Thomas E. Neal, PhD
The Oberon Company

# Oberon Gas Extraction Suit Harness Port Flash Fire Instrumented Manikin Testing Results

**Introduction:**
In late 2003, Oberon developed a new "Gas Extraction Suit" to protect workers who are exposed to severe and/or prolonged flash fire hazards. The most prominent example of this type of flash fire hazard is involved in a gas leak for a pipe line company or gas utility company in which a worker is lowered into a hole or pit wearing a body harness system to repair a natural gas leak in a pipe or valves on a pipe. Since propane or natural gas is heavier than air, it tends to accumulate in the hole. If the accumulated gas ignites, a severe flash fire event is created and the worker must be" extracted" as quickly as possible. Industry experts indicate that the reaction time and extraction time can take eight seconds.

Oberon has designed a Gas Extraction Suit which can protect a worker exposed to this type of flash fire hazard for up to approximately 8 seconds based on instrumented manikin testing according to ASTM F1930 recently conducted at North Carolina State University. The Gas Extraction Suit was a coverall design, which included a harness port in the upper back area, which permitted the harness to be worn under the Gas Extraction Suit so that only the lanyard was outside of the suit in the exposure area. One aspect of the Flash Fire testing of the Oberon Gas Extraction Suit was to determine whether heat could enter the suit through the harness port.

**The Gas Extraction Suit Products:**

- 14 oz/yd$^2$ three layer system similar to but a little lighter than the Oberon ARC65 system **equipped with harness extraction port**. The system is made of inherently flame resistant fibers. Fiber content for the three layer system is 52% Kevlar®, 27% Nomex® and 21% Basofil®.
- The **harness port** consists of a flap opening in the upper back area with Nomex® cuff covered with an extra layer of outer shell fabric (see Figure 1).
- A four layer knit balaclava hood consisting of 80% FR Rayon and 20% PBI fiber. Each layer of the knit fabric is 6 oz/yd$^2$ was used in with a SCBA facemask for head protection.

**Instrumented Manikin Testing:**
The products were put on the instrumented Pyroman manikin system at North Carolina State University and tested according to the ASTM F1930 Standard Test Method.

In addition to the Oberon Gas Extraction Suit and Four Layer Balaclava Hood, the manikin was also wearing the following clothing and equipment:

- 100% cotton work pants
- 100% cotton short sleeve T-shirt and briefs
- SCBA breathing mask

Test Conditions:

- Fire intensity or Heat Flux = 2.0 cal/cm$^2$s
- Exposure Time = 8 seconds

 © 2004 Oberon Company

**Results for Harness Port:**
No burn injuries were observed on the manikin sensors positioned directly under the **harness port area** on the back of the garment.

**Overall Instrumented Manikin Results:**
The following results are the average of two burn tests according to ASTM F1930:
2.4% predicted 2nd degree burn area on body (body represents 93% of the total area)
0.0% predicted 3rd degree burn area on the body

0.9 % predicted 2nd degree burn area on the head (head represents 7% of the total area)
0.4% predicted 3rd degree burn area on the head

Note: Most of the burn area on the head occurred on the eye sensors due to radiant heat transmission through the clear window of the SCBA viewing area.

**Figure 1: Back of Gas Extraction Suit with Harness Port Prior to Testing**

**The Instrumented Manikin Flash Fire Test Method**
Figure 2 below shows the ASTM F1930 Flash Fire test method in progress and the Gas Extraction Suit after the 8-second exposure.

