

## **Flash Fire Hazard and Analysis of Flame Resistant Clothing Performance**

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### **Introduction**

Flash fire hazards are not limited to hydrocarbons, and exist in many industrial environments including refineries, petrochemical and chemical facilities, gas operations, utilities, pipelines, grain, sugar and other dust-related industries, paints and solvents plants, etc. The significant majority of catastrophic injuries and fatalities caused by these incidents are not caused by the flash fire itself, but rather by the ignition and sustained combustion of clothing worn by workers. Process engineering to reduce risk and behavioral safety programs are vital, but cannot completely eliminate risk; therefore, a key component of any safety program requires all personnel entering areas where there is any risk of a flash fire to wear flame resistant protective apparel. When all else fails, and an incident occurs, the flame resistant clothing is the last line of defense, and virtually all that stands between the worker and massive injury or death.

### **What Is a Flash Fire?**

A flash fire is defined as a brief event, involving diffuse fuel in air, a moving flame front, and duration of typically 3 seconds or less. The energy in a flash is sufficient to ignite non-flame resistant work wear, including 100% cotton. Once clothing ignition occurs, the thermal hazard to the worker dramatically worsens. Burn injury will be spread by burning clothing over much larger areas of the body than the flash alone would have caused, and burn severity can be expected to increase significantly as well due to much longer exposure times versus less than three seconds of the flash itself. Because the primary correlative factor to fatality in burn injury is percentage of the body surface receiving 2<sup>nd</sup> degree burn or worse, flame resistant apparel frequently makes a life-and-death difference. Body burn injuries above 50% second degree burn are significantly more likely to result in mortality than lower percentage burns, and almost all incidents recording this level of body burn involve clothing ignition. This is because the flash will rarely impinge on greater than 50% of the body surface; as a moving flame front, the flash is directional, and so is the heat flux. In other words, if one is facing the flash, the front of the body is exposed, but not the back, and vice-versa. If, however, the flash ignites the worker's clothing, the clothing fire will rapidly spread.

Flame resistant clothing, in addition to not supporting combustion in a flash fire, should also be able to insulate the wearer from as much 2<sup>nd</sup> degree burn as possible. Non-ignition is the first goal, but insulation from the radiant component of the flash is also critical to reducing burn injury. There is an excellent full-scale manikin laboratory test which evaluates precisely this performance factor (ASTM F-1930, discussion to follow).

It should be emphasized that flash fire PPE involves protection from brief, unplanned or accidental exposure, not intentional or extended exposures such as structural firefighting. The garment system of choice is secondary protective apparel, generally meaning single layer clothing light and comfortable enough to be worn all day every day in place of standard non-flame resistant work clothing.

## **Is Cotton an Upgrade?**

Unfortunately, there are still many people in the United States today who think 100% cotton non-FR clothing is an “upgrade” from polyester/cotton blends. This is perhaps the most dangerous myth in the FR business. They know that poly/cottons burn and melt, and that molten polymer is bad, but think either that cotton does not burn, or that since it does not melt, it is less hazardous, and thus more acceptable, than poly/cotton. 100% non-FR cotton is NOT an upgrade, and in fact is at least as hazardous as meltable blends. There are four significant issues with non-FR cotton fabrics:

- 1) Cotton ignites just as easily as poly/cotton blends. It does not require any more energy than a given weight of poly/cotton to cause ignition.
- 2) Cotton fires burn hotter, meaning more damage will occur more quickly.
- 3) Cotton fires are harder to extinguish. They tend to smolder long after visible fire is eliminated, and frequently reignite when the wind blows, the victim moves, or garments are removed or cut open and fresh oxygen gets to hot spots.
- 4) Cotton fabrics tend to be heavier, meaning more fuel for a longer fire. Cotton can be heavier because it is less expensive and more comfortable, but cotton also needs to be heavier because it is less durable.

Combusted cotton is also extremely difficult to remove from burn sites. It tends to end up as small particulates and ash, widely scattered, difficult to see, and with significant potential to cause medical problems during recovery if not successfully removed.

## **Standards and Performance Testing**

The ASTM F-1930 standard dictates how to properly perform full-scale manikin testing, and ensures that different labs conduct flash fire testing in essentially the same way, with similar results. However, it is not a pass/fail performance standard. For that, we look to NFPA 2112; this standard evaluates the relative performance of FR garments using the ASTM F-1930 manikin test.

The ASTM F-1930 test involves a human-sized manikin wired with greater than 100 thermocouples, evenly distributed over the manikin surface (except for the hands and feet). Eight to twelve propane torches surround the manikin with a flash fire of 2 calories/centimeter squared/second (84kW). This heat flux is highly representative of most common hydrocarbon

flash fires, and was originally based on JP4 jet fuel. The duration of the flash is computer-controlled in half-second increments, and the thermocouples record predicted body burn injury. Second degree burn occurs within 3 seconds. Third degree burn can occur even after the fire is out, due to stored energy in the skin, the air between the skin and the clothing, and the clothing itself, and onset of third degree burn typically occurs beginning about 8-10 seconds from initiation of the flash fire.

As noted, 1930, while excellent, is not a pass/fail standard; NFPA 2112 is. The NFPA standard requires identically sized and styled coveralls, constructed without pockets, cuffs and other multiple-layer areas, to best reflect the performance of the fabric itself. The coverall is tested over 100% cotton tee shirt and briefs. It then requires tests at 3 seconds flash fire duration, because that is defined as the upper limit of a flash, and it requires less than 50% second and third degree body burn to earn a pass rating. The 2112 test provides excellent and sophisticated data on exact extent, location and severity of predicted body burn, and can be used to evaluate garment design as well as fabric performance.

The simplest approach is to accept any garment that passes NFPA 2112 testing. However, passing alone should not be regarded as sufficient; the data must be carefully examined, because passing can mean 49% body burn in one case, and 1% body burn in another...starkly different results. The test method itself is capable of a high degree of specificity and precision, but the reporting can dilute this down to a single four-letter word, with worlds lost in the translation.

## **Summary**

Flame resistant protective apparel can and does dramatically reduce catastrophic burn injuries and fatalities in a flash fire, by not igniting and continuing to burn long after the flash has ended. Non-ignition can be a life-and-death difference, but flame resistant clothing should also provide excellent insulation to the wearer, to minimize or eliminate second degree body burn altogether. Excellent standards exist to guide in the evaluation and selection of appropriate FR clothing. ASTM F-1930 tells us how to conduct repeatable, reliable full scale manikin testing, and NFPA 2112 tells us how to use 1930 to evaluate comparative performance of FR fabrics and garments. However, there is a very wide range of thermal protective performance among compliant garments. It is incumbent upon us each to look beyond mere compliance, and thoroughly review actual performance data, before specifying flame resistant fabrics for our workers.

### **ASTM F-1930 and NFPA 2112 Independent Testing Labs**

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