RESEARCH FOUNDATION
RESEARCH FOR THE NFPA MISSION

PROJECT PROSPECTUS

Electric Vehicle Hazards in Parking Garages – Full scale Testing

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Background: Vehicles have changed significantly over the years. Modern vehicles incorporate larger quantities of combustible materials (e.g. fuels, plastics, synthetic materials, etc.) into their designs, but there has also been significant advancement in the use and development of alternative fuels for the drive engine. Globally, battery electric vehicles (EV) are seeing significant growth because of their minimal impact to the environment, advancement in the vehicle technology, and government incentive programs. EV sales are expected to increase from 2.5 million in 2020 to 11.2 million in 2025, then reaching 31.1 million by 2030[1].

Modern parking garages have also undergone change. They optimized space requirements for vehicle parking and storage and often implement automated retrieval features and car stacking. To accommodate the growing electric vehicle market, many parking garages now contain high voltage charging stations, which has the potential to create hazards that are unique to traditional garages. Although parking structure fires have not historically posed a significant problem, in recent years we have seen parking structure fires spread to hundreds of vehicles across multiple levels. The engineering and regulatory communities need guidance on how the hazard has changed to inform design and protection requirements.

The 2020 Fire Protection Research Foundation (FPRF) project *Modern Vehicle Hazards in Parking Structures and Vehicle Carriers* identified a number of gaps and research needs for modern vehicles in parking garages settings. One of which being the need for more comparable fire test data to further quantify the EV vehicle fire hazards, burn and spread characteristics in a parking garage setting. In addition to providing protection guidance for parking garages housing electric vehicles and the affiliated charging infrastructure.

Research Goal: The goal of this project is to quantify the fire hazard and spread characteristics of electric vehicles to inform fire protection requirements for parking structures.

Implementation: This research program will be conducted under the auspices of the Fire Protection Research Foundation in accordance with FPRF Policies and will be guided by a Project Technical Panel who will provide input to the project, recommend contractor selection, review periodic reports of progress and research results, and review the final project report. The project will involve the following parties:

- **Fire Protection Research Foundation (FPRF)** is the administrative lead for this project. Both the engineering contractor and the testing contractor shall report to FPRF.

[1] https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html

- **Engineering Contractor** – Combustion Science and Engineering was selected through an open RFP process to be the engineering contractor for Phase I of the "Modern Vehicle Hazards in Parking Garages and Vehicle Carriers" project. They will be continuing this work to further assess the fire spread hazard of EV's and establish protection guidance. CSE shall be responsible for all parts of this study except for the experimental components which are the responsibility of the Testing Contractor. CSE shall be referred to as the Engineering Contractor herein.
- **Testing Contractor** – A testing contractor shall be selected via an open RFP process, who upon selection, will execute the testing portion of this research program. This selected contractor shall be referred to as the "Testing Contractor" herein.

Project Tasks: Under the auspices of the FPRF Project Technical Panel, this project will be completed through the execution of the following tasks:

Task 1: Literature review (Responsibility of Engineering Contractor)

A) Survey of Parking Structures: Conduct an international survey of parking structures to determine representative parking arrangements, garage dimensions, percentage of openness, slope, vehicle distribution (ICE vs AFV), and other characteristics to inform the representative test plan.

B) Characterize the hazard of EVs: Review past EV fire tests to inform the research plan development in Task 2. Using the findings from the available literature, define the key variables to be tested to determine the hazard classification of electric vehicles (e.g. what variables have the greatest impact).

C) Characterize the type, presence, installation characteristics and hazards of electric vehicle charging stations. Identify common types of charging stations, their presence and installation characteristics in parking structures. Conduct a hazard assessment to quantify how charging stations contribute to the overall fire hazard.

D) Modeling: Based on the representative parking garage arrangements identified in Task 1 (A), perform at least 10 simulations using computational fluid dynamics (CFD) models and varying vehicle/parking configurations to inform the scenarios that should be evaluated through full-scale fire testing. The modeling should be used to evaluate parameters such as, heat flux to exterior plastic components and adjacent vehicles interior in different configurations and spacings to estimate ignition times, heat load on surroundings, and establish worst case scenarios.

Task 2: Establish a research plan for full-scale electric vehicle fire tests. (Responsibility of Engineering Contractor)

A) Test Configurations. Since test configurations have a significant impact on fire behavior, conduct a review of the most common parking arrangements (distance between vehicles, clearance to ceiling, etc.) to establish representative test configurations to be implemented within this experimental program.

B) Define Representative Test Variables. Using the findings from the Phase I report and other literature, define the key variables to be tested to determine the hazard classification of electric vehicles (e.g., what variables have the greatest impact).

C) Establish appropriate, repeatable, and consistent ignition scenario and test set-up that will produce consistent and comparable results.

D) Establish evaluation criteria against which the fire hazard and fire spread characteristics of modern vehicles can be assessed.

<u>Task 3: Develop formal experimental test plan (Responsibility of Testing Contractor).</u> Using the information gathered in the above sub-tasks, develop an experimental test plan to be implemented in the subsequent tasks. The tests should focus on horizontal fire spread (e.g., such as in traditional parking garage scenarios). The formal experimental plan shall be reviewed with the project technical panel, prior to implementation.

A) This test program should include multi-vehicle, full scale tests with consistent configurations (e.g., distance between vehicles, vehicle orientation, obstructions/barriers, clarification on the "openness of the garage", ceiling height and presence of beam pockets). A series of proposed tests (calorimeter tests, full-scale fire tests in a garage setting, and sprinklered tests in a garage setting) are provided below.
    i. A mockup of open and closed garage settings shall be designed and constructed, for the purposes of testing. Mockup vehicles (number to be established in the experimental test plan) shall be designed and constructed to essentially serve as an instrumentation framework to capture measurements regarding fire spread to adjacent vehicles beyond the vehicles in the test. The design of the mockup garages and vehicles shall be reviewed with the project technical panel.

