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Traces of Fire in Cases of Car Self-Ignition[1]

Abstract : *Criminalistic and forensic processing of vehicles damaged by fire is a specific field of crime scene investigation because the situation in terms of traceology is significantly different from the ones encountered when investigating other events and criminal offences. Due to the relatively small space of the car and a comparatively high density and flammability of fuel and other materials contained in it, the speed of development and the intensity of fire on such vehicles can be very high. This contributes to the fact that many traces that may indicate possible causes and origins of fire may be largely or completely destroyed. Bearing in mind this danger, but also the transience and unrepeatability of certain phenomena, it is very important to promptly arrive at the scene of fire and quickly extinguish it, as well as to monitor and record the development of fire, observing its characteristics. In addition to this, it should be borne in mind that in these situations the possibilities of proving by personal sources of evidence is minimal, so that criminal investigation must be based on material evidence collected during the crime scene inspection. The paper aims to point out specific traces in cases of spontaneous car combustion, particularly in cases where fire started in the area around the engine and in the passenger area.*

Keywords*: car, fire, self-ignition, trace, (crime) scene.*

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Introduction

The Serbian language uses two different terms to denote fire - *vatra* and *požar* and these are frequently regarded to be synonymous as both of them relate to the process of burning – the chemical process in which chemical substances combine with oxygen from the air, usually giving off intense light, heat and smoke. Yet a distinction can be made between the two terms given the fact that *vatra* denotes the process of burning controlled by humans, whereas *požar* is the process of burning over which man has no control (Marinković, Lajić, 2019:431, Radmilović, Kolar - Gregović, 2010:50). From the aspect of crime investigation, the central question is that of what causes fire? Considering the issue of fire causes and starting from the fact that it is not possible to list and explain all of them, we can observe them from the aspect of human activity and divide them into those originating without the influence of the human factor and those caused by man (Bošković, 1998:193). The latter are natural causes, whereas the former can be divided into accidental (non-intentional) causes and intentional causes of fire, as is the case with arson. This implies that not all cases of fire are criminal offences, but only those caused by human activity or failure to act, whether negligent or intentional.

Fire on motor vehicles represents a specific area of research in the scientific field of fire protection (Zigar, Blagojević, Radovanović 2017:107), but also in the field of crime investigation sciences. The Serbian national crime investigation practice notes examples of self-ignition of vehicles wherein the causes of fire are of technical nature, but also intentional or criminal fire – car arsons, caused by conscious or premeditated action driven by various motives, in different manners, and aimed at destroying property. The motives of these criminal actions can be varied: revenge for a range of insignificant reasons (altercation, fight, jealousy, envy), covering up another criminal activity (theft, murder, embezzlement), intimidation, extortion, pyromania (Radmilac, Jovanov, 2000: 78), warning, threat, etc.

From the technical and technological aspects, the causes of fire are most frequently classified according to the manner of transfer or production of heat (electric power, static electricity, mechanical causes), including spontaneous combustion (self-ignition) which denotes the combustion of matter without the presence of external source of ignition due to self-heating which results from chemical, physical or biological

processes. Self-ignition as a process of spontaneous combustion of a car is a purely physical process, which fundamentally distinguishes it from self-combustion of biological mass (hay, cereal, and other biological matters), wherein the process is of biological origin.

From the aspect of crime investigation, the most important step is to establish the cause of fire. According to research conducted in Croatia, some relevant data have been obtained regarding the dynamics of fire on cars. According to the results of these studies, glass breaks/explodes after 5 to 6 minutes from the outbreak of fire, tires start burning after 15 to 20 minutes, when explosions are also heard, the vehicle burns down completely after 30 to 35 minutes, whereas the fire spontaneously extinguishes itself in 60 to 70 minutes (Peruško, Belaš, 2017:42). These time periods, along with other collected data, can be very useful later for establishing the cause of fire. Additionally, when we speak about fires on cars, all causes of fire in terms of criminal investigation can be divided into two large groups: self-ignition and arson.

