VEHICLE FIRE BURN PATTERN STUDY

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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 prove 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,* 2008 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) 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, 2008)[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 (2008) 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, 17 vehicles were burned, with 11 of the burns being performed in experimental sets, and documented by both still and video photography. These vehicles were donated by Volkswagen, Audi, Chrysler, and Mercedes- Benz. Three of the 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 3 of the 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 vehicle exhaust manifold, the top of the engine, at the head rest of the driver's seat, and below the engine by the exhaust. 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. Five sets of the vehicles were paired based on similarity in manufacture and design. The vehicles that were paired were two Audi A5/S5 series, two Audi TT series products, two Audi A4 series, three Chrysler products, and two Mercedes R series products. Ignition location of the pair of Mercedes, Audi TT series, and the Chrysler products was maintained as close as possible in order to facilitate pattern reproducibility. The Audi S5 and A5 products were ignited at opposite ends of the vehicle to facilitate the comparison of an exterior fire. The Audi S5, A5, TT's, Mercedes, and Chrysler vehicles were able to start and continue running during the tests.

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 2006 Mercedes R500 (Figure 1), and a 2006 Mercedes R350 (Figure 2). Both of these vehicles were ignited by an acetylene torch on the driver side floor next to the center console. Similar fire patterns were found within both of these vehicles showing us an interior compartment fire origin. Some of these patterns included the following. The windshields failed at the top first as evidenced by the extensive oxidation and lack of any glass shards along the top frame, and layed down across the dash panel. 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 front (driver/passenger) areas sustained more fire damage than the rear passenger area, which shows us that the fire was toward the interior front of the vehicle. Oxidation on the vehicles also shows us that the fire progressed from the interior to the exterior.

Figure 1-Silver 2006 Mercedes R350 Burn Data

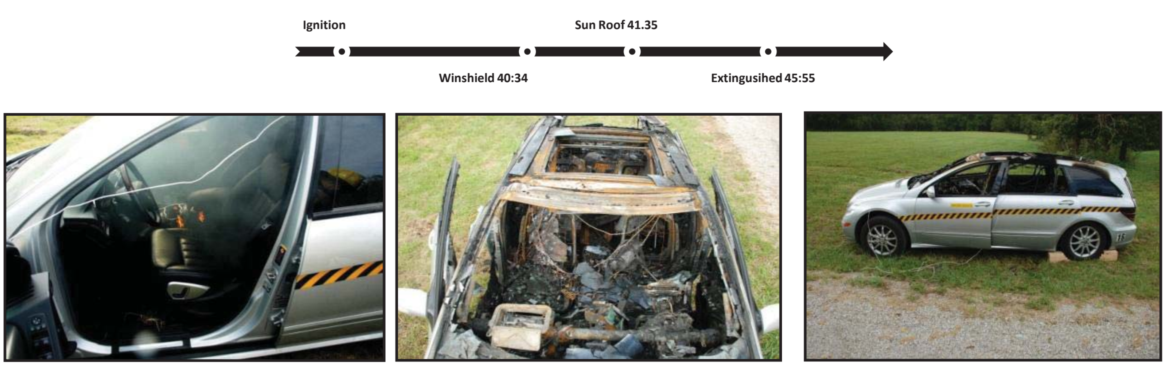
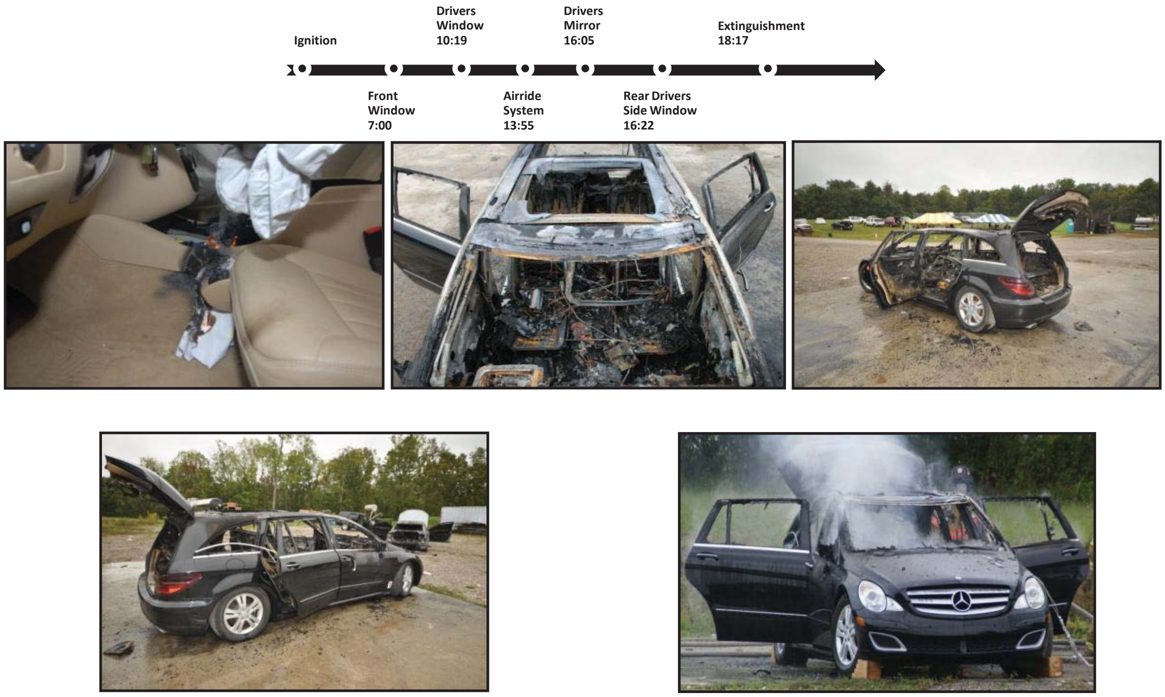


