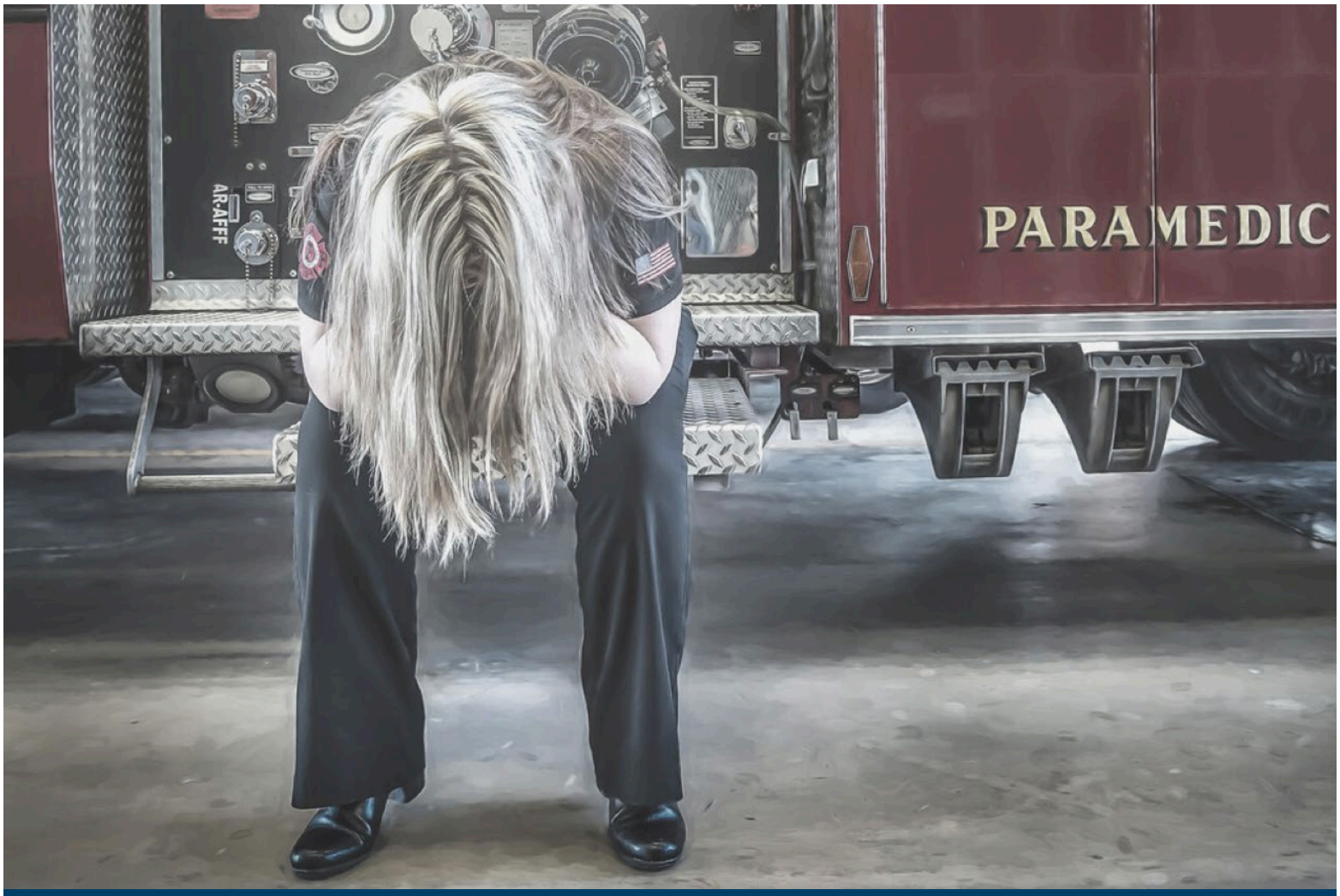

Fire Prevention and Safety (FP&S)

Research and Development (R&D)

Fiscal Year (FY) 2016 Grant Award Results

September 2023

FEMA

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1. INTRODUCTION

The goal of the Research & Development (R&D) Activity within the Fire Prevention & Safety (FP&S) Grant Program is to reduce firefighter line-of-duty fatalities and injuries through research to improve firefighter safety, health, or well-being.

The Federal Emergency Management Agency (FEMA) made six awards under the Fiscal Year (FY) 2016 FP&S R&D Grant Program, for a total of $8,365,202 federal share. This report is based on results from each of the FY 2016 grants awarded in 2017 and ending in 2020 and 2021. Analysis of data and dissemination of results may continue after the end of the award period of performance. Therefore, additional results of interest to the fire service may be available at meetings, in publications, and through on-line podcasts published after this report.

Table 1: FY 2016 FP&S R&D Grant Awards

Grant Number	*Awarded Entity*	*Total Federal Funds Awarded*
EMW-2016-FP-00277	Drexel University	$1,500,000
EMW-2016-FP-00744	North Carolina State University	$935,625
EMW-2016-FP-00754	Oregon State University	$1,500,000
EMW-2016-FP-00788	Salk Institute for Biological Studies	$1,499,710
EMW-2016-FP-00806	NDRI-USA, Inc	$1,499,948
EMW-2016-FP-00833	University of Texas at Austin	$1,429,919

2. EMW-2016-FP-00277 Results (Drexel University)

Table 2: Project Information for EMW-2016-FP-00277

Project Information	
Project Title	Stress and Violence to Fire-based EMS Responders (SAVER)
Organization	Drexel University
Principal Investigator	Jennifer A. Taylor, PhD, MPH, CPPS
Award Total	$1,575,000 ($1,500,000 Federal Share)
Period of Performance	09/01/2017 - 02/28/2021

2.1. PURPOSE

Fire-based Emergency Medical Service (EMS) responders believe they are under severe stress and are concerned about impacts on their physical and mental health. The annual rate of non-fatal injuries among U.S. paramedics is five times greater than the national average for all workers. The annual rate of occupational fatalities among paramedics is two times greater than the national average for all workers. Violence exposure (verbal and physical violence) is associated with increased anxiety, stress, and fear among EMS workers. Currently, only a handful of the existing 30,000 fire and rescue departments in the U.S. have any kind of organizational procedure or policy related to violence.

This study developed the SAVER Systems-level Checklist and a compendium of labor-management model policies (aims 1 and 2) with the intent to reduce stress and violence from fire service work. In aim 3 the investigators sought to increase reporting of violent encounters from the three participating departments using the Center for Leadership, Innovation, and Research (CLIR) in the EMS Emergency Medical Error Reduction Group (EMERG) confidential reporting system. Aim 4 proposed to investigate community need for EMS service and determine areas with clusters of high utilization and calls resulting in verbal or physical abuse injury to firefighters using multiple data systems and GIS.

