# "Stop, Drop, and Roll" – The Technical Substantiation Behind Public Fire Safety Messaging

## Research Project

*Technical report*

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# "Stop, Drop, and Roll" – The Technical Substantiation Behind Public Fire Safety Messaging

A report for the

## Fire Protection Research Foundation
## Quincy, MA

By


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## FOREWORD

In 2005, the National Fire Protection Association's Public Education Division commissioned the Fire Protection Research Foundation to carry out a study on the technical basis for the Stop Drop and Roll message.

The "stop, drop, and roll" (SDR) technique was designed to demonstrate how individuals should respond at the onset of clothing ignition. However, in recent years, suggestions regarding the slogan's revision have arisen. The goal of this study was to determine whether the original concept should be reassessed.

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The content, opinions and conclusions contained in this report are solely those of the authors.

# *"Stop, Drop, and Roll" – The Technical Substantiation Behind Public Fire Safety Messaging*
# Research Project

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# "Stop, Drop, and Roll" – The Technical Substantiation Behind Public Fire Safety Messaging

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## ABSTRACT

The "stop, drop, and roll" (SDR) technique was designed to demonstrate how individuals should respond at the onset of clothing ignition. However, in recent years, suggestions regarding the slogan's revision have arisen. Educators and fire officials widely use the message to teach groups; therefore, the message needs to be accurate. Ultimately, this project is intended to determine whether the original concept should be reassessed.

To truly analyze the slogan's effectiveness, and to provide an adequate substitute, a comprehensive study of the aspects of human response to the slogan is undertaken. This study includes assessing the position of arms and hands, procedure for the individual after rolling, and whether flammability of clothing material influences optimum rolling speed. The proper procedure for the individual after rolling and the issue of clothing flammability is addressed through the review of literature. The behavioral study focuses on five hand positions and is performed to test the variable of appendage position.

The results of the behavioral study indicate that the favored position for hand placement during SDR is with crossed arms. This is a slight variation from the presently-taught method. Also, it is a variation from recommendations of other experts in the fire safety field. The designation of a successful save, considering the severity of burn injuries, and not just survivability should be considered in the interest of raising the level of performance sought with this message. Based on the research, modifying the current four-term SDR slogan to "Stop, Drop, Roll and Cool" has significant merit in attempting to reduce the severity of burn injuries. Studying air gaps and pockets created by certain hand positions and conducting additional research to address the combined issues of clothing flammability and human behavior should be considered to further refine the techniques of Stop, Drop, Roll and Cool being taught.

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## 1. INTRODUCTION

### *1.1 Definition of the Problem*

According to the Consumer Product Safety Commission (CPSC) and as represented by Table 1, fire injuries in which a victim's clothing is the first item ignited represents 7% - 15% of injuries treated during the 2002-2003 year [Miller, 2005]. If incidents with clothing as the second item ignited are included, then this percentage would dramatically increase because fires involving flammable liquids, cooking materials, and mattresses are frequently the first items ignited that could lead to an ignition of a person's clothing. Ideally, to prevent the risk of injury, the risk of clothing ignition should be reduced. "Stop, Drop, and Roll" (SDR) is one solution to this problem, since it suppresses the spread of flames. Other solutions include having less ignitable clothing and better fire prevention behavior. All three solutions are addressed in this paper.

**Table 1. Estimated Number of Fire Injuries Treated in Emergency Departments by Selected Products First Ignited, 7/1/02 – 6/30/03 [Miller, 2005]**

| Item First Ignited | Injuries | 95% Confidence Interval |
|---|---|---|
| Floor Covering or | 1,056 | (0, 2,217) |
| Upholstered Furniture | 779 | (90, 1,468) |
| Mattress, Bedding | 3,038 | (1,495, 4,581) |
| Clothing – Worn | 3,895 | (2,506, 5,283) |
| Clothing – Not Worn | 841 | (309, 1,373) |
| Flammable Liquid Gas | 15,429 | (11,542, 19,317) |
| Cooking Materials | 8,372 | (5,866 10,878) |
| Trash | 1,822 | (714, 2,930) |

(n = 628)

Source: U.S. Consumer Product Safety Commission/EPHA, from data obtained from the National Electronic Injury Surveillance System

The original SDR technique has been recognized for saving lives. The NFPA began to document successes as early as 1975, the same year the message was released [see Appendix A for a listing of the cases along with key factors in these incidents]. A total of 39 individuals

were saved in 38 incidents (one incident included two children). Twenty-eight of the 39 individuals (72%) were male, as indicated in Figure 1.

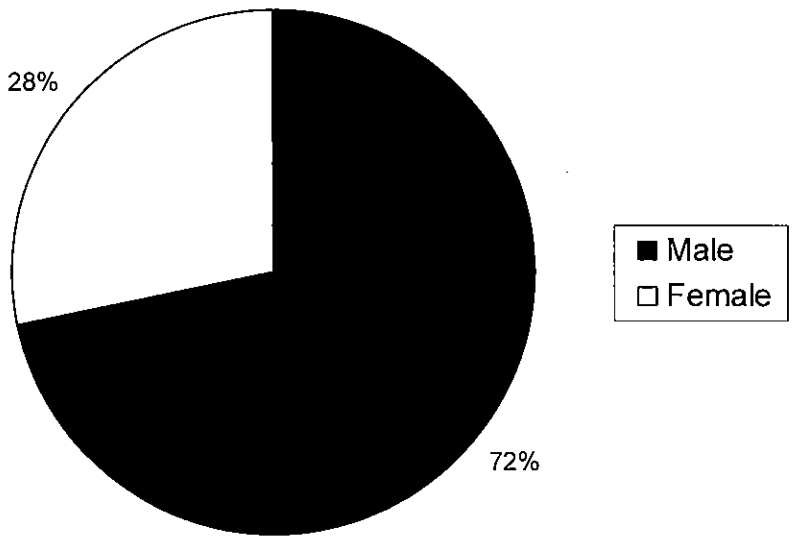



**Figure 1. Gender of Individuals in Documented Saves**

The age range of the individuals involved was 2 to 27 years old, though several of the individuals were noted only as "adults". The distribution of ages is indicated in Table 2.

**Table 2. Age Distribution of Individuals in Documented Saves**

| Age Range | Number of Individuals | Percent of Total |
|---|---|---|
| 2-9 | 14 | 35.9 |
| 10-19 | 12 | 30.8 |
| 20-29 | 2 | 5.1 |
| Other adult | 8 | 20.5 |
| Unknown | 3 | 7.7 |
| Total | 39 | 100.0 |

Most (27) of the individuals were reported to sustain burn injuries. In thirteen of these cases, second and third degree burns were explicitly noted. Comments including several "days of treatment" and "skin grafts" suggest that many more of the individuals received significant burns. Ten of the reports made no comment about injuries received by the individuals. While some of these people may not have been injured, that cannot be confirmed from the information available.

A variety of articles of clothing were noted as being ignited in the incidents. A summary of the articles ignited is included in Table 3.

**Table 3. Article of Clothing Ignited in Documented Saves**

| Age Range | Number of Individuals | Percent of Total |
|---|---|---|
| Pants | 8 | 20.5 |
| Multiple items | 5 | 12.8 |
| Shirt | 2 | 5.1 |
| Coat/jacket | 2 | 5.1 |
| Robe | 2 | 5.1 |
| Dress | 1 | 2.6 |
| Nightgown | 1 | 2.6 |
| Non-clothing (hair) | 1 | 2.6 |
| Unknown | 17 | 43.6 |
| Total | 39 | 100.0 |

Two cases with successful, but very different results are included among the saves. Case A fire occurred in October, 1983 in Kirkland, Washington. In this instance, an eleven-year-old was in his home when an explosion occurred as a result of throwing gunpowder into the fireplace [LNTB, 1983a]. In Case B, which occurred in April, 1984 in Trenton, New Jersey, the mother of a seventeen-year-old was saved when her teenage son "dropped her to the floor" and began rolling her on a carpet to suppress the flames [LNTB, 1987].

