

Disposable Flame Retardent / Chemical Protective Clothing

Guide to the Performance of Pyrolon compared with FR SMS garments



The properties of FR SMS coveralls compared to Lakeland Pyrolon Garments

"The PRIMARY purpose of FR disposable garments is to provide liquid and/or dust protection... and to do so without compromising the thermal protection provided by the TPG worn beneath..."

Pyrolon Plus 2, XT and CRFR disposable coveralls have been used for many years in industries such as petrochemical because of their combined chemical protection and flame retardent properties.

Recent years however have seen an increase in the use of various garments based on polypropylene SMS nonwoven treated with FR chemicals.

Such FR SMS garments have often been certified as Index 1 fabrics according to EN 533:1997... a standard now 15 years old and replaced by EN 14116:2008.

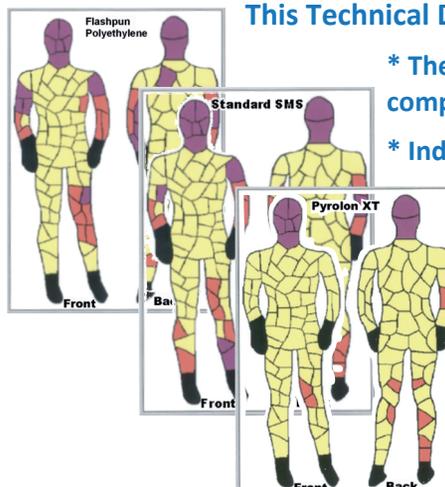
More recently the bigger brands of FR SMS have been [apparently*] certified to EN 14116. Note that there are critical differences between the two standards. (see Page 3).

* see independent testing - page 5



This Technical Document discusses:-

- * Thermal properties of FR SMS fabric compared with Pyrolon
- * Independent flammability testing of FR SMS garments compared with Pyrolon
- * Thermal Mannequin Testing of FR SMS & Pyrolon garments to show the effect on TPG thermal performance



...How can you assess the suitability of disposable FR coveralls for the task when worn over a Thermal Protective Garment?

There are two types of disposable FR garments available

Fabric	Description	Properties
Pyrolon	Viscose-based proprietary fabric specifically engineered for superior FR properties	Intrinsically FR: fabric combusts or oxidises at a temperature lower than its ignition point. Thus the fabric will not ignite in any normal circumstance
FR Treated SMS	A Thermoplastic spunbond / meltblown polypropylene SMS fabric with an FR chemical treatment applied either to the fibre or the finished fabric	FR properties rely on FR treatment to increase speed of combustion and on thermoplastic tendency to shrink from a flame. Fabric may still ignite, melt and drip in a forced ignition situation - ...not reflected by standard flammability testing

Both garment types may be apparently certified to the same EN 14116 FR standard. Yet Are they the same?

...Or are there real differences in performance?

Are there ways to measure the varying thermal performance of different garments beyond EN 14116?

What is the Purpose of disposable FR garments?

Disposable FR garments are not designed to offer protection against heat and flame. *FR disposables will not protect against flames and flame retardancy should not be confused with flame and heat protection.* For this reason both EN 533 and EN 14116 state that Index 1 garments such as these should not be worn next to the skin.

Rather, the PRIMARY purpose of these garments is to provide liquid and/or dust protection when WORN OVER AN EN 11612 Thermal Protective Garment (TPG) such as Nomex® or Fyrban® **and to do so without compromising the thermal protection provided by the TPG.**

Given this key purpose, is there any difference in the performance of the two types of fabrics used? Does the testing required in EN 14116 (or EN 533) provide any information on relative thermal performance in this respect?

How do standard disposables, FR SMS fabrics and Pyrolon compare?

The most important question for safety professionals selecting disposable FR garments is this:

“How does the wearing of either of these two fabrics over a TPG affect the total thermal protective performance offered by the ensemble - and especially compared with lower cost standard disposables?”

In other words... **what are the benefits of paying for FR disposables?**

Thermal properties of Disposable Protective Garments and FR SMS Polypropylene

A Thermal Protective Garment (a “TPG” - such as Fyrban®, Nomex® etc) is worn to protect against flames and heat hazards. Such garments, certified to EN 11612 will provide protection against contact with flames . This often involves the risk of flash fire where the wearer is briefly engulfed in flames as a result of a localised fire, explosion or similar incident. Such hazards are real world scenarios that do occur and a good quality TPG can provide sufficient protection to minimise resultant body burn and save lives.