Bearing in mind that criminalistic and forensic investigation of the scene of fire is one of the most significant activities within investigations in cases of fire on vehicles, the intention of this paper is to give an overview of the most frequent traces of fire in cases of spontaneous combustion of cars. Experts in the field of establishing causes of fire on cars must focus exclusively on material evidence and it is their sole guidance in the process of establishing the cause of fire. They must possess extensive knowledge in various scientific fields (chemistry, electronics, mechanical engineering, traceology). They must also possess substantial knowledge of the structure of the car and its functioning, and a lot of experience in detecting and recognition of traces at the scene of fire.

Vehicle self-ignition

Self-ignition of cars due to technical defects is very rare, but it does occur in practice. Spontaneous combustion may start while the vehicle is on the move, with the engine on, as well as when it is parked and the engine is not in the working regime. The task of an expert investigator is always the same – to establish the cause of fire.

The causes of self-ignition of the vehicle can be of threefold nature: defects on electrical installations, technical defects on the mechanics of

the vehicle, and improper use of the vehicle on the part of the owner.

The most frequent cause of spontaneous car combustion is the defect on electrical installation. As the car industry developed, it accumulated more and more technical devices and electronics, which was not used in the past. Modern cars offer more possibility for fire outbreaks because of more power circuits, devices and electronics under voltage, even when the engine is off. For instance, these novelties include:

- engine fan;
- central lock;
- anti-theft systems;
- direction indicators and the alarm system;
- devi ces for passenger comfort enhancement, such as interior lightin g, modern high-performance audio and video devices (Peruško, Belas, 2010:113).

This list should by all means include the increasing use of polymers for enh ancing the performance of cars, which also increases the likelihood of fire outbreaks and greatly influence the development and movement of fire.[2]

The dev elopment of new electric installations with voltage of 42V has been dictated by the world's largest car manufacturers, along with the largest producers of components for these installations. This means that higher voltage, more electronic devices, and more electrical installations increas e the risk of fire outbreak. Mechanisms of defect occurrence on electrical installations are varied and may be caused by vibration, friction, unskilled repair, modification, aging of material, physical damage, rodents, and the like. Defective electric installations can certainly result in fire that can lead to partial or complete damage on the vehicle.

2 A modern car today may contain up to 13 different polymers, the following three being prevalent: polypropylene (32%), polyurethane (17%), and PVC (16%), which account for approx. 66% of the total plastic used in the car.

***Photograph 1**. Traces of short circuits - causes of fire*

The causes of fire can include: overheating of electric conductors, coils or other devices that conduct electrical power, a short circuit, sparks, and electrothermic devices (Aleksić, Kostić, 1982:40). All of these causes leave characteristic traces of conductor melting in the form of round and solid changes in the cross-section of the conductor – the form of 'balls', bulges, tears, berries, etc. These characteristic traces occur as a consequence of sparks, short circuits or electric arc, and can be found on the conductors themselves or on the materials present in their immediate proximity.

When passing through a conductor or during usage in machines or devices, electric power partially turns into heat energy. Accordingly, any value of electric power is matched by a degree of certain rise in temperature. This increase of temperature has to be limited, which means that the temperature must not reach the insulation ignition point, or ignition point of surrounding objects or materials. According to this, electric power is the cause of fire when it creates heat which reaches the critical temperature of ignition of materials in the immediate proximity, which may be: the material from which insulation is made, structural elements, and other flammable and explosive matters (Aleksić, Kostić, 1982:40).

In any event, fire can occur through ignition or conductor insulation or/and melting of the conductor. In both instances, the combustible material in their vicinity may start burning due to flame

and high temperature of overheated objects. The cause of fire is a malfunction in the electrical wiring, i.e., the malfunction of the conductor, that is, damage on the insulation resulting in a contact of the conductors of different potentials, then heating, ignition of the insulation and/or melting the conductors, ignition of the present combustible materials, and finally fire. The difference is that in the former case there most probably would be no melting of metal conductors due to the delayed reaction of the switch, so there would not be characteristic traces of short circuit taking form of the melted ends of a broken conductor.[3] In this case, the insulation combustion occurred as soon as the conductor started melting, there was a switch that reacted. The flame on the insulation is the cause of fire, however due to reaction of the switch, stops the flow of electric energy, the conductor starts to cool, not significantly changing its form or continuity.

