pennsylvania
DEPARTMENT OF HEALTH

BUREAU OF EMERGENCY MEDICAL SERVICES

EMS Information Bulletin 2011-12

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SUBJECT: Wind Effects on Ambulance Vehicles

TO: Regional EMS Councils, EMS Providers, Licensed Ambulance Services

FROM: Bureau of Emergency Medical Services
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The Wind & Hurricane Impact Research Laboratory at the Florida Institute of Technology has published a study titled "Wind Effects on Emergency Vehicles". The document is available at http://research.fit.edu/whirl/projects/wind_effects.php

The report evaluated wind effect on a fire apparatus, Type III Ambulance and a SUV. The study stresses that the results are based on the individual vehicles tested and warns readers that similar vehicles may be affected at lower speeds.

A section of the report is attached for your information. **When wind speeds exceed 35 mph Ambulances should be operated at lower speeds and ambulances should seek shelter when winds exceed 50 mph.**

This information is provided as a guide for EMS organizations as planning efforts for Hurricane Irene continue.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 TYPES OF VEHICLE ACCIDENTS

Based upon the studies conducted here there are two possibilities of vehicle accidents as a result of strong winds. The first possibility is a course deviation, which can lead to accidents between vehicles or the vehicle being blown off the road. This event is very dependent upon the abilities of a driver to handle a vehicle in extreme driving conditions (abilities of multiple drivers if an accident involves more than one vehicle). Course deviation is also very dependent upon road conditions (i.e. how slippery the road is) and this is an uncontrollable variable.

The second possibility is overturning of a vehicle due to strong winds. If a vehicle is not permitted to slide sideways (parked against a curb, or a day when the roads are hot and dry- conditions leading to high coefficient of static friction.) then wind speeds which will cause overturning are very definite and they can not be corrected for by the driver or good driving conditions.

5.2 FIRE TRUCK CONCLUSIONS

For a range of vehicle speeds between 35 and 55 mph, the wind speed required to cause a course deviation for an empty Typhoon fire truck model decreases from 70 to 64 mph. For the Cyclone model, based upon an extrapolation, the allowable wind speeds are only slightly higher. Overturning, for the fire truck, is unlikely to happen based upon wind speeds alone, but it is possible that it could be blown off course and hit an obstacle in just the right way to cause overturning.

In conclusion for the fire truck, the critical wind speed falls in the range of 64-70mph. Yaw angles for this event range between 45 and 90 degrees. But this is not to say wind angles outside this range are not dangerous. Wind yaw angles between 90 and 180 degrees will contribute largely to a tailwind and not so much a crosswind and will make stopping difficult. For wind yaw angles less than 45 degrees they will contribute largely to a headwind, and will resist the vehicles' motion.

5.3 AMBULANCE CONCLUSIONS

For the ambulance model, for a range of vehicle speeds between 27 and 55 mph, the wind speed required to cause a course deviation decreases from 48 to 34 mph. The ambulance is at risk of overturning for wind speeds above 90 mph. The possibility can be delayed to about 100 mph if the vehicle is driven slowly. As with the fire truck it is possible that overturning can occur at lower wind speeds during a violent course deviation.

In conclusion for the ambulance, the critical wind speeds falls in the range of 35-50mph. The corresponding yaw angles are between 68 and 117 degrees. One explanation for why this range of wind speeds is so much lower than for the fire truck or the SUV is because it has a lower *density*- or mass per unit volume. The fire truck is a large vehicle but it does not have much empty space. The same holds for the SUV. Because of the large patient module on the ambulance- this is mostly empty space- the vehicle is very susceptible to wind effects.

5.4 SUV CONCLUSIONS

From the analysis for the SUV model, for a range of vehicle speeds between 27 and 55 mph, the wind speed required to cause a course deviation is around 77 mph, for yaw angles between 83 and 100 degrees. The SUV is at risk of overturning for wind speeds above 138 mph. As with other vehicles, overturning can result at lower wind speeds during a violent course deviation.

In conclusion for the SUV, the critical wind speeds occur when wind speed is close to 77 mph. As with the other vehicles lower wind speeds will likely lead to dangerous driving depending upon various conditions.

