

for J-Turn tests of various vehicles, taking into account their differences in steering ratio, wheelbase and linear range understeer properties. (See NHTSA's Phase IV report docketed with the NPRM notice as item 38 in Docket No. NHTSA 2001-9663). Under this method, one first measures the handwheel angle that would produce a steady-state lateral acceleration of 0.3 g at 50 mph on a level paved surface for a particular vehicle. In brief, the 0.3 g value was chosen because the steering angle variability associated with this lateral acceleration is quite low and there is no possibility that stability control intervention could confound the test results. Since the magnitude of the handwheel position at 0.3 g is small, it must be multiplied by a scalar to have a high maneuver severity. In the case of the J-Turn, the handwheel angle at 0.3 g was multiplied by eight. When this scalar is multiplied by the average handwheel angle at 0.3 g (observed during NHTSA's 1997-98 rollover research program), the result is approximately 330 degrees. Figure 1 illustrates the J-Turn maneuver in terms of the automated steering inputs commanded by the programmable steering machine. The rate of the handwheel turning is 1000 degrees per second.

To begin the maneuver, the vehicle was driven in a straight line at a speed slightly greater than the desired entrance speed. The driver released the throttle, coasted to the target speed, and then triggered the commanded handwheel input. The nominal maneuver entrance speeds used in the J-Turn maneuver ranged from 35 to 60 mph, increased in 5 mph increments until a termination condition was achieved. Termination conditions were simultaneous two inch or greater lift of a vehicle's inside tires (two-wheel lift) or completion of a test performed at the maximum maneuver entrance speed without two-wheel lift. If two-wheel lift was observed, a downward iteration of vehicle speed was used in 1 mph increments until such lift was no longer detected. Once the lowest speed for which two-wheel lift could be detected was isolated, two additional tests were performed at that speed to monitor two-wheel lift repeatability.

B. Fishhook Maneuver

The second maneuver test, the fishhook maneuver, uses steering inputs that approximate the steering a driver acting in panic might use in an effort to regain lane position after dropping two wheels off the roadway onto the shoulder. In the NPRM notice, we described it as a road edge recovery

maneuver. As pointed out by some commenters, it is performed on a smooth pavement rather than at a road edge drop-off, but its rapid steering input followed by an over-correction is representative of a general loss of control situation. The original version of this test was developed by Toyota, and variations of it were suggested by Nissan and Honda. NHTSA has experimented with several versions since 1997, and the present test includes roll rate feedback in order to time the countersteer to coincide with the maximum roll angle of each vehicle in response to the first steer.

Figure 2 describes the Fishhook maneuver in terms of the automated steering inputs commanded by the programmable steering machine and illustrates the roll rate feedback. The initial steering magnitude and countersteer magnitudes are symmetric, and are calculated by multiplying the handwheel angle that would produce a steady state lateral acceleration of 0.3 g at 50 mph on level pavement by 6.5. The average steering input is equivalent to the 270 degree handwheel angle used in earlier forms of the maneuver but, as in the case of the J-Turn, the procedure above is an objective way of compensating for differences in steering gear ratio, wheelbase and understeer properties between vehicles. The fishhook maneuver dwell times (the time between completion of the initial steering ramp and the initiation of the countersteer) are defined by the roll motion of the vehicle being evaluated, and can vary on a test-to-test basis. This is made possible by having the steering machine monitor roll rate (roll velocity). If an initial steer is to the left, the steering reversal following completion of the first handwheel ramp occurs when the roll rate of the vehicle first equals or goes below 1.5 degrees per second. If an initial steer is to the right, the steering reversal following completion of the first handwheel ramp occurs when the roll rate of the vehicle first equals or exceeds -1.5 degrees per second. The handwheel rates of the initial steer and countersteer ramps are 720 degrees per second.

To begin the maneuver, the vehicle was driven in a straight line at a speed slightly greater than the desired entrance speed. The driver released the throttle, coasted to the target speed, and then triggered the commanded handwheel input described in Figure 2. The nominal maneuver entrance speeds used in the fishhook maneuver ranged from 35 to 50 mph, increased in 5 mph increments until a termination condition was achieved. Termination conditions included simultaneous two

inch or greater lift of a vehicle's inside tires (two-wheel lift) or completion of a test performed at the maximum maneuver entrance speed without two-wheel lift. If two-wheel lift was observed, a downward iteration of vehicle speed was used in 1 mph increments until such lift was no longer detected. Once the lowest speed for which two-wheel lift could be detected was isolated, two additional tests were performed at that speed to check two-wheel lift repeatability.

C. Loading Conditions

The vehicles were tested in each maneuver in two load conditions in order to create four levels of stringency in the suite of maneuver tests. The light load was the test driver plus instrumentation in the front passenger seat, which represented two occupants. A heavier load was used to create a higher level of stringency for each test. In our NPRM, we announced that the heavy load would include 175 lb anthropomorphic forms (water dummies) in all rear seat positions. During the test of the 25 vehicles, it became obvious that heavy load tests were being run at very unequal load conditions especially between vans and other vehicles (two water dummies in some vehicles but six water dummies in others). While very heavy passenger loads can certainly reduce rollover resistance and potentially cause special problems, crashes at those loads are too few to greatly influence the overall rollover rate of vehicles. Over 94% of van rollovers in our 293,000 crash database occurred with five or fewer occupants, and over 99% of rollovers of other vehicles occurred with five or fewer occupants. The average passenger loads of vehicles in our crash database was less than two: 1.81 for vans; 1.54 for SUVs; 1.48 for cars; and 1.35 for pickup trucks. In order to use the maneuver tests to predict real-world rollover rates, it seemed inappropriate to test the vehicles under widely differing loads that did not correspond to the real-world crash statistics. Therefore, the tests used to develop a statistical model of rollover risk were changed to a uniform heavy load condition of three water dummies (representing a 5-occupant loading) for all vehicles capable of carrying at least five occupants. Some vehicles were loaded with only two water dummies because they were designed for four occupants. For pickup trucks, water dummies were loaded in the bed at approximately the same height as a passenger in the front seat.

To avoid disruption, the tests were completed under the original loading