In many applications users also need splash or dust protection - or wish to keep the TPG clean in order to minimise wash cycles, reduce cost and maximise garment life. Thus a disposable coverall will be worn over the TPG. *This is the primary use of disposable FR garments.*

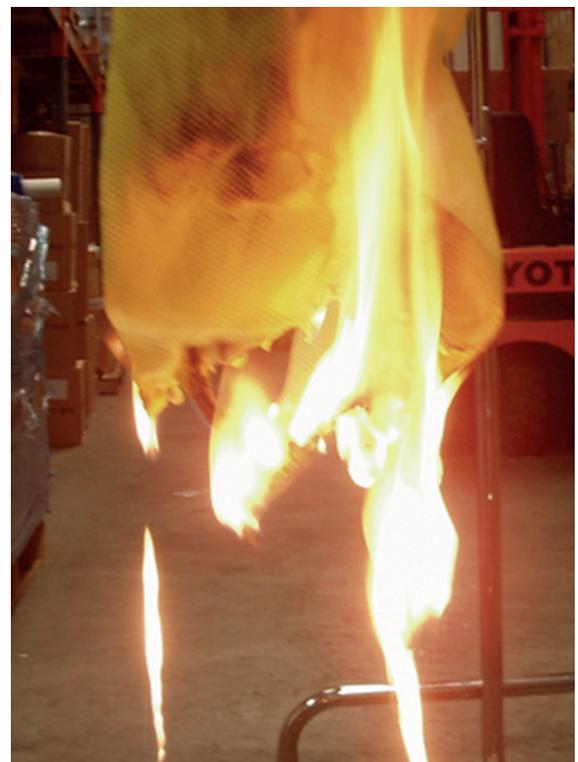
All standard CE Types 5 & 6 coveralls - are based on polypropylene and /or polyethylene - thermoplastic derivatives of oil that intrinsically ignite, burn and drip molten debris which will adhere to surfaces, continuing to burn. In addition *even after combustion has ceased the thermoplastic PP / PE residue will store heat energy and release it slowly, continuing the burning hazard.*

Thus in the event of flash fire a standard disposable will ignite and melt, adhering to the TPG fabric beneath (often penetrating the weave) continuing to burn and release stored heat energy, holding heat against the TPG fabric and skin beneath and thus increasing body burn, often dramatically. This has been proved in Thermal Mannequin Testing (see page 4 & 5)

The process of selecting the performance of a disposable FR garment should include an assessment of its effect on thermal protection to ensure it can be worn OVER a TPG without compromising thermal protection

Disposable FR garments are certified to EN 533 or the more recent EN 14116. Do these standards provide this information?

If the purpose of an FR disposable is to provide splash or dust protection when worn OVER a TPG... why not simply use a standard disposable?



In contact with flame standard disposable fabrics will ignite, burn, drip molten, burning debris and adhere to a TPG worn beneath- actually increasing body burn - often dramatically. 2

How is vertical flammability testing according to EN 14116 conducted?

Vertical Flammability Testing according to EN 533 & EN 14116

The EN 533 standard assessed the suitability of FR fabrics according to three “index’s” (Index 1,2 and 3). Fabrics are tested according to the test method EN 532 in which a fabric sample is held vertically, a small flame applied to the centre and held in the same position for 10 seconds.

