

# SMOKE

Cyanide and Carbon Monoxide:  
The Toxic Twins of Smoke Inhalation





# Firefighter Rehab

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**F**irefighters love making a difference at the emergency scene. This is especially true when they respond to a structure fire. Firefighters recognize there are significant dangers associated with the job and accept extreme risks as part of the profession.

While risks are inherent to the job of the firefighter, diligent training and effective supervision is needed to identify and reduce those risks wherever possible. One risk that firefighters can identify and manage revolves around the physiological effects of maximum effort applied under extreme conditions. In other words, firefighters work hard while fighting fire. Several factors can add to the impact of these physiological effects, including Per-

sonal Protective Equipment (PPE), Self Contained Breathing Apparatus (SCBA), high or low temperatures, humidity, and pre-response hydration. Preventing firefighters from becoming casualties of the event includes recognizing and dealing with the physiological effects of their hard work in extreme environments. This process is defined in NFPA 1584, Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises, 2008 Edition.

Firefighting combines high intensity workloads with high metabolic heat production, limited ability to dissipate body heat, and increased external heat stress from the environment. This combination of factors means that firefighters are producing an incredible degree of heat stress and a high potential for heat related illness. Heat stress produces effects ranging from minor dehydration to heat stroke. In addition, the primary risk of fatality for all firefighters – heart attack – is significantly increased when heat stress is added to high work and stress loads. This occurs because higher body core temperatures place additional strain on the heart. The body then increases the blood volume sent to the skin for cooling.

## Pre-Incident

There is no substitute for pre-incident planning as it applies to all areas of the fireground. From the layout of the fire building to the preparedness of the firefighters who respond, actions taken before the event occurs are crucial.

Fire departments should implement a

wellness and fitness program to increase and monitor the physical ability of their firefighters. Guidelines for implementing such a program are outlined in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Department Members. Departments need a thorough understanding of the effects of specific thermal, stress, and workloads on their firefighters. These factors directly impact the firefighters and should be monitored to determine their ability to perform at an acceptable level for the next work cycle. Information is readily available to support the positive impact of wellness-fitness programs on the overall health of firefighters.

Another step fire departments can take is to reduce the pre-incident heat stress that firefighters endure. Previous studies and common sense demonstrate that people have an improved ability to perform in high heat conditions if they are cool before they start.<sup>1</sup> Fire departments can take proactive measures to ensure that firefighters have appropriate cooling and ventilation in fire stations prior to responding to an incident and on the apparatus while responding. Fire departments should also have Standard Operating Procedures (SOPs) identifying when reductions in training or other outside activities should be reduced in order to prevent environmental injury to firefighters.

## Hydration

Proper hydration is critical to the body's ability to self-regulate and maintain

## Smoke Dictionary

**Rehabilitation:** An intervention designed to mitigate against the physical, physiological, and emotional stress of fire fighting in order to sustain a member's energy, improve performance, and decrease the likelihood of on-scene injury or death.

safe core temperatures. The impact of proper hydration is two-fold in that it supports the body's ability to produce enough sweat for effective cooling while maintaining blood volume in order to support skin surface cooling and blood pressure. Studies conducted as early as 1947<sup>2</sup> demonstrate the need for proper hydration in order to maintain body core temperatures.

**Firefighters must practice self-hydration at all times as they must always be ready to respond on emergency incidents. Rates of fluid loss are documented within NFPA 1584 as follows: "Humans can easily exceed a sweat rate of 64 oz. (2L) per hour in hot and humid conditions. Firefighters can easily lose 32 oz. (1L) of water in less than 20 minutes of strenuous fire-fighting activity."**

Studies have shown it is unlikely that firefighters will be able to comfortably consume enough fluid on the emergency scene to adequately replace the large amounts of fluid lost through sweat in firefighting efforts.<sup>3</sup> Given this, officers must ensure that firefighters drink some fluids at every opportunity, with particular attention paid to ensure firefighters consume appropriate volumes of liquid while in formal rehab.

### Protective Clothing

Changes to firefighter protective clothing have improved the ability of firefighters to withstand temporary exposures in extreme heat environments that are created during pre-flashover conditions. Firefighter protective clothing is severely limited, however, in its ability to protect firefighters from death if exposed to flashover. Any firefighter caught in the flashover compartment, even briefly, will experience significant pain and a prob-

ability of extensive thermal insult.<sup>4</sup> The improvements to the protective clothing have come at the cost of increasing the thermal stress on firefighters.

The protective clothing ensemble severely limits the effects of the body's two primary means of temperature control, surface cooling through increased blood flow to the periphery and evaporative cooling through increased sweat production. Firefighters should consider themselves industrial athletes. Just as a parka on a hot summer day would negatively affect a professional athlete, structural firefighting PPE negatively affects the firefighter's ability to dissipate heat. Understanding the impact of the PPE ensemble will improve the ability of the Company Officer to identify and provide relief for the firefighters under their command.

