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## **Flammability of Coveralls for Offshore Use**

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# EXECUTIVE SUMMARY

## Objectives

To assess the effect of adding a disposable coverall over the top of a flame retardant coverall with respect to flame spread, using the method outlined in ISO 15025:2002 (Protective clothing – Protection against heat and flame – Test method for limited flame spread), and more specifically, to determine the following:

- Does the use of a disposable FR coverall impair the effectiveness of a FR coverall worn underneath?
- Does the use of a disposable FR coverall provide effective protection from flame spread with a non-FR coverall beneath?
- Is the effectiveness of a FR coverall impaired when a disposable non-FR coverall is used over the top?
- Could a disposable FR coverall be used without any form of additional protection, thereby limiting the potential for heat stress?

## Main Findings

Disposable FR coveralls do not appear to adversely affect the protection offered by a FR coverall when worn over the top.

Any other combination of FR and non-FR coveralls does not appear to offer adequate protection.

A disposable coverall on its own does not continue to burn, but it also does not offer any protection to the user.

## Recommendations

Dual layers of coveralls (disposable worn over non-disposable) should not be worn in areas where flame retardant clothing is required unless BOTH coveralls are flame retardant.

Disposable FR coveralls should not be worn as the only means of protection.

The manufacturer's instructions on how coveralls should be deployed should be followed at all times.

# 1 INTRODUCTION

In industries where there is a risk of fire breaking out during normal operation, flame retardant clothing is often worn to reduce the risks associated with this hazard. Such clothing can be expensive to clean and replace, however, and is sometimes protected by means of a cheaper, disposable coverall worn over the top. Additionally, flame retardant coveralls can be heavy and uncomfortable, especially in warm environments. This project aims to examine the effectiveness of various combinations of coveralls in limiting flame spread, with specific reference to the following questions:

- Does the use of a disposable FR coverall impair the effectiveness of a FR coverall worn underneath?
- Does the use of a FR disposable coverall provide effective protection from flame spread with a non-FR coverall beneath?
- Is the effectiveness of a FR coverall impaired when a disposable non-FR coverall is used over the top?
- Could a disposable FR coverall be used without any form of additional protection, thereby limiting the potential for heat stress?

## 2 METHOD

### 2.1 SAMPLES

Nine coveralls were used in total, seven of which were intended to be disposable, and two of which were not. Some of them were flame retardant in accordance with EN533:1997 (Protective clothing – Protection against heat and flame – Limited flame spread materials and material assemblies), to the following levels:

Index 1: Materials do not spread flame, but may form a hole on contact with a flame.

Index 2: Materials do not spread flame and do not form a hole on contact with a flame.

Index 3: Materials do not spread flame and do not form a hole on contact with a flame. They also give only limited afterflame.

#### **Non-disposable coveralls:**

- 100% cotton, non flame retardant coverall (“plain cotton”)
- 100% cotton, Proban treated flame retardant (EN533 Index 3) coverall (“Proban-treated”)

#### **Disposable coveralls:**

- DuPont Tyvek type type 5/6 (particulate / minor liquid splash) coverall (“DuPont Tyvek”)
- Microguard 1500 type 5/6 (particulate / minor liquid splash) coverall (“Microguard 1500”)
- Microguard 2500 type 5/6 (particulate / minor liquid splash) coverall (“Microguard 2500”)
- Orex category 5/6 (particulate / minor liquid splash) coverall (“Orex”)
- Microguard type 4 (chemical splash) flame retardant (EN533 Index 1) coverall (“Microguard CFR”)
- Microguard type 6 (minor liquid splash) flame retardant (EN533 Index 1) coverall (“Microguard FR”)
- DuPont Tempro coverall (“DuPont Tempro”). Although this coverall is not marked as flame retardant, the Tempro material is known to meet the requirements of EN533 Index 1, and shall be treated as such in this project.

Each sample measured 200 mm x 160 mm. The coveralls were tested new and unwashed. All samples for each material were taken from the same coverall.

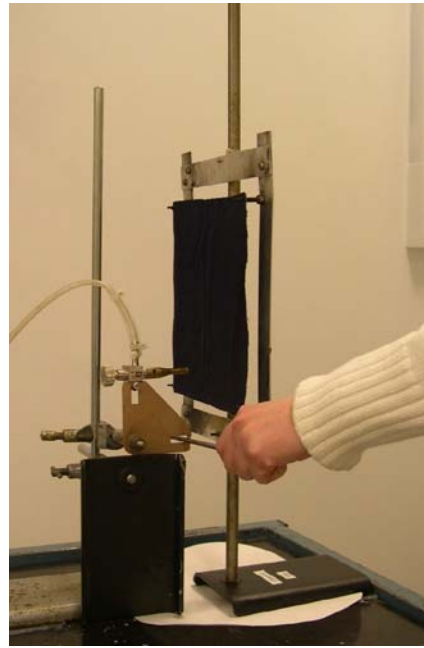
Each coverall was tested individually, and each disposable coverall was tested with each non-disposable coverall. In dual layer tests, the two samples were arranged such that the flame would touch the outer, disposable coverall first.

## 2.2 TEST METHOD

All testing was done in accordance with the methods described in ISO 15025:2002 (Protective clothing – Protection against heat and flame – Test method for limited flame spread). A sample of the coverall measuring 160 mm x 200 mm was attached to a metal frame by pins at the corners, and held vertically in place (figure 1). A burner flame was then brought into contact with the sample at a point 20 mm above the bottom edge, and held there for 10 seconds (figure 2). The sample was then observed, and two time measurements taken: afterflame time and afterglow time. Additionally, filter paper of defined characteristics was placed beneath the test sample, in order to catch any debris. Debris that sets the filter paper alight is defined as “flaming debris”.