Figure 1-Silver 2006 Mercedes R350 Burn Data Cont.

Figure 2-Black 2006 Mercedes R500 Burn Data



EXPERIMENT SET #2

In this second set of test burns two similar vehicles were utilized, a 2008 A5 (Figure 3), and a 2009 Audi S5 (Figure 4). Both of these vehicles were ignited by a propane torch on the exterior of the vehicle. Ignition of the Audi S5 was the front right bumper of the vehicle, whereas the A5 was ignited on the right rear bumper. With the Audi S5, fire patterns show that the fire progresses from the exterior right front bumper into the engine compartment and interior of the vehicle, evidenced by the oxidation and radial patterns on the hood being greatest near the front passenger corner with lesser damage moving towards the passenger compartment. Fire damage in the engine and passenger compartments was minimal, indicating that the fire did not originate in either compartment. The windshield in this showed us that it failed on the bottom of the passenger side. The Audi's A5 fire patterns show that the fire progressed from the vehicles right rear exterior bumper and progressed into the trunk and engine compartment. This conclusion was made by looking at the oxidation and burn patterns on the vehicle. The most extensive damage was low on the vehicle and progressed up the vehicle towards the interior where less fire damage and oxidation was found. The rear window on the A5 sustained more damage on the passenger side than the driver side. The passenger's side of both vehicles has more damage than the driver's side (Figures 3-4).