 © 2004 Oberon Company

**Figure 2A and 2B: Gas Extraction Suit Before and During ASTM F1930 Instrumented Manikin Test Method with a Heat Flux of 2 cal/cm$^2$s.**

**Figure 2C: Gas Extraction Suit After Exposure**

 © 2004 Oberon Company

**Background on Flash Fire Hazards and Use of FR Clothing to Address the Hazard:**
Philosophy: Unlike the arc flash hazard, it is not possible to accurately predict the exposure level for a flash fire hazard. A flash fire could result from the ignition and continued burning of a large gas cloud fed by a major gas leak. Or a small amount of gas from a slow leak. The duration of a flash fire could range for hours at a large refinery fire or seconds for a small gas leak or a small chemical spill. The goal of wearing FR clothing for a flash fire hazard is to save the life of the worker—not to prevent burn all injury. A second goal is to minimize 3rd degree burn injury which tends to require long hospitalization, skin graft surgery and extensive rehab. If the total burn injury can be limited to less than 50% of the body area and 3rd degree burn injury area can be reduced to a few percent of the total body area, there is a high probability that the burn victim will survive and that the quality of life for the worker can be preserved.

Just to summarize: The typical approach for industrial flash fire hazards is to wear an FR coverall or an FR shirt and pants—and accept that workers will receive substantial burn injury in the event of a flash fire. To put this in perspective—if non-FR work clothing is worn in a flash fire accident of 4 seconds, body burn injury can exceed 90% of the body area, and a fatality is very likely. If the victim survives, they will likely wish to be dead and frequently will try to commit suicide while still in the hospital. Since flammable clothing burning on the human body for about 15 seconds begins to create substantial areas of 3rd degree burn, the quality of life cannot ever be fully recovered after this type of burn injury.

**Escape Time**
Another concept used in flash fire exposures is “escape time”, i.e. you have a few seconds of time to escape from the fire before you sustain life threatening levels of burn injury. This is concept doesn’t work for the arc flash hazard since the arc exposure usually only last for a fraction of a second and thus there is not time to escape.

**Heat Intensity**
The heat intensity of a fire is much lower than an electric arc flash. We call the heat intensity of a fire or an arc flash “heat flux” which represents the flow of heat energy onto a surface, i.e. the surface is usually some sort of heat sensor in a test method and in real life accidents the surface receiving the heat is the human body.

Heat Flux Levels:
- For a flash fire: 1 to 3 cal/cm$^2$s (test methods use a value of 2 cal/cm$^2$s)
- For an arc flash: 1 to 200 cal/cm$^2$sec (arc testing uses ~50 cal/cm$^2$s)

**Exposure Times**
- For a flash fire: 3 to 4 seconds is seen as the “Escape Time” and the standard value used F1930 is 3 seconds for conventional industrial FR clothing testing
- For a fire fighter turnout: No standard test requirement but 10 seconds is the typical exposure time used for evaluation. Typically less than 5% body burn results when an NFPA 1971 certified Turnout suit is tested
- For a arc flash: 0.1 up to 1 or 2 seconds is used for testing according to the ASTM F1959 test method