Any save via this technique is significant. Noticeably, however, the definition of success is solely based on whether the technique is attributed to having saved the individual's life. In Case A, the victim received third-degree burns on his left hand and burns on his right hand, neck, and forehead [LNTB, 1983a], while in Case B, the victim received only first and second-degree burns on her arms, face, and upper body [LNTB, 1984]. The effects of burns are often life-altering events for burn victims and to accurately study the successfulness of a technique, the three possible outcomes should be considered. The three possible outcomes include a fatality, a victim who has third degree burns over a percentage of his or her body and an individual who is not severely burned at all (i.e. has no third degree burns).

The current technique acknowledges either of the latter two possibilities as a positive outcome, but does not distinguish between the degree and percentage of burn injuries received by victims. While a save is certainly noteworthy, even if burns are received, questions have been posed as to whether the SDR technique could be improved to prevent or reduce the level of injury sustained by victims from fire.

### *1.2 The Importance of an Accurate Slogan*

A good slogan has three characteristics: it is easily understood, easily remembered, and effectively incorporates the essential aspects required to protect the intended audience. The current SDR slogan has the characteristics of being a good slogan, having only four terms ("stop", "drop", "and", "roll") that members of the general public are able to understand and remember easily. Another important aspect of the SDR message is that the public is able to associate the technique with a specific situation. Primarily, this is due to the exceptional quality of dissemination of the SDR message provided by the *Learn Not to Burn Program* and those in the fire safety field. The need to keep the message short and simple is highly important, since it increases the likelihood of remembrance. Most members of the population were taught the SDR behavior during younger years of life; thus, the message has to be short enough and contain elementary words so that a child can understand and remember the slogan.

The current terms of the slogan are effective at preventing fatalities as shown by the numerous saves of life from potential victim's familiarity with "stop, drop, and roll". The concept covers the basic requirements for a person to survive clothing ignition by providing the basic requirements for suppressing the flames. Matt Maley, Director of Risk Management of the Shriner's Burns Institute, defines the three steps of the "stop, drop, and roll" strategy as [Maley]:

- "STOP: Discontinue moving; prevent fanning of flames
- DROP: Get down – prone; prevent upward movement of flames
- ROLL: Turn over and over; smother the flame"

With the recognition of the slogan having the characteristics of successful slogans, and the long list of documented saves, altering the slogan should be considered only after it can be demonstrated that improvement is needed and that an alternate will be a significant improvement. While the current four-termed slogan does improve survivability, it does not address an important aspect of protecting the intended audience from serious injury. Supplemental topics such as cooling and the issue of hand placement are addressed when the technique is taught [Horrocks, et al., 2004]. Often "cooling" the affected area is forgotten by those who perform the SDR technique because it is not included in the primary slogan. Also, the effectiveness of the current recommendation to cover the face while performing SDR is debated, due to an increased risk of injury when the hands are in this position.

## 2. REVIEW OF LITERATURE

During the late 1980's, the question of revising the SDR slogan was raised by Maley. At the *Learn Not to Burn* Technical Advisory Council Meeting during the September of 1987, Maley presented a number of SDR tests showing variations in appendage placement and other variables. The literature search for this current project was directed by the technical advisory's council's conclusions about Maley's presentation. These conclusions addressed [LNTB, 1987]:

- severity and location of burn injuries for which SDR would be employed
- location of first ignition of clothing for burn injuries for which SDR would be employed
- relationship of burn severity to placement of hands and arms during the technique
- speed of fire spread on fabric and on clothing
- observation of those who have not been trained to perform the procedure.

Further, the need to continue rolling until the fire is extinguished and the position of the legs (straight versus in the fetal position) has been noted. Results from the literature survey for the current effort provide some insight into each of Maley's conclusions.

*2.1 Severity of Burn Injuries as a Measure of Ineffective Suppression*

If the definition of a successful save is redefined, then more attention will be paid to the severity of a victim's injuries, being an important indicator of success. One of the primary effects of ineffective suppression is skin burns from flame. The five classifications of burn degree based on the degree of skin damage are listed as follows:

- First-degree burns are superficial and only involve the epidermis [Sipe, 2005].
- Second-degree burns occur when the entire epidermis is destroyed, with superficial or deep effects" [Sipe, 2005].
- Third-degree burns involve a 75% or greater destruction of the dermis [Lawton, 1994]. Usually, there is no possibility for cell regeneration [Wieczorek and Dembsey, 2001].
- "Fourth-degree burns require skin grafts" [SFPE, 2000].
- "Fifth and sixth degree burns involve destruction of muscles and or bones respectively" [SFPE, 2000].

Classifications of burn severity, as shown in Figure 2 are the focus of this paper. As a result of an ineffective suppression technique, burns obtained can be painful and victims may have difficulty re-integrating into society as a consequence of the resulting scarring [Ahrenholz, et al., 1995]. Also, medical expenses associated with burn injuries are costly and can involve

long hospital stays [Horrocks, et al., 2004]. Therefore, the need to redefine the measure of an effective technique to prevent severe burns injuries is necessary.

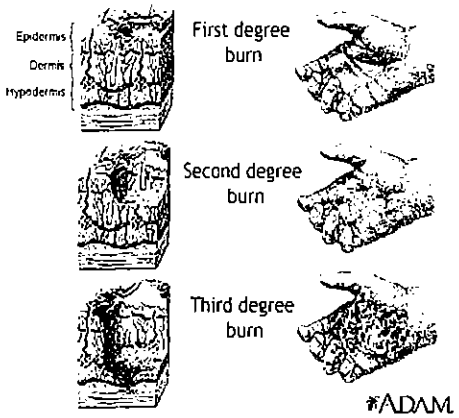



**Figure 2. Burns as Possible Products of Ineffective Suppression Techniques [NIH, 2005]**

*2.2 Placement of Hands and Arms During SDR*

The issue of the optimum appendage position has been highly debated amongst those in the fire safety field. Different positions, such as "extending the hands and arms over the head, ... putting the hands along the side... followed by [covering] the face" [Maley] have all been recommended. Covering the face has been the most controversial since it potentially increases the chance of injury if the item of clothing ignited is along the upper torso or arms [Maley].

*2.3 The Relationship of Burn Severity to Placement of Hands and Arms During SDR*

National Fire Incident Reporting System (NFIRS) data ranging over a ten-year period shows 37% of all fires that result in an injury are cooking-related [FEMA, 2004]. This proportion is second only to arson. The CPSC has also tracked cases involving cooking injuries and concluded that stove range fires are the primary cause of injury for women [CPSC, 1975]. CPSC noted that a majority of these cases involved reaching across, over, or against a stove range prior to ignition of the victim's clothing [CPSC, 1975].

The current SDR technique instructs that an individual to cover his or her face while rolling. As illustrated in Figure 3, covering the face places sleeves in close proximity to the face. If clothing fires involve ignited sleeves, recommending that individuals with ignited sleeves cover their face could promote injury and contribute to facial burns.

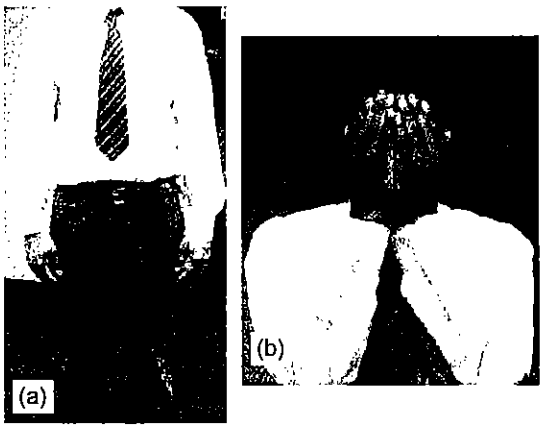



**Figure 3. Subject B Shown with Hands at His Side (a) and Covering Face (b).**

*2.4 Clothing Ignitability and Injury*

One of the factors contributing to the burn injuries from ignited clothing is the relative ease of clothing ignition. Different fabrics have different ignition characteristics as a result of the physical and chemical properties of the material.[1] For example, sheer fabrics, used in some women's clothing are easily ignitable. "Although not always fatal, burns from fabrics containing thermoplastics fibers may still be serious and difficult to treat" [Horrocks, et al., 2004]. According to Horrocks:

> "once the fabric is ignited, the flame size increases and heat emission reaches its peak value. Heat transfer to surrounding surfaces including human skin and hence cooling of the flame front may cause a reduction in net heat release and burning rate as may, of course, the point at which the fabric starts to be fully consumed. Burn hazard may be associated directly with this heat release" [21, p.261].

