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New certification system for enhanced fire safety of vehicles

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Abstract

RISE has initiated and developed a certification scheme for the vehicle industry that will enable manufacturers, operators and service centres (workshops) to certify their fire risk mitigation process. The fire risk management required in the certification is a key safety element, used to identify and evaluate fire hazards. For best results, it is important that manufacturers, operators and service centres are equally dedicated to solve the fire problem. Vehicle fire investigations reveal that design, production, operation and maintenance can all be responsible, however, most important is to ensure that information and experiences from fire incidents and identified fire hazards are linked to relevant personnel, practices, manuals, and quality procedures. The certification cannot guarantee the elimination of vehicle fires, but can ensure that manufacturers, operators and service centres will operate at the front line of vehicle fire safety engineering.

Keywords: fire safety; vehicles; risk management; certification; SP Method 5289; SPCR 190; SPCR 191; SPCR 192

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1. Introduction

Fires in buses, trucks, construction equipment and other heavy vehicles are common around the world and annually involve substantial public cost. For instance, fires in mines are predominantly caused by service vehicles, drilling rigs and loaders (Hansen, 2011), and statistical data indicates that 0.5-1 percent of the buses registered in northern Europe will suffer an incident related to fire each year (Rakovic et al., 2015; Kokki, 2012; Hofmann and Dülsen, 2012). OTSI (2017) reports the same fire incident frequency for buses in Australia. In the US there are several reports on the high number of vehicle fire incidents, e.g. Ahrens (2012) and Meltzer et al. (2012). Furthermore, it is assumed that not all fire incidents are covered in the statistics since some larger companies do not fully insure the vehicles but cover the risk themselves. It also differs between countries if statistics from insurance companies and e.g. the rescue services are available and gathered. From the references mentioned above it is clear that most vehicle fires start in the engine compartment and without target actions there are high risk of an increase of fire incidents in the engine compartment in the future due to stricter regulations on noise and emission levels which result in higher operational temperatures.

The consequences of a vehicle fire depend on the fire scenario, vehicle type and fuel, surrounding environment, and means for fire mitigation. Underground mines, tunnels and cities are environments where a vehicle fire may have dramatic consequences, especially in combination with fuels such as compressed natural gas or compressed hydrogen used in fuel cell vehicles. For buses, the time for evacuation is crucial, and early fire detection and means for fire suppression can be vital. This has effectively been shown by the Swedish Accident Investigation Authority (2013) in the reconstruction of a fire incident involving two biogas buses as well as by OTSI (2011) in one of their investigation reports. Both these accidents ended well due to very few passengers at the time of the incident, however, the investigations reveal that without effective fire detection and suppression measures and with crowded buses the incidents would probably have been catastrophic.

A study on post-crash fires by Ochoterena et al. (2016) show the significance of crash related fire events. In Sweden, 5 % of all fatalities related to collisions with smaller vehicles (cars, minibuses etc.) occurred in burning vehicles between 1998 and 2008. In one third of the reported post-crash fire events the fatalities were due to fire only with no or limited injuries from the collision. In addition, the study put out an important conclusion that: “Trends indicate that the survivable collision energy will continue to increase and, at the same time, the probability of post-crash fires rises with the collision energy. This means that the occupants of a vehicle may survive a high energy collision, but will sustain severe injuries or death due to a post collision fire”. Post-crash fire prevention must keep up with the level of survivable collision energy such that fire related injuries and fatalities are minimized.

In case of a vehicle fire, passive and active fire safety systems and means for safe evacuation are very important. This include fire detection and suppression systems, portable fire extinguishers, fire resistant partitions, shut-off devices for fuel and electricity, fire resistant insulation and fabrics, evacuation routes and emergency exits in buses, etc.. All this is part of vehicle fire risk management. However, fire risk management shall also include e.g. regular risk assessments, training and improved quality procedures to address the problem already before the fires arise. An improvement of the fire risk management procedures for vehicle manufacturers, operators and service centres have potential to greatly reduce the number of fires and to reduce the consequences of the incidents that will still occur.