In the latter instance, liquid metal (most frequently copper), with its very high temperature[4], shall set on fire almost any flammable material (wood, plastic, fibric, paper, etc.) that it comes into contact with and leave the characteristic traces of a short circuit in the form of metal drops, most often on both ends of the broken conductor. In these situations, characteristic material traces can be found, undoubtedly confirming the short circuit, as well as that the conductor was under voltage at the moment of the onset of fire. Solid drops of metal can be detected in the immediate vicinity (on the metal, in sooth, melted into burnt rubber, plastic and the like). They are mainly of irregular ball-like shape, in the shape of tears or little balls, usually tiny, but of varied dimensions and can be felt under fingers because they are not in keeping with the conductor dimensions. The easiest way to visually examine them is to soak them in water first. In this way the products of fire will be washed away and the balls will "shine" in the light.

In any event, as regards these samples, fire will mainly spread **evenly** in all directions with an **upward** tendency; there will be no extremely violent reaction, it will ignite all materials on site and it will leave various traces of thermal degradation on them. Exceptionally, fire may change

3 In such a situation, forensic processing as part of fire site investigation calls for a detailed inspection of the conductor in order to find characteristic traces of a possible electric arc, which does not necessarily break the conductor, but alters its cross-section, so that tiny hard balls of melted metal can be found there.

4 An electric arc develops temperatures ranging between 1500 and 4000 °C and can ignite any material either in contact or by radiation, whereas carbonization of the PVC lining occurs at 200°C, copper melts at 1083°C (Спасић, С., Јованов, Р., Павловић, А., 1998:123).

behavior if it spreads onto some easily flammable or explosive materials, which will certainly visibly impair the 'harmonious' movement of the fire.

Reasons for vehicle self-ignition can also be technical defects on the mechanics of the vehicles, such as: belt slipping, overheating of braking elements[5], sealing of the bearings, grinding of the rotating part against the fixed part, a defect on the exhaust mechanism, the defect on the engine valves, a defect on the fuel supply system, and so on (Peruško, Belas, 2010:108).

Improper use of a vehicle on the part of the user is yet another way in which vehicle self-ignition can be caused. Most frequently this includes driving a car with applied hand brake, driving an overloaded car, where overheating of tires takes place, increasing the vehicle rpm on maximum while the car is not moving and keeping the engine rpm on a maximum while examining the engine.

Also, a frequent cause of fire on cars can be inadequate transport of dangerous and highly flammable materials. Crime investigation practice has recorded cases of transportation of fuel in the trunk, when only one spark is needed to start fire and completely destroy the car or a situation when welders transport the bottles which leak flammable gas in the vehicle, when it is sufficient to open the door and activate the car-roof lighting to initiate a gas explosion.

Establishing causes of fire in cases of car self-ignition

When we speak about fires in cars, the main question is: was the fire caused by human activity or not? If the fire was caused by human activity, it is important to establish whether it was caused intentionally (an arson) or accidentally, without intent, negligently. When we speak about burned cars, fires are far more common than arsons. However, what should be borne in mind here when we speak about their respective incidence is that causes of fire remain unestablished for a number of fires, and there are certainly some arsons among them. Thus, in practice, it happens that arson is sometimes regarded as fire caused by other causes and this means that the perpetrator remains beyond the range of criminal prosecution (Bošković, 1998:195).

5 Overheating of brake elements most frequently occurs due to malfunctioning or blockage of the brakes.

The main question in terms of crime scene investigation is certainly that of the cause of fire, i.e., what the agent of fire was. However, the cause of fire is not easy to establish, just as it is not easy to inspect the scene of fire because it constitutes an intensely contaminated site in terms of traceology. The destruction of traces in terms significant for fire scene investigation and the contamination of the scene of fire in passenger vehicles are caused by concentrated activities of the vehicle owners, persons who come to aid and firefighters in an objectively limited space.

Due to changeable and short-terms phenomena such as smell, smoke color, order and development of burning, flame color, meteorological and lighting conditions, experts who work at the scene of fire are supposed to reach the site promptly, at the earliest possible stage, preferably while the fire is still burning and developing, as well as when it is being neutralized or extinguished (Radmilović, Kolar - Gregović, 2010:52).