Figure 3-Black 2008 Audi A5 Burn Data

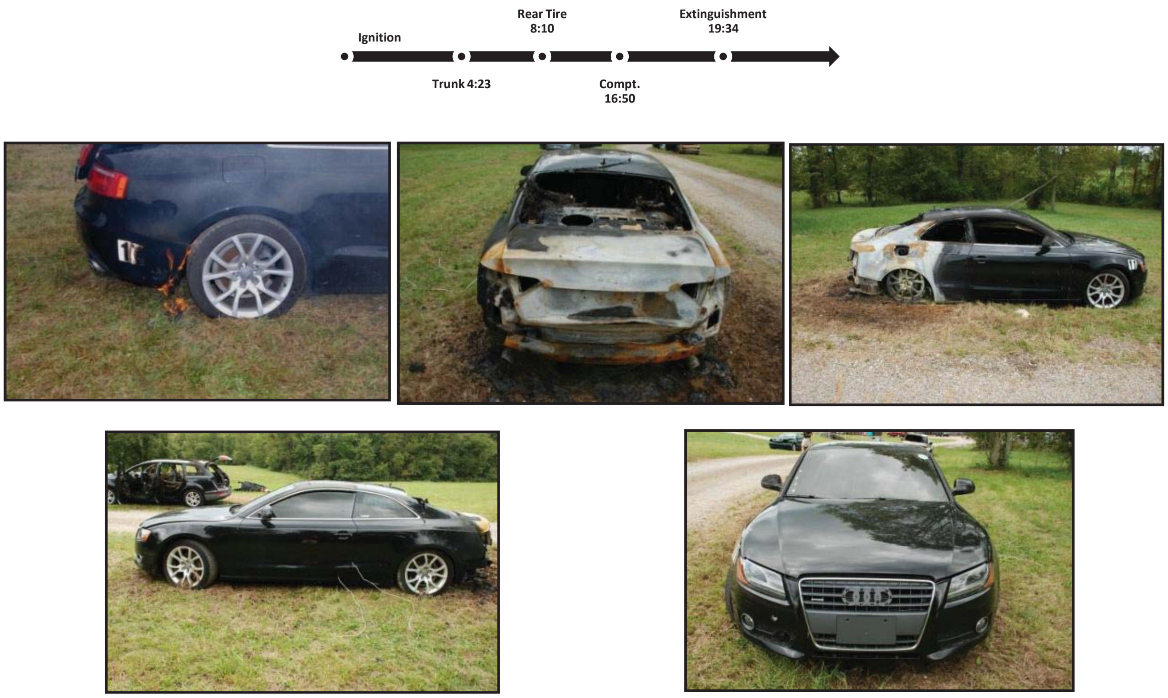


Figure 4-Silver 2009 Audi S5 Burn Data

EXPERIMENT SET #3

In this third set of test burns, three similar vehicles were utilized, a 2008 Jeep Grand Cherokee (Figure 5), a 2008 Jeep Liberty (Figure 6) and a 2008 Dodge Nitro (Figure 7). All three of these vehicles simulated a fuel line leak under the hood. The fuel line was cut near the bulkhead, and the vehicles were started. The fuel was then ignited by a propane torch. Fire patterns within these vehicles show that the fire originated in the engine compartment. These patterns included the following. 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 side of the windshields. The hood on the Jeep Cherokee has a hole burned through indicating a significant loss of mass. All three had the greatest degree of oxidation found on the hood. Based on these observations found, we can say that the area of fire origins of these vehicles was in the engine compartment.

