The Dutch procedure for the fire service response to electrical vehicle accidents and fires by the fire service

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ABSTRACT
The number accidents and fires in electrical vehicles in the Netherlands is steadily increasing due to the increasing popularity of these vehicles. Despite this development there were no procedures how to safely respond to these accidents for the fire service. At the same time there were a lot of questions and myths around this subject. The Institute for Safety (IFV) developed a procedure in collaboration with experts in the field. This paper presents the process and the final result, the present procedure for treating accidents in electrical vehicles.

INTRODUCTION
At the start of 2019 the Netherlands counted 139.000 cars equipped with battery packs, full electrical (BEV) and plug-in hybrids (PHEV's) together. Since 2014, when there were only 4.600 BEV's the number of BEV's increased tenfold. The biggest growth occurred in 2018 (CBS, 2019). Although exact figures regarding fires and accidents with electrical cars are not available, an increasing number of accidents and fires involving these kinds of vehicles is reported, and the media paid more and more attention to fires and the problems with extinguishing fires in electrical vehicles. Because the Netherlands has a very busy highway network, a car fire may immediately cause congestion of the entire country.
The first time the Netherlands Fire Service experienced a major accident with an electrical car was in 2016 (AD, 2016). A passenger BEV hit a tree with high speed and the cars was badly damaged. The driver died during the collision and parts of the car and the battery were spread burning in the environment. The fire service had a hard time assessing the dangers, how to extinguish the fire and how to safely extricate the driver.
The Netherlands Fire Service Academy published a document in 2016 (Brandweeracademie, 2016) regarding knowledge about electrical vehicles, the risks and how to respond. This document was at that time not disseminated into the fire service yet. Although the risks are well known, in practice it is not easy to determine the severity of these risks and to determine which measures are necessary to act safely. There were a lot of differences of opinion in the community how to deal with risks, and there were a lot of questions raised regarding the real risks and how to deal with them. Furthermore, technology is also evolving at high speed and it is hard to keep up with developments and their consequences for safety. This paper describes the process and the result of our journey to provide the fire fighters at the scene with an easy to perform action perspective.

METHOD AND RESULTS
Despite the availability of a document (Fire Service Academy, 2016) describing the ins and outs of dealing with incidents involving modern vehicles, there was still a lack of knowledge within the fire service. The Fire Service Academy (part of the Institute for Safety) noticed the differences of opinion and the lack of actual practical knowledge in the fire service. After the above mentioned accident in Baarn many fire services started collecting knowledge and experts were emerging at different locations. Therefore a Community of Practice (COP) was started in order to share the available knowledge and everybody who had acquired some knowledge of this subject was invited to join. In meanwhile this COP grew to about 30 members who share information and actual knowledge. Participants of a many institutions and companies joined the COP. Apart from fire service for example road side assistance, the towing companies, knowledge institutes, battery handling and charging equipment companies joint. Together, with the IFV as pen holder a procedure was

developed to deal with BEV accidents. This procedure will be presented in this paper. An international exchange of experts was organized in may 2019 with the objective to collect further knowledge, and connection with the CTIF working group fire and extrication experts was made. CTIF, an international working group of experts, there was also a publication with a procedure available (CTIF, 2019). Until recently we were still struggling with the potential and measures to be taken to prevent electrical risks, like electrocution by high voltage system after the battery is severely damaged. This question is answered by a task group consisting of high voltage experts. Having done this we arrived at the stage where we follow new developments. For example test results from DEKRA and a new method for fighting battery fires are published (Thorns, 2019). These new findings might be considered and assessed for applicability for the fire service.

