National Institute of Standards and Technology

FEMA

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**Better fire fighting through research**

**August 2009**



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## What is the Role of Heat Stress And PPE?

More firefighters die in the line of duty from heart attacks than from any other cause. And slips, trips and falls cause a large number of firefighter injuries. While the origins of heart attack and slip, trip and fall may appear unrelated, previous research suggests that heat stress may be a common factor in both heart attacks and slips, trips and falls. Research further suggests that one common, critical factor can potentially mitigate both of these injuries and fatalities: modified personal protective equipment (PPE). The University of Illinois Fire Service Institute has conducted research to learn more about this.

Their research project "Cardiovascular and Biomechanical Responses to Fire Fighting and PPE" provided a review of the known research and new and important findings concerning the interrelationship of cardiovascular function, biomechanics and the design of personal protective equipment. The researchers investigated how PPE influenced the gait and balance parameters and provided a theoretical link to slips, trips and falls. The researchers also studied the influence of firefighting on coagulatory variables based on the hypothesis that firefighting increases clotting potential, thus partially explaining the high rate of sudden cardiac events following fire suppression activity.

Live studies were conducted and 122 male firefighters from across the State of Illinois with a wide range of firefighting experience participated. The group was almost equally divided between career and voluntary firefighters. The participants mean age was 29.5 years, they had no known cardiovascular disease or balance/gait impairment and were not taking medications for hypertension or high cholesterol. Participants engaged in 18 minutes of firefighting activity in a burn tower that contained live fire. Temperatures were at approximately 100 deg F at the floor level and 170 deg F at waist level. The firefighters' activities included stair climbing, search and rescue, and simulated hose pull. This study found that on an acute basis, firefighting increased blood clotting potential and lead to significant cardiovascular strain, however, the PPE configuration worn during 18 minutes of firefighting did not significantly effect the magnitude of this response.

The donning of PPE did cause significant detriments in gait and balance parameters. Part three of the report contains recommendations to the fire service based on the research conducted and also consists of additional recommendations from national organizations, fire departments, and individual fighters.

This study was sponsored by the Department of Homeland Security's Assistance to Firefighters Fire Prevention and Safety via the Assistance to Firefighters Grant (AFG) program. To learn more about the research activities and the recommendations download the report, "*Firefighter Fatalities and Injuries; the Role of Heat Stress and PPE*" from the University of Illinois' web site: http://www.fsi.uiuc.edu/documents/research/FFLSRC_FinalReport.pdf. If additional information is needed, contact Gavin Horn: ghorn@fsi.uiuc.edu.

*Research showed that the simple task of ducking under an obstacle appeared to be significantly more difficult while wearing PPE than while not wearing PPE, which has important implications both for safety and in affecting functional capabilities of the firefighter on the fireground, as well as any other response requiring firefighting PPE. (Photo Credit: Board of Trustees of the University of Illinois)*

## Wind Driven Fire in Structures -- Research Results on DVD

Thousands of high-rise apartment fires occur annually. Beginning in one room, a fire can quickly spread smoke, heat and gases through hallways and stairwells thus limiting the occupants' chances to escape and the firefighters' ability to rescue them. NIST researchers conducted two series of experiments to study the effect of wind on structure fire and techniques for fighting these fires.

These experiments demonstrated the "extreme" thermal conditions that can be generated by a "simple room and contents" fire as well as how these conditions can be extended along a flow path within a real structure when wind and an open vent are present. This results in a wind driven fire. Test results show that wind speeds as low as 10 mph can result in a wind driven fire condition. The wind driven condition can be described as hot gases or flames flowing horizontally out of the room of fire origin. The wind driven fire condition has been described as a "blow torch" by firefighters.

The first experiments were conducted in NIST's Large Fire Laboratory and created a wind driven fire condition as well-mixed fire gases of equally high temperature, at least 400 ºC (752 ºF), from the floor to the ceiling. For this condition to occur inside a structure the fire must be in a flow path. In these experiments the inlet to the flow path was the upwind window in the room of fire origin. The flow path then went through the apartment, into the corridor, and exited out of the bulkhead door on the roof via the stairwell. Without a flow path the wind driven fire condition inside the structure cannot occur.

