
1530  GO TO 1001
1540  52 IF(TL.GT.T0/2.) GO TO 600
1550  PRINT,"COULD NOT BRACKET ROOT OF T0 - CHECK INPUT DATA !!!"
1560  1001 RS(J)=0.
1570  IRUNS(J)=J
```

```
CDS(J)=0.
RMSS(J)=0.
GO TO 1000
50 CONTINUE
*
*       FROM THE SUBROUTINE OUTPUT CONSTRUCT THE COEFFICIENTS F0 AND F2.
*       THE COEFFICIENTS ARE LABELED R AND B HERE IN THE LISTING, AGAIN
*       AS A HOLDOVER FROM AN OLDER PROGRAM.  THE METRIC COEFFICIENTS ARE ALSO CALCULATED.
*
B=ATAN(BETA)
CD=B*W*2.*BETA/(V0*T0*RH0*A*88./60.)
R=W*B*V0*88./(BETA*T0*32.2*60.)
RMET=R*4.448
BCOEFF=RHO*A*CD*88.*88./(60.*60.*2.*32.174)
BMET=BCOEFF*1.7181
CALL SPEEDS(V0,RMS,UNIT1)
RMSMET=RMS*1.609
*
*       IF NOTYPE=1, PRINT OUT ALL THE VARIOUS PARAMETERS IN BOTH SYSTEMS OF UNITS.
*
IF(NOTYPE.EQ.1) PRINT 6,R,RMET
6 FORMAT(" F0 CONSTANT COEFFICIENT:",T40,F8.4," LBS."T60,F8.4,"NEWTONS")
IF(NOTYPE.EQ.1) PRINT 7,BCOEFF,BMET
7 FORMAT(" V**2 COEFFICIENT;",T40,F8.4,"LBS/MPH**2",T60,F8.4,"N/KPH**2")
IF(NOTYPE.EQ.1) PRINT 8,BETA
IF(NOTYPE.EQ.1) PRINT 12,V0,V0MET
12 FORMAT(" INITIAL VELOCITY:",T40,F5.1," MPH",T60,F5.1," KPH")
8 FORMAT(1H0,"PARAMETER BETA",T40,F8.4)
IF(NOTYPE.EQ.1) PRINT 9,T0
9 FORMAT(1H0,"TOTAL COASTDOWN TIME IN SECONDS",T40,F8.4)
IF(NOTYPE.EQ.1) PRINT,RMS,RMSMET
15 FORMAT(" TOTAL RMS ERROR IN VELOCITY FIT:",T40,F8.4," MPH",T60,F8.4," KPH")
BS(J)=BCOEFF
BSMET(J)=COEFF*1.7181
IRUNS(J)=J
CDS(J)=CD
RS(J)=R
RSMET(J)=R*4.448
*  BETAS(J)=BETA
RMSS(J)=RMS
RMSSM(J)=RMS*1.609
IF(NOTYPE.EQ.1)PRINT 11
11 FORMAT(1H0)
1000 CONTINUE
*
*       READ IN THE REST OF THE DATA AND PARROT IT BACK IN THE APPROPRIATE UNITS.
*       IF CDY IS NOT READ, SET IF EQUAL TO THE STANDARD VALUE.