2. New certification system

In 2016, RISE initiated the work on a certification scheme for the vehicle industry that will enable manufacturers, operators and service centres (workshops) to certify their fire risk mitigation process. Certification rules for vehicle manufacturers have been published (SPCR 190, 2016) as well as a specific method for vehicle fire risk management (SP Method 5289, 2016). The method includes requirements and extensive guidelines for the process required in the certification rules. At present, RISE is working together with IRU, the International Road Transport Union, with the development of SPCR 191 “Certification rules for vehicle operators with respect to vehicle fire safety”. Shortly after there will also be certification rules for service centres established, SPCR 192. The requirements in the different certification rules will be similar and the certified company must be able to assure the quality of their design, production, operation and/or maintenance process in order to secure a high level of safety and to keep the fire risks as low as reasonably practical. The fire risk management process required in the certification is a key safety element, used to identify and evaluate fire hazards. In the process, identified hazards must be documented together with suitable remedies aiming at control or elimination of the hazards. If no action is recommended for a specific hazard, the documentation should clarify the reasons for this decision.

The certification system is based on experience and knowledge gained through research, fire investigations and other industry professional services. A new research report by Volpe (2016), ordered by Federal Motor Carrier Safety Administration (FMCSA) in the US, put out recommendations for motorcoach and school bus fire safety enhancement. The recommendations are in line with the new certification system and suggest improvement actions within data quality and reporting, vehicle design and safety equipment, operational training, and inspection frequency. A certified company will have to comply with these recommendations to fulfil its commitment to the certification.

The certification system is composed of the following five elements:

- Fire risk management
- Fire safety training
- Reporting of thermal events
- Quality procedures and configuration management
- Surveillance inspections

2.1. Fire risk management

The client must do regular fire risk assessments, i.e. a systematic study to identify fire hazards, and document decisions for risk elimination, control or acceptance. The input from the fire risk assessment should be used for future design improvements, installation of fire protection systems, enhancements to maintenance documents, enhancements to operation manuals and practices, replacement cycles of critical components etc.

The fire risk management procedure includes:

- Hazard identification
- Risk estimation
- Risk evaluation
- Risk reduction or risk acceptance

The procedure must be implemented in the company's own quality procedures to the extent regarded as necessary in order to mitigate the risks. SP Method 5289 (further discussed in chapter 3) contains guidelines on how to perform fire risk management. The checklists provided in the method are required to be implemented in the inspection documents of the company.

2.2. Fire safety training

Training of design engineers, quality control inspectors, managers, drivers, production personnel and maintenance personnel is the basis of the certification. This includes training in vehicle fire risk management as well as study of fire hazards and mitigation methods specific to different types of vehicles and fuels. It must be assured that all relevant personnel get knowledge of vehicle fire hazards and fire risk management.

Some important objectives for the training are:

- Understanding why fires occur on vehicles
- Understanding the impact of fires
- Raising awareness of fire risks on vehicles
- Learning how to inspect a vehicle and be able to detect fire risks
- Understanding how fires can be prevented, detected and suppressed

2.3. Reporting of thermal events

The client must have procedures for linking information, data and experience from actual thermal events in the field to relevant personnel, including design engineers, quality control inspectors, drivers and maintenance personnel. The information will be gathered in a database common for all certified companies, which means that a large amount of data will be available for research purposes, increasing fire safety of vehicles worldwide. Data will be stored confidentially and only general anonymized statistics will be available to all certification holders.

The client should also have procedures for when and how to investigate fire events. It is important to determine the underlying causes and not only look into the consequences, which means that affected parts are repaired with no consideration to the actual cause of the event. For instance, a primary cause of fire could be a hot surface igniting some fuel leakage. An underlying cause could then be abrasion of a fuel hose due to a loose attachment, which in turn could possibly have been caused due to shortcomings in quality routines at a workshop, in the production line or at the operator.

