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Some basic facts about ignition events during fueling of motor vehicles at filling stations

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The January 2005 issue of *The California Fire-Arson Investigator* contains a story (p. 20) on the legal aspects of a Louisiana case where the responsibility for a fire at a filling station was being litigated. The fire was a static-electricity-caused ignition of gasoline vapors, which led to burn injuries to an individual engaged in filling in his truck. While the story focuses mostly on the legal issues of that case, the presentation of the relevant physics will not leave the reader with a competent understanding of this—yet, to a fire investigator, understanding the fire physics should be at least as important as understanding legal issues. The problem is that the story presents a description of such ignition as a novel event and furthermore presents an erroneous account of static electricity. In fact, such an event is not novel and about 150 – 200 fires of this kind occur each year in the U.S. alone. In my recent **Ignition Handbook**[1], I have devoted a section to explaining some of the technical issues involved with these fires and I would like to summarize here some of the research that has been done on this topic and the salient findings of that research.

For an ignition to occur of gasoline vapors mixed in air, the mixture must be within its flammable range, which are approximately 1% to 7%. With rare exceptions of very cold climates, the interior of the fuel tank is above the UFL, while the outside atmosphere will be below the LFL, thus, once the gas cap is removed, a concentration must exist somewhere between the tank interior and the outside world which is within the flammable range. This flammable zone can surround the filler opening and extend some distance down the filler tube. If a spark occurs in that zone, a fire is likely to result, since an exceedingly small spark energy suffices to ignite gasoline vapors. In view of this innate hazard, there should be absolutely no surprise that accidents of this kind occur—perhaps we should be surprised that the probability of this occurrence is quite low.

Electrostatic charging can occur due to the flow of gasoline, as noted in the original story. But with the right combination of weather, clothing, and car-seat materials, getting in and out of the vehicle seat can cause substantial charging of the person, and this charge is not necessarily dissipated by grabbing a door handle, especially since in cases in many cases the resistance between the vehicle and ground may be very high. In the latter case, a third cause of charging also exists: the movement and braking of the vehicle on the pavement. Most of the incidents occur under low-humidity conditions, consequently, they are more prevalent in cold weather. A disproportionate fraction of these incidents (55% of the incidents where the ignition details are known) have involved an individual who re-enters and re-exits the vehicle during the fueling operation[2]; see Figure 1. But a substantial number of the fires (20%) have occurred while the person was initially in the process of removing the filler cap, prior to actual commencement of refueling.

It was of course completely wrong for the Court conclude that the clothing and the car seat could not have been involved in electrostatic charging because they were determined to be “poor conductors of electricity.” Hopefully, most CCAI members will know that precisely the opposite is true—rubbing two objects that are good conductors of electricity (e.g., metal against metal) will not result in electrostatic charging, but rubbing two electrical insulators (e.g., fabric against fabric or plastic) can well do so.

This charging effect explains why fueling is more likely to result in an accident if a person gets out of the vehicle, inserts the filler nozzle into the tank, then gets back into the vehicle, then gets out of the vehicle again to remove the nozzle. Since charging is caused each time by rubbing the clothing against the car seat, charging to a higher potential can occur if there are three actions of moving out, moving in, and moving out, instead of a single action of moving out. The individual who was injured in the case described, in fact, did re-enter and re-exit his vehicle. Also, in the case delineated in the story, the individual claimed to have first touched a metal part of his truck prior to beginning the filling; however, in the case of the re-entry/re-exit scenario, the individual would have to touch a grounded object *both* times upon going from the seat to the fueling area for this action to be of benefit.

German researchers have conducted extensive studies on the problem of static electricity-caused fires during fueling operations. Their study was published in an English language journal in 1997[3]; thus the basic information had been available to fire safety professionals even before the accident occurred in the year 2000. The study identified the major factors leading to ignitions as being:

- Cars using plastic filler tubes without proper bonding straps between metal parts of the filler neck and the car body. Flow of only a few liters of fuel was sufficient to create a voltage over 4 kV in this type of design.
- Inadequate grounding of the filling hose nozzle.
- Ground surfaces that are of excessively high electrical resistivity (often due to use of sealers).
- Tire rubber formulations that are vulcanized with SiO_2 and have very high resistivity.
- Static-prone seats in vehicles, allowing a high charge to be built up on a person moving in or out of the seat.

For German cars, the first of these factors was found to be the most significant in actual field incidents; but for accidents in the U.S., this would not necessarily apply, since the models with this defect were primarily German-made cars that were recalled.

A British study[4] found that a single action of getting out of a car seat can charge an individual to over 15 kV, although 5 – 8 kV values were more typical. Other studies have shown that charging an individual to around 6 kV can suffice to produce an incendive spark[1].

Contrary to the thinking evidenced in the case discussed, in terms of responsibility, there can be at least three parties involved—the person doing the fueling, the filling station operator (or designer), and the car manufacturer. However, whether a condition is or is not a defect may not necessarily easily be established, since, for the last three factors listed above, there are no generally-accepted design guidelines.

In terms of the responsibility of the individual doing the refueling, the American Petroleum Institute issued a widely-publicized press release[5] on February 3, 2000, specifically warning (in bold-letter type): “Do not get back into your vehicle during refueling.” Their press release also emphasized that if for some reason the person does have to re-enter the vehicle, “Discharge the static electricity buildup when you get out by touching the outside metal portion of your vehicle, away from the filling point, before attempting to remove the nozzle.” If a flash fire does occur, the individual should *not* attempt to remove the nozzle; many incidents which would have been minor became tragic because the person attempted to remove the nozzle and caused a large amount of liquid gasoline to thereby be splashed on themselves.

Figure 1 Driver starts fueling, re-enters car, re-exits car, approaches nozzle, sparks a gasoline vapors fire
(Courtesy Purdue University)

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