Figure 5-Green 2008 Jeep Cherokee Burn Data

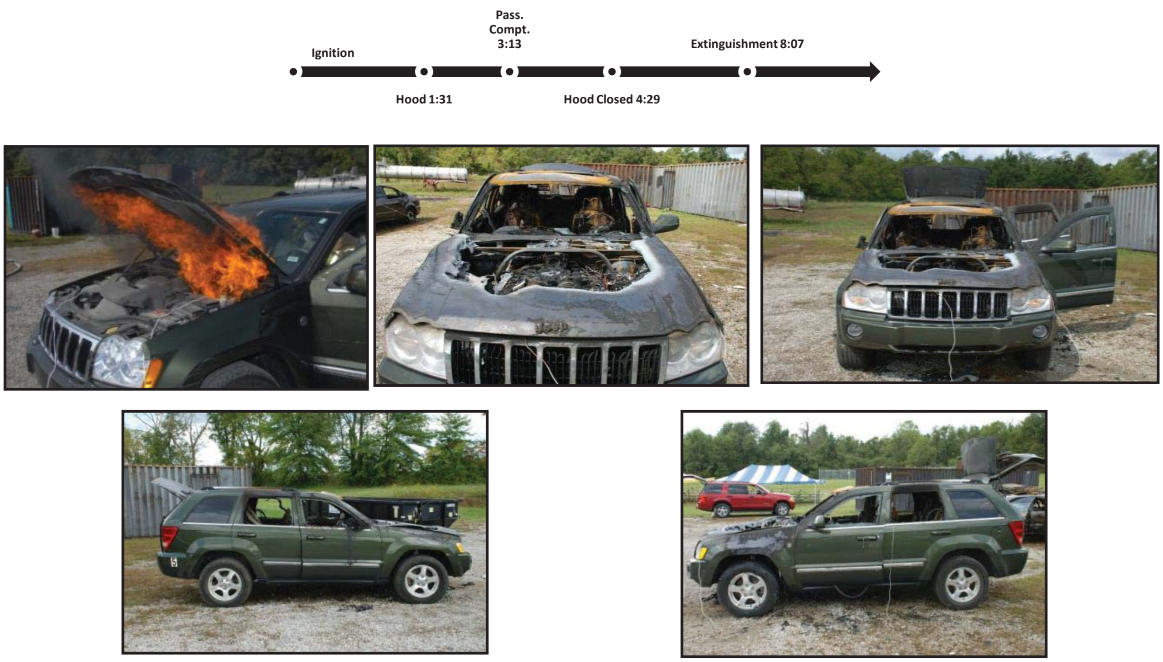


Figure 6-White 2008 Jeep Liberty Burn Data

Figure 6-White 2008 Jeep Liberty Burn Data Cont.

Figure 7-Black 2008 Dodge Nitro Burn Data

EXPERIMENT SET #4

In this fourth set of test burns, two similar vehicles were utilized, a 2002 Audi TT (Figure 8), and a 1999 Audi TT (Figure 9). This set of burns utilized an interior fire located behind the driver's seat. Paper was utilized as the first fuel ignited by a propane torch. These two vehicles show almost identical fire patterns on the exterior of the vehicles showing us an interior fire origin. These patterns include the observation that the paint on the roof of both vehicles is burned away, and oxidation is visible on both roofs. Both vehicles have lost the rear window. The windshields of both vehicles show that the top failed first and laid down on the front dash, which recognized in NFPA 921 as being an indication that the fire was a passenger compartment fire (NFPA 921, 2008 25.8.1.1). The heaviest amount of fire damage is found to be in the interior of the vehicles. Based on these observations, it can be said that the origin of these fire is an interior origin.

