1.0 INTRODUCTION

This test is used to assess the transient and steady state turning performance of a vehicle in the "linear" (normal customer) driving domain. The "linear" range includes all turning maneuvers where lateral acceleration levels are between 0.1 and 0.35 g's (For heavy trucks i.e., GVWR > 8350 kg, the linear range includes turning maneuvers between 0.1 and 0.2 g's). The test is run at three speeds. Changes in turning performance with speed are an important indicator of vehicle characteristics.

1.1 Proposed revisions to this procedure must be submitted per FAP03-179.

2.0 INSTRUMENTATION

Instrumentation to measure and record the following vehicle responses are required.

NOTE: The amplitude of the frequency response of the transducers shall be constant to at least 5 Hz. If filtering is used on the recorded signals, no phase shifts should be introduced between channels. If a transducer contains internal signal conditioning that causes attenuation of the signal or phase shifts, the data should be compensated before it is reported.

2.1 STEERING WHEEL ANGLE (SWA). This transducer should be accurate to at least 0.2° at less than 45° of steering wheel angle. At greater than 45° the transducer should be accurate to 0.5° or 0.5% of the measured value, whichever is greater. Linearity shall be within 0.5%.

2.2 STEERING WHEEL TORQUE (SWT). This transducer can measure torque up to 20 N•m with an accuracy of 0.5% of the measured value or 0.05 N•m, whichever is greater.

2.3 YAW VELOCITY. This device shall measure yaw velocities up to 50° per second with an accuracy of 0.05° per second or 0.5% of the measured value, whichever is greater. The sensitivity to all accelerations shall be less than 0.1° per second per g.

2.4 LATERAL ACCELERATION (AY). This transducer shall measure lateral acceleration of the vehicle sprung mass relative to the ground plane up to a minimum of 0.5 g. Lateral acceleration shall be measured with an accuracy of 0.002 g or 0.5% of the measured value, whichever is greater.

2.5 ROLL ANGLE. This transducer shall measure the roll of the vehicle relative to the ground plane. This device shall be accurate to 0.05° or 1% of the measured value, whichever is greater.

2.6 SIDESLIP ANGLE (OPTIONAL). This transducer shall measure direction of vehicle travel relative to the vehicle at specific locations on the vehicle. This device shall be accurate to 0.1° or 1% of the measured value, whichever is greater.

2.7 VEHICLE VELOCITY. This transducer measures vehicle speed in the direction of travel to within 1 kph.

2.8 All test measurement equipment must be calibrated and maintained per FAP03-015, Control, Calibration, and Maintenance of Measurement and Test Equipment.

2.9 All applicable safety guidelines and procedures must be followed.

3.0 EQUIPMENT AND FACILITIES

3.1 Uniform, dry, clean, hard road surface made of asphalt or concrete. The road gradient should be 2% or less in any direction.

3.2 A test area at least 12 meters wide and long enough to obtain data for at least 30 seconds at the highest test speed (approximately 1 km once the vehicle has attained 120 kph).

3.3 It is recommended that testing occur when the average wind speed does not exceed 5.4 m/s.

3.4 All testing/evaluations must be in compliance with the Ford proving grounds safety guidelines regardless of where the tests are conducted.

4.0 SAMPLE PREPERATION

4.1 Ensure that the complete test vehicle, including subsystems and components, is representative of the appropriate design level. Inspect the vehicle to ensure that it is mechanically sound and safe for testing. Ensure that all parts are properly attached and lubricated, there are no fluid leaks, and all electronic controls work properly. All loose parts must be secured.

4.2 Check tires for tire wear. Tests can be conducted with tires at any state of wear, however it is recommended that standard tests be run with full tread depth tires that have not experienced any harsh use (e.g., hard cornering, braking or acceleration). Before commencing tests, verify that the speed rating of the tires is acceptable.

4.3 Check wheel alignment and adjust to vehicle specifications.

4.4 Measure and record all the vehicle information required. See section 7 for details.

4.5 Weigh the vehicle at Curb Weight in accordance with CETP 00.00-R-614, Vehicle Dynamics Test Loading Standards.

4.6 Install instrumentation in the vehicle according to the manufacturer’s specifications. The transducer that measures lateral acceleration should be located as close to the driver H-point as possible and on the vehicle centerline. All other transducers can be located at any convenient location on the vehicle.