2.4. Quality procedures and configuration management

The client must have documented procedures for quality control. There shall be quality procedures in place to manage and mitigate the risks that arise or are found, and procedures ensuring that findings are linked to design engineers, fleet managers, drivers, maintenance personnel, etc., such that they are resolved properly. All previous described elements of the certification shall be incorporated in the company's quality control system. In addition, the company must have procedures for documented reviews of their inspection procedures at regular intervals to ensure the efficacy of the inspections. It is also important with procedures to collect and retain relevant documents, to ensure traceability and to ensure that current editions of documents are available to the persons concerned in the company.

2.5. Surveillance inspections

Annual inspections shall ensure that the client fulfils the requirements in the certification rules. During the inspections quality procedures and records are reviewed with focus on risk assessments performed, risk reduction measures, training and qualification of personnel, reporting of thermal events and procedures for internal inspections.

3. Method for vehicle fire risk management

The method (SP Method 5289, 2016) complements the certification rules with some detailed requirements of the fire risk management process which consist of four steps, see Fig. 1. The risk assessment is followed by measures for risk reduction or decisions for risk acceptance to complete the risk management process. For hazard identification and risk reduction the method provides extensive guidelines for assistance in the process.

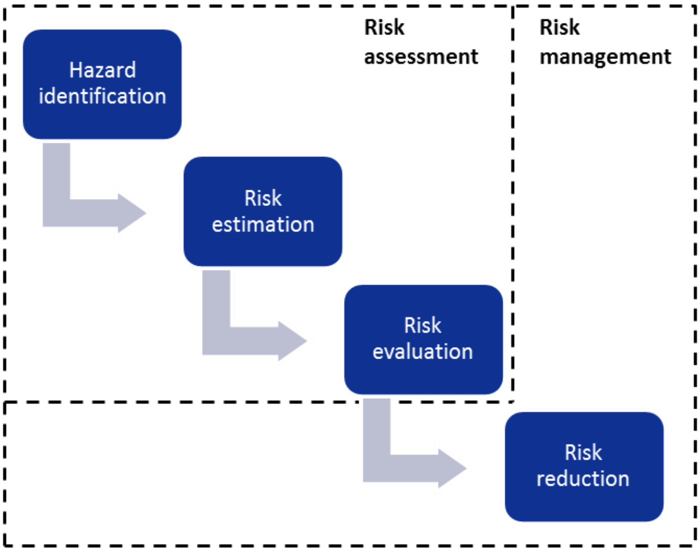

Fig. 1 Flow chart of the risk management process

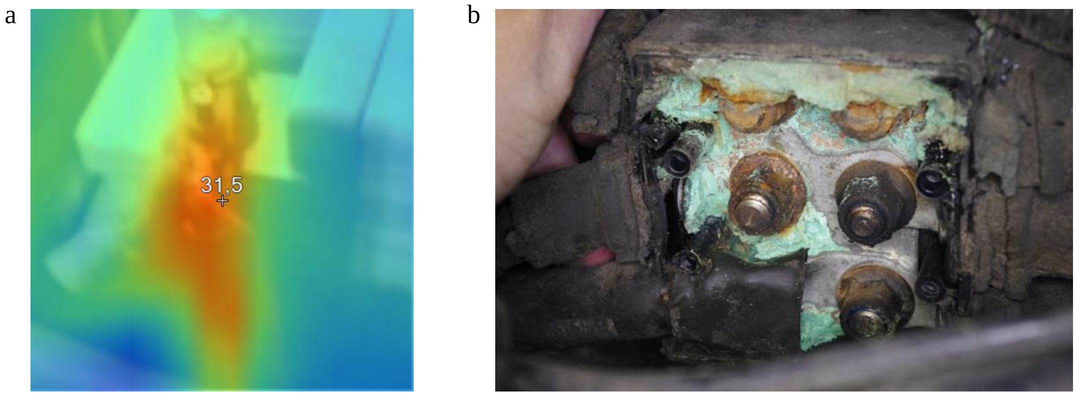

Fig. 2 (a) Thermal image of the positive terminal of a car battery which indicates a poor connection, marker displays degrees Celsius; (b) Oxides in a terminal block detected by a thermal imaging camera