General procedure

We defined three scenarios': a BEV fire, a collision with passengers trapped in a car and a collision without persons trapped. The procedure is applicable for Lithium-ion batteries. NiMH-batteries are considered not to go into a thermal runaway. We use the five-step procedure which is internationally quite common: recognize, explore, stabilize, intervention and after care.
If the car is on fire, but the battery pack is not involved, intervention should be directed to prevent involvement of the battery pack, and monitoring is necessary to be sure that the battery pack is undamaged. If the battery pack has gone into a thermal runaway or is involved in the fire, we consider it to be the best way is to let the car burn at a safe place, away from surroundings. If this is not possible, at the moment there is no other option than cool with a lot of water and extinguish the fire. We are aware that the thermal runaway is probably not stopped, that is why we advise to call for an expert towing company who can tow the car to a safe place.
If the car was involved in a collision and there is no fire, then it is continuously necessary to monitor the battery pack with thermal imaging camera in order to be sure that the temperature does not increase. Furthermore we advise to use the explosion sensor to determine whether combustible gasses are emitted from the battery pack. If the battery pack temperature increases and / or gasses are emitted, cooling is advised. If there is a person trapped, the person should be protected against toxic gasses, and fire should be prevented while the extrication should be prompt.
All the time firefighters should wear PPE with SCBA and 1000V gloves. According to experts in high voltage systems this should be safe enough. If the battery is severely damaged by the collision, and a person is trapped, the person should be protected with rubber mats.

The general procedure we developed in this process is presented in Figure 1, and in Table1 we present the pocket card procedure for intervention to be used by firefighters as a reminder.

Table 1. One page action perspective Dealing with Incidents involving Electrical Vehicles[a]

Phase		**Method**
1. Recognize		Identify the vehicle and energy source / fuel (via CRS or FIA Rescue Sheets[b]).
2. Explore		> Approach the vehicle from the front at an angle of 45 degrees. > Gather additional information on vehicle construction and safety features, battery pack stability (TIC), 4 gas meter or explosion hazard meter; symptoms of smoking, hissing noises), victim (s) and surroundings.
3. Stabilize		If possible, make sure that the vehicle cannot move / roll: > Put the vehicle in the parking position and apply the parking brake. > Turn off the engine and keep the key at least 5 m away. > Chock the wheels.
4. Intervention	Fire	> Stay out of (visible) gas clouds. > Approach the fire from the front (parts and flames from the car) and at an angle of 45 degrees (due to the vehicle rolling) with two low pressure jets (1 Low Pressure hoseline for battery pack and 1 LD for vehicle). > Maintain 1 throw length as the extinguishing distance. > Extinguish vehicles with a NiMH battery pack like a normal vehicle fire. > Extinguish a Li-ion fire with excessive water or immerse the battery pack / car in a water bowl / container until no more gas bubbles are released. > If in doubt about the type of battery pack, follow the procedure for Li-ion. > Continue to monitor the temperature of a non-combustible Li-ion battery pack for a long time with a WBC (> 60 ° C a thermal runaway3 is possible).
4. Intervention	Damaged battery	> Stay out of (visible) gas clouds. > Cool a damaged NiMH or Li-ion battery pack immediately with LD to prevent that

	pack	released flammable gases can ignite. > Use with 4 gas meter or explosion hazard meter the release of flammable and toxic monitor gases. > With a Li-ion battery pack, continue to monitor the temperature for a long time (WBC). > Stay out of (visible) gas clouds. > Approach the fire from the front (parts and flames from the car) and at an angle of 45 degrees (due to the vehicle rolling) with two low pressure jets (1 LD for battery pack and 1 LD for vehicle). > Maintain 1 throw length as the extinguishing distance. > Extinguish vehicles with a NiMH battery pack like a normal vehicle fire. > Extinguish a Li-ion fire with excessive water or immerse the battery pack / car in a water bowl / container until no more gas bubbles are released. > If in doubt about the type of battery pack, follow the procedure for Li-ion. > Continue to monitor the temperature of a non-combustible Li-ion battery pack for a long time with a WBC (> 60 ° C a thermal runaway[c] is possible).
	Passengers	> Extricate passengers as soon as possible during or after extinguishing a fire and with a damaged battery pack. > When extricating passengers, make sure that the battery pack is not damaged by the use of scissors and spreaders. > Provide passengers with respiratory protection with a smoking / hissing battery pack. Ventilate if that doesn't work > if risk of electrocution is expected, use rubber mats to isolate the casualty.
5. Aftercare		> Hand over the vehicle to an expert / towing company who is specialized in the towing of e-vehicles. > Advise to take the vehicle to a safe place (at least 15 m away from other objects) due to the risk of (re-)ignition due to unstable battery pack and cause fire spread to the environment. > Transfer the disposal of the released electrolyte and the cleaning of the road surface to the road authority.
Safety		Dry PPE: fully enclosed turn-off clothing, independent respiratory protection, 1000 V gloves. Passengers trapped and degassing of battery: respiratory protection passenger (s) Tools: WBC, 4 gas meter or explosion hazard meter, dry insulating tools. Electrocution: The risk of electrocution is neglectable[d]

Pay attention! Perform a Last Minute Risk Analysis (LMRA) at each step, because the dangers are diverse and not always visible or recognizable.