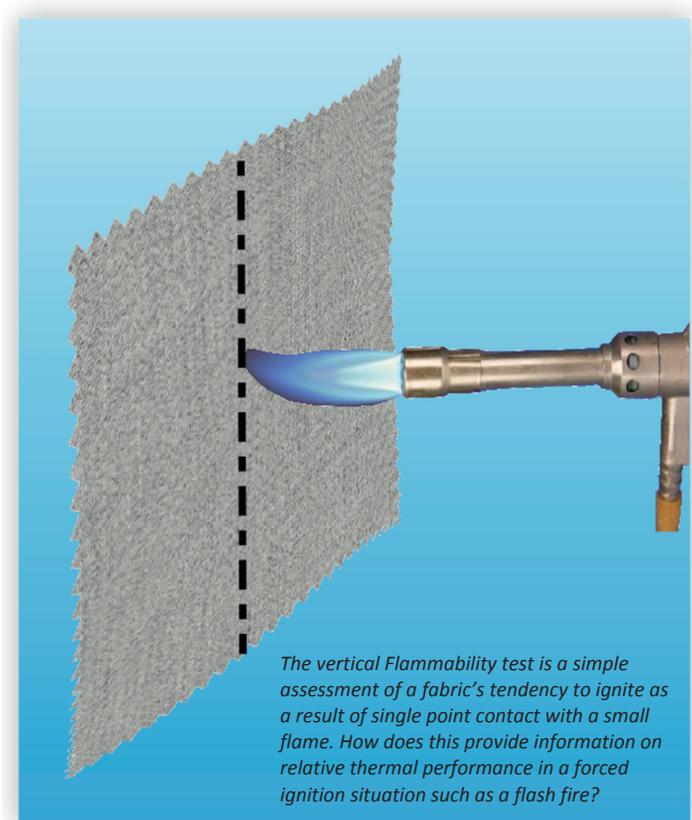
“Index 1 materials do not spread flame but may form a hole on contact with a flame”

According to the standard *“Index 1 materials do not spread flame but may form a hole on contact with a flame”* *. In addition Index 1 materials must meet the requirements shown in the table below.

EN 533 was a standard referring purely to fabrics and featured no finished garment requirements.

Its replacement, EN 14116, published in 2008, has the same, and some additional requirements including a recognition of the need to consider the performance of the finished garment as well as the fabric itself by requiring a flammability test on a seam as well as on the fabric.

** (Index 2 and 3 materials additionally require no hole formation)*



Requirements for Index 1 materials in EN 533 (& EN14116)	
Property	Requirement
Flame Spread	No specimen shall permit any part of the lowest boundary of any flame to reach the upper or vertical edge
Flaming Debris	No specimen shall give off flaming debris
Afterglow	No afterglow shall spread from the carbonised area to the undamaged area after the cessation of flaming

Differences between EN 533: 1997 and EN 14116: 2008

Standard EN 14116 recognised the need to assess the FR properties as part of a garment and introduced additional requirements. The most critical being that the Vertical Flammability Test *must be conducted on a fabric sample with a seam placed vertically down the middle so that the flame is applied to the centre of the seam.*

Importantly, the EN 14116 standard makes the following vital requirement in the test:-

“Seams shall not separate” *

Any garment certified only to the old EN 533 standard has not passed this requirement for garment seams.

** Note: the latest draft version of the standard may make this requirement on Index 2 and 3 fabrics only*

Even if a garment has (apparently) passed the vertical flammability test how does this inform the user on total thermal protection when a disposable is worn over a TPG? How does it assess how the fabric might react when it cannot shrink from a small flame such as in a flash fire situation? How does it account for the affect of thermoplastic residue releasing heat energy over time following the burn? The answer is that it does not. This test - the only test required by EN 14116, offers no information on these questions. It simply suggests that the fabric might not propagate a small, static flame.... Only Thermal Mannequin Testing can answer these questions

EN 14116 is a minimum standard designed for re-usable fabrics for flame and heat protection and makes no specific mention of disposable or thermoplastic fabrics.

Disposable fabrics made from thermoplastic materials such as PE and PP, including FR treated SMS, have a tendency to shrink rapidly from the heat of a flame at a single ignition point. The vertical flammability test fails to account for this as the small flame stays in one position so ignition is not “forced”. How does this compare with a real world flash fire situation in which a garment may be engulfed in flame?

In such a situation the thermoplastic material cannot “escape” from the ignition source... the vertical flammability test has limited relevance for disposable fabrics

The vertical flammability test required for Index 1 materials is not adequate for providing information on

3 performance of a garment used for wearing over a TPG... but how do FR SMS garments actually perform in this test?

Independent testing has confirmed problems for FR SMS garments in actually passing the vertical flammability requirements of EN 14116



There are an increasing number of FR SMS garments - often at low prices - available on the market and variously certified to either the old EN 533 standard or in some cases to the new EN 14116 standard. How do these various garments actually perform in flammability testing?

