Determining a "Safe" Driving Speed in Fog

By David Chandler
Education Coordinator; Physics and Mathematics Teacher
Eleanor Roosevelt Community Learning Center
Visalia, CA

Abstract

Most drivers, when asked to cite a rule for choosing a safe driving speed in fog, cite the old freeway following rule, "one car length for each 10 miles per hour," or the more recently advocated "2 second rule." These rules are totally inappropriate as guides for driving in fog, leading to collisions with stationary obstacles at essentially full speed. A much more appropriate rule is developed which can be easily implemented by typical drivers.

Several years ago I taught physics at Corcoran high school, which involved a substantial commute in San Joaquin Valley. The Tule Fog is particularly dense in the middle of the valley in the winter and we had a bad fog season that year. I quickly realized I had no guidelines to judge safe driving speed. The only rules-of-thumb I knew were the old freeway driving rules, "one car length for each 10 miles per hour," or the more recently advocated "2 second rule." I was bothered by the fact that both of these give the following distance as a linear function of speed, whereas stopping distance is a quadratic function of speed. But until I analyzed the problem I had no better rules to guide me. Neither does the typical driver.

Assuming a car length to be about 15 feet, the "one car length for each 10 miles per hour" rule translates to a "1 second rule." (A car traveling at $10 \cdot n$ mi/hr will cover $14.7 \cdot n$ ft in 1 sec.) The "2 second rule" gives twice the margin, but it is still a linear function of speed. These rules are intended to suggest a reasonable following distance for freeway driving in clear weather. Given a reaction + response time in the range of 1-2 seconds, if you are following a car and see its brake lights come on in an emergency braking situation, a 2-second gap would allow you to start your actual deceleration at about the same place in the road where the car in front of you started to decelerate. You would thus presumably come to rest at about the same place as the car ahead of you, hopefully with at least a few inches to spare. (This rule optimistically assumes that the car ahead of you successfully comes to a natural stop without a collision.) Thus the 1 to 2 second rule seems intended only to absorb the response + reaction time.

If you apply the 2-second rule to following a wall of fog and a stationary obstacle appears out of the fog, you will consume the entire distance in the 2-second reaction + response time and hit the obstacle at full speed. The fact that this rule is the only one known to

many drivers makes it an "attractive hazard" and likely contributes to the frequency and severity of multi-car pileups.

As I commuted to my physics class through the fog several questions became critical to me:

1. How can one determine a safe speed for a given visibility distance?
2. How can this be translated into a method that can be easily and reliably applied by a typical driver?
3. Is driving at the "safe" speed safe? In particular, doesn't driving at the computed safe speed increase the risk of being hit from behind?

I must also add that in order to make the problems tractable, I assume uniform fog, which I acknowledge is an optimistic assumption.

The third question is the easiest to answer. If you are traveling at "the safe speed," whatever that may be, you can view the problem of a car approaching from behind from your own moving frame of reference. For instance, if the computed "safe speed" is 30 mi/hr, then the "safe speed" you would compute for the car behind you would also be 30 mi/hr in your moving frame of reference. But this translates to 60 mi/hr relative to the highway. This is because the car behind you doesn't have to stop. It merely has to match speeds with you. (This computation is based on your continuing to move at the computed safe speed.) Therefore, as long as you are moving unimpeded, you should worry more about what you might hit in front of you than about the cars coming from behind. However, if you slow down significantly or are forced to stop, your danger of being hit from behind is greatly increased. In that case moving off the highway should become a high priority.

The first two problems are intertwined. The most obvious solution to the first problem involves estimating the distance to the wall of fog, yet this distance estimation is difficult and unreliable. Furthermore, the reaction/response time would have to be converted to an equivalent reaction/response distance and added to the deceleration distance. Instead, consider converting the deceleration distance to deceleration time and then simply adding the reaction/response time. Estimating the travel time to the wall of fog is far easier and more reliable than estimating the distance, but this approach also leads to another key simplification. For a uniformly decelerating car, the speed vs. deceleration distance relationship is quadratic ($d = \frac{v_0^2}{2\mu g}$), whereas the speed vs. deceleration *time* relationship is linear ($t = \frac{v_0}{\mu g}$)!

For a typical dry-pavement skidding coefficient of friction, $\mu = 0.7$, 1 second of braking time produces a speed reduction of about 15 mi/hr. (Wet pavement can reduce the coefficient of friction by half.) Since the speed-time relationship is linear, this leads to an easily formulated and remembered rule: allow 1 second of braking time for each 15

miles per hour of speed. To this should be added about 2 seconds of reaction/response time. Thus:

15 mi/hr → 1 sec braking + 2 sec reaction/response time = 3 sec to the wall of fog
30 mi/hr → 2 sec braking + 2 sec reaction/response time = 4 sec to the wall of fog
45 mi/hr → 3 sec braking + 2 sec reaction/response time = 5 sec to the wall of fog
60 mi/hr → 4 sec braking + 2 sec reaction/response time = 6 sec to the wall of fog

Conclusion:

A basic "safe" speed recommendation for light-to-medium, uniform fog conditions on dry pavement can be made that is easy for typical drivers to implement reliably:

> Round up your speed to the nearest multiple of 15 miles per hour (i.e. 15, 30, 45, or 60 mi/hr). Test the visibility distance to the effective "wall" of fog by watching for the emergence of a dark object (road sign, telephone pole, etc.). Start counting seconds starting with Zero when you first see the object. The goal is 2 seconds plus 1 second for each 15 miles per hour of speed. At 30 mi/hr allow 4 sec. At 45 mi/hr allow 5 sec. At 60 mi/hr allow 6 sec. If you pass the object too quickly, slow down. If the pavement is wet, double the time allowance.
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> If the fog becomes dense and/or non-uniform, the danger increases substantially and you should pull completely off the road and wait for conditions to improve.