2.2. METHODS

Figure 1: In July of 2018, over 40 Fire and EMS thought leaders from 27 organizations were convened for the SAVER Systems Checklist Consensus Conference (SC3). For two days attendees helped to modify and revise the checklist to ensure it would meet the needs of responders.

The first aim of SAVER was to convene diverse subject matter experts representing the fire service and EMS organizations, government, academia, unions, and fire departments. Using approaches to facilitate consensus, collaboration, and evaluation of the checklist, each phase of emergency response from dispatch through assessing readiness to return to service was carefully considered. The SAVER Systems-level Checklist contains items focused on actions that leadership can institute through training and policy. Participants ranked the checklist items based on difficulty to implement (extremely difficult, less feasible, and more feasible). From 174 original items, the fire service chose 80 as being feasible to implement in their departments within 3-6 months. Using these items leadership, labor union representatives, firefighters, paramedics, and dispatchers from the three fire

department study sites organized the items into eight Model Policy topics. These policy statements listed below provide a clear statement about the importance of safety, health, well-being, and aftercare for members, with attention to minimize concerns related to rank, power, and distribution of available services.

1. Defining Violence. The policy statements define who the perpetrators of violence may be and define each of the following violence types: verbal abuse, property damage or theft, intimidation, physical abuse, sexual harassment, and sexual assault.
2. Dispatch: Communication & Coordination. The policy statements establish a collaborative and highly communicative relationship between EMS, dispatch, and law enforcement so that information is shared concerning violent locations, patients, or other circumstances in a timely manner.
3. Assessment and Communication of Scene Conditions. The policy statements establish the requirement to assess scene safety and communicate conditions on the ground to others, including standardizing language that initiates action to rescue members in need.
4. Standard Operating Procedures During Patient Care. Although a variety of checklists and guidelines exist for patient care, the policy statements deal with SOPs for patient care activities with a focus on protecting the EMS responder as well as the patient.
6. Readiness to Return to Service. The policy statements confer authority and autonomy to the EMS responder to decide what resources or help is needed for their continued well-being after every call, including a provision to stay out of service for a period. The policy also includes a statement to require the department to use after-action reviews after violent events to understand what was done well, what can be improved, and how to change SOPs/SOGs to improve safety.
7. Reporting of Violence. The policy statements encourage members to report all incidents of violence as well as provide a system by which data related to the event are captured for the purpose of learning and advocating on behalf of membership.
8. Mental and Physical Health Support. The policy statements identify and provide access to resources for EMS responders to assist them with the physical and psychological well-being. The policy acknowledges both the reality of and the need for attention towards the mental health and well-being of members.

For aim 3, the current confidential reporting system CLIR in the EMERG system was modified. Working closely with the fire service unions, changes were made to the EMERG system to further ensure confidentiality and anonymity for the participating departments. Due to the COVID-19 pandemic, agreements to obtain the data needed for aim 4 were not able to be completed within the period of performance for all three departments. Some partial data was obtained, but not sufficient to do the proposed analyses.

2.3. OUTCOMES

The model policy checklist developed in this study has the potential to directly benefit EMS responders by reducing violent injury exposures, work-related mental health impacts, and improving organizational outcomes (e.g., burnout, job satisfaction, engagement). It may also lead to improved

quality of care and patient outcomes. Unfortunately, the onset of the COVID-19 pandemic during this study prevented the planned efficacy testing of the eight policies with fire department partners to compare trends over time, including before, during, and after implementation, and to assess outcomes. Despite this, the Checklist has inspired policy development in project partners. The Philadelphia Fire Department created "Standard Operating Procedure #42 on Assaulted Members." The Dallas Fire-Rescue Department established a resiliency program after interpretation of burnout data provided by the FIRST Center at Drexel University.

In one year of use (December 2019 through November 2020) by three fire departments, using the study modified CLIR in the EMERG system, 126 total reports of violence were received and analyzed. There were a greater number of reports received than what the fire departments were capturing through other systems. Some findings were:

- The rate of violence among the three departments ranged from 1.61 - 4.69/10,000 EMS runs.
- Patients were the most frequently reported perpetrator of violence (80%).
- Most of the violence occurred on scene (82%), with the most frequently reported places of assault as: ambulance (46%), street or highway (27%), and home or residence (25%).
- 62% of violence was perceived to be committed intentionally.
- 83% of reports indicated the EMS provider had no knowledge the patient or location was potentially violent.
- The most frequently reported injury was emotional stress (70%).
- Occurrence of verbal and physical violence simultaneously was reported in 41% of cases, followed by verbal violence only (40%) and physical violence only (19%).
- A closer look at the method of verbal violence revealed general verbal violence (68%), verbal violence using slurs and hate speech (45%), and graphic threats (39%) as the top three types.

2.4. ADDITIONAL INFORMATION

Professor Taylor explains the significance of the study on local NBC-10 Philadelphia news broadcast, February 8, 2019. Link: https://www.nbcphiladelphia.com/news/local/under-attack_-when-first-responders-are-hurt_philadelphia/1748/

Taylor JA, Murray RM, Davis AL, Shepler LJ, Harrison CK, Novinger NA, Allen JA (2019). Creation of a Systems-Level Checklist to Address Stress and Violence in Fire-Based Emergency Medical Services Responders. Occupational Health Science, 3, 265-295.
Link: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8596461/

3. EMW-2016-FP-00744 Results (North Carolina State University)

Table 3: Project Information for EMW-2016-FP-00744

Project Information	
Project Title	Developing a New Basis for Rating the Heat Strain of Firefighter Turnout Gear
Organization	North Carolina State University
Principal Investigator	Roger Barker, PhD
Award Total	$982,406 ($935,625 Federal Share)
Period of Performance	09/01/2017 - 08/31/2020

3.1. PURPOSE

The thermal burden of turnout suits is a primary contributor to firefighter heat strain and to heat-related injuries occurring in structural firefighting. The NFPA 1971 Standard Technical Committee lacked sufficient data to justify inclusion of a R_{ef}, evaporative heat strain resistance factor, requirement into the 2018 edition of the standard. This need motivated the effort to provide an improved technical basis for rating the heat strain performance of firefighter turnout suits. This study was designed to examine performance metrics across a broad range of environmental temperature and humidity conditions to develop a heat strain index for predicting heat strain of firefighter's work in hot environments, which was needed to facilitate a change in the NFPA 1971 Standard[1].

3.2. METHODS

The initial phase of this project was devoted to gathering firefighter input on factors associated with heat strain in structural firefighting operations. Working in collaboration with the Firefighter Industrial Equipment Research Organization (FIERO), a survey of more than three thousand firefighters performing various duties in fire departments across North America was conducted. The survey showed many firefighters (about 50%) have experienced heat stress while on the job. Heat stress can occur in different conditions and stress levels but is most associated with environmentally stressful (hot) conditions. It is associated with the cumulative effect of prolonged work activity in firefighter operations. Firefighters believe their gear contributes to heat stress, and that incident

[1] NFPA 1971: Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting applies to design, performance, testing, and certification for structural and proximity firefighting ensembles and ensemble elements that include coats, trousers, coveralls, helmets, gloves, footwear, and interface components.

thermal radiation from the sun probably contributes to heat strain. Survey findings were foundational for this project because they confirmed the firefighters' perceived importance of reducing turnout heat strain. Perhaps most significant for this project, the survey results validated the need to develop a heat strain index for predicting heat strain of firefighters' work in hot environments.