The effectiveness of the vertical flammability test for assessing the FR properties of a disposable FR fabric when used in conjunction with a TPG is questionable. The test was not designed for thermoplastic materials so fails to account for such fabrics' tendency to shrink from the heat of a flame which is applied to a single, static point.

To test both the effectiveness of the test on disposable fabrics and the performance of garments currently in use Lakeland have obtained several such garments from the market - purchased at different times and from different sources to ensure a suitable "spread" of samples - and had them independently tested to the vertical flammability requirements. Each of these sample garments were major international brands and each marked as certified to either EN 533 or EN 14116.

In every single test the garments FAILED to meet the EN 14116 requirements.

In addition to testing market sourced and apparently certified garments Lakeland has tested several samples manufactured using FR SMS fabric from several different manufacturing sources. In some cases samples have been made with FR thread; *again, in no case did any sample, either with or without FR thread, pass the test.*

To re-iterate, in not one single case can we state that a sample purchased in the market has passed the flammability test required by EN 14116. However, this is not the full story. Not only did every sample fail to meet the basic FR requirements but most didn't even come close to passing, in some cases the test reports making supplementary comments on the magnitude of the failure

Comments from Test House	<i>"The test specimens fail as flaming debris was produced and flames reached the edge of each specimen. Additionally it should be noted that Specimen 2 was largely consumed by flames generated during the test".</i>
Supplementary Comments	<i>"The specimens of [Brand T] however suffered almost complete destruction with flame propagating to all parts of the specimens. One specimen was completely consumed by flames"</i>

"The specimen of [Brand T] however suffered almost complete destruction with flame propagating to all parts of the specimens. One specimen was completely consumed by flames"

How is it that market-sourced major international branded FR SMS disposable coveralls, apparently certified to EN 14116, along with a variety of samples sourced from FR SMS fabric manufacturers, when independently tested to the vertical flammability test, have consistently failed to meet the requirements... and not only failed, but in many cases failed catastrophically?

"On this basis you certainly cannot assume or be sure that the FR SMS garment you are wearing would achieve a pass when tested or will perform in use as its apparent certification indicates.

The table on the next page summarises all the tests conducted along with the results.

The table below summarises the results from EN 14116 vertical flammability testing of market-sourced FR SMS garments compared with testing of Pyrolon garments

The table summarises the specific FR requirements in the standard and shows where each sample passed or failed. Red denotes a fail; green a pass

Garment tested	FR SMS Samples									Pyrolon Samples											
	Brand T (1 st)			Brand T (2 nd)			Brand T (3 rd)			Brand M			Pyrolon Plus 2			Pyrolon XT			Pyrolon CRFR		
Test Date	8/8/2012			31/8/2012			12/12/2012			12/12/2012						29/8/2008			8/8/2008		
Specimen	FR SMS Garment Market-sourced Garment Samples									Pyrolon FR garments sample tests											
	1	2	3	1	2	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Flaming to edge?	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	no	no	no	No	No	No	No	No	No
Flaming/molten debris	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
Afterflame to edge?	No	N/A	N/A	Yes	Yes	Yes	No	Yes	No	No	No	No	No	no	No	No	No	No	No	No	No
Seam Parted?	Yes	Yes	Yes	See note	See Note	Yes	No	Yes	No	No	Yes	No	No	No	No	No	No	No	No	No	No
Summary	FAIL 2 specimens flaming to edge / all specimens with flaming/molten debris / all seams parted			FAIL On all requirements			FAIL All showed flaming/molten debris / 2 seams parted			FAIL All showed flaming/molten debris / 1 seam parted			Pass* All requirements satisfied including no parting of seams			Pass All requirements satisfied including no parting of seams			Pass All requirements satisfied including no parting of seams		
Comments	None			See below			None			None			None			None			None		
Supplementary Comments	None			See below			None			None			None			None			None		

See comments on previous page

* In fact in Pyrolon Plus 2 testing 12 specimens - 6 fabric and 6 seam, were tested. There were no fails on any specimen

There are clear conclusions to be drawn from these test results:-

First, **NONE OF THE FR SMS SAMPLES CAME EVEN CLOSE TO MEETING THE FR REQUIREMENTS IN EN 14116.**

All failed on several counts, but commonly on the production of molten & flaming debris (in every case) and on the fact that the seams parted - the key requirement in EN 14116 (8 out of 11 cases).