5.5 RECOMMENDATIONS

Wind speed rather than wind direction should be used in determining safe driving conditions. Roads in a city go in every direction; a vehicle going to and from a location will encounter the critical yaw angle regardless of the yaw angle at the beginning of its trip. To define the critical wind speed, a factor of safety should be used with the numbers provided in this report, to reflect the fact that:

- There is a margin of error inherent in any experimental study. For example, turbulence could not be simulated in the wind tunnel and the forces that would contribute to lift and a pitching moment beneath a vehicle were not measured because the moving ground plane could not be simulated.

- The actual wind induced forces might change for different models of the same vehicle.

- The actual weight of the vehicle is a random variable that depends on the amount of people and type equipment on board. In the case of the SUV it was assumed that the vehicle was a 4x4 ¾ ton Suburban. If the vehicle were in fact a 2x4 ½ ton suburban then the vehicle would not be as heavy as the one studied here and thus more prone to course deviation or overturning at lower wind speeds. The same is true for the ambulance, the study here was for a F-450, but there exists a lighter F-350 which would also be more prone to course deviation or overturning at lower wind speeds. Finally, with the fire truck there exists the variable of how much cargo or water is carried.

- The coefficient of friction for the tires is highly dependent on a number of factors that make its actual value determination uncertain. Because heavy rains usually accompany strong winds this is the assumed worst-case scenario for this study and hence the coefficient of static friction of 0.2 was used. It cannot be stressed enough that this is not an exact value.

- Some conditions like centrifugal forces in a curve, or operation on open causeways were not taken into account.

- Finally, the actual wind speeds in the field can be different than the one announced by the weather service.

Therefore, it is recommended that a factor of safety of 1.25 be adopted when applying the results of this study. Any final decision concerning safe wind speeds should be made by the fire chief based on the results of this study, the urgency of the situation, and personal judgment.

Consequently, a classification of wind speeds is provided in the following table for each vehicle. The lower end of the Critical range is for wind speeds that will make driving the vehicle difficult. The upper end of the Critical range is for extremely dangerous driving conditions, and finally Seek Shelter indicates the wind speed for which this vehicle should not be driven, and parked indoors if possible.

The lower wind speed limit for Critical conditions for each vehicle was computed as the lowest critical wind speed from the tests that marks the onset of course deviation at a vehicle speed of 55 mph divided by 1.25, and rounded to the nearest multiple of 5.

	Critical	Seek Shelter
Fire Truck	**50**-70 mph	70+ mph
Ambulance	**30**-50 mph	50+ mph
Suburban (SUV)	**60**-70 mph	70+ mph

Table 5.1: Classification of wind speed driving conditions for each vehicle

It is the firefighter's job to routinely put the safety of others above their own. Regardless of the fact that it has been stated that it is unsafe to drive these vehicles in winds in the Critical zone, it is likely occur anyway. But there are some basic recommendations that can be done to ensure the safety of the personnel as much as possible. First ensure that the vehicles have good tires at all times. Secondly, send only experienced drivers into winds within the Critical zone. Finally; remember that the critical wind speed is a function of the speed of the vehicle.

Therefore, the information in Table 5-1 is repeated in Figures 5-1 to 5-3, where the Critical zone is divided into a Hazardous (yellow) and a Dangerous (orange) zone. If the vehicle must be operated in wind speeds in the Critical zone, slow down and make sure to drive slowly at vehicle speeds that will put you in the Hazardous zone. For example, at wind speeds of 60 mph, the graph of Figure 5-1 shows that a fire tuck should never be driven at speeds higher than 23 mph, and that extreme caution should be taken at speeds at or below 23 mph. It is recommended that under no circumstances should a vehicle be driven in wind speeds approaching the "Seek Shelter Category".