*
PRINT,"CORRECTION FACTOR DATA INPUTS BEING READ ARE :"
READ(1,'(#,v)') WACT,W0,ALPHA,L1,CDY
```

```
IF(UNIT1.EQ.0)GOTO854
PRINT'(T1,"ACTUAL MASS",F8.2," KG",/,T1,"WIND SPEED ",F4.1," KPH",/,
&T1,"WIND DIRECTION ",F6.1," DEGREES FROM NORTH")',WACT,W0,ALPHA
W0=W0/1.609
WACT=WACT/0.4536
854 CONTINUE
PRINT'(T1,"ACTUAL WEIGHT ",F8.2," LBS",
&/,T1,"WIND SPEED ",F3.1," MPH",/,
&T1,"WIND DIRECTION ",F6.1," DEGREES FROM NORTH")',WACT,W0,ALPHA
867 IF(L1.EQ.0)PRINT,"TRACK A"
IF(L1.EQ.1) PRINT,"TRACK B"
IF(L1.EQ.2) PRINT,"TRACK C"
IF(L1.EQ.3) PRINT,"TRACK D"
IF(L1.LT.0.0R,L1,GT.3) PRINT,"TEST TRACK CODE ERROR -- BUT WILL CONTINUE"
PRINT'(T1,"CROSSWIND FACTOR (CDY) = ",F5.3)',CDY
PRINT
PRINT,"DYNAMOMETER PARAMETERS BEING READ ARE :"
READ(1,'(#,V)') XID,XIDLC
IF(UNIT1.EQ.1)DLCMET=XIDLC
IF(UNIT1.EQ.1)XIDLC=XIDLC/0.4536
IF(UNIT1.EQ.0)DLCMET=XIDLC*0.4536
PRINT'(T1,"DYNO INERTIA WEIGHT",F8.2," LBS")',XID
PRINT'(T1,"DRIVELINE EFFECTIVE INERTIA:",F8.2," LBS",F10.2," KG")',XIDLC,DLCMET
READ(1,'(#,V)') MODYR,DIVISN,MODEL,VEHNO,TRANS,TIRE,TMFG,TPF,TPR,TDATE,DRIVER
PRINT,"..............................................................................................."
IF(NOTYPE.EQ.2)GOTO901
*
*        BEGIN THE PRINTING BY SKIPPING TO THE TOP OF THE NEXT PAGE.
*
PRINT 99
99 FORMAT(1H1)
PRINT,"              COASTDOWN TEST DATA PROCESSING PROGRAM:  COASTSAE"
IF(NRUNS.EQ.1)GOTO1003
PRINT
PRINT,"MODEL YEAR _______________  TIRE SIZE ________________   AXLE RATIO ___________ "
PRINT'(1H+,11X,A4,21X,A10)',MODYR,TIRE
PRINT,"MAKE (DIVISION) ___________  TIRE MAKE ________________   TRANS. TYPE __________ "
PRINT'(1H+,15X,A10,11X,A3,27X,A2)',DIVISN,TMFG,TRANS
PRINT,"MODEL TYPE _______________  TIRE PRESSURE  F ___   R ___   BRAKE TYPE  F ___  R ___"
PRINT'(1H+,11X,A10,23X,I3,3X,I3)',MODEL,TPF,TPR
PRINT,"CAR NO. __________________  TEST WEIGHT    F ___   R ___   AERO DEVICES _________ "
PRINT'(1H+,8X,A5)',VEHNO
PRINT,"ODOMETER _________________  TRIM HEIGHT    LF ___  RF ___  TEST DATE ____________ "
PRINT'(1H+,64X,A8)',TDATE
PRINT,"VIN ______________________                 LR ___  RR ___  TESTED BY ____________ "
PRINT'(1H+,64X,A8)',DRIVER
PRINT,"TOE-IN (+=IN) _______________  COMMENTS ______________________________________ "
PRINT
PRINT,TITLE
PRINT
```

```
PRINT 20,
20 FORMAT(1H ,T12,"SUMMARY OF RESULTS FOR UNCORRECTED INDIVIDUAL RUNS")
PRINT,"                              ROAD LOAD FORCE = F0 + F2*(V**2)"
62 CONTINUE
PRINT 22,
22 FORMAT(1H0,T1,"RUN",T9,"F2 COEFFICIENT",T28,"F0 COEFFICIENT",
&T48,"R.M.S. ERROR")
*
*     PRINT OUT F0, F2 AND RMS ERROR FOR EACH RUN
*
IF(UNIT2.EQ.0)PRINT 23
IF(UNIT2.EQ.1)PRINT 855
855 FORMAT(1H ,T10," N/KPH**2",T28,"CONSTANT ( N )",
&T48,"VELOCITY FIT(KPH)")
23 FORMAT(1H ,T10,"LBS/MPH**2"T28,"CONSTANT (LBS.)",
&T48,"VELOCITY FIT(MPH)")
901 CONTINUE
D0 25 I=1,NRUNS
IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT 26,IRUNS(I),BS(I),RS(I),RMSS(I)
IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT 26,IRUNS(I),BSMET(I),RSMET(I),RMSSM(I)
26 FORMAT(1H ,T1,I2,T12,F6.4,T31,F6.1,T49,F7.4,T66,F6.3)
IF(UNIT2.EQ.0)GOTO856
*
*     IF THE RMS ERROR IS EXCESSIVE, FLAG IT.