"The conclusion is you certainly cannot be sure that the FR SMS garment you are wearing would achieve a pass when tested - and therefore if it will perform in use as its apparent certification indicates.

...And bear in mind the garments tested are major international brands - which would draw into even greater question the various cheaper versions now available."

Second, **THERE IS A HIGH LEVEL OF INCONSISTENCY IN THE RESULTS FOR FR SMS COMPARED TO THE HIGH LEVEL OF CONSISTENCY IN THOSE FOR PYROLON.**

Brand T, a major international brand, failed in all cases, but often on different areas. Why? Surely a product which meets a standard should always pass the required tests. This perhaps explains how these products have come to be certified; such inconsistency means if sufficient samples are submitted a pass might eventually be achieved. A certified product needs one pass and it can then remain certified indefinitely on that basis.

Compare the FR SMS sample test results to those of Pyrolon. Pyrolon meets all the requirements - including the seams not parting - in all cases. This is because Pyrolon is made from an entirely different non-thermoplastic fibre and has been specifically engineered as an flame retardant product... not a thermoplastic fabric with an added and clearly questionable attempt give it FR properties...

Why is it so difficult for FR SMS fabrics to pass this test?

Could it be that the FR properties of FR SMS materials are uncertain, varied and dependent on both a property that is unrelated to any genuine FR property (i.e.; the thermoplastic tendency to shrink rapidly from heat) and on a test which was never designed to assess disposable fabrics of this nature? This seems quite likely.

Or perhaps it could be that the effects of topical, chemical FR treatments on SMS fabric wear off quickly in storage so that by the time they are purchased in the market the FR properties have become uncertain and variable? Has any research been conducted into this possibility? It is well known that anti-static treatments will wear off over time so it is quite possible that FR treatments may suffer the same fate.

It could also be that different test houses are interpreting the standard and tests differently; that one interpretation of "flaming debris" for example, is different from another...

Whatever the reason the testing clearly shows that it is rare for FR SMS garments taken from the market to unquestionable meet the EN 14116 requirements... despite their increasingly common presence in the market

Testing shows FR SMS garments perform inconsistently in the vertical flammability properties required by EN 14116. Yet how do they perform in actual use... how do they effect Total Thermal Protection when worn over a Thermal Protective Garment?

In a flash fire a standard disposable coverall will ignite and drip molten material, increasing body burn. Will an FR SMS perform differently? An assessment of an FR SMS disposable coverall should include its affect on total thermal protection when worn over a TPG.

Thermal Mannequin Testing to show Predicted Body Burn

Thermal Mannequin Testing assesses flame and heat protective garment performance, indicating predicted body burn by replicating a flash fire situation. The equipment comprises of a mannequin which is covered in heat sensors designed to replicate the rate at which human skin absorbs energy. Each sensor is connected to a computer which monitors the heat energy absorbed by each sensor during and after the burn.

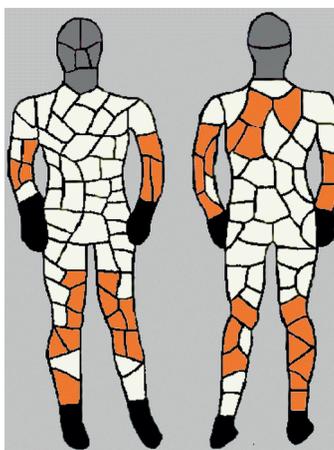
The test garment or ensemble is put onto the mannequin and the flame jets from four surrounding burners applied, normally for three or four seconds. Heat energy absorbed by the sensors is recorded by the computer, with data normally collected for up to 90 seconds after the burn. From this information the computer can produce a report showing:-

- * A "Body map" indicating predicted body burn of either 2nd or 3rd degree would have occurred
- * Information on when the body burns are occurring during the data record

Thermal Mannequin Testing is provided as an option in European standards for thermal protective Garments (ISO 13506) and as a result many TPG's in Europe are not tested.

