VEHICLE FIRE BURN PATTERN STUDY Part 2

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ABSTRACT

Vehicle fire investigation is one of the primary aspects in the profession of fire analysis. Few studies have been completed in analyzing the creation of and documentation of various fire patterns with vehicles. However, no study had sought to test and determine the reproducibility of fire patterns used for vehicle fire scene investigations. Although some of these studies have been subjected to peer review, the purpose of this research was to evaluate the reproducibility of fire patterns used by investigators in the determination of origin and cause, as well as to evaluate the contents of Chapters 6 (Fire Patterns) and Chapter 25 (Motor Vehicle Fires) of National Fire Code Component document NFPA 921-*Guide for Fire & Explosion Investigation,* 2011 edition [9]. This paper is to serve as a primer for further study on the use of fire patterns to determine origin during motor vehicle fire analysis.

These test burns were conducted in Georgetown, Kentucky at the Scott County Fire and Rescue Training Facility. Key questions to be addressed by the research burns were: (a) second round of reproducibility of patterns in minimal variable testing methods, and (b) reaffirmation of standard vehicle fire pattern analysis methodologies, such as heat and flame vector analysis.

INTRODUCTION

Fire investigators have relied upon fire patterns (the geometric shapes and the effects of fire on materials) as their basis for determining the place where a fire started (origin). Examination of the exterior may reveal significant fire patterns. The location of the fire, and the way that the windshield reacts to it, may allow a determination of the compartment of origin. Engine compartment fires may spread into the passenger compartment through preexisting penetrations in the bulkhead, and typically will cause a failure at the bottom of the windshield often on the passenger side. A passenger compartment fire will frequently cause failure at the top of the windshield and will leave radial fire patterns on the hood indicative of fire spread from the base of the windshield. Other patterns that may be looked at are oxidation effects, as well as heat effects and burn patterns on other exterior parts of the vehicle (NFPA 921, 2011)[9].

Cole (2001) states that at the beginning of a motor vehicle fire our most important consideration must be to identify the origin.[1] In most situations, the fire investigator is required to determine the origin or point of origin of a fire by utilizing the physical evidence left by the fire, or the visible and measurable effects of the fire (fire patterns). Fire origin determination is a key component of the investigation process, and is largely related to fire pattern recognition and analysis. Several studies have been performed on fire patterns reproducibility and persistence in full scale room burns and various single fuel packages, but none which have focused on patterns in vehicles. [2,3,4,5,6,7]

Morrill (2006) recognized that the field of vehicle fire investigation is "probably one of the fastest growing aspects of what fire investigators are being asked to do. Vehicles are one of the highest priced assets most people have with the exception of their residence. The accurate determination of the compartment of origin is one of the first steps the investigator must perform".[8] Any vehicle fire origin determination begins with the observations and analysis of fire patterns. Heat, smoke, and flames will change the base material by consumption, distortion or discoloration. The interpretation of these patterns is what allows the investigator to make statements as to the origin, intensity and movement of the fire. [8] The windshield is very useful in the determination of the fire's compartment of origin. In most interior vehicle fires the windshield will fail at the top first and lay down across the dash panel. Even in a "total burn," often evidence of the lower edge of the windshield can be seen. Interior compartment fires will also leave radial burns patterns that extend onto the hood and trunk. Radial burn patterns are also often found on door and fenders of the vehicle. Engine compartment fires will fail the windshield at the bottom first and usually will not lie across the dash. They also typically pass through the passenger side bulk head due to larger openings than on the driver side.

NFPA 921 (2011) recognizes that the fire or damage patterns remaining on the body panels and vehicle frames, and in the interior of the vehicle are often used to locate the areas or point(s) of origin and for cause determination.[9] NFPA 921 goes on to recognize that examination of the exterior may reveal significant fire patterns. As such, a better understanding of the reliability of fire patterns is necessary, as limited studies have been published on the subject. In order to better understand the use of fire patterns in vehicle fire origin determination, a series of test burns were preformed in September 2009 during the National Association of Fire Investigators Vehicle Fire, Arson, and Explosion Investigation Training program. This seminar had many co-sponsors, which are listed at the end of this paper.

During this seminar, 15 vehicles were burned, with 6 of the burns being performed in experimental sets, and documented by both still and video photography. These vehicles were donated by Volkswagen, Audi, and Chrysler. The three sets of the test burns were monitored with thermocouples, and the results of which are presented in this paper in Figure 12. Although this paper focuses on the use of patterns to determine compartment of origin, ignition scenarios were developed for each burn for the sole purpose of examination by attendees enrolled in the seminar, and not to attempt to recreate any specific type of previous failure event.