4.7 Inflate all tires to specified pressure in accordance with CETP 00.00-R-603, Tire Pressure Standards. Tires should be stored at ambient temperature prior to use. Warm up tires and break in new tires in accordance with CETP 00.00-R-600, Tire Warm-up and Break In.

4.8 Weigh the vehicle at Lightly Loaded in accordance with CETP 00.00-R-614, Vehicle Dynamics Test Loading Standards.

5.0 OPERATION

5.1 Drive the vehicle at 75 kph, keeping the speed constant throughout the test.

5.2 Input a sine wave of constant amplitude and varying frequency into the steering system.The frequency range of the input should vary from about 0.2 to 3 Hz. The magnitude of the steering input is set so that the low frequency input (<0.2 Hz) yields 0.32 +/- 0.04g's lateral acceleration. For heavy trucks (GVWR > 8350 kg) the magnitude of the steering input is set so that the low frequency input yields 0.2 g's lateral acceleration.

Note: A PSD (Power Spectral Density function or auto spectrum function) of the steering wheel magnitude of the total data set shall not vary more than one decade within the frequency range.

5.3 Collect and analyze at least 3 minutes of data for each test condition.

5.4 Repeat steps 5.1 through 5.3 at 100 and 120 kph. For heavy trucks (GVWR > 8350 kg) do not run 120 kph set. Optional higher test speeds include 140, 160, 180, 200, 220, 240 km/h and Vmax.

6.0 GENERAL INSTRUCTIONS

6.1 All presentation data in this section are from a Frequency Response Function (FRF) magnitude or phase. Each is the result of analyzing at least 5 minutes of data with a FFT (Fast Fourier Transform) algorithm. The frequency resolution should equal to or less than 0.1 Hz. Data should have good coherence in the range from 0.2 to about 3 Hz., except where the magnitude of the function is very high or very low. Good coherence is defined as being at 0.9 or above.

6.2 Definitions of abbreviations and terminology used in this procedure.

6.2.1 SWA = steering wheel angle.

6.2.2 SWT = steering wheel torque.

6.2.3 AY = lateral acceleration.

6.3 The magnitude, phase, and coherence information shall be presented in the following plots:

6.3.1 FRF of yaw velocity gain (degrees/second/100° of SWA).

6.3.2 FRF of lateral acceleration gain (degrees/second/100° of SWA).

6.3.3 FRF of roll flexibility (degree/g).

6.3.4 FRF of steering wheel torsional rate (N•m/degree).

6.4 Characteristic vehicle responses can be obtained from each FRF. These responses are defined as follows:

6.4.1 Yaw Velocity Peak Frequency (Hz): The frequency where the FRF of yaw velocity gain is at a maximum. A higher yaw velocity peak frequency indicates a quicker vehicle response.

6.4.2 Steady State Yaw Velocity Gain (degrees/second per 100° of SWA): The steady state value of yaw gain derived from the lowest frequency response computed by the FRF algorithm. It is a measure of vehicle response sensitivity.

6.4.3 Peak to Steady State Yaw Velocity Ratio: The ratio of peak yaw velocity magnitude to the steady state yaw velocity gain. This is an indicator of yaw damping.

6.4.4 Yaw/SWA Phase Lag Time (ms): The equivalent time at the frequency when the yaw velocity lags the SWA signal by 45° (yaw lag time = 1/ {8 * frequency [45° phase lag]}). Lower values indicate quicker vehicle response.

6.4.5 Steady State Lateral Acceleration Gain (g's per 100° of SWA): The steady state value of lateral acceleration gain estimated from the lowest frequency response computed by the FRF algorithm. This is a measure of vehicle response sensitivity.

6.4.6 Lateral Acceleration –3dB Frequency (Hz): The frequency where the lateral acceleration gain FRF magnitude is reduced 3 dB from the steady state lateral acceleration gain. This number indicates the vehicles lateral acceleration bandwidth or the frequency boundary where the response tends to fall off as frequency increases.