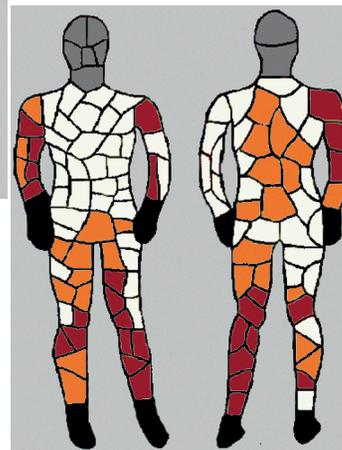
In North America TPG garments are required to undergo Thermal Mannequin Testing for compliance with NFPA 2012 & NFPA 2013 criteria

Below are two extremes of Predicted Body Burn maps produced by Thermal Mannequin Testing



The map to the left shows the result of a test using an aramid TPG .

It indicates a Total Predicted Body Burn of 37% and all burns are 2nd degree burns only - coloured in orange in the map

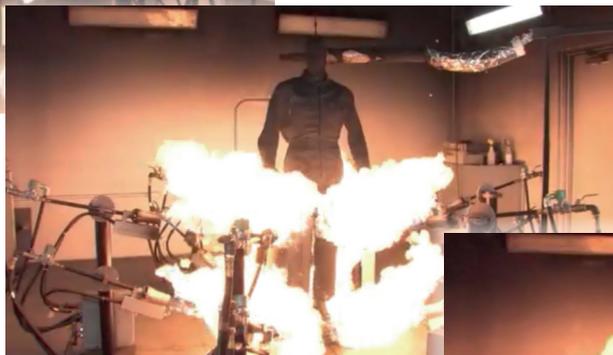


The second map is from a test using a standard PP/PE disposable worn over the same aramid TPG.

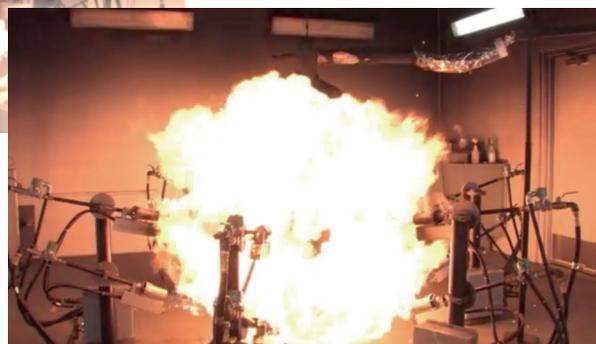
It indicates a much higher Total Predicted Body Burn of 53% with the darker red areas indicating more critical 3rd degree burns - proving a standard disposable should not be worn over a TPG



The pictures show three stages in a Thermal Mannequin test - the mannequin with an aramid TPG and the initiation and continuation of the burn



Thermal Mannequin testing provides a detailed predicted Body Burn including 2nd and 3rd degree burns resulting from a real flash fire.

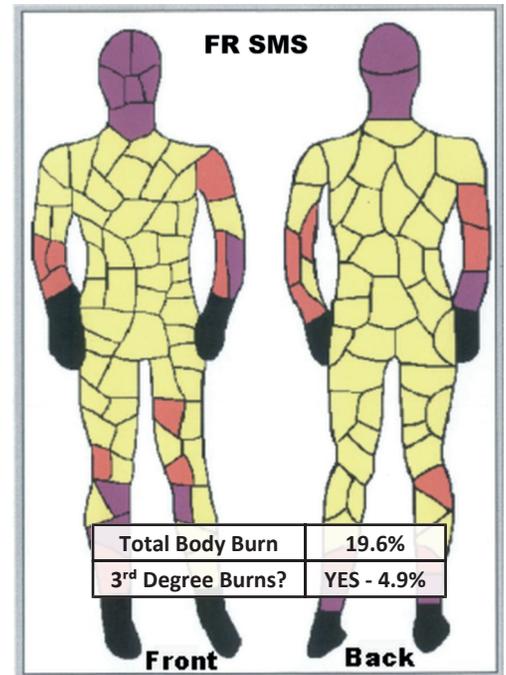
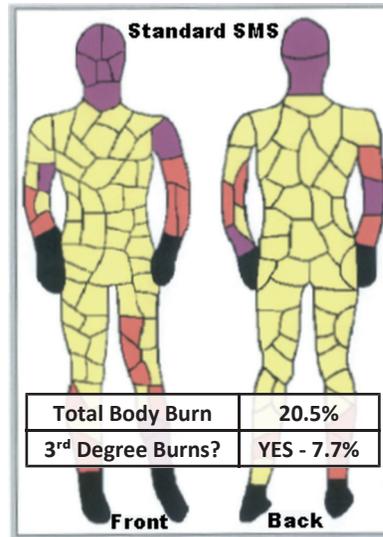
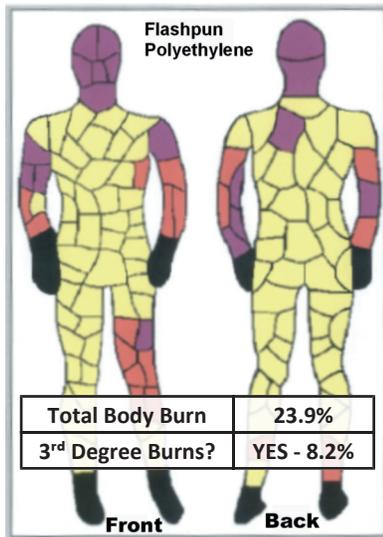