DOCUMENTATION

Each vehicle was photographed before, during ignition, during the test fire, during suppression and after the fire had been extinguished prior to being disturbed. Each test burn was videotaped, with several series being taped from two different angles to facilitate review of the burn for purpose of further analysis of fire pattern development.

Thermocouples were placed in various locations in each experimental sets of vehicles, and this data is provided at the end of this paper as Figure 12. These locations, which are listed specifically in the results section of each burn, included steering wheel, front of dashboard, interior roof, rear window and at the point of ignition. Additionally, temperature data was collected from bulk heads and compartment separation points as required by the scenario of the burn. This data was collected in excel spreadsheets which are represented in this paper as line graphs.

BURN SCENARIOS

Each vehicle had debris removed for safety reasons as well as to prevent any additional fuels that were not native to the vehicle from influencing the patterns produced. Three sets of the vehicles were paired based on similarity in manufacture and design. The vehicles that were paired were two Dodge Chargers series, a Volkswagen Passat series with an Audi A4 series, and two Audi A6 series. The Dodge Chargers were ignited in the interior while the vehicle was running to facilitate the comparison of an interior fire. The Volkswagen Passat and Audi A4 were ignited in the engine compartment, whereas the Audi A6's were ignited in the cargo department.

FIRE SUPPRESSION METHODOLOGY

During these live fire activities, only IFSAC or PRO Board Certified experienced firefighters were utilized. A 2005 Pierce Pumper was utilized and was supplied by a Ford Tanker both owned by Scott County Fire & Rescue. Two 1 ¾ inch lines were manned by two firefighters on each line, one as the primary suppression team and the other as back up team. Knockdown was accomplished with a combination nozzle, being supplied at 100 psi at the tip. Suppression personnel were instructed to minimize water damage and to focus on the fuel packages.

RESULTS

EXPERIMENT SET #1

In this first set of test burns, two similar vehicles were utilized, a 2009 Dodge Chargers (Figure 1) and a 2011 Dodge Charger (Figure 2). Both of these vehicles were ignited by a propane torch in the rear passenger compartment just behind the center console. Similar fire patterns were found within both of these vehicles indicating an interior compartment fire origin. These patterns included the following. The windshields started to fail at the top first as evidenced by the extensive oxidation and the cracking of the glass along the top frame. There was minor heat damage in the engine compartment indicating that the fire origins were not in the engine compartment. The elevation of oxidation damage along the roof and the A & B posts indicate that fire progressed from the interior to the exterior of the vehicles. The rear passenger areas sustained more fire damage than the front driver and passenger area, which indicated that the fire was toward the interior rear of the vehicle.