[1] An example of one significant physical property is the thermal inertia of the fabric. Thermal inertia is the product of the thermal conductivity, density and specific heat of the material.

### *2.4.1 Time as a Critical Factor in Reducing Injury*

When performing the SDR technique, the ability of a victim to escape from the situation without injury is proportional to the time elapsed between ignition and suppression. Generally, the greater the time elapsed, the greater the clothing deterioration and flame propagation, making it more difficult to suppress the flames. In addition, an increase in the time between ignition and suppression causes an increase in the depth of burn injury. Associated with the increase in flame propagation is an increase in the area of burn injury. Understanding flame propagation rates along common fabrics will give an understanding of the time required to extinguish flames before the victim's skin is contacted by burning material and he or she is injured.

### *2.4.2 Speed of Fire Spread on Fabrics and Clothing*

The occurrence of skin burns are dictated by clothing ignitability, heat released by the fire, and the heat transferred of burning materials to the skin [Rossi, 2005]. A study comparing the flame spread of textiles to burn injury conducted by the Laboratory for Protection and Physiology in Gallen, Switzerland, attempted to gain insight into these factors. Using the EN 1103 bench scale test, a large variety of natural and synthetic fabrics, commonly used to make clothing, were tested for the flame propagation rate or the speed of fire spread. Using a burn prediction model, researchers were also able to determine a critical time to feel pain on the human skin, in addition to the critical time for second degree burns to develop [Rossi, 2005].

In Rossi's study, the flame propagation rate (FPR) is given as a function of the time to break threads at a pre-determined length. The FPR is defined as $FPR = \frac{300\,mm}{t_2 - t_1}$, where $t_1$ represents the time to break the thread at 220 mm and $t_2$ represents the time to break the thread at 520 mm [Rossi, 2005]. From the test data, the FPR of various fabrics were plotted against various weights as seen in Figure 4. Notably in Figure 4, polyester has a tendency to retard flame propagation and cotton and cotton blends have a tendency to allow flame spread. With

the exception of polyester, the FPR for each material decreased as the weight of the sample increased. Overall there was a direct correlation between the fabrics with a high FPR and those with the fastest times to burn injury [Rossi, 2005].

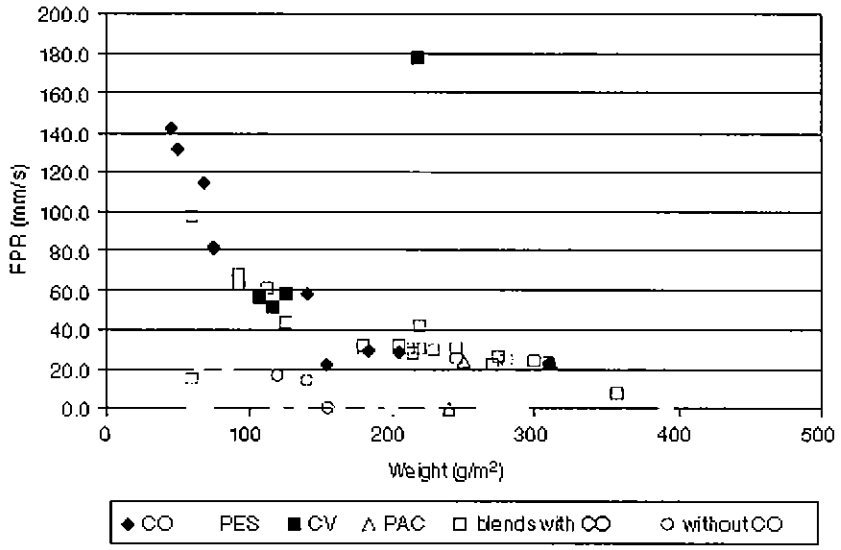



**Figure 4. FPR as a Function of Fabric Weight for the Samples CO: cotton; PES: polyester; CV: viscose; PAC: acrylic [Rossi, 2005]**

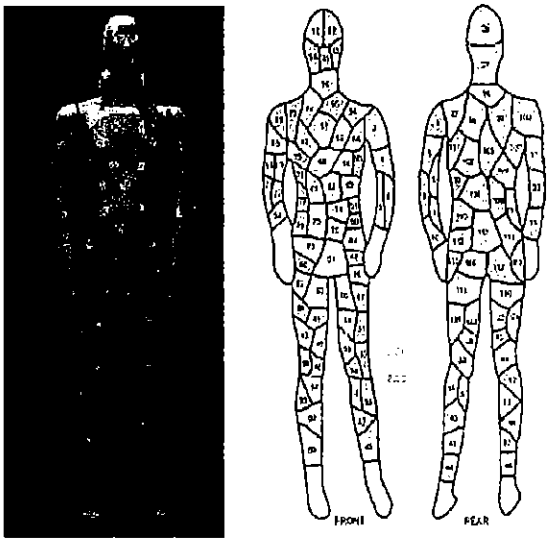
*2.5 Investigation of Air Gaps*

The issue of air gaps involves two conditions: the area between an individual's clothing and the skin and the area between the individual's clothing and the floor. Both are important in that as the two areas increase, the likelihood of injury during the SDR increases because of increased oxygen availability to support combustion of the burning fabric.

According to a study conducted by the U.S. Army Soldier and Biological Chemical Command, experiments have demonstrated that the air gap size between an individual's clothing and the skin is critical. If the gap is too small, heat passes across the space easily and if the gap is too large, convection may begin [Kim, et al., 2002][Lee, et al., 2002]. For the purposes of this project, the air gap present between the clothing and the floor is addressed in the behavioral study (see section 3).

The location of the air gaps is closely related to burn location. The study conducted by the U.S. Army focused on loose-fitting clothing. Using 3-D surface digitizing equipment, skin and clothing layers are overlaid on a digitized thermal manikin. As shown in Figure 5, sensors are distributed over the manikin's body. The three indicated colors represent sensor location with pink as sensors on the front or rear, blue on the outer side, and green on the inner side [Kim, et al., 2002].

**Figure 5. Sensor Locations on a Thermal Manikin. [Kim, et al., 2002]**




The original intent of the study was to explore the benefits of protective clothing. The particular trial of interest focused on the control test that lacked the use of protective garments of aviators and involved two layers of fabric, consisting of a coat, pants, a t-shirt, and undergarments, having a total thickness of 2.54 mm [Kim, et al., 2002]. The manikin was exposed to a heat source of 84 $kW/m^2$ for six seconds. The results from the test are shown in Figure 6. As indicated in the figure, severe burns on the facial and upper body regions resulted from not covering the face with hands. Because heat and flame rise, the individual is less protected from burns while in the upright position. From this, the importance of dropping before rolling is evident. Researchers also determined that air gaps ranging from 0 to 45 mm could potentially contribute to burns as illustrated in Figure 7.