In the laboratory a validated physiological manikin method qualified environmentally dependent correlations between composite total heat loss (THL) and R_{ef} indexes and core temperature rise associated with stressful work conducted in mild (25 °C, 65%RH) and in hot (35 °C, 40%RH; 40 °C, 28%RH) conditions. The effects of moisture barrier, thermal liner, and outer shell components on turnout THL and R_{ef} indexes were studied.

A testing protocol for the sweating manikin that simulated the leg and arm motion of walking at various speeds was designed to produce heat strain sufficient to cause core temperature to rise to between 38 °C and 39 °C. The work rate needed to produce this level of heat strain depended on environmental conditions. The protocols included environmental conditions, work rates, and work rest cycles that reasonably represent firefighter activities and environmental conditions encountered in structural firefighting response scenarios. The work rates fell within levels typical of real-world firefighting activities, as measured by the Illinois Fire Services Institute (IFSI). The IFSI study determined the average metabolic (MET[2]) rate for fire attack was 4.2 METs while overhaul had a rate of 5.2 METs. Search, rescue, and venting activities produce 4.6-5.0 METs. The protocol used included high MET rates to simulate these strenuous activities, and lower rates to simulate less strenuous activities outside the fire environment.

Each turnout suit was tested in triplicate in each of the environmental conditions maintained in a climate-controlled chamber. To enable maximum heat loss, the investigator tested the turnout suits configured on the sweating manikin with the manikin wearing only a cotton t-shirt, briefs, and socks as undergarments. The manikin wore the basic elements of a structural firefighter ensemble including turnout suit, helmet, and gloves. The manikin did not wear a self-contained breathing apparatus (SCBA) or face piece (Figure 2).

The sweating manikin was operated in dynamic mode to enable realistic simulation of the effects of walking on air circulation in the microclimate formed between the manikin form and turnout suit. Because the tested turnouts were of identical design, the garment effects were expected to be the same for all the study materials.

Figure 2. Fully dressed physiological manikin wearing turnout suit

[2] A MET is the ratio of metabolic rate of energy expended in an activity relative to rate while resting. One MET is 1 kcal/kg/hour and is roughly equivalent to the energy expended by a person per unit time while sitting still.

The effects of the color and texture of the turnout outer shell fabric on these heat strain indexes in simulated solar exposures were evaluated. The effect of shell fabric discoloration through smoke and washings exposures on THL and Ref in exposure to incident solar simulating radiation were investigated.

3.3. OUTCOMES

This study provided a technical basis for the most significant advance in the NFPA 1971 Standard requirements for firefighter heat strain in more than twenty years. Results support the incorporation of the R_{ef} heat strain index, along with THL, as dual metrics for certifying the heat strain performance of turnout suits into a future edition of the NFPA 1971 Standard.

A nation-wide firefighter survey supported the need for the R_{ef} heat strain rating of turnouts, finding that firefighters most frequently encounter heat stress in hot working environments. Project studies showed that THL accurately forecasts thermal burden in mild environments (<25 °C); R_{ef} provides accurate prediction in hot environments (>35 °C). The R_{ef} index is more useful for evaluating turnout heat strain. THL index has no value for predicting heat strain in hot environments. It provides an inflated comparison of the ability of many turnout systems to dissipate evaporative heat in hotter working conditions. No correlation was observed between the THL and R_{ef} heat strain indexes; a high THL value does not necessarily correlate with low R_{ef} rating. This is a significant finding because it means that exclusive reliance on either THL or R_{ef} could lead to diametrically different conclusions about the comparative breathability performance of turnout systems.

The comprehensive performance measurements in this study provided useful information on effects of turnout materials on firefighter heat strain. They showed that hydrophilic bi-component barriers absorb moisture in the mild, non-isothermal conditions of the standard THL test giving them advantage in heat loss that does not translate to more thermally stressful hot environments. The study found no difference in heat strain performance in mild environments among composites with different thermal liner systems. This finding is counter to the perception that choices of thermal liner materials, from one-layer or two-layer spun laced nonwovens to needle punched battings, affect the heat strain performance of turnout suits. The color of the outer shell fabric or discoloration of the shell material due to smoke (Figure 3), had a surprisingly sizeable influence on THL and R_{ef} heat

Figure 3. Visual effects of washing on turnout shell fabric appearance: (a) new condition, (b) new sample after 40 cycles of washing and (c) new sample after 40 cycles of smoke exposure and washing (E&W)

strain ratings of turnout systems exposed to radiant heating. A follow-on study is needed to develop and validate a test method and performance criteria for evaluating the significant effects of radiant heating revealed by this project.

3.4. ADDITIONAL INFORMATION

Roger Barker, Xiaomeng Fang, Shawn Deaton, Emiel DenHartog, Huipu Gao, Robert Tutterow & Marni Schmid, (2022) *Identifying factors that contribute to structural firefighter heat strain in North America*, International Journal of Occupational Safety and Ergonomics (JOSE), 28:4, 2183-2192. Link: https://doi.org/10.1080/10803548.2021.1987024

Huipu Gao, A. Shawn Deaton, Roger Barker, Xiaomeng Fang & Kyle Watson (2022) *Relationship between heat loss indexes and physiological indicators of turnout-related heat strain in mild and hot environments*, International Journal of Occupational Safety and Ergonomics (JOSE). Link: https://doi.org/10.1080/10803548.2022.2058746.

4. EMW-2016-FP-00754 Results (Oregon State University)

Table 4: Project Information for EMW-2016-FP-00754

Project Information	
Project Title	Novel Approach to Measuring Firefighter Chemical Exposure
Organization	Oregon State University
Principal Investigators	Kim A. Anderson, PhD
Award Total	$1,575,000 ($1,500,000 Federal Share)
Period of Performance	09/01/2017 - 2/28/2021

4.1. PURPOSE

The United States (US) Fire Service has assumed increasing responsibility not only for fire suppression, but as first responders for nearly every emergency and disaster which occurs in a community. Unfortunately, previous research suggests firefighters have a relatively high incidence of serious negative health outcomes, with cancer being one of the leading causes of morbidity and mortality. Occupationally related exposures to chemical toxicants are thought to be part of the reason firefighters are more likely to get cancer or suffer other negative health effects.