Figure 1-2009 Dodge Charger

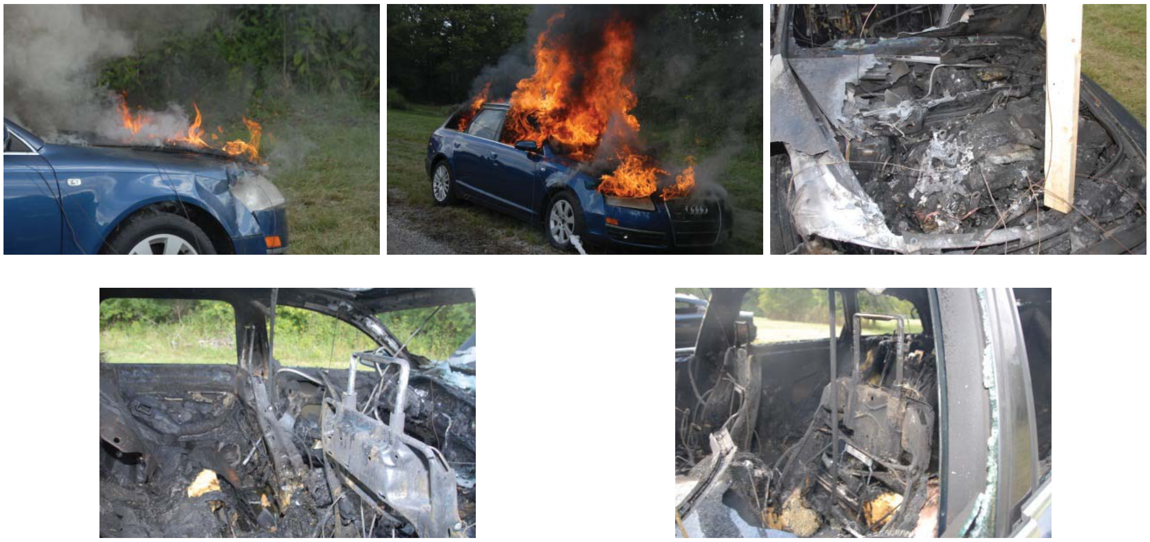
Figure 2-Black 2011 Dodge Charger

EXPERIMENT SET #2

In this second set of test burns two similar vehicles were utilized, a 2006 Volkswagen Passat (Figure 3), and a 2006 Audi A4 (Figure 4). Both of these vehicles were ignited by a propane torch in the engine compartment. The Passat was ignited near the bulkhead on the driver side, whereas the A4 was ignited on the passenger side near the bulkhead. Fire patterns within these vehicles indicated that the fire originated in the engine compartment. The following patterns were observed that supported this observation. The windshields failed at the base which can be indicative of an engine compartment fire. Oxidation patterns indicate that the fire progressed from the engine compartments and into the passenger compartment from the windshield and bulkheads. The hoods for both vehicles have circular patterns moving away from the area directly above where the fire was ignited. The hood for the Audi A4 was partially consumed on the passenger side. The engine compartment sustained a greater amount of mass loss than anywhere else in the vehicle. Both vehicles had the greatest degree of oxidation found on the hood. Based on these observations found, the area of fire origins of these vehicles was in the engine compartment.

Figure 3-2006 Volkswagen Passat

Figure 4- 2006 Audi A4



EXPERIMENT SET #3

In this third set of test burns, two similar vehicles were utilized, a 2006 Audi A6 (Figure 5) and a 2005 Audi A6 (Figure 6). Both of these vehicles were ignited by a propane torch in the storage compartment. Hay and paper was used to help fuel the fire. Fire patterns within these vehicles show that the fire originated in the cargo compartment. These patterns included the following. Consumption of furniture material the interior show more fire damage to the rear passenger compartment than to the front passenger compartment. Oxidation patterns indicate that fire progressed from the cargo compartment to the interior passenger compartment. The back window started to fail at the top, indicating a fire progressed into the passenger compartment. The cargo compartment sustained the area of most mass loss. Both vehicles had the greatest degree of oxidation to the cargo area. Based on these observations found, the area of fire origins of these vehicles was in the cargo compartment.