### Self-Contained Breathing Apparatus (SCBA)

The SCBA is widely recognized in the fire service as the single biggest improvement for firefighter safety and health. By providing a reliable supply of uncontaminated air for the firefighter operating in an IDLH environment, the SCBA allows firefighters to work for extended periods while protecting their respiratory system. SCBA have improved over the years and now represents a relatively lightweight and reliable piece of equipment that firefighters should use at all times. Exposure to products of combustion is an unnecessary and unacceptable risk for firefighters in the modern era. In addition, improved air management techniques, including the Rule Of Air Management<sup>5</sup> (ROAM), help to maintain an effective work/rest interval while operating in SCBA and maintaining an appropriate margin for safety.

While SCBA provide a significant increase in overall safety, there is a cost to the wearer. SCBA can easily add in excess of 25 pounds to the firefighter. In addition, the backpack carrying system compresses the thoracic cavity and restricts the ability of the respiratory muscles to function normally.<sup>6</sup> Each 1kg increase in the weight of the SCBA ensemble has

related impacts on the respiratory rate, heart rate, and energy expended. This increases the workload of the firefighter, thereby increasing the rate of metabolic heat that is produced simply through the effort of breathing.

### Work Rate

Fire grows at an exponential rate, doubling in size every minute. An excellent



average response time for a fully staffed paid department is approximately four minutes. When firefighters arrive at the scene of a fire, it is necessary to provide a maximum level of work immediately. The critical need and type of workload are combined to produce large amounts of metabolic heat that the body must dissipate. High work levels may be necessary for a significant time if the fire is difficult to fight or is present in a large occupied structure. Early recognition of increased staffing needs is important to ensure effective crew rotations on these incidents.

### Environmental Factors

Environmental factors include the ambient temperature, humidity, wind, and exposure to direct sunlight. On the hot side, temperature and humidity will have the most impact on how much heat is produced, as well as determining how quickly heat can be shed by firefighters during a rest cycle. High heat and hu-

midity have an immediate impact on the firefighter responding to, operating at, or resting during the firefighting effort. Low temperatures will have most of their impact during the rest and rehabilitation cycle.

High heat and humidity temperatures are recognized by NFPA standards<sup>7</sup> as having a significant impact on structural firefighters operating at incident scenes. The 2008 edition of the standard provides heat stress index charts, sample SOGs, and other resources outlining identification and prevention methods for heat stress and other environmental factors.

### Company Level Rehab

Company officers and incident commanders must take all of the above into consideration when determining when crews must rotate through an assignment at rehab. Current recommended<sup>7</sup> practice identifies work-to-rest intervals in terms of “30-minute” cylinder rotations for interior operations and time-based 20-minute work cycles for non-SCBA operations. Company officers or crew leaders should perform self-rehab after one “30-minute” cylinder use or 20-minutes of intense work.<sup>7</sup> This rehabilitation process is informal and is most often conducted and supervised by the company officer during the SCBA cylinder exchange at the apparatus. NFPA 1584 recommends that fire departments “store fluids on the apparatus where spare SCBA cylinders are located so that members can replace fluids while changing SCBA cylinders.”<sup>7</sup> The recommended work-to-rest interval includes 10 minutes of rest for each “30-minute” cylinder work cycle. Incident commanders must be able to forecast incidents where rehab will be needed beyond the company level and establish a formal rehab area early.

When firefighters must report to the rehabilitation area is outlined in NFPA 1584 and is defined by the two primary methods of cylinder use and time. Cylinder use is predicated on the knowledge that “Air = Time” and that the requirements of the standard are a recognition that the amount of time working (with

or without SCBA) must be balanced with appropriate rest and fluid intake resulting in a safe work-to-rest ratio. NFPA 1584 explanatory material outlines this for the Company Officer in A.6.3.2.1:

■ There should be at least 10 minutes of self-rehabilitation after using one “30-minute” cylinder or after performing 20 minutes of intense work without SCBA.

■ There should be at least 20 minutes of rest (with hydration) in a rehabilitation area after using two “30-minute” SCBA cylinders, one “45-minute” cylinder, or performing 40 minutes of intense work without SCBA.

While acknowledging the standard requires assignment to the rehabilitation area after one “45-minute” cylinder, it is important to understand that even the 2008 edition of NFPA 1584 does not address the use of air management techniques or the ROAM on the fireground. Because “Air = Time”, we recommend that the industry accepted standards for the “30-minute” cylinder work interval can also be extended to the “45-minute” cylinder if air management is practiced in accordance with the Rule Of Air Management (ROAM). NFPA 1584 permits this adjustment in 6.2.2.2.1 stating, “A supervisor shall be permitted to adjust the time frames depending upon the work or environmental conditions.”