One can use the method, which provides examples as well as checklists, as a tool in the hazard identification process. The method provides elaborate support for identification of fire hazards in newly assembled vehicles as well as fire hazards resulting from operation, maintenance and retrofitting of the vehicles. Visual inspection is the basis for identification of fire hazards and includes inspection of the electrical systems, pneumatic and fluid systems, the exhaust system, brakes and tyres, and other relevant areas and systems. To enhance the visual inspection there are also guidelines for the use of thermal imaging camera, which can be used to identify potential fire hazards concealed from a traditional visual inspection. Fig. 2 shows two examples where the use of a thermal imaging camera can be crucial. A few degrees off compared to surroundings are enough to be considered as a potential risk and in Fig. 2 (a) one can see the positive terminal of a car battery which is about ten degrees warmer than the surrounding, indicating a poor connection. The terminal block in Fig. 2 (b) was separated, revealing the corrosion, due to the heat loss detected by a thermal imaging camera. Other useful tools that are recommended to be used for fire risk assessments are a multimeter for further analysis of the electrical systems, temperature strips to be attached to components close to e.g. the exhaust systems for indication of maximum temperatures experienced, and an endoscope with lighting and monitor features for visual access to unapproachable components, cables or hoses.

An important part of the hazard identification process is to anticipate post-crash fire risk scenarios, including collisions as well as e.g. mechanical impacts to the underbody of the vehicle. Of most interest are e.g. positions of fuse boxes, batteries, cables without preceding fuses, fuel tanks and filler pipe, and fluid lines in combination with hot surfaces. Furthermore, ensure to include the fire safety systems in the inspection routines, which affect the consequences of a fire event. This includes active and passive fire protection systems as well as emergency routes, lights, hammers, etc.

The method presents how the identified hazards can be translated to estimations of fire risks and how these can be evaluated. There are several different estimation methods that could be used, and most of them are based on estimations of the likelihood and consequence of the identified hazardous events. The evaluation aims to provide an overview of the risk image and to separate the risks which need to be addressed from risks that are acceptable. Fig. 3 gives an example of a risk assessment matrix that can be used for this purpose.

RISK ASSESSMENT MATRIX				
Severity / *Probability*	Catastrophic	Critical	Marginal	Negligible
Frequent	High	High	Serious	Medium
Probable	High	High	Serious	Medium
Occasional	High	Serious	Medium	Low
Remote	Serious	Medium	Medium	Low
Improbable	Medium	Medium	Medium	Low

Fig. 3 Fire risk assessment matrix

The risk assessment (identification, estimation and evaluation) should be followed by risk reduction. Risk reduction measures can be considered at following four levels:

- Risk elimination or minimization by design
- Passive and active fire protection systems
- Improved maintenance and cleaning procedures
- Improved training and quality procedures

Proposed risk reduction measures must also be assessed such that no other unacceptable risks are introduced, including fire risks as well as e.g. impaired access to vital parts or general performance of the vehicle.

The method also provides recommendations on general fire safety measures for common designs, procedures and systems. A few recommendations that can be crucial are to keep conductors without preceding fuses as short as possible, to position main fuses already in the battery box and to provide a main switch adjacent to the batteries to isolate power to the vehicle if required, including starter/generator circuit. Moreover, be aware that rubber may be conductive and unspecified rubber shall not be used for isolation purpose of the electrical system. Further, avoid construction solutions where failed fuel lines could spray fluid onto exhaust pipes, turbo charger or other hot parts of the exhaust system and use an automatic or semi-automatic fire suppression system in the engine compartment.

Easily implemented measures that have potential to greatly reduce wheelhouse fires are monitoring of tyre pressures and critical temperatures of brake systems. Tyre pressure monitoring is common today and especially important for dual-wheels, where low pressure in one of the tyres could be hard to notice. An alternative would be to use wide-base single tyres where it is suitable. Fire resistant material is important in wheelhouses as well as in other areas.

