## C22 Vehicle Steering Caused by Tire Blowout

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The purpose of this presentation is to provide the forensic community with an analysis of an unusual automotive accident in which a hole in a tire sidewall caused an abrupt turning maneuver.

This presentation will impact the forensic community and/or humanity by demonstrating how a seemingly small defect can have very large consequences.

This paper presents an analysis of the effects of a left-front tire blowout on a 2-day-old 1990 Nissan Pathfinder. The subject vehicle suddenly turned left and struck an oncoming vehicle on a narrow two-lane roadway. Immediately after the collision, the responding police officer discovered a hole in the outboard sidewall of the Pathfinder's left front tire. A major issue of the resulting liability case was whether the accident was due to the Nissan driver's error or was caused by the tire failure. This paper will show that the accident was caused by the tire failure. Specifically, the paper will present evidence that:

- The tire's sidewall hole was not caused by the collision;
- If the hole was present before the collision, the force of escaping air from the hole would have caused the vehicle's front wheels to rapidly steer left; and
- The vehicle did steer left.

The subject tire was examined. It was determined that the sidewall hole was created from the inside of the tire and not by some external cutting object. That conclusion made it likely that the hole was created before the collision, by the following logic: Engineering judgment (unquantified) suggests that the probability was near zero that such an unusual tire failure could occur in a collision event during which the driver also performed an inexplicable steer-left maneuver into oncoming traffic. That is, two extremely improbable events did not occur during the same collision. Based on the following analysis of forces that would have been exerted on the tire by escaping air, it was concluded that the hole appeared in the tire's sidewall and caused the rapid left-turn maneuver into oncoming traffic, which caused the subject collision.

When the hole was created in the tire's sidewall, high-pressure air within the tire escaped through the hole into the atmosphere. Maximum flow rate was achieved when air velocity reached the speed of sound, a condition known as choked flow. Choked flow lasted for about one half second after the sidewall rupture, lowering both the source and critical pressures until the flow was no longer choked. During this time of choked flow, the escaping air developed a force perpendicular to the sidewall of the tire that ranged from 22.5 pounds to 11.7 pounds, creating an average thrust force of 17 pounds. At the Pathfinder's estimated speed of 30 mph, the tire (and the hole) made 2.7 rotations during the half second of choked flow.

A total-station surveying instrument was used to measure the spatial relationships among tire footprint, wheel spin axis, and wheel steering axis. As the vehicle moved forward and the left front tire rotated about its spin axis, the force of the escaping air produced a torque on the steering axis. When this force (i.e., the hole) was forward of the wheel's steering axis it produced a clockwise (CW) torque (as seen from above) which tended to steer the wheel into a right turn. Similarly, when the force from escaping air was aft of the steering axis, it produced a counter-clockwise torque (CCW) tending to steer the wheel into a left turn. On the subject vehicle, the steering axis was just forward of the wheel's spin axis at the axle, so as the jet of air revolved about the axle it spent a greater amount of time behind the steering axis than in front of it, and the torque-arm from hole to steering axis was larger when the hole was behind the steering axis than when the hole was in front of it. Therefore, the CCW (leftward) steering torque produced by the hole lasted longer and was stronger than the CW (rightward) steering torque as the hole traveled one revolution.

The steering motion of the front wheels under these conditions was dependent on the rotational position of the tire when the hole first appeared. For this analysis, it was assumed that the hole appeared when the tire's sidewall was under maximum stress, i.e., when the hole would have been at the six o'clock position.

In order to quantify the left-steer theory, steering torque was calculated and plotted against time for ½ second, starting with the hole at the six o'clock position. The result was the decreasing-amplitude sine wave shown in Figure 1. Integration of the steering torque versus time curve produced the steering impulse curve shown in Figure 2. The impulse varied in amplitude but always increased a left-turn steer angle. Thus, the wheel always turned to the left during the time of choked flow.

There were no data available on the resisting torques of tire footprints to steering rotation. Common driving experience in the era before power steering revealed very large resisting torques at very slow or zero forward speed, and extremely low resisting torques at higher speed. For simplicity, and recognizing the existence of inaccuracies in this method, analysis of vehicle response to sudden discharge of air through the sidewall assumed zero resisting torque at the tire footprint and from the steering linkage.

This paper will supply the following evidence in support of the above argument:

- Photographic evidence demonstrating that the tire failure originated on the inside of the tire's sidewall;
- An explanation of why the hole in the tire's sidewall could not have been created during the collision;
- An analysis of the forces developed by the airflow through the tire sidewall;
- An analysis and graphical results of the steering torque produced by airflow out of the hole in the tire;

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• Graphical results of an analysis of estimated steering wheel position versus time; and
• A representation of vehicle behavior in response to the assumptions of the above analyses.

The subject accident caused substantial emotional turmoil (and physical injury) to the driver and passenger of the Pathfinder. The driver was very relieved to learn the above explanation of the accident. He had been blaming himself for over 10 years for the collision and its resulting harm, even though he knew that he had not steered left into oncoming traffic.

**Steering, Tire Blowout, Accident Reconstruction**

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