B) The sprinklered tests should focus on the impact of sprinkler protection on fire spread. The sprinklered test program should include multi-car, full scale tests with representative sprinkler protection and consistent vehicle configurations (e.g., distance between vehicles, vehicle orientation, obstructions/barriers, clarification on the "openness of the garage", ceiling height and presence of beam pockets).

C) The Test Contractor shall propose recommendations for how to improve efficiency of the experimental test plan and resources used.

Table 1: Proposed Series of Tests (TBD)

Test	Type	Variable	
1	Calorimeter	EV	• Establish baseline data (e.g. HRR)
2	Open Garage	Spacing A	• At least 2 vehicles (look at horizontal spread from one vehicle to the adjacent vehicle) in a garage setting. • Variables: Spacing, beam height, and % opening (consistent with NFPA 88A opening %). • Introduce airflow to simulate open garage conditions. • Place a mockup vehicle on both sides to collect additional data. • Have a charging station as a target to evaluate its contribution (if any) to the hazard.
3	Closed Garage	Spacing A	• 2 vehicles (look at horizontal spread from one vehicle to the adjacent vehicle) in a garage setting. • Variables: spacing, orientation, beam height ○ Modify spacing; keep other variables consistent. • Place a mockup vehicle on either side to collect additional data
Panel to review results of Tests 1, 2, and 3 to determine the parameters of Test 4			
4	Garage (open/closed based on worst case	Spacing B	• 2 vehicles (look at horizontal spread from one vehicle to the adjacent vehicle) in a garage setting. • Variables: spacing, orientation, beam height, and % opening

	result of tests 2 & 3).		○ Modify spacing; keep other variables consistent. ○ Open/closed based on worst case result of tests 2 & 3. • Place a mockup vehicle on either side to collect additional data
Before continuing to Test 5, confirm the sprinkler design with the panel.			
5	Sprinkler in closed garage	Closed Garage + Sprinkler Design Density A	• Ignite one vehicle – with mockups on either side. • Measure sprinkler activation time. • Design density shall be based on current design requirements for closed garages. • Worst case sprinkler location
Panel to provide feedback on sprinkler design of Test 6 based on the results of Test 5			
6	Sprinkler in open garage	Open Garage + Sprinkler Design Density TBD	• Ignite one vehicle – with mockups on either side. • Measure sprinkler activation time. • Worst case sprinkler location

Task 4: Implement Research Plan for Full-Scale Electric Vehicle Fire Tests and Analyze Results.

A) Full-scale Fire Testing of Electric Vehicles (Responsibility of Testing Contractor). Based on the experimental test plan established in Task 3, conduct full-scale fire tests (Tests 1 – 3) as proposed in Table 1. The tests should examine horizontal fire spread (e.g. such as in traditional garage scenarios).
    i. After the testing is complete, develop an experimental test report (Responsibility of Testing Contractor). This shall include a summary of the tests and results.
B) Fire Test Data Analysis. (Responsibility of Engineering Contractor) Using the evaluation criteria established in Task 2(d), assess the data captured from the fire tests in Task 4(a). Based on the fire test data (e.g., HRR), classify the hazard of electric vehicles, in accordance with the hazard classifications identified in NFPA 13.
C) Determine the occupancy/hazard classification and sprinkler protection criteria. (Responsibility of Engineering Contractor) Determine the occupancy/hazard classification and provide recommendations on the sprinkler protection criteria to be used in the sprinklered tests in Task 4(d). Based on the hazard classified in Task 4(b), establish the design criteria to be utilized in the sprinklered fire tests, that is representative of the most common parking structure designs/occupancy classification, and what is likely to be deployed in parking structures per current and future fire codes.
D) Implement Sprinklered Fire Test of Electric Vehicles (Responsibility of Testing Contractor). Based on the experimental test plan established in Task 3, implement sprinklered fire tests of electric. These tests should focus on the impact of sprinkler protection on fire spread.
    i. After the sprinkler testing is complete, develop an experimental test report (Responsibility of Testing Contractor). This shall include a summary of the sprinklered tests and results.
E) Sprinklered Test Data Analysis (Responsibility of Engineering Contractor). Using the evaluation criteria established in Task 2(d), assess the data captured from the sprinklered fire tests in Task 4(d) and compare it against the results from Task 4.

Task 5: Model Validation (Responsibility of Engineering Contractor). Compare vehicle fire test results (Task 4) to computer model predictions from Task 1d to determine accuracy and validity of model inputs and configurations. Determine best practices for achieving improved model accuracy and identify where input data is lacking.

Task 6: Provide recommendations and develop a final report (Responsibility of Engineering Contractor).

A) Knowledge Gaps. Identify any knowledge gaps in need of further research.
B) Provide Recommendations. Based on the free-burn and sprinklered fire tests, provide recommendations and quantified classifications of electric vehicles overall fire hazard, burn and spread characteristics, as well as the impact of sprinkler protection.
C) Develop Final Report. Develop a final report summarizing all the information established herein.

Project Deliverables: The deliverables from this project are:

- A final report that summarizes all the full-scale test data and analysis, along with associated recommendations.
- Data, photos, and video footage of the fire tests conducted.

Schedule: This research project shall be completed within 11 months of project initiation.

Intellectual Property: The Research Foundation will retain rights to all project deliverables including, the project report, which will be published on the Foundation website. The project deliverables also include the test data, videos and images captured and data collected over the course of the project.

About Us:

About the Fire Protection Research Foundation

The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission. All NFPA codes and standards can be viewed online for free. NFPA's membership totals more than 65,000 individuals around the world.