P1.68 CRITICAL WIND SPEEDS TO UPSET TWO STYLES OF AMBULANCES AND A LARGE CITY BUS

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1. INTRODUCTION

A landfalling hurricane poses threats to life and property, including to motorists on the highways. First responders in ambulances assist persons during the storm and the need for first responders will likely continue throughout the storm. However, at some hurricane intensity, authorities may order first responders off the roadways for their own safety. In addition to emergency vehicles that may operate during the storm, large city buses are used in some communities to evacuate special-needs populations. There is a need to know the wind speeds at which ambulances and city buses can be operated with relative safety during a hurricane. This knowledge will have application in other severe wind events.

Our previous research reported on field studies of the stability of 291 parked passenger vehicles actually struck by tornadoes and wind tunnel tests of the wind speeds required to upset a sedan and minivan (Schmidlin et al. 2002). Results showed that common passenger vehicles become vulnerable to being upset by wind speeds of about 50 m/s (113 mph) on the vehicle. The most vulnerable direction is wind from the front quarter or rear quarter, about 45^o and 135^o, as measured from the front of the vehicle. Other research on stability of vehicles in strong winds is sparse.

The purpose of this research was to conduct wind tunnel experiments to determine the minimum wind speed required to “upset” two styles of ambulances and a city bus. This will provide guidance for the safe operation of these vehicles during hurricanes and other severe winds.

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2. METHODS

Scale models of Type I and Type II ambulances and a large city bus were constructed by the Wichita State University National Institute for Aviation Research Machine Shop. The tests were performed in the Wichita State University Low Speed Wind Tunnel. The tunnel is a commercial grade facility used by aircraft developers and government labs, with a test section size of 2.1 by 3.0 m. Each model was mounted to the tunnel’s exterior balance via a cylindrical pedestal support that rotated 180^o. Model loads were measured using a six-component external balance capable of resolving the lift, drag, and side forces, and the pitching, rolling, and yawing moments. Data were recorded by a high-speed computer acquisition system. Classic and widely accepted techniques to reduce and correct measured data (such as for blocking and buoyancy) were applied to assure accuracy.

Testing for each model was conducted at a flow speed of 71 ms^{-1}. Results suggested supercritical Reynolds number conditions, so aerodynamic coefficients obtained would indicate full-scale loads with reasonable accuracy. The pedestal and vehicle models were moved through a 180^o yaw sweep with data on six components of load collected at 5^o yaw increments. Vehicles were tested with 5^o of sideward tilt to simulate body roll due to suspension compliance under wind loads and to assess the resulting impact on aerodynamic loads.

We calculated components of all six loads for each 5^o increment of yaw angle. An “upset” was said to occur when the static aerodynamic loads exceeded vehicle weight loads; that is, at least one tire would come off the ground. This does not imply that the vehicle was modeled to flip over in each case, since a tire can rise off the ground and then return to a stable position. We assumed that the vehicle was in a static position (not moving), with rigid suspension, no translational or yawing motion (sliding or spinning), and in a uniform and steady airflow.

3. RESULTS

The Type I ambulance model had a critical "upset" wind speed of 60-67 ms^{-1} (135-150 mph) over wind angles of 40^o to 145^o. The Type II ambulance model had a critical wind speed of 63-76 ms^{-1} (140-170 mph) over wind angles of 30^o to 145^o. The city bus model had a critical wind speed of 27-33 ms^{-1} (60-75 mph) over wind angles of 35^o to 145^o. Much higher wind speeds are required for upset with wind angles from the front or rear of the vehicles, as is typical (Schmidlin et al. 2002).

The minimum wind speeds to cause an "upset" of two common styles of ambulances are 60-63 ms^{-1}, or about 10 ms^{-1} higher than for a typical passenger car or minivan (Schmidlin et al. 2002). This is the wind on the vehicle, centered about 1.5 m above the ground. Equation 1 (from Stull 1995, p. 164) can be used to compare wind speed on the vehicles (U_2) at 1.5 m height (z_2) to the wind speed (U_1) at the standard 10 m height (z_1) of wind measurement (and the Saffir-Simpson hurricane scale). Using a roughness length, z_o, of

$$U_1 = U_2 (\ln (z_1/z_0)/\ln (z_2/z_o)) \qquad (1)$$

0.01 m for open terrain, such as a prairie or farm field environment (Stull 1988), a wind speed of 60 m/s at 1.5 m height converts to a wind speed of 83 ms^{-1} at 10 m. Further, if the critical winds reported here are assumed to be the fastest 3-second gust that might upset a vehicle, they can be converted to a mean one-minute wind, as used in the Saffir-Simpson Hurricane Scale, using a gust factor of 1.19 between 3-second gusts and 1-minute mean wind speeds (Krayer and Marshall 1992). Thus, a 3-second gust of 83 ms^{-1} at 10 m converts to a 1-minute mean of 70 ms^{-1} (83/1.19) at 10 m. A one-minute mean wind of 70 ms^{-1} (156 mph) at 10 m height is the lower threshold for Category 5 on the Saffir-Simpson Hurricane Scale. This is a rare hurricane and an even rarer wind speed inland where ambulances would operate.

The city bus, on the other hand, is very vulnerable in high winds. This research shows that a loaded bus will be "upset" in winds as low as 27 ms^{-1} on the vehicle. If this is taken as the maximum 3-second gust at 1.5 m, then this converts to a one-minute mean 10 m wind speed of 31 ms^{-1} (70 mph). This is below hurricane strength on the Saffir-Simpson Hurricane Scale.

4. CONCLUSIONS

These results show that ambulances are quite stable in high winds, can be operated at higher wind speeds than common passenger vehicles, and it is unlikely that their (low) tendency to overturn in wind will be a limiting factor in their operation. Other hazards must be considered, of course, including debris on the highway, flooded highways, debris in the air, the difficulties of working outdoors in severe winds, and impacts of the driver's reactions while operating an ambulance in high winds. The city bus has a shape and size similar to a small mobile home and becomes unstable at about the same wind speed as an unanchored mobile home. Therefore, the operation of city buses must be stopped at relatively low wind speeds.

This research reports on an initial study of the stability of three types of vehicles in severe winds through wind tunnel testing of the minimum wind speed required to "upset" *stationary* vehicles. The problem of a vehicle moving down the highway in severe winds is made more complicated by the additional aerodynamic considerations and the skill and reactions of the driver, the latter especially is difficult to quantify. The aerodynamic effects of severe wind on a *moving* vehicle is not a focus of this research, but can be approximated by adding the vehicle motion vector to the wind vector and will be presented in subsequent publications.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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