Figure 8-Blue 2002 Audi TT Burn Data

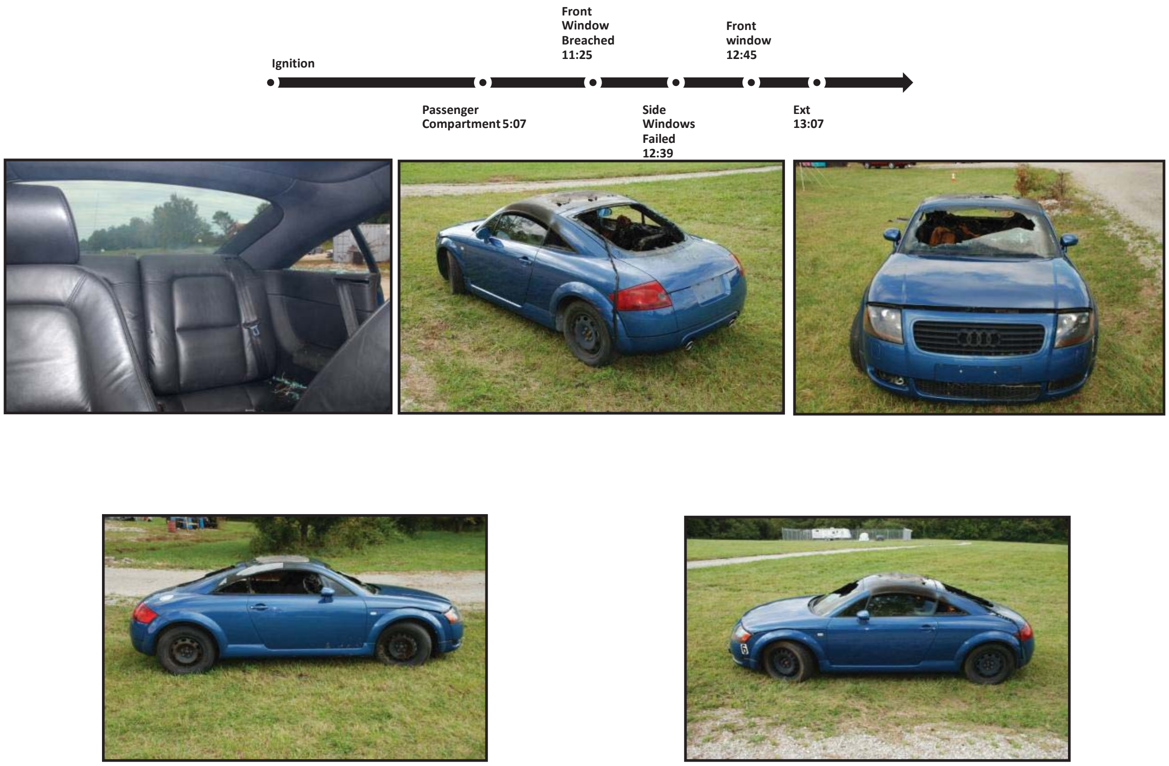
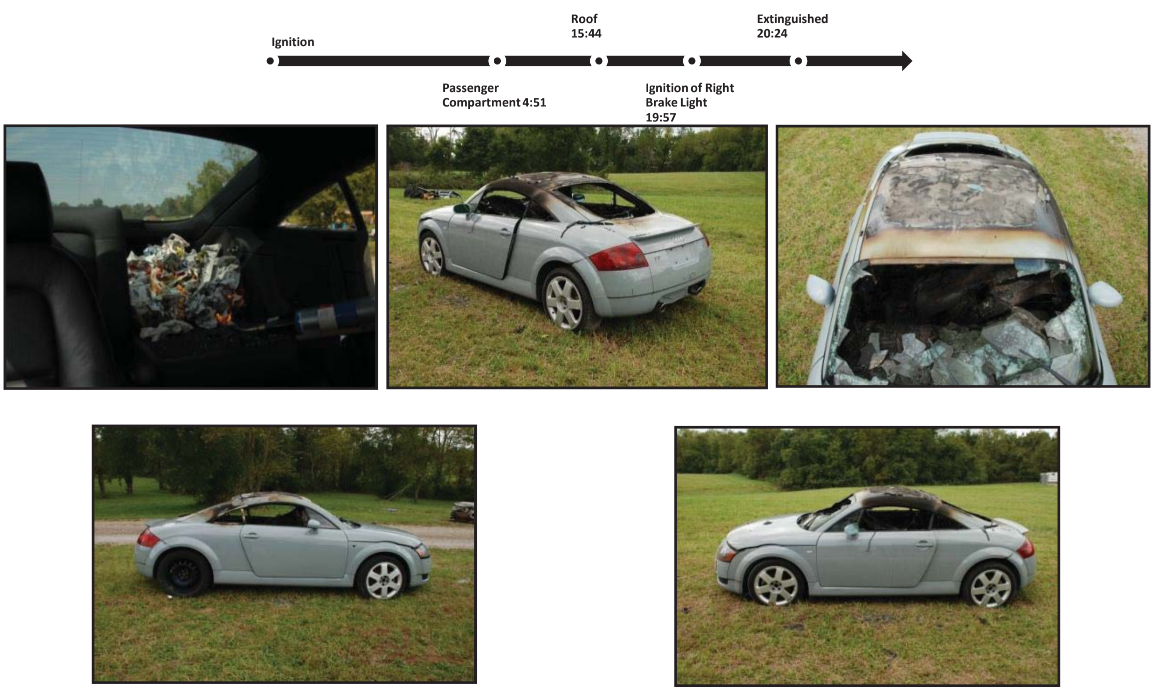