The experiments demonstrate several tools and techniques for controlling a wind driven fire. These include: door control, wind control devices, high-rise nozzles and positive pressure ventilation fans. The results of the study also conclude that wind driven fire is not limited to highrise buildings; this condition can occur in any structure. Therefore wind conditions should always be considered. The laboratory tests that NIST conducted with the support of the Fire Protection Research Foundation are described in NIST Technical Note 1618, "Fire Fighting Tactics Under Wind Driven Conditions: Laboratory Experiments" and can be found at, http://fire.nist.gov/bfrlpubs/fire09/PDF/f09002.pdf .

Next, researchers conducted a series of fire experiments that were performed in a 7 story building on Governors Island in New York City in partnership with the Fire Department of New York City and Polytechnic Institute of New York University. The experiments evaluated the ability of positive pressure ventilation fans, wind control devices and external water application with high-rise nozzles to mitigate the hazards of a wind driven fire in a structure. Each of the 14experiments started with a fire in a furnished room. The air flow in the experiments was intensified by a natural or mechanical wind. NIST Technical Note 1629 "Fire Fighting Tactics Under Wind Drive Fire Conditions: 7-Story Building Experiments." (http://fire.nist.gov/bfrlpubs/fire09/PDF/f09015.pdf).

Both projects were supported by the Department of Homeland Security's Federal Emergency Management Agency Assistance to Firefighter Research and Development Grant Program and the United States Fire Administration.

A set of instructional DVDs based on the research is available for firefighter training. The double DVD set on the research is available for teaching purposes. It includes a video overview, both reports, a PowerPoint presentation summarizing the results, training videos, and video documentation of all of the experiments. The DVD set can be ordered by emailing a request to madrzy@nist.gov.

*Photograph of a wind driven fire that has vented out of the living room windows. The fire started in the bedroom (two windows to the left).*

*This experiment was conducted on Governor's Island, NY with FDNY and the Polytechnic Institute of NYU .(Photo Credit: NIST)*

## Ethanol and How it Reacts

As interest in, and the use of, the fuel Ethanol E85 (normally called simply E85) increases, the importance of understanding its fire and explosion characteristics becomes apparent. SP Technical Research Institute of Sweden was interested in evaluating the fire and explosion risks that could be found along all parts of the E85 distribution chain, as well as the fuel vapor concentration and composition when filling tanks. As the quality of E85 can vary with the time of year, tests were conducted using both winter and summer grades. Tests also were conducted using regular unleaded 95 octane gasoline. The researchers studied:

- Concentrations and composition of fuel vapors in a closed vessel at different temperatures,
- The temperature range over which the fuel vapors in a fuel tank could be ignited,
- Effects of igniting fuel vapors in a fuel tank in an automobile, and
- Fuel concentration and gas composition around the filling pipe when filling the tank.

The project was done in several stages, starting with the ignition properties up to and including the impact of fuel vapors in the vehicle's fuel tank. The studies concluded that summer grade E85 fuel vapors in a closed vessel or fuel tank are

*Cont. on page 3.*

## Ethanol and How it Reacts, cont.

flammable over a temperature range from about -18°C (-0.4°F) up to +5°C (41°F). In the case of the winter grade E85, the upper temperature limit for ignition was assessed at approximately -8°C (18°F). to -9°C (16°F). The tests demonstrated that E85 can be classed in explosion group IIA, the same one as gasoline. Ignition tests in the fuel tanks, for the worst-case scenario, can result in a pressure rise in the tank sufficient to deform or the rupture the tank. The explosion could be powerful enough to damage the underside of the vehicle.

Other test results from this study concluded that fuel vapors in a closed vessel containing E85 consisted largely of gasoline (approximately 70-90%), even though the gasoline content in the liquid phase consisted of only about 15% .