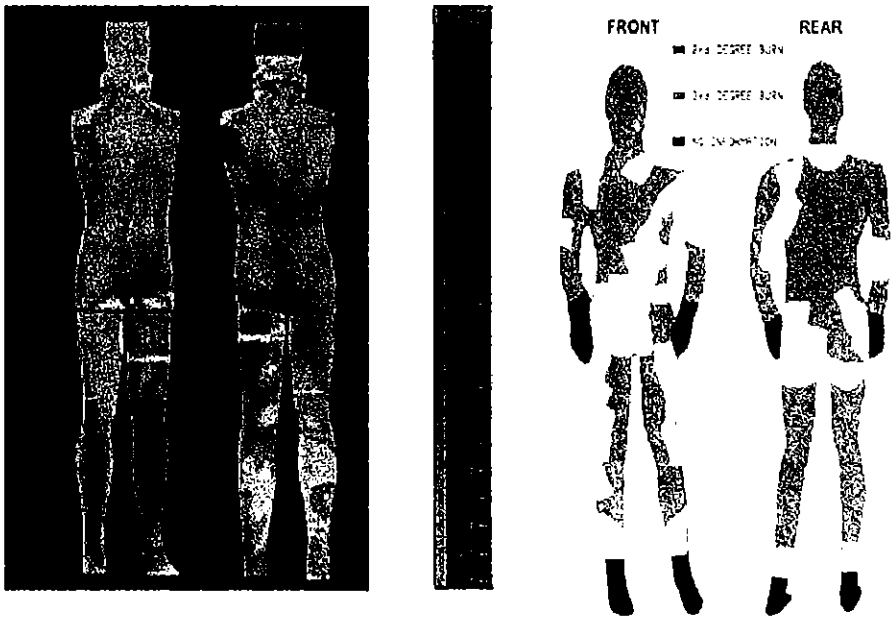



**Figure 6. (a) Heat distribution. (b) Resulting Burn Injury. [Kim, et al., 2002]**

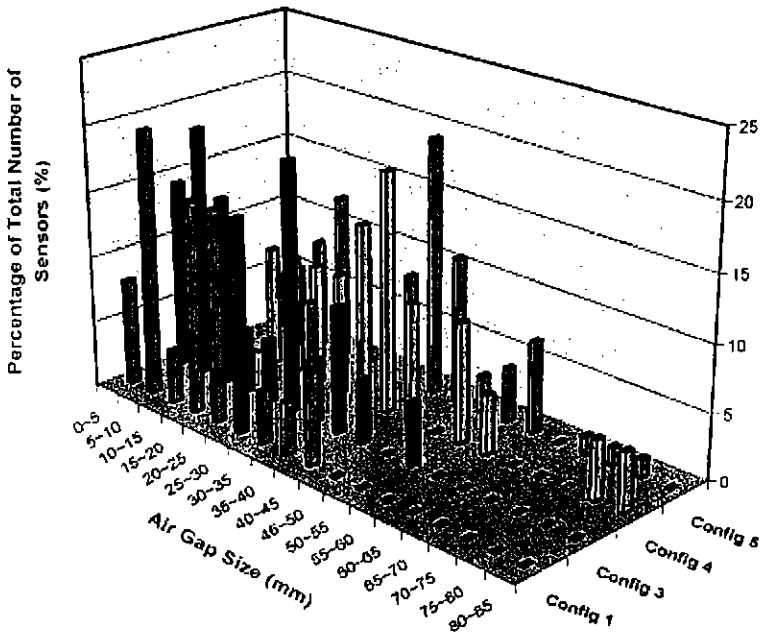



**Figure 7. Air Gap Size and Distribution for Different Configurations of Protective Clothing Systems [Kim, et al., 2002]. The trial of interest is Configuration 1.**

However, the test has significant limitations if applied to support placement of arms or hands in the SDR technique. Primarily, the thermal manikin was in the upright position for this set

of experiments. Ideally, for direct application to SDR, the manikin should have been placed in a horizontal position. This could serve as an area of future research.

### *2.6 Cooling as a Beneficial Addition*

The examples of successful saves include Case C which occurred in Falmouth, Massachusetts in the July of 1983. In this instance, an eight-year-old was playing on his bedroom loft and fire broke out. The child's pants ignited and he performed the SDR technique in order to extinguish the flames [LNTB, 1983b]. In this particular case, cool water was placed on the burns of the child after he performed the SDR technique [LNTB, 1983b]. The child received only minor burns, which is a different outcome than the burns previously mentioned for Cases A and B [LNTB, 1983a][LNTB, 1983b][LNTB, 1984].

The threat of injury is present until the temperature of the skin falls below a critical temperature. According to research performed by the National Bureau of Standards (now the National Institute of Standards and Technology) in 1975, the initial reaction after clothing ignition is essential in reducing the degree of burn injury [CPSC, 1975]. Rolling is designed to suppress the flames on the victim's clothing and cooling should be seen as prevention of burns from worsening after initial suppression.

One of the essential elements for injury includes the rise in skin temperature above the critical level. According to Stoll and Chianta [1968], burn severity increases with an increase in the time for the skin to decrease to 44 °C. Ng and Chua showed that cooling therapy needs to be applied within 27 seconds after the burn is received in order to affect the temperature distribution in the skin [UCB, 2006]. Cooling also helps to decrease edema, reduce inflammation or hyperalgesic responses and decrease the number of blood vessels [UCB, 2006]. Because of the importance of prompt cooling to reduce burn damage indicated by these studies, cooling should be included in the primary slogan.

The contributory effect of cooling to treat a burn is addressed in the *Learn Not to Burn* literature [NFPA, 2005]; however, it is not included in the four term slogan and is only

addressed in a supplement. Understandably, the slogan was created with successful saves defined as prevented fatalities. However, if the extent and severity of injuries sustained by the victims are included in this definition of success, then cooling would be a beneficial addition to the current four-term slogan.

## 3. BEHAVIORAL STUDY

### *3.1 Problem and Hypothesis*

At a meeting of the Learn Not to Burn Technical Advisory Council in September 1987, Maley presented data and various tests supporting the revision of the "Stop, Drop, & Roll" procedure. Maley's demonstrations included the rolling of dolls in different rolling positions and also adults who were instructed to perform the procedure. Notably, the adults had some previous training on the method of "Stop, Drop, & Roll" [LNTB, 1987]. Ultimately, the untrained individual's interpretation of the procedure and relevant data that could illustrate an optimum method was accessed in the behavioral study included in this current study. The test results provided a better understanding of the behavioral process associated with SDR.

### *3.2 Methodology*

The behavioral study conduct as part of this current project was intended to assess the familiarity of people with the SDR method and the technique followed in carrying out SDR. The behavioral study included two trials. In the first trial, SDR was performed by volunteers without any instructions or directions, relying on their memory from past presentations of SDR (perhaps many years ago) or on their intuitive understanding of the technique from the words in the slogan. In the second trial, volunteers were asked to perform SDR in a particular manner. In the third trial, the air gap under the chest was measured for two of the volunteers with arms either crossed over the chest or placed to cover the face.

Four engineering students (three male and one female) at the University of Maryland volunteered to participate in the behavioral study to demonstrate aspects of the SDR

procedure.[2] Due to Institutional Review Board (IRB) restrictions, the students volunteering had to be 18-years-old of age and capable of physical activity. The student volunteers were not compensated for their participation. Except for these two restrictions, subjects were not selected for any specific characteristics.

### *3.3 Trial 1*

#### *3.3.1 Procedure, Trial 1*

The first behavioral trial was designed to study the subject's previous knowledge of the SDR procedure which would then serve as a baseline case, or "control" for analyzing the results from the tests in the second trial. Because the advisory committee showed interest in observing those who have not been trained to perform the procedure, this portion of the study was designed to accomplish this goal. Subjects were asked three questions pertaining to their previous knowledge of the procedure. The questions were intended to give some background on where the person was taught the technique and also provided a "control" case for comparison with techniques used as part of Trial 2. The three questions were:

- Are you familiar with the SDR procedure?
- Do you remember where you learned it and when?
- Could you demonstrate the procedure exactly how you learned it?

The behavioral trial was done without any actual or hypothetical ignition of the volunteer's clothing that could affect their rolling action. Similarly, the memory and ability of adults to perform this action could be different than those from other age groups.

#### *3.3.2 Results, Trial 1*

In some respects, the three volunteers performed the SDR method similarly. However, there were some differences in the technique used by the three volunteers. Subject A rolled with his hands placed at his chest without covering his face. Subject B covered his face with his hands, while subject C rolled with his arms crossed at chest. All three methods were

[2] Only three of the four volunteers participate in Trial 1, while all four participated in Trial 2.

originally determined as one of the five most likely methods an individual could possibly use when performing the SDR procedure.

Noticeably, all subjects choose to roll back and forth instead of performing a continuous roll in one direction. Subject A rolled approximately two times and then reversed the rolling pattern. Subject B rolled once and reversed, while subject C rolled one and a half to two times and then reversed. All subjects indicated an awareness that the rolling was meant to suppress the flame.

### *3.4 Trial 2*

#### *3.4.1 Procedure, Trial 2*

Trial 2 focused on the participants' abilities to roll when asked to place their hands in varying positions in comparison to the control situation explored in Trial 1. The various hand positions included hands covering face, arms held to chest without covering face, arms at the sides, arms crossed and arms above head. Qualitative and quantitative measurements were used to evaluate the methods. The qualitative measurement was based on assessment of the apparent ease of rolling and the quantitative measurement examined the rolling speed and variations in a prescribed distance over time.