When we speak about fires in passenger vehicles, the time constantly works against the CSI team because with the passage of time - due to burning and other accompanying phenomena – the circumstances whose establishment may help in elucidating or proving the facts about fire may change or completely disappear (Saferstien,1987:291). Because of this, the investigating team must observe the principle of expedience and operative work when coming to the scene of fire in order to be able to monitor the development of the fire, note key parameters, and primarily the phenomena that are unrepeatable and of limited duration.

The scene of fire abounds in traces because there is virtually no part of the object on fire on which there are no traces, yet this apparent traceological abundance hides an actually acute deficit of traces relevant to the elucidation of the events. All traces found at the scene of fire are of significance and that is why they need to be observed both separately and as a whole, but their mutual relations have to be observed as well, that is, how they influence one another, in the spirit of critical and self-critical thinking.

The leader of the CSI team in charge of processing the scene of fire immediately upon arrival, on the basis of obtained information and assisted by other professionals, performs spatial and time orientation of the location; carefully surveys the scene; establishes more precisely the perimeter of the scene[6]; identifies especially problematic zones; chooses

6 In these situations, the leader of the CSI team usually extends the initial perimeter of the scene.

appropriate techniques of narrative description; takes preliminary photographs and video recordings; develops a general version of the event; deploys personnel and equipment for specific tasks; identifies and protects relevant objects and traces; takes down extensive notes in order to document the circumstances and conditions at the crime scene and its surroundings (Žarković, Kesić, Bjelovuk, 2012;104). At the very start of a reconstruction of the event, the following questions should be answered:

- Did the fire start inside the vehicle or on the outside of the car body?
- Did the fire start under the hood or on the hood?
- Did the fire start while the door and the hood were in the closed or open position?
- What was the positions of the doors and windows at the onset of fire?

Upon examination of a vehicle affected by fire, experts on fire pay a lot of attention to thermal damage and deformations on the car body, as well as to traces inside the vehicle in order to establish the point of origin of fire, the so-called fire center. It is the center of the fire wherein we should look for the cause of fire, and the traces found at the scene will lead us to it. *For instance, characteristic traces of a short circuit, which are found outside the center of fire and far from it can in no way be the cause of fire, but rather its consequence.*

It is an old crime investigation rule that every version of an event has its counter-version and that is why experienced crime investigation officers, when inspecting a crime scene, always ask themselves the following questions: "Why is it not different?", "What would the traces look like if the cause of fire was different or if the center of fire was elsewhere?" or "What characteristic traces would appear if the cause of fire was different and the center was elsewhere?" and so on. All these are creative questions to which members of the fire investigation team need to answer first to themselves and later – in the following stages of criminal procedure – to other interested subjects as well.

It is therefore very important that the experts have experience and knowledge for finding traces, their description and elaboration. Skills, experience and knowledge of the experts come to the fore when interpreting the traces that have changed position in the course of extinguishing fire. Namely, when extinguishing a fire on a car, changes

at the scene of fire frequently occur due to the water jet, i.e., traces are moved or even relocated due to intervention of firefighters or because of activities aimed at rescuing people and property in and around the vehicle (Peruško, Belaš, 2017:43).

Following a detailed examination of the vehicle during which the center or several centers of the fire are established, an expert must determine which group the cause of fire belongs to: whether it was a technical defect, negligence or arson. **The examination begins where the vehicle is most heavily burned, yet it does not have to be the center of fire.** One layer is examined after another, because the layers give us data on the order of overheating, the movement and dynamics of fire spreading.

If experts establish that the cause of fire is of a technical nature, that is, that it is the case of spontaneous combustion, then the next step would be to establish whether the vehicle was parked or driven, on which further forensic processing of the scene of fire will be based.

If the vehicle is equipped by a computer and if the computer is not thermally damaged, it is necessary to take it to an authorized service and retrieve the data (Peruško, Belaš, 2017:43). The retrieved data can provide us with the information on the condition of the vehicle before the outbreak of fire, that is, whether it was defective.

After absolutely positively establishing that the cause of fire is spontaneous combustion of the car, the investigation is closed.

Wrongly established cause of fire can lead to difficulties in investigation, to looking for a non-existent perpetrator or a failure to find and prosecute an actual perpetrator.