*
IF(RMSSM(I).GT.0.40)PRINT'("+",T56,"<---EXCESSIVE")'
IF(RMSSM(I).GT.0.40)RS(I)=0.0
IF(RMSSM(I).GT.0.40)EXCESS=1.0
GOTO25
856 CONTINUE
IF(RMSS(I).GT.0.25)PRINT'("+",T56,"<---EXCESSIVE")'
IF(RMSS(I).GT.0.25)RS(I)=0
IF(RMSS(I).GT.0.25)EXCESS=1.
25 CONTINUE
24 PRINT
J=-1
*
*     AVERAGE THE COEFFICIENTS, LEAVING OUT THE RUNS WITH EXCESSIVE RMS.
*
D0 96 I=1,NRUNS,2
IF(RS(I).EQ.0.0R.RS(I+1).EQ.0)GOTO96
J=J+2
IRUNS(J)=IRUNS(I)
IRUNS(J+1)=IRUNS(1+1)
BS(J)=BS(I)
BS(J+1)=BS(I+1)
RMSS(J)=RMSS(I)
RMSS(J+1)=RMSS(I+1)
RS(J)=RS(I)
RS(J+1)=RS(I+1)
```

```
CDS(J)=CDS(I)
CDS(J+1)=CDS(I+1)
96 CONTINUE
NPAIRS=(J+1)/2
NRUNS=NPAIRS*2
IF(NPAIRS.LT.3)PRINT,"     INSUFFICIENT DATA REMAINING FOR VALID STATISTICAL PROCESSING"
IF(NPAIRS.LT.3)PRINT'(1H ,///,"*** DATA NOT BOUNDED BY CONSTRAINTS ON INTERNAL CONSISTANCY ***",///)'
IF(NPAIRS.LE.0)GOTO63
IF(LIST.EQ.0)GOTO66
IF(NOTYPE.NE.2)PRINT22,
IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT23,
IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT855,
D0 67 I=1,NRUNS
IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT26,IRUNS(I),BS(I),RS(I),RMSS(I)
67 IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT26,IRUNS(I),BSMET(I),RSMET(I),RMSSM(I)
66 CONTINUE
D0 30 I=1,NPAIRS
PAIRR(I)=(RS(2*I-1)+RS(2*I))/2.
30 PAIR(I)=(BS(2*I-1)+BS(2*i))/2.
CDMEAN=0.
RMEAN=0.
D0 31 I=1,NPAIRS
RMEAN=RMEAN+PAIRR(I)
31 CDMEAN=CDMEAN+PAIR(I)
RMEAN=RMEAN/NPAIRS
CDMEAN=CDMEAN/NPAIRS
SDR=0.
SDCD=0.
D0 32 I=1,NPAIRS
SDR=SDR+(PAIRR(I)-RMEAN)**2
32 SDCD=SDCD+(PAIR(I)-CDMEAN)**2
SDR=SQRT(SDR/NPAIRS)
SDRMET=SDR*4.448
RMET=RMEAN*4.448
PERCR=SDR/RMEAN
SDCD=SQRT(SDCD/NPAIRS)
IF(NOTYPE.NE.2)PRINT58,NPAIRS
58 FORMAT(1H ,T20,"SUMMARY OF RESULTS FOR ",I1," PAIRED RUNS")
IF(EXCESS.EQ.1.0.AND.UNIT2.EQ.0)PRINT,"RUNS WITH EXCESSIVE ERROR (>.25 MPH) WERE DELETED"
IF(EXCESS.EQ.1.0.AND.UNIT2.EQ.1)PRINT,"RUNS WITH EXCESSIVE ERROR (>.40 KPH) WERE DELETED"
PRINT
BMEAN=CDMEAN
BMET=CDMEAN*1.7181
BSD=SDCD
BSDMET=SDCD*1.7181
PERCB=BSDMET/BMET
*
*       CHECK THAT THE S.D. OF F0 AND F2 ARE WITHIN LIMITS.  IF NOT, THROW OUT
*       THE RUN AND ITS PAIR FURTHEST FROM THE MEAN AND RE-COMPUTE.