 © 2004 Oberon Company

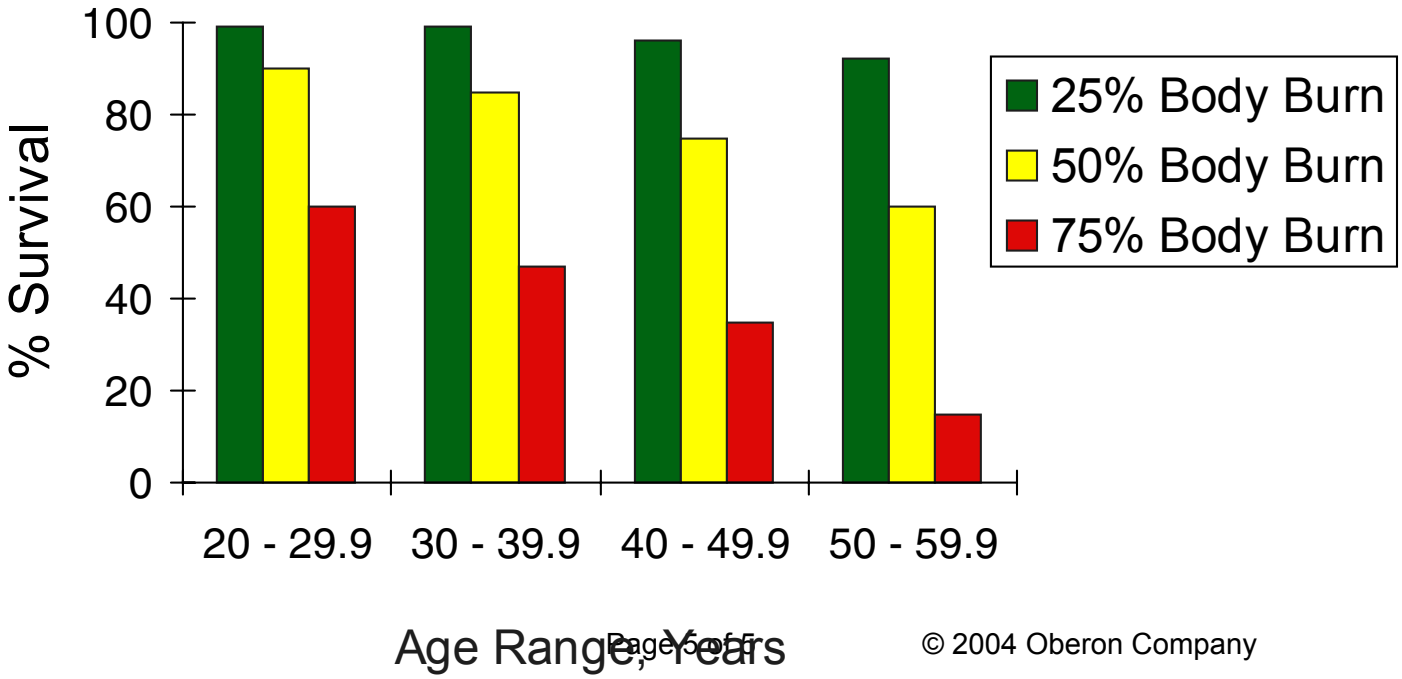
**Standards**
ASTM D6413: All FR materials used for flash fire hazards must pass D6413 the vertical flame test—this is very similar to the requirement for materials used for the arc flash hazard.

NFPA 2112 is the FR garment specification standard for FR clothing to protect workers from industrial flash fires

- Requires ASTM F1930 instrumented manikin test of 3 seconds for a standard FR coverall plus cotton T-shirt and briefs.
    - The sum of 2nd degree and 3rd degree Body area burn injury must be 50% or less (yes—I said 50% of the area of the body).
    - The probability for a person to survive 50% burn injury is fairly high especially for victims less than 50 years old (see Figure 2 at the end).

There are several other tests that are also required but nothing that our Gas Extraction Suit would not pass. **It is important to recognize that we far exceed the protection requirements of the NFPA 2112 standard. Our aim is to reduce burn injury to close to zero for an 8 second exposure as opposed to the NFPA 2112 requirement for less than 50% body area burn injury for a 3 second exposure.**

**Gas Extraction Flash Fire Hazard is Not a Typical Flash Fire Hazard**
Since the work on a gas line usually occurs in a situation where the worker will need to be "extracted", the escape time can be up to 8 seconds due to the time for personnel tending the safety line to react to the emergency (they will also be impacted by the fire) and to apply the needed force to pull the worker out of the flash fire area. The value of 8 seconds is an industry estimate—not an Oberon estimate. The Oberon Gas Extraction suit is designed to provide 8 seconds of "escape time" from a 2 cal heat flux fire and leave the worker with only a few percent of body area burn injury.





© 2004 Oberon Company

**Figure 3: Survival of Burn Injury Victims for Age Groups form 20 to 60 with a range of body area burn injury. The total areas of 2nd and 3rd degree burn injuries are included. Source: American Burn Association (1991-1993 Study)**

 © 2004 Oberon Company