Specific traces in cases of self-ignition

Specific traces in this case are the traces that are typical only of fires and arsons, such as the traces of burning, short circuit, and thermal destructions. In order to detect and properly lift them, it is necessary to have comprehensive perception, based not only on knowledge but also on experience. All these traces can be found in the center of fire[7], in the immediate proximity of the fire scene and on persons who happened to be at the place of fire origin (Pavšić, Modly, Veić, 206:616).

7 These traces are vital for establishing the cause of fire, that is, for establishing the way in which high temperatures developed or other conditions occurred that were necessary for the outbreak of the fire.

The most intense damage by initial fire caused by electric power can most often be observed on both sides of the fire protection in the vehicle (the partition separating the engine from the passenger area) because the largest portion of electric installations is found there (Kulišić, Medić, 2012:316).

Most fires on cars that are caused by electric power result from a short circuit, that is from direct contact of non-insulated conductors which are under voltage. When a damaged electric conductor under voltage touches metal parts of the vehicle, sparking take place and a short circuit occurs. The temperature of 1500°C develops at the spot of the short circuit due to which combustible materials (rubber, plastic, oil, petrol vapor) are ignited. Very intense power in the circuit occurs because the resistance in the circuit is minimal, i.e., it approaches zero, and the power increases without restraint, i.e., indefinitely. The likelihood of fire is higher in modern vehicles because of a larger number of electric circuits, devices and electronic parts under voltage, even when the car engine is off.

Some traces of vehicle self-ignition in the engine area

Conductors of electric installations are found in almost every part of the vehicle, including the engine compartment. As the engine area also contains a part of the system that supplies the engine with fuel, there is a possibility for an initial fire to be caused by electric power, spreading very fast on to the fuel supply system and result in a sudden outbreak of fire. Upon investigation, it is necessary to pay special attention to examining electric conductors which are frequently without insulation (most prominently in the fire center), as it burns or is charred. Special attention should be paid to broken conductors and establish whether the disruption occurred due to a mechanical cause (tear) or a thermic one (melting). In a mechanic disruption of the conductor, edges are sharp at the place of disruption and in the case of a thermal cause, the edges are curved. The shape of the edges is established immediately at the scene of fire and this can be done easily with the help of a magnifying glass or a microscope.

Photographs 2 and 4 show specific traces which indicate that the fire started under the hood of the car engine while it was in a closed position.

Photograph 2. *Seal-like burning marks on the outside of the hood*

These traces can be found on the outer surface of the hood, alongside hood edges, on the inside of the hood and on electrical installations under the hood. Every trace that is found needs to be meticulously, clearly and expertly elaborated on and accompanied by photographs in keeping with the rules.

Seal-like burning as a trace

Looking at the photograph no. 2, partial thermic degradation may be noted on the outside surface of the hood in the form of 'seal-like' burnt patches of paint and varnish of clearly defined forms. Between the burned 'seals', surfaces may be observed that are not completely burnt. These surfaces delineate and separate these 'seals', apparently making them stand out from the whole. This trace indicates the direction of fire spreading, that is, it shows that fire started under the engine hood, from the inside. Namely, if the fire had started on the outside, on the external surface of the hood, combustible materials (paint and varnish) would

have burned evenly, so there would be no seal-like (partial) burning, because there would have been no obstacles. In other words, the fire would not have 'skipped' the material of the same composition.

Photograph 3. *Hood reinforcement on the inside*

However, if we carefully examine Photograph no. 3, we may notice that a reinforcement structure on the inside of the hood, that is metal beams that constitute the skeleton of the hood. These beams act as obstacles in cases of fire, as they hamper uniform movement and development of flame and temperature. They physically prevent the temperature and flame to spread evenly. That is why the fire leaves 'a pattern' on the outside surface of the hood. Experienced crime scene investigators can draw conclusions regarding the design of structure on the inside of the hood when they see the its outer surface.

In the specific case, the temperature was higher on the surface next to the metal beams and lower in places where the (structural) beams touch the internal surface of the hood. Due to such uneven spreading of flame and temperature, the 'seal-like' thermal degradation occurred as an instance of **trace indicating the direction of fire spreading**.