*
```

```
IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT48,BMEAN,BSD
IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT857,BMET,BSDMET
IF(UNIT2.EQ.0)GOTO858
IF(BSDMET.GE.0.011.0R.PERCB.GE.0.03)PRINT3
IF(BSDMET.GE.0.011.0R.PERCB.GE.0.03)DELETE=1.0
GOTO859
858 CONTINUE
IF(BSD.GE.0.001.0R.PERCB.GE.0.03)PRINT3
IF(BSD.GE.0.001.0R.PERCB.GE.0.03)DELETE=1.0
3 FORMAT(1H+,T66,"<---EXCESSIVE")
48 FORMAT(1H ,"OBSERVED F2 COEFFICIENT (LBS/MPH**2)",T40,F7.4,T60,F6.4)
857 FORMAT(1H ,"OBSERVED F2 COEFFICIENT ( N/KPH**2)",T40,F7.4,T60,F6.4)
859 CONTINUE
IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT,"OBSERVED F0 CONSTANT (LBS)"
IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT41,RMEAN,SDR
IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT,"OBSERVED F0 CONSTANT (N)"
IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT860,RMET,SDRMET
860 FORMAT(1H+,T33,"MEAN",T40,F7.1,T50,"STD. DEV."T60,F6.1)
IF(UNIT2.EQ.0)GOTO861
IF(SDRMET.GE.11..0R.PERCR.GE.0.05)PRINT3
IF(SDRMET.GE.11..0R.PERCR.GE.0.05)DELETE=2.0
GOTO200
861 CONTINUE
IF(SDR.GE.2.5.0R.PERCR.GE.0.05)PRINT3
IF(SDR.GE.2.5.0R.PERCR.GE.0.05)DELETE=2.0
41 FORMAT(1H+,T33,"MEAN",T40,F7.1,T50,"STD. DEV.",T60,F6.1)
200 CONTINUE
IF(DELETE.EQ.0.)GOTO61
TEMP=0.
NGRUN=0
ERROR=0.
D0 60 I=1,NPAIRS
TEMP=ABS(RMEAN-PAIRR(I))
IF(TEMP.GT.ERROR)NGRUN=I
60 IF(TEMP.GT.ERROR)ERROR=TEMP
NGRUN=NGRUN*2
RS(NGRUN)=0.
IF(NOTYPE.NE.2)PRINT
PRINT,"          SUMMARY OF REMAINING UNCORRECTED RUNS"
PRINT,"          WITH WORST ERROR RUN PAIRS DELETED"
DELETE=0.
LIST=1
EXCESS=0.
GOTO24
61 CONTINUE
*
*      CORRECTION FACTOR APPLICATION
*
RH0=RH0/32.174
*
```

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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 *
4100 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*RH0*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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```
IF(UNIT2.EQ.1)F=TERM1+TERM2*80.0*80.0
IF(UNIT2.EQ.0)PRINT'(" ROAD LOAD AT 50 MPH =",F6.1," LBS (CORRECTED)")',F
IF(UNIT2.EQ.1)PRINT'(" ROAD LOAD AT 80 KPH +",F6.1," N (CORRECTED)")',F
TRLHP=F*50.*88./60./550.
TRLKW=T*0.02222
IF(UNIT2.EQ.0)PRINT'(T1,"TOTAL ROAD LOAD H.P. = ",F6.2)',TRLHP
IF(UNIT2.EQ.1)PRINT'(T1,"TOTAL ROAD LOAD POWER = ",F6.2," KW")")',TRLKW
PRINT
F2X=TERM2*50.*50.
IF(UNIT2.EQ.1)F2X=TERM2*80.*80.
IF(NOTYPE.NE.2.AND.UNIT2.EQ.0)PRINT'(T1,"F2 X 2500 = ",F6.2,".....F2 UNROUNDED")',F2X
IF(NOTYPE.NE.2.AND.UNIT2.EQ.1)PRINT'(T1,"F2 X 6400 = ",F6.2," N....F2 UNROUNDED")',F2X
IF(UNIT2.EQ.0)GOTO862
CLARK1=SQRT(TERM2/TERM1)*88.
CLARK2=SQRT(TERM2/TERM1)*72.