Figure 5-2006 Audi A6

Figure 6-2005 Audi A6

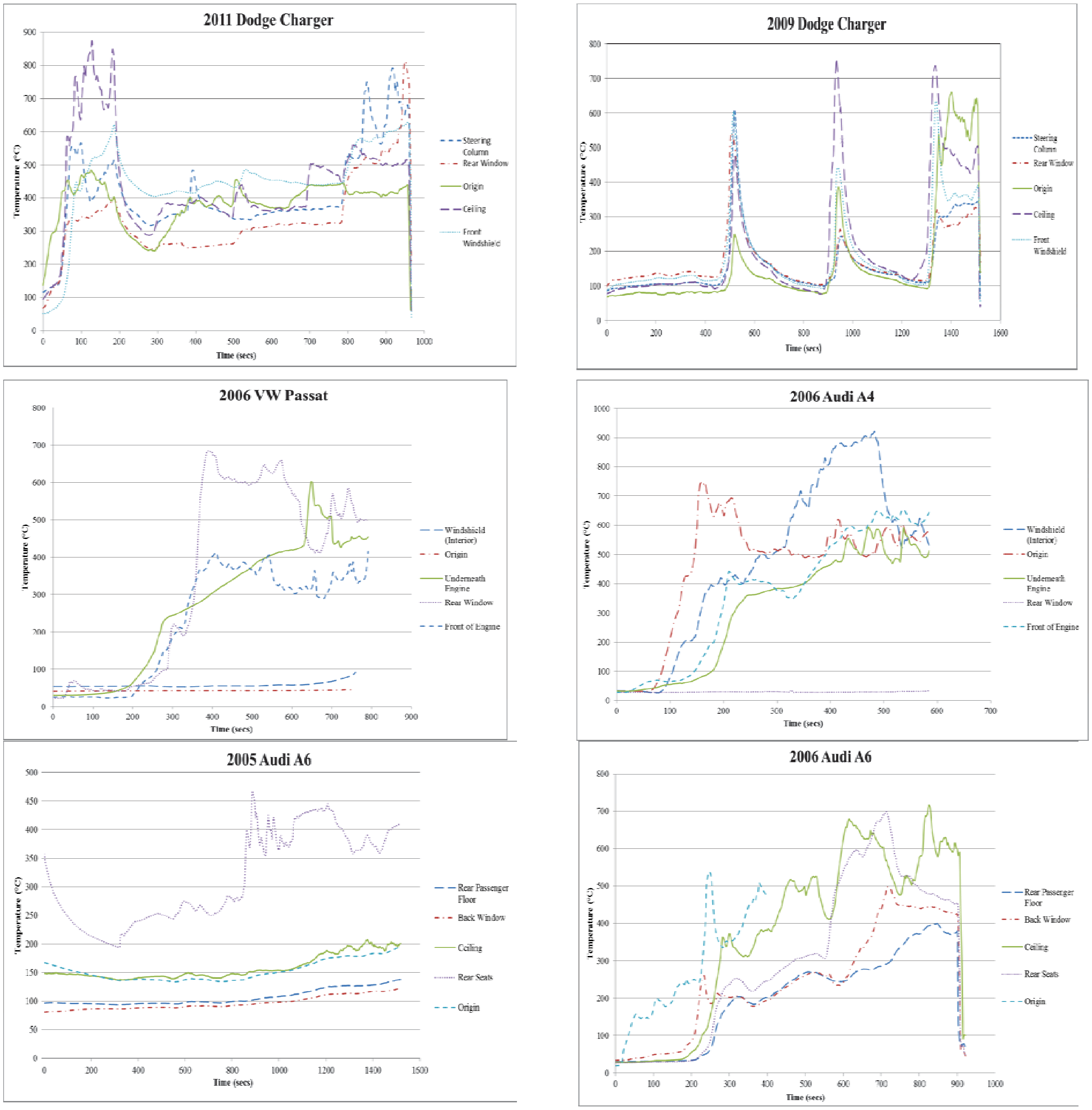
CONCLUSIONS

Fire patterns are recognized as a valuable tool for analysis of motor vehicle fires. The use of fire patterns must be cultivated with knowledge of fire dynamics, fire pattern development and the variables which affect pattern production, such as ventilation, fuel and witness surface characteristics and the passive and active systems designed into the motor vehicle. Further study of the patterns produced by motor vehicles is necessary to build a base of knowledge for utilization in the profession. Vehicles are just as necessary in everyday life as are homes, and as we use fire patterns to determine point of origin in homes, and we should be able to do the same with motor vehicles. The most important finding from these burns is that patterns provide substantial evidence for the accurate identification of the correct area of origin.

The fire patterns found within each test burn, whether it was in interior compartment fire, engine compartment fire, or storage compartment fire was all consistent in the reproducibility of the patterns. All interior compartment fires showed evidence of failure at the top of the windshield. Radial burn patterns and oxidation, was also found either on the hood, roof, doors and truck, and was consistent of what you would find in an interior, engine, or exterior fire origin. Engine compartment fire origins showed us that failure at the bottom of the windshield was consistent throughout, along with the fire patterns whether they were radial fire patterns and oxidation. The storage compartment fire origins showed us that radial patterns can be produced and will also affect the windshield the same way it does in an interior compartment fire. The fire patterns found within all of the test burns can be reproducible and were consistent within each of the test. The patterns found were also indicative of what can be typically found depending on the compartment of origin which has been set forth by NFPA 921 (2011).

Additional research is needed and as of this time, we plan to expand the scope of the current research. These changes will include moving the origin within the compartments, and analysis of the persistence of fire patterns well after burn to completion. The patterns that develop during a single compartment fire will then be compared to patterns after a complete burn of the vehicle to identify similarities.

Figure 7-Thermocouple Data For Experiment Sets 1-3



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END NOTES

[1]Cole, L., "Investigation of Motor Vehicle Fires", Lee Books, 2001, p. 27
[2]Kennedy, P., and J. Shanley. "USFA Fire Burn Pattern Tests — Program for the Study of Fire Patterns." FA 178, 7/97 (Federal Emergency Management Agency, United States Fire Administration, Emmitsburg, MD, 1997).
[3]Milke, J.A., and Hill, S.M. "Full-Scale Room Fire Experiments Conducted at the University of Maryland.", NIST GCR-96-703, National Institute of Standards and Technology, October 1996.
[4]McGarry, A.J., and Milke, J.A. "Full-Scale Room Fire Experiments Conducted at the University of Maryland.", NIST GCR-97-716, National Institue of Standards and Technology, March 1997
[5]Putorti, A.D. "Full-Scale Room Burn Pattern Study.", NIJ Report 601-97, National Institute of Justice, December 1997.
[6]Hicks, W. Gorbett, G., Hopkins, R., Kennedy, P., and Abney, W., "Advanced Fire Pattern Research Project: Single Fuel Package Fire Pattern Study, ISFSI 2005 Proceedings,
[7]Gorbett, G., Hicks, W., Hopkins, R., Kennedy, P., (2006). *Full-Scale Burn Patterns Study*. ISFSI: Cincinnati, OH.
[8]Morrill, J., (2006). "Vehicle Fire Pattern Recognition", Full-Scale Burn Patterns Study. ISFSI. Cincinnati, OH.
[9]National Fire Protection Association, "NFPA 921 Guide for Fire and Explosion Investigations", 2011 Edition, NFPA: Quincy, MA.