Further analysis of Photograph no. 2 shows black triangles that are actually the image of the structure on the inside of the hood which is shown in Photograph no. 3. This trace is particularly important in the initial stage of the investigation for determining the center of fire, the

direction of its spreading, and the position of the hood at the time of the onset of fire. However, even when we do notice such a trace, care should be taken not to draw conclusions too early, as every trace at the scene of fire needs to be previously checked and compared against other evidence at the scene of fire and investigation has to be regarded as a puzzle wherein each and every trace separately constitutes a part of the puzzle. What is required for an expert and scientific analysis, as well as for explaining discovered traces in a way that is readily understandable, is a multidisciplinary approach.

Smoke halo as a trace

A smoke halo is yet another in the multitude of traces that may be found in the course of fire scene investigation and forensic processing of burned cars (Photograph 4). This trace rules out both the possibility of combustion accelerator presence on the hood and the possibility that the fire started on the outside surface of hood. If the surface of the hood had been splashed with combustion accelerating agent, such as, for instance, petrol, it would drip under the influence of gravity and we would quite certainly have traces of overheating on the front edge, as the lowest point of the hood.

Photograph 4. *Smoke halo on the edge of the hood.*

In this way we undoubtedly exclude the presence of a burning agent but also the outside surface of the hood as the place where fire originated. Namely, smoke haloes in the form of blackening of hood edges and the area immediately beneath them indicate without any doubt that smoke passed by them along with other products of burning, which stuck to the surface on their way out. As smoke always moves upwards, there can be no doubt that the fire started under the hood.

This trace also shows without a doubt that the hood was in the closed position at the time when the fire broke out. If it had been open, there would be no traces of this kind. The flame in such a case would catch the hood mostly on the inside and would be free to move in space. Had the hood been lifted, there would be no reason for flame and smoke to sneak through.

There would be no seal-like burning, as the flame and smoke would rather leave a funnel-shaped trace of burning, widening towards the higher part of the hood. The way it happened, coming against physical barriers due to the closed hood, the temperature and flame could not spread freely and without obstacles but had to come out where there was at least some space to move in the upward direction, which resulted in this type of trace.

Sometimes these traces are prominent as in photographs 2 and 4, whereas in some cases they may be barely noticeable, yet they always have the same significance in terms of fire investigation.

Finally, in almost all cases of spontaneous combustion of vehicles that are caused by a short circuit and where the point of fire origin is the area around the engine under the closed hood, this enclosed space will reach the effect of the 'baking oven', so that all combustible materials around the engine would be thermally degraded to a smaller or greater extent, **but certainly more so than on the outside surface of the vehicle**. This difference can also be treated as a trace which, combined with other traces, is of great significance for investigation as it indicated the point of fire origin. In the specific case, applying the method of comparison, we come to the conclusion that the fire started around the engine when the hood was closed.

This kind of scene of fire investigation calls for intellectual engagement, analytical thinking, specialist knowledge, as well as experience which allows for keen observation, skilled processing and interpretation of detected traces. As part of reconstruction of the event,

attention should be paid to all traces that support the version that any specific case involves spontaneous ignition of the vehicle, but we also have to explain possible presence of traces which may indicate otherwise. An old rule of crime scene investigation requires that we must have at least two versions of the case under review. In order to establish the whole truth in the course of investigative proceedings, it is not sufficient to prove the truthfulness of one version, but also the untruthfulness of all other versions.

Photograph 5. *The trace of a short circuit.*

After a detailed inspection of the fire center, we finally establish the cause of fire, that is, the characteristic trace of melted copper conductor in the form of interrupted conductor with rounded edges at the interruption, originating in a well-known way that has already been described (Photograph 5).

Traces indicating that the fire center is inside the passenger area

In situations when fire occurs in the vehicle passenger area, we should always check the possibility that the fire started due to ember of an unextinguished cigarette that fell on to a highly flammable surface in the passenger area or smoldering of an unextinguished cigarette butt in an ashtray full of other cigarette butts, tissues, pieces of paper and the like. In the course of forensic processing as part of fire site investigation, samples should be taken from the fire center in order to establish possible presence of a combustion accelerator. When a fire starts inside the passenger area in situations of spontaneous combustion, the central part of the vehicle will be most affected. The fire will spread evenly in all directions, with an upward tendency, as always. If the doors and windows of the cabin are closed, the effect of the 'oven' will be present in the same way as in cases of spontaneous combustion of the vehicle in the engine area with the closed hood. This means that all combustible materials (cloth, plastic, sponge, rubber, etc.) would be thermally degraded depending on the intensity and duration of fire.