DT=(XID+XIDLC)*0.4536/(SQRT(TERM1*TERM2))*(ATAN(CLARK1)-ATAN(CLARK2))*5.0/18.0
PRINT
PRINT'(T1,"CALCULATED 88-72 KPH DYNO COASTDOWN TIME =",F6.2," SEC")',DT
GOTO863
862 CLARK1=SQRT(TERM2/TERM1)*55.0
CLARK2=SQRT(TERM2/TERM1)*45.0
DT=(XID+XIDLC)/32.174/(SQRT(TERM1*TERM2))*(ATAN(CLARK1)-ATAN(CLARK2))*1.466667
PRINT
PRINT'(T1,"CALCULATED 55-45 MPH DYNO COASTDOWN TIME = ",F6.2," SEC")',DT
863 CONTINUE
T=T-459.67
63 CONTINUE
PRINT,
IF(NPAIRS.LT.3)PRINT,"*** HOWEVER INSUFFICIENT DATA ARE PRESENT FOR THESE TO BE ACCEPTABLE VALUES ***"
PRINT," INPUT DATA :"
WKG=W*0.4536
WACTKG=WACT*0.4536
AM3=A*0.0929
TMET=(T-32.0)/1.8
PBAR=PRESS*25.4
W0KPH=W0*1.609
*
*      PRINT OUT THE INPUT DATA, BUT IN THE OUTPUT UNIT SYSTEM.
*
IF(UNIT2.EQ.1)PRINT 864,WKG,WACTKG,AM3,TMET,PBAR,W0KPH,ALPHA
864 FORMAT(T1,"EFFECTIVE WEIGHT (KG)",T30,F8.2,T43,"ACTUAL WEIGHT (KG)",T67,F8.2,/,
&T1,"FRONTAL AREA (m**2)",T30,F8.3,T43,"AIR TEMPERATURE (DEG C)",T67,F8.1,/,
&T1,"ATM.  PRESSURE (MM HG)",T30,F8.0,T43,"WIND SPEED (KPH)",T67,F8.1,/,
&T1,"WIND DIRECTION FROM NORTH (DEG)",T30,F8.1)
IF(UNIT2.EQ.0)PRINT 46,W,WACT,A,T,PRESS,W0,ALPHA
46 FORMAT(T1,"EFFECTIVE WEIGHT (LBS)",T30,F8.2,T43,"ACTUAL WEIGHT (LBS)",T67,F8.2,/,
&T1,"FRONTAL AREA (SQ. FT.)",T30,F8.2,T43,"AIR TEMPERATURE (DEG F)",T67,F8.0,/,
&T1,"ATM. PRESSURE (IN.HG.)",T30,F8.2,T43,"WIND SPEED (MPH)",T67,F8.1,/,
&T1,"WIND DIRECTION FROM NORTH (DEG)",T33,F5.1)
IF(L1.EQ.0)PRINT'(1H+,T43,"TRACK A")'
```

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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,"UNKNOWN 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,XLI,XRI,EPS,IEND,IER)
5320 IER=0
5330 XL=XLI
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 D0 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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7 TOL=F-FL
A=F*TOL
A=A+A
IF(A-FR*(FR-FL))8,9,9
8 IF(I-IEND)17,17,9
9 XR=X
FR=F
TOL=EPS
A=ABS(XR)
IF(A-1.)11,11,10
10 TOL=TOL*A
11 IF(ABS(XR-XL)-TOL)12,12,13
12 IF(ABS(FR-FL)-TOLF)14,14,13
13 CONTINUE
IER=1
14 IF(ABS(FR)-ABS(FL))16,16,15
15 X=XL
F=FL
16 RETURN
17 A=FR-F
DX=(X-XL)*FL*(1.+F*(A-TOL)/(A*(FR-FL)))/TOL
XM=X
FM=F
X=XL-DX
TOL=X
CALL VALU8T(TOL,F)
IF(F)18,16,18
18 TOL=EPS
A=ABS(X)
IF(A-1.) 20,20,19
19 TOL=TOL*A
20 IF(ABS(DX)-TOL)21,21,22
21 IF(ABS(F)-TOLF)16,16,22
22 IF(SIGN(1.,F)+SIGN(1.,FL)) 24,23,24
23 XR=X
FR=F
GO TO 4
24 XL=X
FL=F
XR=XM
FR=FM
GO TO 4
25 IER=2
RETURN
END
*
*       SUBROUTINE VALU8T(T0,DVDT0)
*
SUBROUTINE VALU8T (T0,DVDT0)
COMMON V(150),TAU(150),TIME(150),N
```