This project investigated firefighter occupational exposures and aimed to determine the acceptability of military style silicon dog tags capable of absorbing chemical samples from the air for specimen

collection in firefighters. Firefighters were asked to wear the dog tags over their clothing while off-duty and under turnout gear while on-duty. Second, this project assessed which chemicals firefighters were exposed to by monitoring firefighters in high- and low-call volume departments. Third, the project aimed to determine differences in chemical exposures of firefighters both on- and off-duty. The focus of the analysis was exposure to polycyclic aromatic hydrocarbon (PAH) compounds, a group of carcinogenetic chemicals commonly found in smoke from fires. Lastly, the project aimed to describe the bioavailable chemicals present in occupational exposures from the set of 1530 chemicals measured from the dog tags to explore those possibly unique to firefighters.

4.2. METHODS

Silicone passive samplers worn in the form of wristbands or dog tags continually absorb chemicals from the air. The material allows very low levels of toxicants to be measured. The silicone passive samplers are very lightweight and unobtrusive. In this study the sampler was worn like a dog tag on a chain around the neck (Figure 4) for 30 consecutive days. The sampler required no battery and no maintenance. The investigators have used the silicone samplers in previous studies to measure exposure from general air pollution and to measure exposure at specific sites such as hot tar roofing and natural gas drilling operations.

Figure 4: Silicone dog tags were worn around the neck underneath firefighting

A total of fifty-six firefighters from the Southern Platte Fire Protection District (SPFPD), a combination department, and Raytown Fire Protection District (RFPD), a career department, both in the Kansas City metro area participated in this study. For this study SPFPD served as the low-call volume department (averaging 2 calls/month) and RFPD served as the high-call volume department (averaging 12 calls/month).

Firefighters wore one sampler tag while on-duty and another while off-duty. During firefighting the tag was worn under the turnout coat. The two tags accumulated their respective exposures over the 30-day collection period. Activities of the firefighters were not logged.

Each dog tag was screened for the presence of 1,530 different chemical compounds. This comprehensive chemical analysis created an exposure database for firefighter occupational exposure. This study concentrated on a subset of 63 PAH chemical compounds because they are commonly found in the environment, or they are suspected to be more harmful than other PAHs.

4.3. OUTCOMES

The study yielded a large quantity of chemical exposure data documenting the chemicals the firefighters were exposed to and the concentration of each on the individual dog tags. Results from analysis of the data focused on possible carcinogenetic PAH chemical species associated with

impaired lung health and with cancer. Many PAH chemicals are found in soot on turnout gear, but many more PAHs are in the air and invisible. Some of these chemicals are common indoor pollutants. During a fire, household objects – plastic toys, furniture, utensils, household pesticides, dyed textiles, and items containing rubber and plastic components – may burn and release PAHs into the air.

The silicone dog tags were demonstrated to be a feasible method of monitoring exposures over long periods of time. As expected, firefighters were found to have had more exposure to PAH compounds on-duty than off-duty. The firefighters at the high call department had greater exposure than the low volume department. Figure 5 shows a comparison of concentrations of 20 selected PAH chemicals found absorbed by the silicone tags. In each case, exposure to the PAH chemical was found both on-duty and off-duty, but of the selected PAH chemicals measured, the on-duty tags absorbed statistically significantly greater concentrations than the off-duty tags for most chemicals.

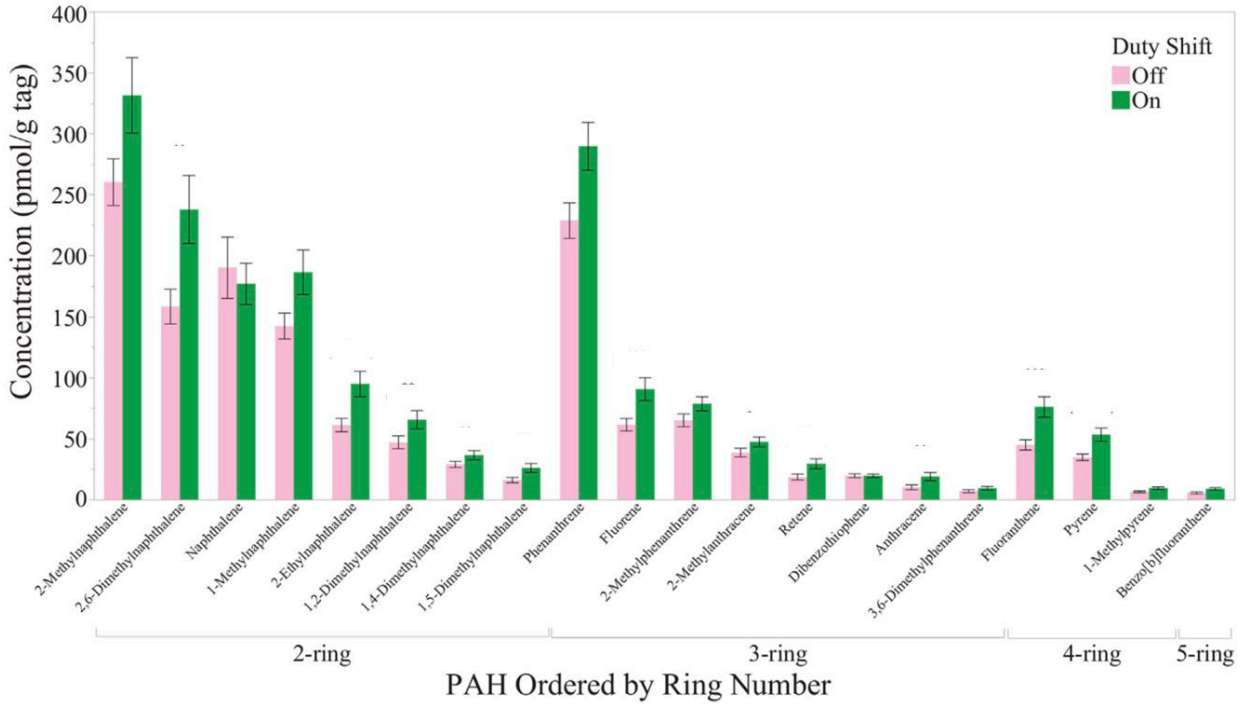

Figure 5: Bar graph compares 20 of the PAH compounds found in greatest concentrations, ordered by the number of aromatic rings in the structure between on- and off-duty paired dog tags.

The comprehensive chemical screening of the silicone dog tags identified 18 PAH compounds that had not been detected in firefighter studies before and possibly unique to firefighter activities. In some cases, the newly detected compounds may have been found on tags from only one or two of the participating firefighters.