To learn more about the test procedures and other results, view the paper, "*Fuel Vapour Composition and Flammability Properties of E85*" by Henry Persson, Peter Bremer, Lars Rosell, Karine Arrheinius and Kent Lindstrom (SP Report 2008:15.) available on the SP website: http://www.sp.se. Click on Publications, and then scroll down to the report (SP Report 2008:15) in English. If additional information is needed, contact Henry Persson, henry.persson@sp.se

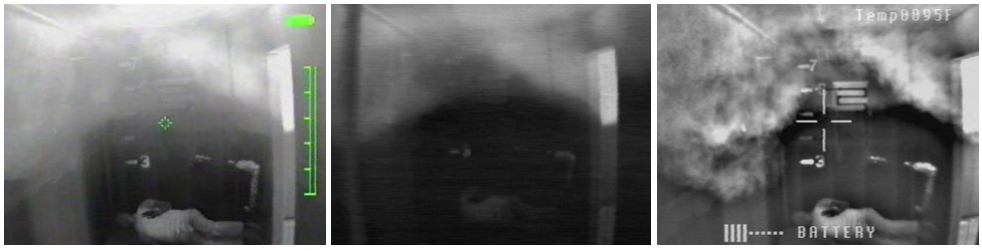
*Explosion Chamber Used in Test.* *(Photo Credit: SP)*

## Performance Metrics for Thermal Imaging Cameras

Thermal imaging cameras (TICs) have become important tools for firefighters and other first responders. However, due to the lack of performance standards for TICs, a wide variety of designs and capabilities are provided to end users with little consistency in reported performance. In order for the fire service to understand the performance characteristics of TICs during fire fighting applications, it was critical that a set of performance metrics and standard testing protocols be developed.

With the support of the U.S. Fire Administration (USFA) and the Department of Homeland Security (DHS), NIST has conducted research to characterize and understand TIC performance. This work began with an assessment of the thermal imaging needs and activities of first responders. Existing standards were collected and reviewed to ensure that the recommended testing conditions resulting from this work are consistent with standards on other first responder equipment that are exposed to similar operating conditions, as well as standards and test protocols on infrared cameras that are used in other applications, when appropriate. A survey of the literature was also performed to explore existing work in which the fire environment was well characterized and pertinent to TIC testing. The consolidation of all of this information, provided a basis for defining test conditions that challenge TICs in meaningful ways. Performance metrics that describe the TIC's image contrast, effective temperature range, spatial resolution, image non-uniformity, and thermal sensitivity were selected or developed based on an analysis of the information gathered. These performance metrics and test methods have been provided to standard development organizations, such as National Fire Protection Association (NFPA). NFPA's Technical Committee on Electronic Safety Equipment has incorporated these metrics and test protocols in a draft version of *NFPA 1801, Standard on Thermal Imagers for the Fire Service*. Two reports have been developed, "*NIST TN 1499 Performance Metrics for Fire Fighting Thermal Imaging Cameras – Small- and Full-Scale Experiments,*" and "*NIST TN 1630 Evaluation of Image Quality of Thermal Imagers Used by the Fire Service*." These reports can be downloaded from http://fire.nist.gov/bfrlpubs/fire08/PDF/f08017.pdf, and http://fire.nist.gov/bfrlpubs/fire09/PDF/f09032.pdf respectively. NIST is continuing to work closely with the NFPA and the U.S. Army's Night Vision Laboratory to develop test methods to support and enable thermal imaging camera performance standards. The proposed NFPA 1801 is in the 2009 Fall revision cycle, for more information on the status of the standard go to http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=1801.

For additional information contact Francine Amon, francine.amon@nist.gov.




*Comparison of three different TIC detector technologies of the same fire environment at the same time. From left to right, vanadium oxide (VOx), amorphous silicon (ASi), and barium strontium titanate (BST). Combustion products from the fire room (on the right) are flowing through an open doorway into a corridor with a mannequin on the floor and other thermal targets on the wall at the end of the corridor.* *(Photo Credit: NIST )*

## Home Fires Involving Cooking Equipment

A recent analysis by John H. Hall, Jr., of the National Fire Protection Association (NFPA), "*Home Fires Involving Cooking Equipment*" uses information collected by the National Fire Incident Reporting System (NFIRS) and the NFPA fire experience survey to give a detailed account of scope of fire incidents related to cooking equipment.