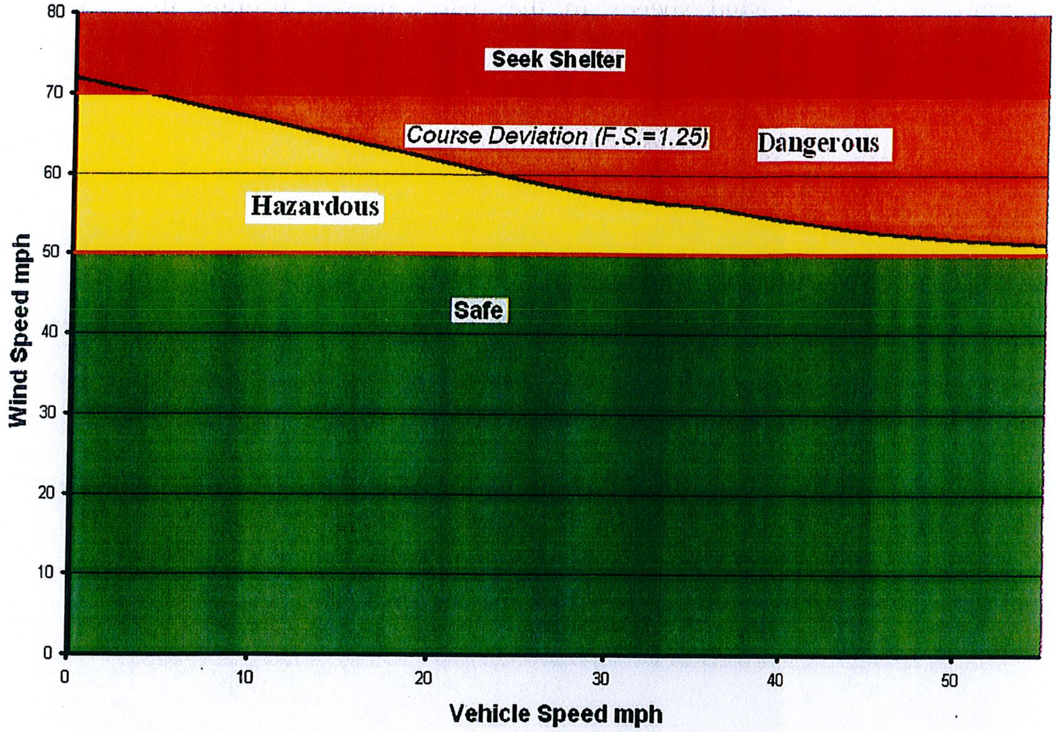

Figure 5-1: Wind speed- vehicle speed recommendations for the Typhoon fire truck

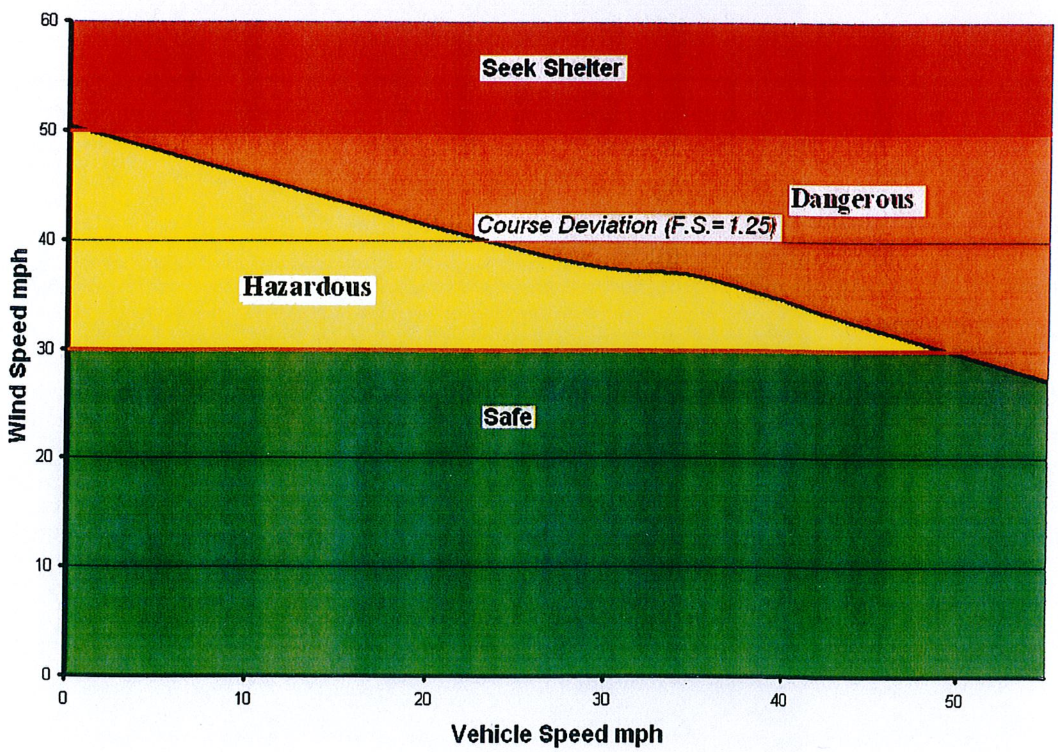

Figure 5-2: Wind speed – vehicle speed recommendations for a F-450 Type I ambulance

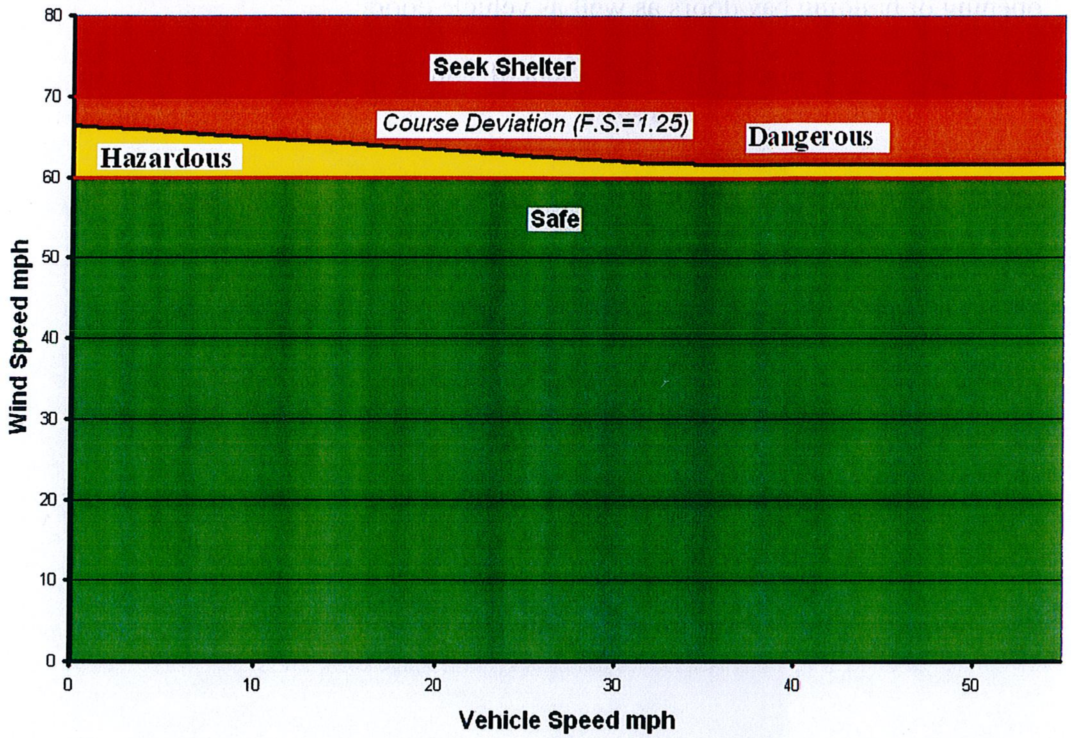

Figure 5-3: Wind speed – vehicle speed recommendations for a 4x4 ¾ ton Suburban (full of equipment)

5.6 RECOMMENDATIONS FOR FURTHER STUDIES

The project scope and objectives of this investigation was to define the upper limit wind speeds at which a fire truck, ambulance, and emergency SUV vehicle can operate safely. In a second phase, the investigative team could carry on similar studies on other types of vehicle such as:

- buses used to evacuate elderly residents or hospital patients,
- bucket trucks used by electric companies to fix line problems;
- types II and III ambulances;
- other law enforcement vehicles;
- trucks with aerial ladders.

Similarly, research could be carried out to define the upper limit wind speeds at which the overall safety of response personnel will not be compromised. Such a study could include impact tests of vehicles and related materials, and look at the issues of:

- flying debris, shattered windshields, and safety of personnel;
- protective clothing and equipment;
- effect of the rain;