Cleaning procedures are important, allowing no build-up of flammable deposits and facilitating detection of possible leakages. In addition, good drivers training focused on fire risks are essential for increasing fire safety of vehicles. Except that all drivers should be trained in the correct emergency response procedure some recommendations for drivers are to:

- Always react to any warning light (e.g. ABS warning light may indicate a wheel bearing failure)
- Regularly monitor air pressure gauges, temperature gauges for overheating, coolant temperature gauge and engine oil pressure gauge.
- Never ignore electrical misbehaviour.
- Never ignore small impacts
- Ensure that their parked or idling vehicle cannot ignite grass or dry leaves under the vehicle

4. Conclusions

The new certification system will allow personnel, strategies, and techniques involved in fire risk mitigation of new and existing vehicles, to be kept at the highest performance level. The certification cannot be a guarantee for elimination of vehicle fires but can ensure that manufacturers, operators and service centres will operate at the front line of vehicle fire safety engineering. For best results, it is important that manufacturers, operators and service centres are equally dedicated to solve the fire problem. Vehicle fire investigations reveal that design, production, operation and maintenance can all be responsible, however, most important is to ensure that information and experiences from fire incidents and identified fire hazards are linked to relevant personnel, practices, manuals, and quality procedures. Understanding the reasons behind a thermal event and not only replace the obviously damaged component, but investigating why it was damaged and treat the root cause is crucial to avoid future fires. For example, a newly replaced main bearing can fail within a few hundred miles and cause a fire, if the cause of the failure was not taken care of the first time. Further, a plastic component replacing one that was heat damaged may catch fire the second time if it is not protected from the external heat source.

The method for fire risk management in vehicles is a hands-on and important guideline, which together with enhanced quality procedures and training of the personnel form the basis for the certification aiming to reduce the number, and to limit the consequences, of vehicle fires.

References

Ahrens, M., 2012. Automobile Fires in the U.S.: 2006-2010 Estimates. Chicago, USA: Proceedings of FIVE – Fires in Vehicles

Hansen, R., 2011. Design fires in underground hard rock mines. Västerås, Sweden: Licentiate Thesis 127, School of Sustainable Development of Society and Technology, Mälardalen University.

Hofmann, A., Dülsen, S., 2012. Fire safety performance of buses. Chicago, USA: Proceedings of FIVE – Fires in Vehicles.

Kokki, E., 2012. Bus Fires in 2010-2011 in Finland. Chicago, USA: Proceedings of FIVE – Fires in Vehicles.

Meltzer, N. R., Ayres, G., Truong, M., 2012. Motorcoach Fire Safety Analysis: The Causes, Frequency, and Severity of Motorcoach Fires in the United States. Chicago, USA: Proceedings of FIVE – Fires in Vehicles

Ochoterena, R., Roux, F., Sandinge, A., Nylander, C., Lindkvist, M., Björnstig, U., Sturk, D., Skrifvars, M., 2016. Post-collision fires in road vehicles, a pre-study. RISE Research Institutes of Sweden, SP Report 2016:55.

OTSI (Office of Transport Safety Investigations), 2017. Bus Safety Report – Bus fires in New South Wales in 2016. Sydney, Australia.

OTSI (Office of Transport Safety Investigations), 2011. Technical inspection findings, Fire involving Transdev Shorelink Bus MO1970, Mount Colah, 16 December 2011. Sydney, Australia.

Rakovic, A., Försth, M., Brandt, J., 2015. Bus Fires in Sweden. RISE Research Institutes of Sweden, SP Report 2015:43.

SP Method 5289, 2016. Fire risk management procedure for vehicles. RISE Research Institutes of Sweden, Borås.

SPCR 190, 2016. Certification rules for vehicle manufacturers with respect to vehicle fire safety. RISE Certification, Borås.

Swedish Accident Investigation Authority, 2013. Slutrapport RO 2013:01, Brand med två biogasbussar i stadstrafik i Helsingborg, Skåne län, den 14 februari 2012. ISSN 1400-5743.

Volpe (John A. Volpe National Transportation Systems Center), 2016. Motorcoach and School Bus Fire Safety Analysis. U.S. Department of Transportation (USDOT), Federal Motor Carrier Safety Administration (FMCSA).