Figure 9-Silver 1999 Audi TT Data



EXPERIMENT SET #5

In this fifth set of test burns, two similar vehicles were utilized, a 2001 Audi A4 (Figure 10), and a 1998 Audi A4 (Figure 11). This set of burns utilized an interior fire placed in the back seat on the floorboard of the passenger's side seat. Paper was utilized as the first fuel and ignition was by a propane torch. These two vehicles show almost identical fire patterns on the exterior of the vehicles showing us an interior compartment fire origin. These patterns included the following observations. Oxidation patterns can be seen on the roof of both vehicles and the rear passenger doors. Radial patterns were also found on the rear doors and top of the trunk of both vehicles which can be an indicative of an interior fire origin. The windshield of these vehicles failed only at the top. There was no fire damage found in the engine compartment, thereby eliminating it as the area of origin.

Figure 10-Brown 2004 Audi A4 Burn Data

Figure 11-Green 2001 Audi A4 Burn Data

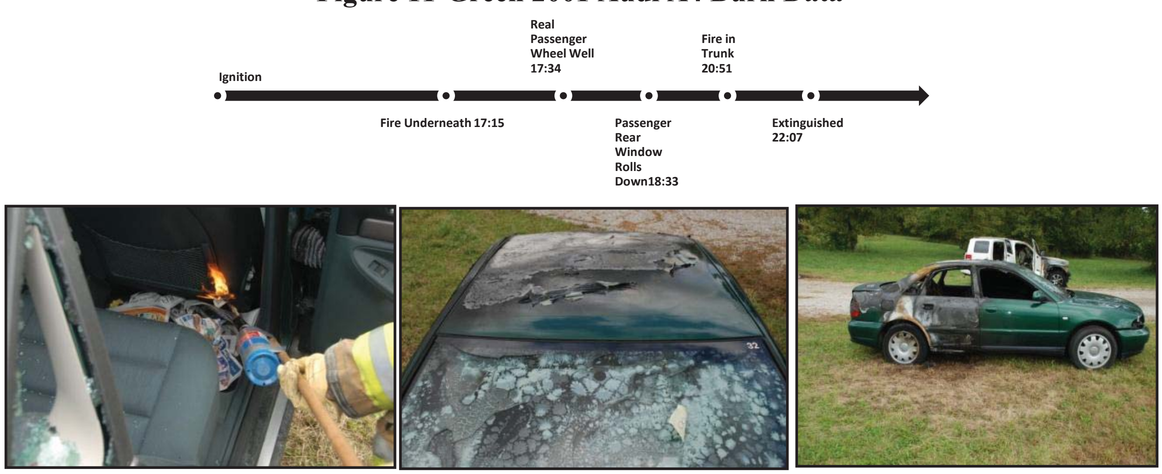


Figure 11-Green 2001 Audi A4 Burn Data Cont.

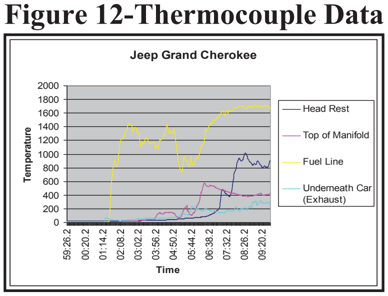
CONCLUSIONS

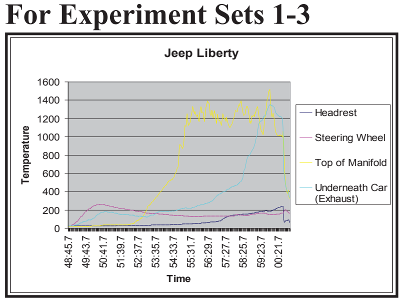
Fire patterns are recognized as a valuable tool for analysis of motor vehicle fires. The use of fire patterns must be cultivated with knowledge of fire dynamics, fire pattern development and the variables which affect pattern production, such as ventilation, fuel and witness surface characteristics and 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 exterior 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 exterior fire origins showed us that radial patterns can be produced and will also affect the windshield the same way it does in and engine 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 (2008).