Rolling speed may be an important factor in extinguishing the flames. Research on the dependence of the ease of success to extinguish flames and rolling speed is needed. With flames only involving a limited area of the clothing, a slow rotational speed would seem to be best, in order to smother the flames with the subject's body. In contrast, in cases where a wide area of the clothing is involved, a fast rolling speed may be preferred.

The speed was also considered to be another indication of ease of rolling and how comfortable the individual was with the position. Speed was calculated by dividing the furthest distance traveled by the rolling individual (before reversing direction) by the total time for the individual to reach point.

*3.4.2 Results, Trial 2*

From the general contact test, the matrix of data presented in Table 4 was obtained. Each subject attempted the procedure with the prescribed hand position and the time he or she passed specific markers is indicated in seconds and fractions of a second.

**Table 4. Trial 2 Processed Data**

| Variation | Subject A | Subject B | Subject C | Subject D |
|---|---|---|---|---|
| **Hands Covering Face** | 3ft - 1.0sec | 3ft - 1.5sec | 3ft - 1.0sec | 3ft - 1.0sec |
| | 6ft - 2.5sec | 6ft - 3.5sec | 6ft - N/A | 6ft - 3.0sec |
| | 9ft - 4.3sec | 9ft - 4.5sec | 9ft - N/A | 9ft - 4.0sec |
| | 12ft - 6.5sec | 12ft - N/A | 12ft - N/A | 12ft - 5.8sec |
| | 14ft - N/A | 14ft - N/A | 14ft - N/A | 14ft - N/A |
| **Arms to Chest w/o Covering Face** | 3ft - 1.5sec | 3ft - 1.1sec | 3ft - 1.5sec | 3ft - 1.8sec |
| | 6ft - 3.2sec | 6ft - 2.6sec | 6ft - 2.5sec | 6ft - 3.0sec |
| | 9ft - 4.5sec | 9ft - 3.9sec | 9ft - N/A | 9ft - 4.7sec |
| | 12ft - 6.5sec | 12ft - N/A | 12ft - N/A | 12ft - 6.0sec |
| | 14ft - N/A | 14ft - N/A | 14ft - N/A | 14ft - N/A |
| **Arms Above Head** | 3ft - 2.0sec | 3ft - 1.5sec | 3ft - 1.0sec | 3ft - 2.3sec |
| | 6ft - 3.5sec | 6ft - 3.0sec | 6ft - N/A | 6ft - 4.0sec |
| | 9ft - 6.0sec | 9ft - 4.9sec | 9ft - N/A | 9ft - 5.7sec |
| | 12ft - N/A | 12ft - 7.0sec | 12ft - N/A | 12ft - 7.2sec |
| | 14ft - N/A | 14ft - N/A | 14ft - N/A | 14ft - N/A |
| **Arms at Sides** | 3ft - 1.5sec | 3ft - 2.0sec | 3ft - 2.1sec | 3ft - 2.6sec |
| | 6ft - 4.5sec | 6ft - 4.0sec | 6ft - 3.3sec | 6ft - 7.8sec |
| | 9ft - 7.5sec | 9ft - 6.5sec | 9ft - 4.8sec | 9ft - N/A |
| | 12ft - N/A | 12ft - N/A | 12ft - 5.3sec | 12ft - N/A |
| | 14ft - N/A | 14ft - N/A | 14ft - N/A | 14ft - N/A |
| **Arms Crossed** | 3ft - 1.2sec | 3ft - 1.8sec | 3ft - 1.0sec | 3ft - 1.8sec |
| | 6ft - 3.0sec | 6ft - 3.5sec | 6ft - 2.0sec | 6ft - 2.9sec |
| | 9ft - 4.6sec | 9ft - 4.5sec | 9ft - 3.3sec | 9ft - 4.6sec |
| | 12ft - 6.5sec | 12ft - N/A | 12ft - N/A | 12ft - 5.5sec |
| | 14ft - N/A | 14ft - N/A | 14ft - N/A | 14ft - 6.0sec |

A series of graphs were created to analyze the results of Trial 2. The graphs indicate the subject's performance during the five tests to compare the distance traveled for each position

of the arms or hands. The performance of Subject A is presented in Figure 8. Subject A took longer to perform the method with arms above the head and at the sides. Qualitatively, these two tests appeared to be the most uncomfortable to perform. From the graph, covering the face appeared to be the optimum method based upon time and distance.

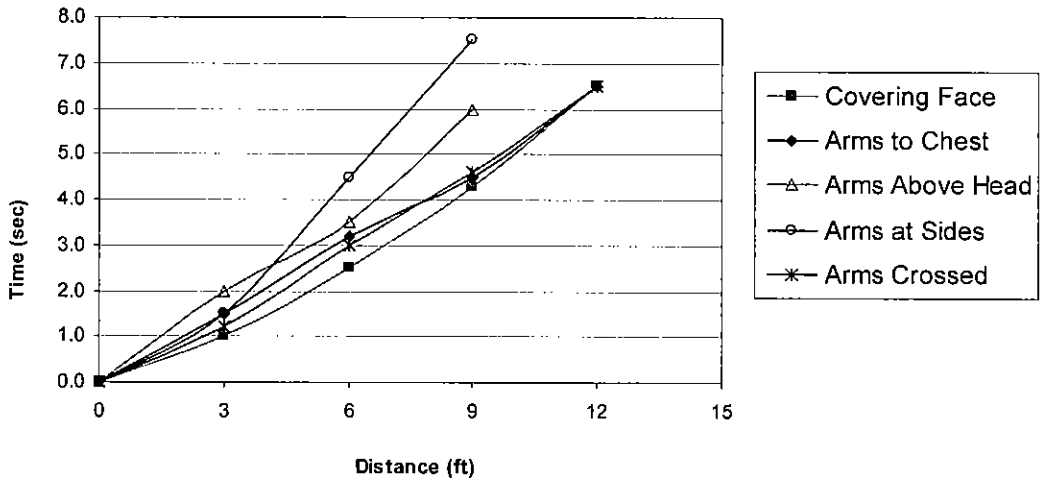



**Figure 8. Subject A's Performance in Trial 2**

In Subject B's graphed results (Figure 9), the performance with "arms at the sides" is similar to that from Subject A, taking the longest time to move a particular distance. For Subject B, having the arms at the chest seemed most ideal, which is different from the hand position he demonstrated in the control trial. This is inconsistent with the information instructing individual's to cover the face with their hands.

For Subject C (see Figure 10), having arms crossed appears to be the one with the fastest speed. Data for two of the methods performed by this individual was not evaluated because the subject rolled in a circular fashion and the setup was not prepared to address this particular behavior. Therefore, complete lines representing the arms above the head method and the covering the face method are not presented.