Notes:

a E-vehicles are defined as both electric and hybrid vehicles: bicycles, mopeds (two-wheelers), disabled vehicles, motor vehicles, trams and wagons (NEN 9140 (NL). NB All precautions when operating with regular vehicles also apply to e-vehicles (airbag covers , shield sharp objects from the victim, etc.).

b In the course of 2020, intervention s=heets from EURO NCAP will become available that meet the information needs of the fire service.

c With a thermal runaway, the chemical reaction in the battery pack "runs wild" and a lot of heat is produced within a short time. Because of that If the battery pack fails, flammable and toxic substances are released, and fire and an explosion are possible.

d Only when the both poles of the battery are touched with bare hand this risk exists, or when both poles are connected to galvanically separated parts of the vehicle. PPE with 1000V gloves is sufficient to protect Firefighters. If a person is trapped, it is advised to use rubber mats to protect the casualty. Measuring if there is a potential difference is very difficult and can easily result in a false sense of safety.

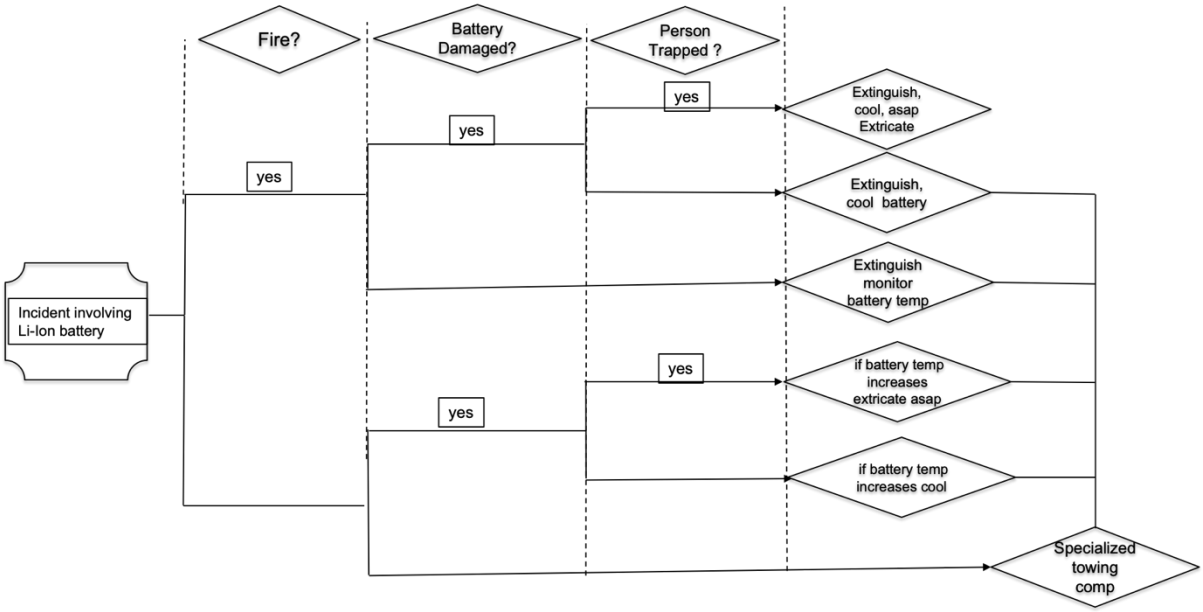

Figure 1: Flow chart of interventions regarding accidents involving electrical vehicles

CONCLUSIONS

The number of accidents with electrical vehicles is expected to increase drastically in the next decade. Therefore it is necessary for the fire service to possess safe procedures to act in case of a collision accident, and in case of a fire in an electrical car. The Netherlands Fire Service now has such a procedure, based on collection of knowledge of experts nationally and internationally.

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