Analysis of the large volume of data collected in this study continues. The chemical exposure database has been examined for firefighter exposures to endocrine disrupting chemicals that can interfere with hormonal actions regulating and maintaining many developmental and physiological

processes in the body. The silicone tags contained evidence of exposure to 47 potential endocrine disrupting chemicals.[3]

4.4. ADDITIONAL INFORMATION

Rohlman, D. and Poutasse, C. M., *The invisible danger: Studying PAH exposure on the fireground and after the call*, FireRescue1, January 9, 2021, Link: https://www.firerescue1.com/cancer-risk/articles/the-invisible-danger-studying-pah-exposure-on-the-fireground-and-after-the-call-uynWwuUCHvwDzW6F/

Poutasse CM, Poston WSC, Jahnke SA, Haddock CK, Tidwell LG, Hoffman PD, Anderson KA. Discovery of firefighter chemical exposures using military-style silicone dog tags. Environ Int. 2020 Sep;142:105818. Link: https://pubmed.ncbi.nlm.nih.gov/32521346/

Two downloadable infographics:

- Firefighter Chemical Exposures infographic http://fses.oregonstate.edu/file_store/public/infographs/firefighter_infographic_main.pdf
- Firefighters and Cancer Risk infographic http://fses.oregonstate.edu/file_store/public/infographs/firefighter_infographic_cancer.pdf

5. EMW-2016-FP-00788 Results (Salk Institute for Biological Studies)

Table 5: Project Information for EMW-2016-FP-00788

Project Information	
Project Title	Optimizing Circadian Rhythms by Regulating Eating Patterns to Reduce Cardiometabolic Disease Risk among Firefighters
Organization	Salk Institute for Biological Studies
Principal Investigator	Satchidananda Panda, PhD
Award Total	$1,574,695 ($1,499,710 Federal Share)
Period of Performance	09/01/2017 - 02/28/2021

[3] Poutasse CM, Haddock CK, Poston WSC, Jahnke SA, Tidwell LG, Bonner EM, Hoffman PD, Anderson KA. Firefighter exposures to potential endocrine disrupting chemicals measured by military-style silicone dog tags. Environ Int. 2022 Jan;158:106914. Link: https://pubmed.ncbi.nlm.nih.gov/34649051/

5.1. PURPOSE

Career and volunteer firefighters do shift work or work irregular hours, which increases the risk for cardiometabolic disease. Novel interventions that are feasible among firefighters are needed to reduce their risk of cardiometabolic disease. Circadian rhythm research supports that consuming all caloric containing food and beverages within a consistent 10 hours each day may improve sleep and reduce cardiometabolic disease risks. This study was conducted to evaluate the impact of time restricted eating (TRE) on glucose homeostasis and to assess changes in metabolic and neuroendocrine biomarkers in response to the imposed feeding/fasting cycles.

5.2. METHODS

A total of 137 career firefighters, from San Diego Fire-Rescue Department, working 24-hour shifts completed the 12-week trial. The volunteers were ages 21-65, with varying degrees of health status, all worked 24-hour shifts and included 13 females. After completing a 2-week baseline/screening period, participants were randomized to a 12-week active intervention of either (1) standard of care (SOC) with Mediterranean Diet counseling or (2) SOC and 10-hour TRE. The SOC group was allowed to eat ad libitum and the TRE group followed a self-selected 10-hour eating window. Some participants in both groups continued the eating style for an additional 9-months of self-guided behavioral modifications.

5.3. OUTCOMES

At the end of 12-weeks of active intervention, the TRE group decreased their median eating window by 3 hours. Glucose homeostasis did not significantly change in the TRE group as compared to the SOC group, as most participants had normal levels at baseline. The TRE group lowered their very-low-density-lipoprotein (VLDL) particle size significantly as compared to the SOC group. In a small subgroup analysis of firefighters who had cardiometabolic abnormalities at baseline, glycated hemoglobin A1c (HbA1c) decreased in the TRE group compared to SOC: (TRE N=10; SOC N=11) and diastolic blood pressure (DBP) decreased (TRE N=9; SOC N=6). The Quality of Life of the TRE group as assessed by the RAND 36-Item Health Survey (SF-36) questionnaire did not show any lasting improvements at the 12-month assessment between treatment groups. Participants did not report any adverse effects from the study. A limitation of the study was the recruitment of a heterogeneous cohort with varying degrees of health status which may have led to modest change to

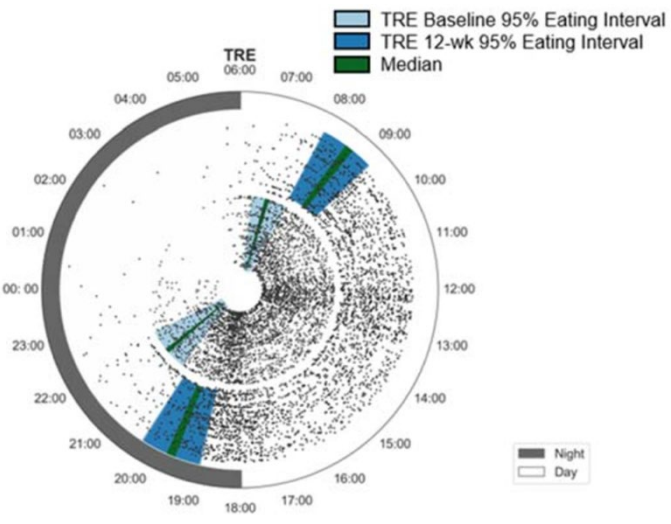

Figure 6: Decrease of 3 hours in median eating interval for the TRE group.

overall health of each group in response to Mediterranean diet or the TRE intervention. The length of the intervention was not long enough to capture preventative or treatment-related cardiometabolic changes.

This study demonstrates the feasibility of adopting a 10-hour TRE lifestyle among career firefighters working 24-hour shifts. Future studies should focus on longer and larger studies to assess cardiometabolic parameters and the feasibility of self-guided TRE with virtual occasional support from study staff to ensure this lifestyle can be scalable and applicable across career and volunteer fire departments working different types of shifts.

5.4. ADDITIONAL INFORMATION

San Diego Fire - Rescue Battalion Chief David Picone discusses the experience of firefighters in his department that participated in the time restricted eating study with KBPS Science and Technology reporter Thomas Fudge (October 5, 2022). Link: https://www.youtube.com/watch?v=kULstctqzH0

Drs. Panda and Manoogian discuss their research in a NFPA Research Foundation webinar: Time-Restricted Eating for Improving Overall Health and Sleep Among Firefighters, August 11, 2020. Link: https://players.brightcove.net/1640544031001/default_default/index.html?videoId=6180577913001

6. EMW-2016-FP-00806 Results (National Development and Research Institutes, Inc.)

Table 6: Project Information for EMW-2016-FP-00806

Project Information	
Project Title	Bullying, Harassment & Resilience in the U.S. Fire Service
Organization	National Development and Research Institutes, Inc.
Principal Investigator	Sara Jahnke, PhD
Award Total	$1,574,945 ($1,499,948 Federal Share)
Period of Performance	09/01/2017 - 02/28/2021

6.1. PURPOSE

Bullying and hazing have become a critical area of concern in the fire service; from face-to-face and online intimidation to extreme instances of harassment resulting in assault. These negative behaviors erode safety and teamwork in addition to being in stark contrast to the fire service core values of duty, pride, and tradition and put departments at risk for litigation. Bullying can impact

recruitment and retention, disrupt careers, cause behavioral health outcomes, and impact suicide risk. Bullying/hazing and assault in the fire service are underreported and, in many instances, exist as traditionally accepted aspects of the job. The purpose of this project was to qualitatively and quantitatively explore the range of experiences and perspectives nationally about bullying and harassment and develop next steps and recommendations for training and prevention efforts.