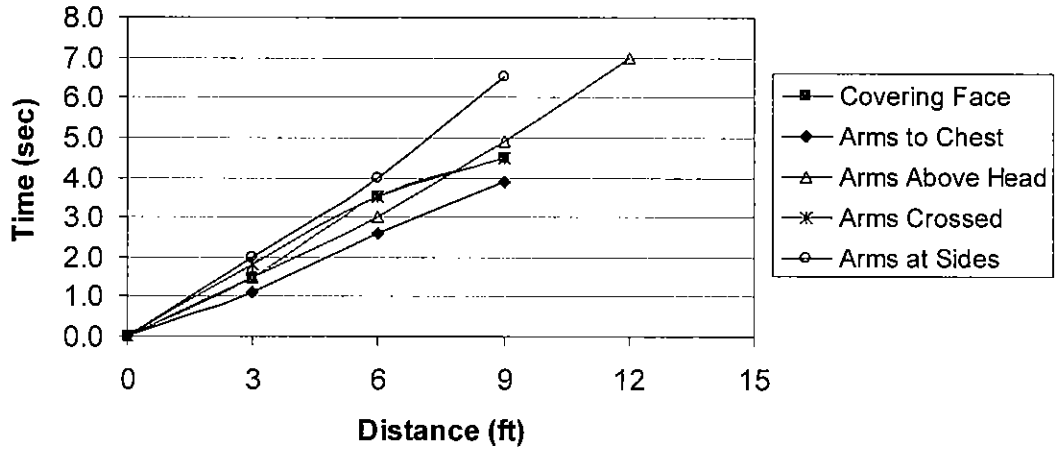



**Figure 9. Subject B's Performance in Trial 2**

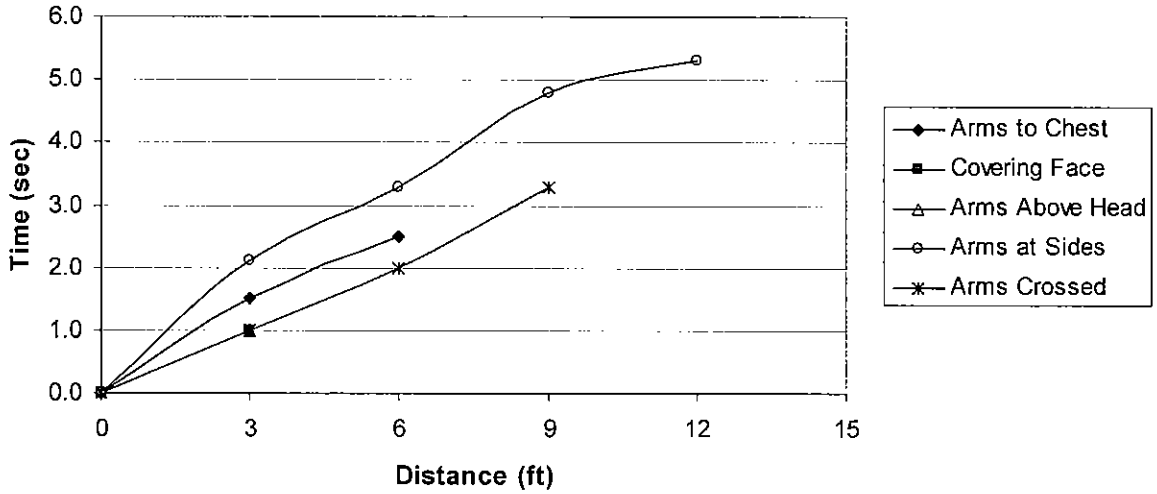



**Figure 10. Subject C's Performance in Trial 2**

The longest time for Subject D (see Figure 11) is the method "arms at the sides", similar to that for Subject C. The differences in the times are most significant for this individual, apparently as a result of significant differences in comfort level with the various methods.

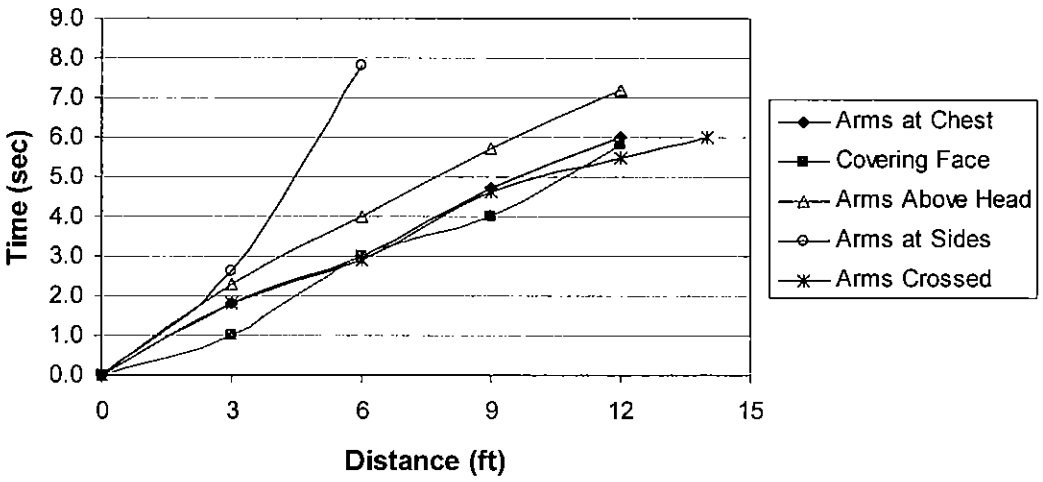



**Figure 11. Subject D's Performance in Trial 2**

Examining the average distance versus time for the five methods for each subject is done by normalizing the results from Trial 2 by those from Trial 1. In this manner, inherent differences in abilities between individuals are accounted for. The results of this comparison are provided in Table 5. As a result of the comparison of the velocities, having the arms crossed while rolling appears to give the greatest speed. Notably, arms at the sides and arms above the head methods represented the slowest velocities. Subjects stated that these two positions were also the most troublesome and uncomfortable to perform.

The bolded numbers in Table 5 represent the greatest velocity for each individual. Subject A showed equivalent measurements in three of the tests, while Subject B, C, and D had one specific hand placement that seemed to be the most comfortable.

**Table 5. Varying Velocities (ft/s)**

| | Hands Covering Face | Arms to Chest w/o Covering Face | Arms Above Head | Arms at Sides | Arms Crossed |
|---|---|---|---|---|---|
| **Subject A** | **1.85** | **1.85** | 1.50 | 1.20 | **1.85** |
| **Subject B** | 2.00 | **2.31** | 1.71 | 1.38 | 2.00 |
| **Subject C** | N/A | 2.40 | N/A | 2.26 | **2.73** |
| **Subject D** | 2.07 | 2.00 | 1.67 | 0.77 | **2.33** |

*N/A = not applicable.

### *3.5 Trial 3*

#### *3.5.1 Procedure, Trial 3*

The chest area contact test was based upon the original Consumer Product Safety Commission statistics on the location of burns presented by Maley. The tests focused on the availability of oxygen near the chest area. The hypothesis was that if the hands either crossed the chest or covered the face, an air pocket was left open in the area beneath the elbows that could result in an increased number of chest burns. To access the results from this test, the area of this space was examined from measurements by analyzing photographs taken while the individual was carrying out the procedure.

#### *3.5.2 Results, Trial 3*

Due to the nature of the arm position, one can see that the arms crossed over the chest exposed slightly more area in Figure 12. This is also based on the small opening between the subject's chest and the subject's arms.

**Figure 12. Subject A Demonstrating Trial 3 with Arms Crossed Over Chest**

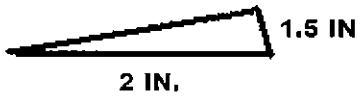



**Figure 13. Graphical Representation of Air Pocket with Arms over Chest (Not to Scale)**

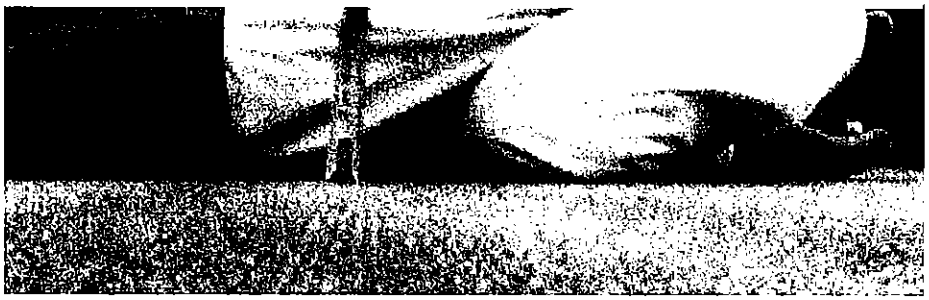


**Figure 14. Subject B Demonstrating Trial 3 with Hands Covering Face**

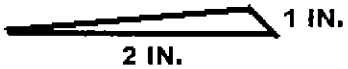



**Figure 15. Graphical Representation of Air Pocket with Arms Covering Face (Not to Scale)**

The difference in gap size is most distinct in Figures 12 and 14. As shown by Figure 13, the arms crossed test gives an area of 2 in. wide by 1.5 in. high. Given the triangular shape, a rough estimate of the contact area would be 0.75 $in^2$. In Figure 15, the area can be given as 2 in. wide by 1.0 in high and the area can be roughly estimated as 0.5 $in^2$.

*3.6 Study Limitations*

The behavioral studies had some limitations that may affect the validity of the test results. Primarily, the test assumes that the subject will act similarly in an actual fire situation as in the behavioral study. Also, more replications with additional people are needed in order to further support the applicability of the results to the overall population.