Thermal mannequin testing of different combinations of garments can produce comparative results relative to body burn predictions - giving the user a view of how different garments perform relative to each other in actual flash fire scenarios

Thermal Mannequin Comparative Test results

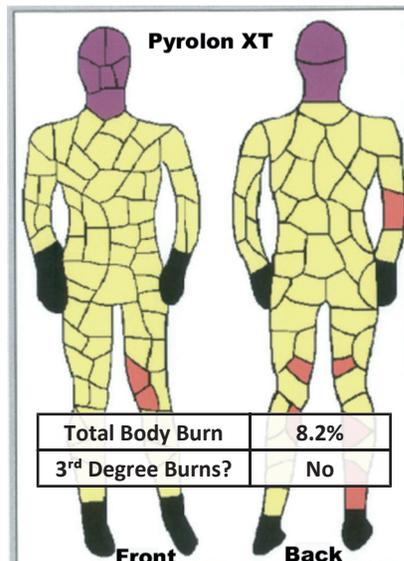
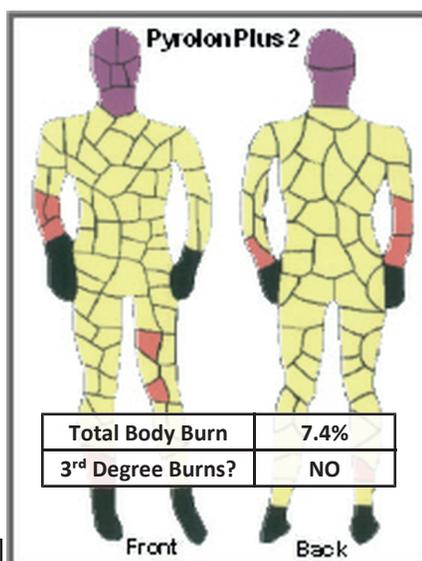
Lakeland has commissioned independent thermal mannequin testing of various disposable FR over-garments worn over Primary Thermal Protection aramid TPG's to allow comparison of percentage predicted body burn in flash fire scenarios

In each test a different disposable garment was worn over the same type of aramid TPG



All tests were conducted with the test garment worn over an identical branded Aramid Thermal Protective Garment and with standard cotton underwear beneath
 Test parameters are according to ASTM 2112: Burn: 3 seconds / Heat Flux: 2.0cal/cm²/sec
 Data was recorded for 90 seconds