6.2. METHODS

To develop an understanding of the culture of bullying, harassment, and hazing a purposive sampling strategy was used to conduct key informant interviews and focus groups with a nationally representative cohort of firefighters, fire service leaders, and Human Resources (HR) representatives. The data coding process organized the comments into domains including general perceptions of bullying and harassment, perceptions and experiences with probationary initiation, and acceptance of diversity in the fire service.

The purpose was to describe the culture of bullying and harassment in the fire service. Researchers traveled to seven fire department training facilities to recruit and interview firefighters for focus groups. Interviews took place over the phone via a private conference call line to facilitate recording. Researchers developed the interview guide with assistance from a fire service expert stakeholder panel comprised of fire service researchers, leadership in the fire service, and members of leading national fire service organizations. The interview guides assured topic consistency among interviews and were designed to capture broad themes related to bullying and harassment. The guides reflected open-ended questions about workplace climate, general perceptions of bullying and harassment, expectations of hazing, and perceptions of diversity in the fire service.

A total of 162 firefighter recruited from seven fire department training facilities voluntarily participated in 1-hour focus groups at their respective training academies. Thirty-three (33) separate participants completed phone interviews including 15 firefighters, 16 fire service leaders, and two human resources (HR) representatives. Demographic information for participants is in Table 7.

Table 7: Participant Demographics

Participants	Firefighters	Leaders	HR	Focus Groups
Number	15	16	2	162
Gender, % Male	27%	50%	50%	91%
Average Age, years	42.1	53.4	54.5	28.0
Race, number (%)				
White	13 (87%)	14 (88%)	1 (50%)	Race
Black	1 (6.7%)	1 (6.3%)	1 (50%)	unknown for
American Indian/Alaska Native	0	1 (6.3%)	1 (50%)	all
Hispanic	1 (6.7%)	0	0	participants

6.3. OUTCOMES

Examining participants' general perceptions of bullying and harassment led to the discovery of the following themes:

- There are varying levels and perceptions of probationary initiation.
- Firefighters have varying definitions of bullying.
- Bullying is prevalent in the fire service.
- There are varying definitions of harassment.
- Harassment is prevalent in the fire service.
- The fire service generally does not accept diversity.
- Diversity in the fire service is improving.

A fascinating notion that emerged from the data was the realization that some concepts which provided positive initiation experiences, could also provide negative initiation experiences. This may be due to the dual purpose of the new recruit probationary year, that of fitting in while simultaneously proving one's worth to the crew and department. It may also be because one's perception of different initiation traditions. Proving one's worth emerged through initiations designed to treat new firefighters differently, which included specific work assignments and participation in pranks. Participants were asked about their beliefs regarding the prevalence of bullying in the fire service and most participants believed bullying was very common, perhaps "more common than we realize" (leader, male, white), and was imbedded into the fire service culture. Many of the participants defined bullying and/or harassment as singling out someone because they are different, whatever that difference was. Often, participants cited race, gender, and ethnicity as culprits for disparate treatment. Perhaps these perceptions of what bullying and harassment encompasses are related to the apparent lack of diversity in the fire service.

Researchers interviewed firefighters and fire service leaders from across the nation to determine perceptions and experiences with assault in the fire service. Overall, the firefighters and leaders we interviewed were aware of workplace violence, either because they'd experienced it personally or knew someone who had. Instances of sexual assault escalated from saying inappropriate things to repeated sexual assault and on-the-job stalking. When participants were asked about reporting incidents, women often noted they were hesitant to report for fear of retaliation or not being taken seriously.

Results from the firefighter interviews were categorized into three groups based on reported levels of discrimination and harassment: low, medium, and high severity of discrimination and/or harassment. Those that reported experiencing the most severe discrimination and harassment, also reported experiencing it more often. Trends for nine types of discrimination and harassment are shown below in Figure 7.

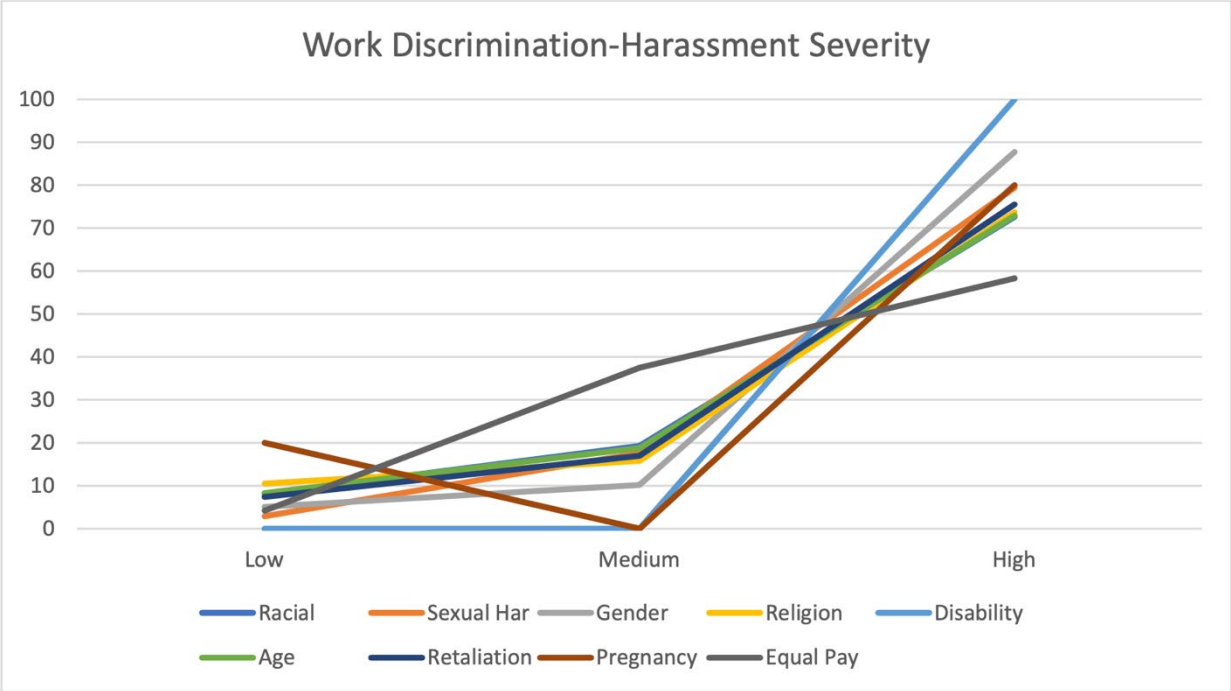

Figure 7: Prevalence and severity of sexual harassment, racial, gender/sex, religion, disability, age, and pregnancy discrimination, and instances of retaliation and unequal pay.