The fire center will as a rule be the spot where such damage is most prominent and it will most frequently match the place where the fire started. The dynamics of fire spreading is such that naturally, the combustible materials on the inside will be the first to burn, then those on the outside and finally the materials at the lowest points of the vehicle (the bottom section of the doors, lower side edges, the foot of the vehicle). If the fire is localized, extinguished or goes out in a vehicle in whose passenger area self-ignition occurred, the vehicle will look as in the photographs 6, 7, and 8.

Photograph 6. *The appearance of a truck in which fire started in the cabin due to a short circuit on the installation around the fuse*

Photographs 7 and 8 show a typical example of a fire center in the passenger area, which is characterized by the lower burning line on the doors and on the lower side edges of the vehicle. These are the places where unburnt combustible matter (paint and varnish) always remains, clearly delineating the burning on the door, **which is not vertically interrupted**. It stretches along the lower side edges, mostly at the same height, as shown in Photograph no. 8.

Namely, these parts are the last to catch fire and when fire stops or is extinguished at some point, such a trace will remain, clearly indicating that the fire started inside the passenger area. The trace is sometimes of a crucial importance as it remains even when a vehicle is almost completely burnt, because the lower edges of the car are the last to catch fire.

Photograph 7. *The appearance of a vehicle side affected by spontaneous burning due to a defect on the heating installations in the driver's seat*

In such situations, the described trace is more difficult to spot, yet it may be present, so a distinction can be drawn between burning of upper and lower parts of the door, and the trace can be preserved in a photograph. This trace may lead us to a conclusion as to where the center of fire was and it is the place where we should look for the cause of fire.

Photograph 8. *The appearance of a vehicle following self-ignition of the central console inside the passenger area*

If there is any vertical interruption of this trace, it indicates the possibility of presence of a highly flammable fluid, which left the interruption due to burning while flowing. In this case, the content found under the interruption is analyzed, compared against other combustible

materials under the interruption and in its immediate vicinity. Namely, some cardboard, paper, rubber, plastic etc. may be present that may have caused the interruption, which must be taken into consideration. If there are no traces of highly flammable material under the vehicle, a highly flammable liquid probably flowed on that spot, making a funnel-like damage due to local burning. We can look for it in the area immediately below the interruption and thereby find the center and the cause of fire.

Conclusion

Exploring the dynamics of fire ignition, fire center and the cause of fire on burned vehicles is a demanding and characteristic area of crime scene investigation and forensic processing due to numerous specific features, primarily related to traceology. Challenges in this area are yet to come, bearing in mind the use of new materials in car construction and the manufacturing of cars using alternative fuels, as well as hybrid and electric engines. Increasingly larger batteries, increased tank capacities, and the presence of modern materials, such as polymers, composites and others, may significantly influence the development and spreading of fire, and thereby the traces of fire, which should be taken into consideration.

The paper analyses the most frequent traces in cases of spontaneous combustion of vehicles in which the fire started in the area around the engine and in the passenger area. From analyzing all aspects and specific traces characteristic of such events, certain lessons can be learned that may be useful for similar cases in future. Standardization of the procedures, especially in the field of traceology, and familiarity with the most frequent traces that occur in cases of car self-ignition represent necessary steps for successful investigation of fires and reaching relevant conclusions. When a fire breaks out in the engine area, characteristic traces (seal-like burning, smoke halo) appear on the outside surface of the hood, along the edges of the hood, on the inside of the hood and on electric installations under the hood, indicating the place of fire origin and spontaneous combustion as the cause of fire.

If the place where the fire originated is in the passenger area, some combustible materials always remain unburned, most frequently on the lower edges of the doors and lower side edges of the vehicle, with clearly outlined limits of burning. These parts are the last to catch fire, so the

unburned matter on these locations indicates that the fire started inside the vehicle cabin. A competent and scientific analysis and clarification of these traces in an understandable manner calls for a multidisciplinary approach and possession of adequate specialist knowledge. Due to this, establishing the cause of fire can be performed only by competent professionals and experts who are, from a forensic point of view, qualified to investigate such events.

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