6.4.7 Ay/SWA Phase Lag Time (ms): The equivalent time of the frequency when the lateral acceleration lags the SWA signal by 45° (AY time lag = 1/ {8 * frequency [45 deg phase]}). Lower values indicate quicker vehicle response.

6.4.8 Steady State Roll Flexibility (deg/g): The steady state value of flexibility which is estimated from the lowest frequency response computed by the FRF algorithm. This is an indication of a vehicle's roll stiffness.

6.4.9 Peak to Steady State Roll Gain Ratio: The ratio of peak flexibility gain magnitude to the steady state roll flexibility. This is an indicator of roll damping. Lower values indicate more roll damping and therefore less roll overshoot in turning maneuvers.

6.4.10 Roll Angle Response Peak Frequency (Hz): The frequency where the FRF of roll angle to lateral acceleration is at a maximum. It is an indicator of roll natural frequency. Higher values indicate larger roll stiffness to inertia ratios.

6.4.11 Steady State Torsional Rate (N•m/deg of SWA): The steady state value of steering wheel torsional rate estimated from the lowest frequency response computed by the FRF algorithm. It is an indicator of steering effort.

6.4.12 Suspension Roll Rate Gradient @ 1Hz (deg/s / g): The value of the suspension roll rate to lateral acceleration FRF averaged from 0.8 - 1.2 Hz.

6.4.13 Total Roll Rate Gradient @ 1Hz (deg/s / g): The value of the total roll rate to lateral acceleration FRF averaged from 0.8 - 1.2 Hz.

7.0 PRESENTATION OF DATA

7.1 Record the following vehicle information:

7.1.1 Year, make, model, type.

7.1.2 Vehicle number.

7.1.3 Wheel base.

7.1.4 Front and rear track.

7.1.5 Steering type.

7.1.6 Suspension type – front and rear.

7.1.7 Overall steering ratio.

7.1.8 Engine type and size.

7.1.9 Transmission and drivetrain.

7.1.10 Tire manufacturer, model and size.

7.1.11 Tire construction number.

7.1.12 Tire condition – tread depth – front and rear.

7.1.13 Tire pressure – front and rear.

7.1.14 Wheel alignment, suspension settings, and vehicle component changes that effect performance.

7.1.15 Vehicle weight (curb) at each wheel.

7.1.16 Vehicle weight (as tested) at each wheel.

7.2 Record the following test track conditions:

7.2.1 Test Track name.

7.2.2 Weather conditions.

(a) Temperature.

(b) Wind speed.

(c) Wind direction.

7.2.3 Test personnel.

(a) Driver.

(b) Engineer.

(c) Technician.

7.2.4 Transducer locations.

(a) Lateral accelerometer.

(1) Longitudinal position (relative to front axle centerline).

(2) Vertical position (relative to ground plane).

(b) Front lateral sideslip.

(1) Longitudinal position (relative to front axle centerline).

(c) Rear lateral velocity.

(1) Longitudinal position (relative to front axle centerline).

(d) Front height sensors.

(1) Longitudinal position (relative to front axle centerline).

(2) Lateral position (relative to vehicle centerline).

(3) Vertical position (relative to ground plane).

(e) Rear height sensors.

(1) Longitudinal position (relative to front axle centerline).

(2) Lateral position (relative to vehicle centerline).

(3) Vertical position (relative to ground plane).

8.0 REFERENCES

8.1 CETP 00.00-R-600, Tire Warm-up and Break In.

8.2 CETP 00.00-R-603, Tire Pressure Standards.

8.3 CETP 00.00-R-614, Vehicle Dynamics Test Loading Standards.

8.4 FAP03-015, Control, Calibration, and Maintenance of Measurement and Test Equipment.

8.5 FAP03-179, Developing Corporate Engineering Test Procedures.

9.0 RECORD OF REVISIONS

See metadata field "Review Note".

9.1 A history of this test procedure is available on the Test Comminization Meeting web site at http://www.vehdyn.ford.com/vdtest/testcom/CETPHistoryDocs.

10.0 ATTACHMENT

None.