The study was performed on twenty-year old college students. In order to apply results to the general population, tests with subjects having a greater range of age need to be performed. Finally, for the contact exposure test, the measurements were estimated based on photographic documentation of the tests. However, this specific limitation could be eliminated by overlaying a computer-generated grid on a photo of the test.

## 4. CONCLUSIONS

The importance of cooling to reduce burn severity has been highlighted in several studies. As such, the slogan should be modified to draw more attention to the need for immediate cooling. A suggested new slogan is "Stop, Drop, Roll and Cool." The additional, simple word ("cool") is not expected to detract from the population being able to remember the slogan in general, as well as to recognize the importance of the cooling step.

Optimum hand placement during the rolling portion of the technique has been debated previously. Covering the face has been encouraged to prevent the inhalation of smoke from the fire. However, a rolling individual will be in a horizontal position and thus the flames will point upward (not toward the face). As such, covering the face will only provide a benefit if the area of clothing ignited is high on the torso (to prevent radiant heating of the facial area). Covering the face may be detrimental if the sleeves of the clothing are ignited.

The results from behavioral trial 2 show that individuals roll fastest with arms at their side, with the speed for all other arm positions being approximately equal. The decreased contact

area and increased availability of air gaps for the arm position needed to cover the face decreases the ability to suppress flames when rolling with hands covering the face.

The following recommendations should be considered:

- For the purpose of providing a better assessment of the effectiveness of the SDR (and Cool) technique, the severity of injury should be recorded for the saves in a consistent manner, i.e. where burns experienced, if so, what degree and over what portion of the body.
- Additional research should be conducted with a horizontally positioned thermal manikin to study flame propagation on clothing. The various hand positions described in the behavioral study should be included. This research could also investigate optimum rolling speeds for fire suppression.
- Cooling should be included in the slogan. Although cooling has proven effective at reducing the severity of burn injuries, this action is often not taken as shown by the incident saves.
- An in-depth study of the size of the air pocket created when the individual is in a horizontal position with his arms crossed or covering the face should be done. The individuals should be of varying age, size, and gender.

## 5. REFERENCES


Ahrenholz, D.H., Clayton, M.C. and Solem, L.D., 1995, "Burns and Wound Management," Otolaryngologic Clinics of North America, 28, 5, 1039-1055.

CPSC, 1975,. CPSC Urges Observance Of National Fire Prevention Week, Bethesda, MD, Office Information and Public Affairs, October.

FEMA. 2004, Fire in the United States: 1992-2001, 13th Ed, Washington, DC, United States Fire Administration, October.

Hammorcks, A R., Shonali Nazare, and Baljinder Kandola, 2004, "The particular Flammability Hazards of Nightwear," Fire Safety Journal, 39, 259-276.

Kim, Il Y., Calvin Lee, Peng Li, Brain D. Corner, and Steven Paquette, 2002, "Investigation of Air Gaps Entrapped in Protective Clothing Systems," Fire and Materials, 26, 121-126.

Lee, C., Kim, H.Y., and Wood, A., 2002, "Investigation and Correlation of Manikin and Bench-Scale Fire Testing of Clothing Systems," Fire and Materials, 26, 269-278.

Lawton, B., 1994, "Heat Dose to Produce Skin Burns In Humans," in Proceedings of the 1994 International Mechanical Engineering Congress and Exposition, Fundamentals of Biomedical Heat Transfer, HTD V 295, American Society of Mechanical Engineers, New York, NY, 31-37.

LNTB, 1975-1987, Learn Not To Burn TV Saves.

LNTB, 1983, Learn Not To Burn Program Save. Falmouth, Massachusetts. 24 July.

LNTB, 1983, Learn Not To Burn Program Save. Kirkland, Washington. 14 Oct.

LNTB, 1984, Learn Not To Burn Program Save. Trenton, New Jersey. 19 April.

LNTB, 1987, Minutes from the Learn Not to Burn Technical Advisory Council. Sept. 10-11.

Maley, Matt, undated, Review of Fire Safety/Burn Prevention Concepts. Shriners Burns Institute.

Maley, Matthew, 2005, E-mail interview, October 8

Miller, David. 2005, "Estimate of Fire Injuries Treated in Hospital Emergency Departments," Bethesda, MD, Consumer Product Safety Commission.

NIH, 2005, http://www.nlm.nih.gov/medlineplus/ency/imagepages/1078.htm, November.

Rossi, Rene M., Georg Bruggman, and Rolf Stampfli, 2005, "Comparison of Flame Spread of Textiles and Burn Injury Prediction with a Manikin," Fire and Materials, 29, 395-406.

SFPE, 2000, "Engineering Guide for Predicting 1st and 2nd Degree Skin Burns from Thermal Radiation, Bethesda, MD, Society of Fire Protection Engineers.

Sipe, Joel E., 2004, Development of an Instrumented Dynamic Mannequin Test to Rate the Thermal Protection Provided by Protective Clothing. Worchester Polytechnic Institute, MS Thesis, April.

Stoll, A.M. and Chianta, M.A., 1968, "A Method and Rating System for Evaluation of Thermal Protection," Report No. NADC-MR-6809, Naval Air Development Center, Johnsville, PA, 649-670.

UCB, 2006, www.me.berkeley.edu/ME212/lec6/c_burn_injury.pdf, December.

Wieczorek, Christopher J., and Nicholas A. Dembsey, 2001, "Human Variability Correction Factors for Use with Simplified Engineering Tools for Predicting Pain and Second Degree Skin Burns," Journal of Fire Protection Engineering, 2, 89-111.