The preliminary results of this project emphasize the importance of examining bullying and harassment in the fire service and highlight the need for education, training, and policy change to address these issues. It is importance to note that what works in one department may not work in another, and career and volunteer services will likely have different challenges when it comes to changing the culture of their organization. This study is an important first step in understanding the state and severity of bullying and harassment in the fire service.

The research team worked on two areas for dissemination of results. The first was training disseminated by the IAFC bullying task force titled “Not in Our House”. The train-the-trainer course was centered around talking points, objectives, reference materials, instructor requirements, classroom set up, and resource/marketing materials. The second was an online training that will be housed within the Center for Fire, Rescue, and EMS Health Research at NDRI-USA’s online learning management system based on the qualitative data collection in this study. The training focus is on the prevalence and impact of bullying as well as bystander approaches for addressing the challenges. Results of the study can inform recruitment and retention strategies and may assist in development of training designed to change the culture of bullying and harassment in the fire service.

Understanding workplace violence is essential as it can lead to lower levels of organizational commitment and job satisfaction, and negatively impact a sustainable workforce. Further, research has linked workplace violence to adverse health effects including depression, anxiety, burnout, and high rates of turnover within an organization.

6.4. ADDITIONAL INFORMATION

The results of this research were used as the empirical basis for the IAFC Bullying and Workplace Violence Prevention Toolkit, "Respect Our House". Link: https://www.iafc.org/topics-and-tools/resources/resource/bullying-and-workplace-violence-prevention-toolkit.

Koeppel, M.D.H., Hollerbach, B.S., von Thaden, T.L., Kelley, H., Kaipust, C.M., Jitnarin, N., Khurram, S., Poston, W.S.C., Haddock, C.K., and Jahnke, S.A., "Trying to Eat an Elephant": The Complexities of Bullying Training in the Fire Service, American Journal of Qualitative Research 2022, Vol. 6 No. 3, pp. 155-167. Link: https://www.ajqr.org/download/trying-to-eat-an-elephant-the-complexities-of-bullying-training-in-the-fire-service-12533.pdf

7. EMW-2016-FP-00833 Results (University of Texas at Austin)

Table 8: Project Information for EMW-2016-FP-00833

Project Information	
Project Title	Firefighter Safety in Battery Energy Storage System Fires
Organization	University of Texas at Austin
Principal Investigator	Ofodike A. Ezekoye, PhD, PE
Award Total	$1,501,414 ($1,429,919 Federal Share)
Period of Performance	09/01/2017 - 12/30/2020

7.1. PURPOSE

The world is rapidly undergoing the process of electrification. There have been 43 fire and explosion incidents worldwide involving lithium-ion battery energy storage systems (LiBESS) in the past 10 years[4]. For a fire involving a LiBESS, it is critical for the fire service to have a better understanding of the possible hazard evolution scenarios. The severity of hazards such as explosions, extreme fire behavior, stranded energy in damaged cells, etc. are not fully understood. The purpose of the project

[4] As part of this study the University of Texas Fire Research Group using data provided by Hazard Dynamics, created an interactive database tool to track and display worldwide battery failure, fire, and explosion incident data. The data is collected from governmental regulatory authorities, consumer safety information, media coverage, and other sources. The database tracks 16 classes of battery applications including energy storage. Link: http://tools.utfireresearch.com/apps/incident_map.

was to improve fire service knowledge of LiBESS fires and explosions to reduce the risk to firefighters responding to emergencies involving lithium-ion batteries. The project sought to fill in knowledge gaps on failure modes and effects of LiBESS by carefully testing and characterizing the thermal runaway and venting processes for several classes of battery systems at different scales. As a result of this study, the improved understanding of LiBESS fire hazards will better prepare the fire service to develop standard operating guidelines (SOGs) to ensure firefighter and public safety.

7.2. METHODS

The project employed both experimental tests at various scales and computational models to better understand LiBESS failures, fire development, gas generation, and possible explosion hazards. Experiments were conducted at progressively greater scales utilizing small 5 Ah capacity cells to investigate fire initiating failures and how to best replicate those failures in experiments, 94 Ah capacity commercial cells, single rack modules made up of 14 commercial cells (Figure 8), and finally a commercial cabinet holding many rack modules. These experiments over a wide range of scales were needed to build a strong foundation to understand the important underlying physical processes associated with LiBESS fires. Applying computational modeling in concert with experimental testing resulted in more complete understanding of the underlying physics and the capability to extrapolate results to larger scale. Knowledge gained was incorporated into the Lithium Battery Simulation and Training (LiBSAT) system capable of safely simulating the potential for explosion conditions generated from battery failure events in occupied structures.