By expanding on the premise that “Air = Time”, we can make the case effectively. A “30-minute” cylinder contains 1200L of air. The standard allows a company to use 1200L of air followed by company level rehab (10 minutes) and a return to the firefight for a second 1200L

of air use. Since “Air = Time”, a firefighter following the ROAM and using a “45-minute” cylinder that holds 1800L of air uses a maximum of 1350L of air, leaving 450L of air in the emergency reserve. The maximum difference between the two work intervals is about 150L of air. Firefighters working hard can easily use air at a rate exceeding 100L/min. Since “Air = Time”, the increase in the work



photo: Robert Yates

cycle for a firefighter using a “45-minute” cylinder and the ROAM over the “30-minute” cylinder is approximately 1-2 minutes. This means that the “work conditions” of the “45-minute” cylinder and ROAM are consistent with that of a “30-minute cylinder”, permitting the use of the 2-cylinder rotation in both cases.

Without adhering to the ROAM, company officers should follow the recommended practice of using only one “45-minute” cylinder before rotating to a designated rehabilitation area. Any use of a “60-minute” cylinder should be followed by an assignment to the rehab area.

### Tactical Level Rehab

Formal incident scene rehabilitation is a tactical level function normally assigned as a division, group, or sector. The rehab supervisor should be trained in all the functions and responsibilities inherent to the position and should understand how rehab operates within the Incident

Management System (IMS) and the SOPs of the department. Rehabilitation areas should be far enough from a working incident to provide protection from the products of combustion and from apparatus exhaust. They should also be close enough so ready access can be made between the incident scene and the rehab area. Rehab should also provide appropriate protection from the environment, whether this includes hot or cold weather. Companies should be able to re-supply and stage firefighting equipment before entering the rehab area.

When and how unit's are assigned to rehab should be dictated by formal department SOPs or implemented based on trained observation of the above listed factors that impact firefighters physiological status. Minimum standards should include the following:

■ **Identified work-to-rest intervals before company level rehab are listed below and should require a 10 minute company rehab, including rest, hydration and an evaluation of the company's readiness for reassignment at the completion of the 10 minute rehab:**

- One "30-minute" cylinder without air management.
- One "45-minute" cylinder following the ROAM.
- 20 minutes of intense work.

■ **Identified work-to-rest intervals before assignment to the rehabilitation area:**

- Two "30-minute" cylinders without following the ROAM, including a 10 minute rest and hydration period between cylinders.
- Two "45-minute" cylinders following the ROAM, including a 10 minute rest and hydration period between cylinders.
- One "45-minute" cylinder or "60-minute" cylinder work cycle without following the ROAM.
- One "30-minute" cylinder without following the ROAM or one "45-minute" cylinder following the ROAM after having rotated through rehab previously or when extreme conditions are present. This requirement recog-

nizes the cumulative impact of repeated work-rest intervals over the course of an incident and promotes coordinated company rotations and incident accountability.

■ **In addition to the work-rest interval considerations, any SOP should include the following for assignment to rehab:**

- When adequate resources are available, every company should be assigned to the rehab area after each cylinder used or 20 minutes of intense work.
- Whenever the company officer recognizes that any member of the company requires rehabilitation.
- The incident commander assigns the company to rehab.

### What Happens At Rehab?

Once units are assigned to report to rehab, they should report to the rehab supervisor for check in and recording of their arrival time. According to NFPA 1584, each department Standard Operating Guideline (SOG) for a systematic approach for the rehabilitation of members "shall include, but not be limited to, the following: Relief from climatic conditions, rest and recover, active and/or passive cooling or warming as needed for incident type and climate conditions, rehydration (fluid replacement), calorie and electrolyte replacement, medical monitoring, emergency medical services treatment in accordance with local protocol, member accountability, and release."

### New Equipment for Medical Evaluation

More recent improvements in medical evaluation equipment provide the ability to screen all firefighters entering rehab for exposure to carbon monoxide (CO). CO exposure can be indicative of exposure to products of combustion, including hydrogen cyanide. While no exposure to CO or other products of combustion is safe, department SOPs should clearly identify screening protocols and when exposure indicates firefighter treatment and transport is necessary. Recommendations for CO screening and exposure protocols are outlined in the article written by Drs. James Augustine, Daniel J. O'Brien, and

Donald W. Walsh found in this supplement. Serious consideration should be given to screening firefighters exposed to products of combustion for cyanide poisoning. Recent events have demonstrated the potential for cyanide exposure both during fire and post-fire operations, and significant risk of harm is present when firefighters are exposed to cyanide in the form of hydrogen cyanide gas.<sup>8</sup>

Following initial medical monitoring, companies should spend a minimum of 15 minutes in an appropriate climate environment before being re-evaluated for their ability to return to incident operations. Department SOPs should clearly identify minimum standards that personnel must meet before returning to work from rehab. Such standards should meet the intent of NFPA 1584 and provide an adequate level of protection for the firefighters operating at the incident.

Given the choice between rehab and fire ops, most firefighters will choose the fire operation. Written standards provide clear guidance to personnel responsible for operating the rehab area and ensure that firefighters do not return to the incident until they have been properly rested and medically evaluated. 🧯

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