Additional research is needed and as of this time, we plan to expand the scope of the current research. Changes will include moving the origin within the compartments, and analysis of the persistence of fire patterns well after burn to completion.

Figure 12-Thermocouple Data For Experiment Sets 1-3





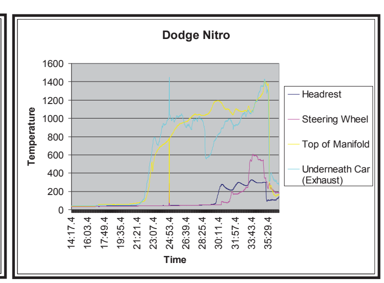
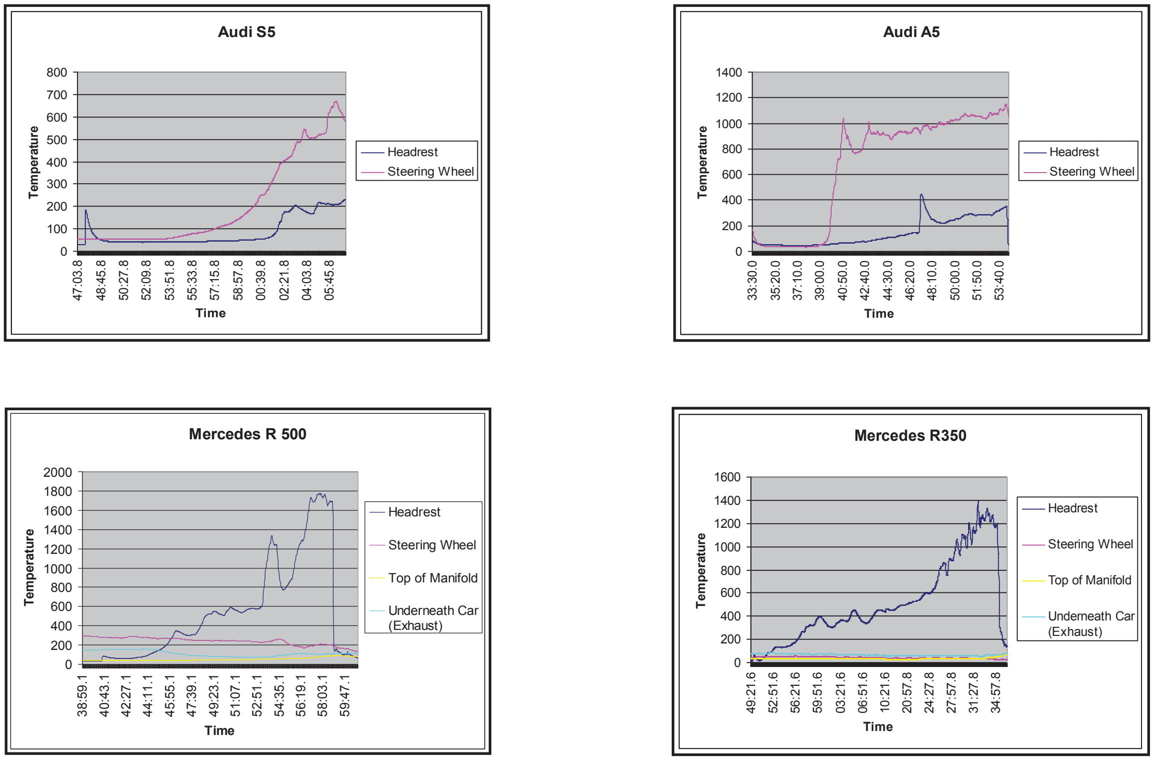


Figure 12-Thermocouple Data For Experiment Sets 1-3 Cont.



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END NOTES

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