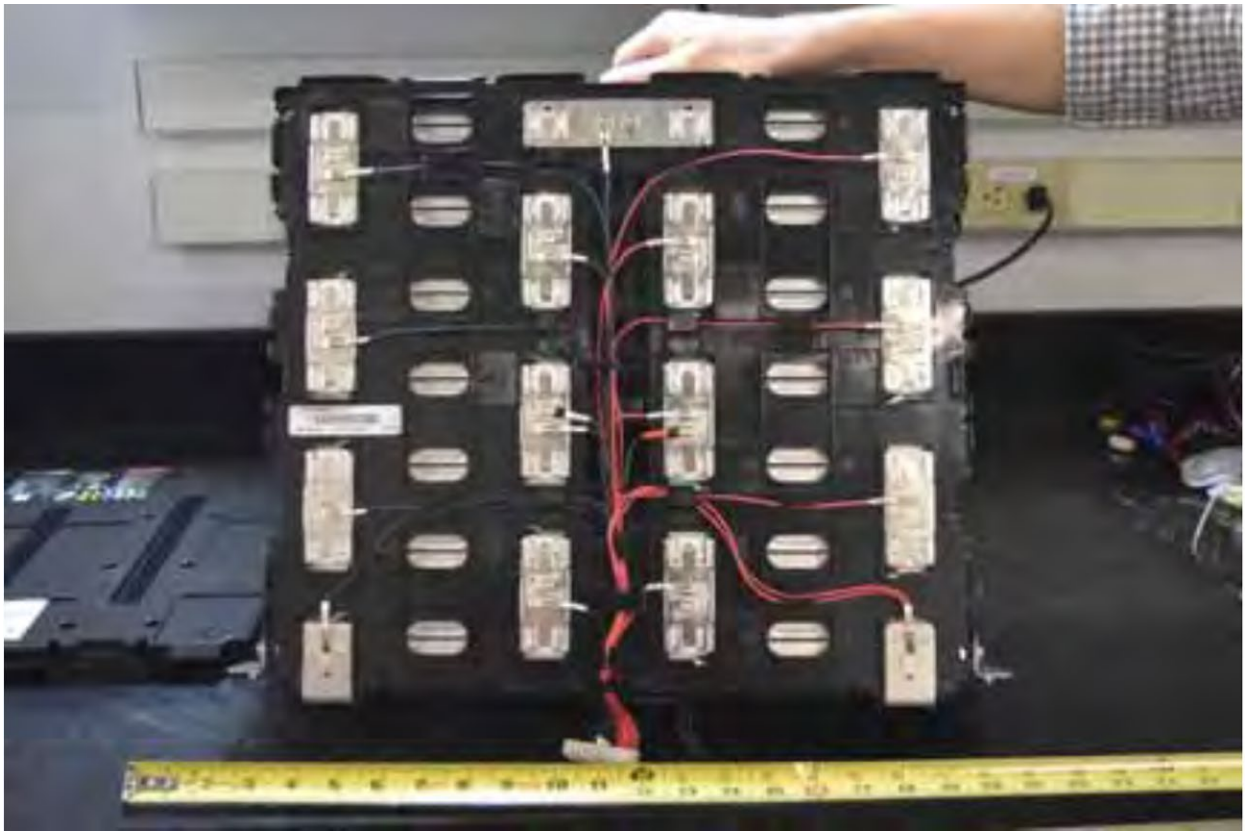

Figure 8: Array of 14 individual 94 Ah commercial cells connected to form one commercial cabinet module. Commercial cabinets may hold up to 10 cabinet modules.

7.3. OUTCOMES

Only a portion of the study results are documented in this summary. Preference was given to the fire test results with supporting results from extensive laboratory testing, fire modeling, and other demonstration tools omitted.

Figure 9: Casing of a 94 Ah cell flies apart as battery cell material inside burns in a fireball

Extensive laboratory experiments with individual 5 Ah and 10 Ah battery cells provided fundamental information about ignition, burning, and resulting damage to Li-ion batteries cells. The 94 Ah commercial cell is the building block for larger rack modules and the cabinet LiBESS. When the individual 94 Ah battery cell was heated rapidly using a cartridge heater in contact with the metal case, the result was a catastrophic battery cell explosion. The cell burst open and the metal casing to the shell was violently thrown to the opposite side of the test room. Some of the insides of the cell were left in place on the test stand, while other parts were thrown to the opposite side of the room (Figure 9). Instead of venting out the top of the case as designed, the cell responded to the over pressure venting from one of the sides of the casing failing rapidly.

When heated gradually at approximately 5 °C (9 °F) per minute until the cell went into thermal runaway, the cell vent opened as designed releasing a jet of flammable gases and electrolyte vapors that burned in an intense flame for about 10 seconds (Figure 10).

Figure 10: Images of the 94 Ah single cell during the intense venting and burning period lasting about 10 seconds.

In the experiments where slow heating was used to initiate thermal runaway, there were no explosive failures.

In a commercial unit, the single 94 Ah cells tested above are packed into a case for rack mounting. The hardware used in the study utilized 14 single cells arranged as shown in Figure 8. The 14 cells module when fully charged has a stored energy capacity of 4.8 kWh. Commercial racks used for a LiBESS system holding ten of these modules could provide a day of electric power for a home. Failure of one cell resulting in a fire will spread throughout the rack module and between rack modules mounted in a cabinet.

Tests of a fully charged rack module with 14 single 94 Ah module cells wired together in series demonstrated the potential for thermal runaway was strong. Initial gas release was typically followed by ignition of the vent gas jet, producing a dramatic jet flame. As a result, subsequent ignition of the plastic module rack mount housing was reliable despite any flame retardant that may have been present in the plastic. Figure 11 shows the failure of the first module cell. A video[5] shows the spread of fire throughout the module as more cells are involved.

Figure 11: Sequential images of the failure of the first 94 Ah module cell in a rack mounted case containing 14 modules. Continued fire propagation and growth is displayed in the video[5].

[5] Single rack module fire (https://www.youtube.com/watch?v=9OXeh5ZQA80&t=247s). This experiment uses a module taken from a commercially available battery energy storage system. Inside the module are fourteen 94Ah nickel-manganese-cobalt cells connected in series. Overall, the module has an energy capacity of 4.8 kWh. Once the first cell experiences thermal runaway, the propagation to surrounding cells can be readily observed. The experiment was conducted on June 12, 2019. The video duration is 7:38 showing segments of the 18 minutes of burning.

When LiBESS systems fail in a confined space, explosive conditions can result. This was demonstrated with a single 94 Ah cell forced into thermal runaway conditions while contained within a closet. Combustible gases released by the cell accumulated in the confined space and ignited when gases continuing to escape from the battery ignited. The rapid burning of the accumulated gases over-pressurized the closet, and the structure failed suddenly and violently (Figure 12 & video[6]).

Figure 12: Sequential of images from the test video[6] showing the short time from the venting of gases from the failed 94 Ah module to explosion blowing the door off the closet. Image (Time 0 seconds): exterior view of the enclosure at the time the battery module begins to vent gases. Image (Time 3 seconds): first exterior visual evidence of venting. Image (Time 5 seconds): closet door blown away from the structure when accumulated combustible gases ignite.

This study contributed to greater awareness of LiBESS fire, gas explosion, and toxic gas release hazards. High severity consequences from LiBESS failures were identified and characterized. A framework was developed for evaluating LiBESS failure and consequences (explosion and other extreme fire behavior). Scientific understanding of failure propagation in components and commercial systems was improved as a result of these experiments. The study revealed that firefighters may not have the tools needed to assess the appropriate response if a fire incident involves burning of lithium-ion batteries.

Results of the study were disseminated in workshops conducted with the Honolulu Fire Department, and the Peoria and Surprise, Arizona Fire Departments that have had experience with energy storage

[6] Single 94 Ah battery module ignites inside closed 4 ft x 4 ft x 8 ft closet (https://www.youtube.com/watch?v=NoVUkUC_o7E&t=10s). Battery failures are dangerous in large part due to their unpredictability. If the vent gas emitted by a failing battery does not ignite and burn right away, it can accumulate and lead to unexpected explosions. This experiment conducted March 13, 2019, demonstrated the potential for explosions when battery vent gas is allowed to accumulate inside of an enclosed space. Video duration 53 seconds.

facility fires. By discussing issues, the researchers were able to understand the problem space better and the firefighters gained better understanding of the science behind the LiBESS fire hazards.

7.4. ADDITIONAL INFORMATION

Fire Science Show, Session 44, March 30, 2022, Improving Fire Safety of Batteries. Dr. Ofodike Ezekoye discusses battery system fire safety on the Fire Science Show, Session 44, March 30, 2022. Link: https://www.firescienceshow.com/044-improving-fire-safety-of-battery-systems-with-ofodike-ezekoye/

Series of videos showing failures to flaming of commercial energy storage systems and lithium-ion battery modules components in tests conducted at the University of Texas – Austin. Link: https://www.utfireresearch.com/bess-videos