Test garment	2 nd Degree Burns	3 rd Degree Burns	Total predicted Body Burn	Notes
42gsm Flashspun Polyethylene	15.7%	8.2%	23.9%	Both the non-FR standard disposables show a similar predicted body burn of over 20%, the flashpun polyethylene being highest at 23.9%. Importantly both show indications of more critical 3 rd degree burns. This is where the flesh is burned deeply, destroying the nerves beneath and is probably a result of thermoplastic material from the disposable continuing to release heat energy.
Standard (Non-FR) SMS Polypropylene	13.9%	7.7%	20.5%	
Branded FR SMS Polypropylene	15.6%	4.9%	19.6%	The branded FR SMS coverall shows a slight reduction in 3 rd degree burns but they are still present. However total body burn remains at almost 20%. In fact the FR SMS indicates a similar body burn to the standard SMS. So what does the FR treatment in an FR SMS do? Very little according to thermal mannequin testing...
Pyrolon Plus 2	7.4%	None	7.4%	Both the Pyrolon garments show a dramatically reduced Total Body Burn of under 10% - less than half of that shown by the other garments. Most importantly there are no predictions of critical 3 rd degree burns and only less critical 2 nd degree burns are apparent.
Pyrolon XT	8.2%	None	8.2%	



These results show conclusively that:-

- * The additional cost of so-called FR SMS disposable garments results in almost no improvement over standard SMS with almost no difference in Predicted Body Burn
- * The use of Pyrolon FR garments provides superior thermal performance - total thermal protection substantially improves and Predicted Body Burn is dramatically reduced

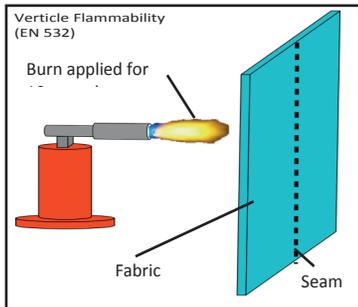
** This 90 second data acquisition period may actually LIMIT predicted body burn with thermoplastic materials: thermoplastics store heat energy and release it slowly over time - so it is quite possible that burns would occur AFTER 90 seconds and that a longer data acquisition period would result in an even higher predicted body burn*

Still using FR SMS?

FACT Independent EN 14116 flammability testing by a recognised Notified Body of multiple FR garments purchased in the open market shows they meet the requirements only intermittently at best... in fact in testing conducted NO FR SMS garment has successfully meet the EN 14116 vertical flammability requirements...

... send your FR SMS suit for EN 14116 flammability testing and Lakeland will pay for it!*

See Page 4 & 5



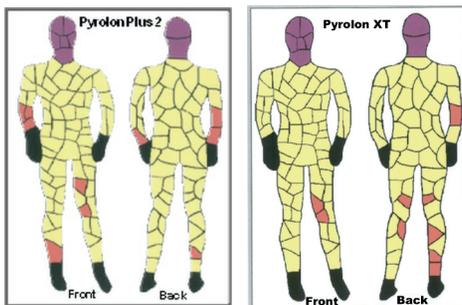
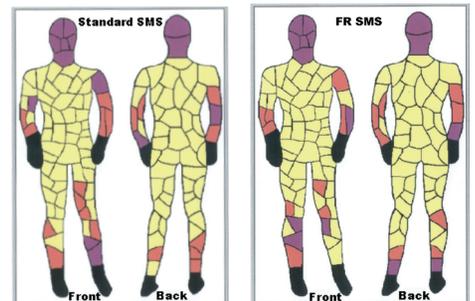
FACT EN 14116 Vertical Flammability testing is neither designed nor effective in indicating FR performance characteristics when used for the purpose they are actually worn... specifically the effect on total thermal protective performance when worn over an EN 11612 Thermal Protective Garment...

... only Thermal Mannequin Testing can show this...

See Page 2 & 3

FACT Independent Thermal mannequin testing shows almost no difference in Thermal Performance between a standard SMS garment and an FR SMS garment... in fact predicted body burn is almost the same for both...

See Page 6 & 7



FACT Lakeland Pyrolon garments, based on an entirely different technology, both consistently pass EN 11416 FR requirements AND in Thermal Mannequin Testing show a marked reduction in predicted body burn compared to any other disposable worn over a TPG...

See Page 7

* Contact sales-europe@lakeland.com for details: no refunding of cost without prior agreement

When it comes to thermal performance testing proves Pyrolon Works...
...can you be sure your FR SMS coverall does?



All EN 14116 testing has been conducted independently by Notified Bodies. Thermal Mannequin testing has been conducted independently to NFPA requirements by approved labs in North America. Details and copies of relevant test reports are available on request. Contact sales-europe@lakeland.com for further information.

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