## Appendix. Tabulation of NFPA Incident Saves [LNTB, 1975-1987]

| No. | Year | Location of Incident & Victim Description | Degree of Injury | Location of First Ignition | Cooling Attempted? | Accelerant | Key Factors |
|---|---|---|---|---|---|---|---|
| 1 | 1975 | Jamaica Plain, MA Thirteen Year Old Male | Second Degree Burns Over 10% of his body | No Specific Area Mentioned | Not mentioned | Gasoline | Clothing caught fire; At first he panicked and ran; His friend tackled him and rolled him on the ground until flames were extinguished |
| 2 | 1975 | Muskegon, MI Nine Year Old Male | Burns on Right Side of his face and neck, right arm, and chest | No Specific Area Mentioned | Not mentioned | Gasoline | He rolled over several times in sand |
| 4 | 1975 | Medicine Springs, MT An Older Gentleman | Second Degree Burns on both hands and Third Degree Burns Around His Waist | Belt Line of Pants | Not mentioned | Gasoline - Oil Mix | The already ignited mixture spilled into his belt line; Attempted to run a nearby creek; Chose to roll instead |
| 5 | 1975 | Tucson, AZ Male | Not mentioned | No Specific Area Mentioned | Not mentioned | Not mentioned | Trapped in a burning car after an automobile accident; Clothing caught on fire when he tried to free himself |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **6** | 1976 | La Crosse, WI Female | Treated for burns at a hospital | No Specific Area Mentioned | Not mentioned | Gasoline Mix | Poured mix into her kitchen stove; Clothes ignited by flashback; extinguished flames by rolling on the floor |
| **8** | 1976 | Elmore, OH Eight Year Old Male | 13 Days of Treatment for Leg Burns | Leg | **Pants removed before the flames could be extinguished completely** | Gasoline | Began to run; brother caught him and rolled him on the ground; removed pants before the flames could be completely suppressed |
| **9** | 1976 | Waterford, CT Eighteen Year Old Female | Second Degree Burns on Both Arms, Side of Her Nose | No Specific Area Mentioned | Not mentioned | Propane Gas | explosion and flash fire ignited when husband tried to light a hot-water heater; ran out front door and rolled in the grass |
| **10** | 1976 | Waterford, CT | | | Not SDR Related | | |
| **12** | 1977 | Clifton, CO Ten Year Old Male | Burns on 50% of Body | No Specific Area Mentioned | Not mentioned | Gasoline | attempted to make a gasoline torch; rolled himself on the ground; his friends threw dirt on his leg to finish putting out flames |
| **14** | 1977 | Roseville, MN Ten Year Old Male | Second and Third Degree Burns on Both Legs | Pants | Not mentioned | None | attempted to stomp out a small grass fire; pant leg ignited and he started to run; he then remembered to stop, drop, and roll |
| **19** | 1977 | Taunton, MA Twelve Year Old Male | Second and Third Degree Burns | Pants | Not mentioned | Gasoline | playing with gasoline and his pants caught fire |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **20** | 1978 | Tonawanda, NY Eleven Year Old Male | Not mentioned | Sneakers and Pants | Not mentioned | Not mentioned | attempted to stomp out flames while walking in a park; shoes and pants caught fire; rolled on the ground following his friends instruction while his friends smothered the flames with his own jacket |
| **24** | 1978 | Waterford, CT Nine Year Old Male | Burns on Face, Hands, Hair. One Side of the Body | Pants | Not mentioned | Possibly Gasoline | lawnmower exploded igniting his pants |
| **25** | 1978 | Toronto, CANADA Eight Year Old Female | Both Arms, Legs, Stomach | Dress | Not mentioned | Flammable Liquid | flammable liquid that had spilled on her dress caught fire; friends instructed her to roll |
| **26** | 1978 | Duxbury, MA Adult Male | Not mentioned | Thigh down on Both Pant Legs | Not mentioned | Gasoline | used gasoline to burn a pile of brush; explosion followed; both pant legs caught fire; immediately dropped to ground and rolled |
| **27** | 1978 | Chelsea, MA Twelve Year Old Male | Not mentioned | Both Pant Legs | Not mentioned | Spray Paint | tip of spray paint can came off when can fell off of the table; resulting spray from the can came into contact with the gas hot water heater |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **31** | 1979 | Sunnyvale, CA Twenty Year Old Male | First and Second Degree Burns | No Specific Area Mentioned | Not mentioned | Gasoline | while under a car hood, his clothing caught fire from gasoline he had poured into a carburetor; after attempting to bat out the flames, he dropped and rolled |
| **32** | 1977 | Lima, OH Adult Female | Suffered Severe Burns | Flashback sent flames up her hands, arms, legs and stomach | Not mentioned | Gasoline | gasoline accidentally thrown in fireplace; flashback sent flames up her body; she started to run but then remembered to lay down and roll |
| **34** | 1978 | Fort Worth, TX Adult Female | Second Degree Burns across her back and Third Degree Burns under her left arm | Back of her flannel shirt | Not mentioned | Hair Spray | back of her shirt became soaked with hair spray; heat from the kitchen stove ignited her clothing; ran out into the yard and rolled in the grass |
| **38** | 1981 | Hope Mills, NC Five Year Old Male | Minor First and Second Degree Burns on his face, hands, and legs | Coat | Not mentioned | Spray Paint | attempted to build a fire; a spray paint can exploded after it was thrown into the fire; his coat ignited and he ran; a friend knocked him to the ground and smothered the fire |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **41** | 1981 | Holland, MI<br>Adult Male | Not mentioned | No Specific Area Mentioned | Not mentioned | Gasoline | poured gasoline into a carburetor of a car; the enginer started and the excess gasoline ignited; the gasoline spilled onto the victim and the man began to run; his son knocked him to the ground and smothered the fire |
| **43** | 1980 | Urbandale, IA<br>Mother of a Nine Year Old | Minor Burns | Robe | Not mentioned | None | she attempted to beat out the flames and the flames spread; son instructed her to roll and then smothered flames with a comforter |
| **44** | 1980 | Dakota City, NE<br>Six and Seven Year Old Males | Not mentioned | No Specific Area Mentioned | Not mentioned | Fuel Oil | children were playing in oil; the oil on the clothing ignited; two of their friends rolled them on the ground |
| **46** | 1982 | Detroit, MI<br>Young Boy | Second Degree Burns on his chest and abdomen | Undershirt | Not mentioned | None | while frying some food his undershirt ignited; began to roll on the kitchen floor |
| **47** | 1979 | Red Lion, PA<br>Nine Year Old Male | Severly Burned on his face, neck, arms, and body | No Specific Area Mentioned | Not mentioned | Gasoline | was playing with gasoline and it ignited along with victim's clothing; began to roll over and over on the ground |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **48** | 1982 | Scituate, MA Thirteen Year Old Male | Second and Third Degree Burns on his legs | No Specific Area Mentioned | Not mentioned | Gasoline | attempted to build a small fire; the vapors ignited and victim caught fire; immediately he rolled and put the flames out |
| **49** | 1981 | Huslia, AK Thirteen Year Old Female | Some injury | No Specific Area Mentioned | Not mentioned | Gasoline | used gasoline to start in a wood stove; clothed ignited from the flashback; remembered how to stop, drop, and roll |
| **50** | 1982 | Waco, TX Nine Year Old Male | Required skin grafts on his legs | Jeans | Not mentioned | Gasoline | ignited some gasoline in a pan; victim attempted to suppress flames by kicking at the pan; jeans ignited as a result; began to roll on the ground until the flames were out |
| **52** | 1983 | Westwood, MA Male Car Driver | Not mentioned | No Specific Area Mentioned | Not mentioned | Possibly Gasoline | car ignited into flames after it crashed; victim trapped inside; victim removed by passerby; passerby rolled victim until flames were extinguished; victim covered with jackets afterward |
| **55** | 1983 | Hollywood, FL Fifteen Year Old Male | Second Degree Burns on the back of both legs | No Specific Area Mentioned | Not mentioned | Gasoline | attempted to destroy weeds by burning with gasoline; gasoline can ignited; as flames cover his legs, he dropped and rolled on the ground |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **57** | 1983 | Montclair, CA<br>Two Year Old Male | Saved from severe injury | Hair | Not mentioned | Gas from stove | child's hair ignited when he turned on the burner of a stove; older cousin pushed him to the floor and rolled him until the flames in his hair were out |
| **59** | 1982 | Leominster, MA<br>Adult Female | First and Second Degree Burns on his hands | Terrycloth Robe | Not mentioned | Gas from stove | cooking in the kitchen when the burner from her gas stove; attempted to smother the flames; then she remembered to drop, and roll |
| **60** | 1983 | Bridge City, TX<br>Five Year Old Male | First, Second, and Third Degree Burns on his face and head | Face, Back, and Head | Not mentioned | Spray paint | child's mother was burning trash; child was close to the fire and a paint can exploded; another child that was nearby tackled the child and extinguished the flames |
| **62** | 1983 | Chesterfield, VA<br>Seven Year Old Female | Third Degree Burns on her neck to just above her knees | Homemade Nightgown | Not mentioned | None | child's nightgown caught on fire when mother used a cigarette lighter to burn a string off of her nightgown |
| **65** | 1985 | Phoenix, AZ<br>Eight Year Old Female | Burns on her right hand, Singed back and hair | Jacket | Not mentioned | None | while playing near a campfire, the victim fell in the fire; victim's jacket caught fire and was instructed to stop, drop, and roll to suppress flames |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **70** | 1986 | Glasgow, DE Three Year Old Female | Not mentioned | Hair & Clothes | Not mentioned | Gasoline | children set dolls on fire with a cigarette lighter and a gasoline additive; one dropped the gasoline bottle and the victim was sprayed with fire; initially she ran with her hair and clothes on fire; another child instructed her to stop, drop, and roll |
| **73** | 1986 | Greenville, SC Fourteen Year Old Male | Burns over 46% of his body; most of the burns were third degree | No Specific Area Mentioned | Not mentioned | Gasoline | while working on a go-kart, gasoline spilled onto child's clothing; |
| **74** | 1987 | Lee, ME Twenty-Seven Year Old Male; Lacks Ability to Read or Write; Memory Loss from a childhood accident | Burns on his abdomen and both arms from hands to his shoulders | No Specific Area Mentioned | Not mentioned | Gasoline | While pouring gasoline into the carburetor of his truck, a backfire occurred and flaming gasoline ignited his clothing; he immediately rolled on the ground |
| **76** | 1987 | Newcastle, PA Twelve Year Old Male | Not mentioned | He was on fire from head to toe | Not mentioned | Gasoline | Two adult females saved the life of a twelve year old that was playing with gasoline; The two women instructed the boy to roll and the flames were smothered with a blanket |