In 2005, U.S. fire departments responded to 146,400 home structure fires that involved cooking equipment. These fires caused 480 civilian fire deaths, 4,690 civilian fire injuries,$876 million in direct property damage.

Ranges, with and without ovens, accounted for 67% of the total reported confined or non-confined home structure fires, and even larger shares of the related civilian deaths (85%) and civilian injuries (82%.) Portable cooking or warming devices had the third largest share of home cooking fires but they also had the second largest share of associated civilian deaths.

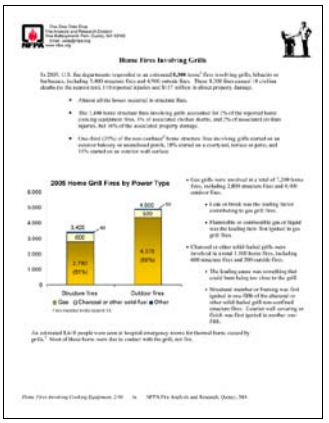
Contributing factors to cooking-related home fires from 2002-2005 included:

- 38%- Cooking equipment was left unattended
- 12%- Heat source too close to combustibles
- 10%- Unintentionally turned on or not turned off
- 8%- Abandoned or discarded material or product

Frying was the highest risk of fire. Of the 218 range top cooking material ignitions studied by the U. S. Consumer Product Safety Commission (CPSC), 63% involved frying. Electric ranges have a higher risk of fires and associated losses than gas ranges.

The report contains many more interesting statistics, including those involving grills and microwave ovens. It also provides safety tips to avoid cooking fires.

To learn more, go to www.nfpa.org or contact John Hall, jhall@nfpa.org for additional information.



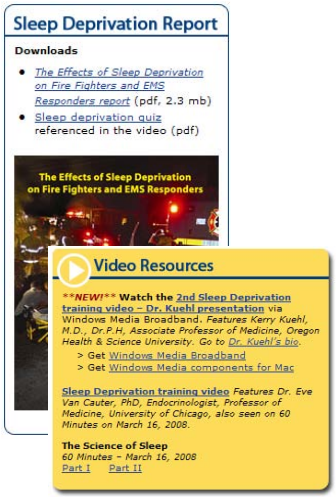
*Home Fires Involving Grills Fact Sheet, from the report.*

## How Much Sleep is Enough?

This is a question that is often asked of shift workers -- and in particular of firefighters and emergency medical services responders -- because like doctors, they must perform their jobs with precision and awareness. It is important to understand the hazards and/or benefits of long days and nights without sleep. The International Association of Fire Chiefs (IAFC) sponsored a research project to address some of the causes and needs of the people on the "front line". The report, "*The Effects of Sleep Deprivation on Fire Fighters and EMS Responders*," by D. L. Elliot and K. S. Kuehl, along with its accompanying computer-based educational program, presents background information on normal sleep physiology and the health and performance effects of sleep deprivation. Further, it provides the fire chief with a tool to understand and to apply strategies to minimize duty-related sleep deprivation and, further, to understand when a member of the organization is sleep deprived, along with suggestions on how to handle that situation.

Some of the research findings include the fact that shifts lasting more than 10 to 18hours have been linked to errors when vigilance and focused alertness are required. The report also identifies five areas especially appropriate for further study, 1) better identification of the impact of fire fighting and EMS response work on the family, 2) monitoring crashes during commuting, 3) utility of strategic napping, 4) the prevalence of sleep disorders among fire fighters and EMS responders and 5) cardiovascular risks and other lifestyle issues and their relationship to work hours.

The report was supported by a cooperative agreement between the International Association of Fire Chiefs (IAFC) and the U. S. Fire Administration (USFA), and with assistance from the faculty of Oregon Health & Science University. Find the report on the IAFC website: http://www.iafc.org/sleep/.




*Watch the videos and take the Sleep Deprivation Quiz on the IAFC website.*

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