**Figure 1** – Equipment set up with the burner in the standby position



**Figure 2** – Equipment set up with the burner in the test position

Afterflame time is measured from the moment of the flame being taken away to the moment at which all flaming of the sample stops.

Afterglow time is measured from the end of flaming to the time at which all afterglow stops. Afterglow is defined as glowing combustion; the glowing associated with re-emitting heat that has been previously absorbed is not classed as afterglow.

The test was performed with three specimens of each material or combination of materials. All tests were videoed for later examination, but all timings were carried out at the time.

The full details of the test method are laid out in ISO 15025:2002. There were two deviations from this test method:

- The weave direction of the material was not taken into account
- Samples were not conditioned to  $25\pm 2^{\circ}\text{C}$  and  $65\pm 5\%$  RH before testing.

None of the disposable coveralls are of woven construction, and all samples were stored and tested in our controlled laboratory environment (nominally  $23\pm 3^{\circ}\text{C}$ ,  $45\pm 15\%$  RH, but invariably

more stable than these ranges allow). Any effect of this deviation is very unlikely to be significant for these materials.

### **2.3 PASS CRITERIA**

The following criteria, taken from BS EN 531:1995 (Protective clothing for workers exposed to heat) were used to decide whether each material or combination of materials could be considered to have limited flame spread:

- No specimen shall give flaming to the top or either side edge.
- No specimen shall give hole formation.
- No specimen shall give flaming or molten debris.
- The mean value of afterflame time shall be  $\leq 2$  s
- The mean afterglow time shall be  $\leq 2$  s.

### 3 RESULTS

#### 3.1 SINGLE LAYER TESTS

The seven coveralls fell into four categories as regards limited flame spread. Brief descriptions of the results of each test are below, and a summary is shown in Table 1.

**Table 1** Summary of single layer tests

Material	Afterflame time (s)	Average afterflame time (s)	Afterglow time (s)	Average afterglow time (s)	Hole formed?	Flaming debris?	Pass or fail?*
100% plain cotton	113	118	61	57	Yes	No	Fail
	116		61		Yes	No	
	126		49		Yes	No	
100% cotton Proban-treated	0	1	0	0	No	No	Pass
	3		0		No	No	
	0		0		No	No	
DuPont Tyvek	0	0	0	0	Yes	No	Fail
	0		0		Yes	No	
	1		0		Yes	No	
Microguard 2500	98	56	0	0	Yes	Yes	Fail
	45		0		Yes	Yes	
	26		0		Yes	Yes	
Microguard 1500	38	13	0	0	Yes	Yes	Fail
	0		0		Yes	No	
	0		0		Yes	No	
Orex Deluxe	59	44	0	0	Yes	Yes	Fail
	0		0		Yes	No	
	72		0		Yes	Yes	
Microguard CFR	0	0	0	0	Yes	No	Fail
	0		0		Yes	No	
	0		0		Yes	No	
Microguard FR	0	0	0	0	Yes	No	Fail
	0		0		Yes	No	
	0		0		Yes	No	
DuPont Tempo	0	0	0	0	Yes	No	Fail
	0		0		Yes	No	
	0		0		Yes	No	
*Pass criteria		≤ 2s		≤ 2s	No	No	

**Plain cotton**

The material was entirely consumed, and there was some afterglow. Debris was formed, but none of it flaming. This coverall did not meet the criteria for limited flame spread.

**Proban-treated**

There was little or no afterflame and no afterglow, and no hole developed. There was no debris. Only the Proban-treated cotton coverall behaved in this way. This coverall met the pass criteria for limited flame spread.

**Microguard 2500, Microguard 1500, Orex**

On at least one of the tests, the specimen burned mostly or completely, dripping molten, flaming debris, which set the filter paper alight. There was no afterglow. The Orex and Microguard 1500 also had at least one test where the only effect was a small hole; no burning or debris. The mean afterflame times were still >2s in these three cases, however, so none of them met the pass criteria for limited flame spread.

**DuPont Tyvek, Microguard CFR, Microguard FR, DuPont Temprow**

A hole formed in the specimen, mostly through melting or burning at the initial application of the burner, but there was no debris and little or no afterflame. There was no afterglow. It should be noted that all the flame retardant disposable coveralls fall into this category, as well as the non flame retardant DuPont Tyvek. These coveralls did not meet the criteria for limited flame spread, due to hole formation.

## 3.2 DOUBLE LAYER TESTS

### 3.2.1 Plain cotton lower layer

A summary of the results of the dual-layer tests with a plain cotton coverall as the lower layer is shown in Table 2. More detailed descriptions follow.

**Table 2** Summary of double layer tests using plain cotton coverall

Material	Afterflame time (s)	Average afterflame time (s)	Afterglow time (s)	Average afterglow time (s)	Hole formed in inner layer?	Flaming debris?	Pass or fail?*
DuPont Tyvek	116	117	48	46	Yes	Yes	Fail
	132		26		Yes	Yes	
	102		65		Yes	Yes	
Microguard 2500	123	111	40	47	Yes	Yes	Fail
	103		56		Yes	Yes	
	106		44		Yes	Yes	
Microguard 1500	103	120	52	38	Yes	Yes	Fail
	125		43		Yes	Yes	
	132		18		Yes	Yes	
Orex Deluxe	74	85	25	40	Yes	Yes	Fail
	91		41		Yes	Yes	
	89		53		Yes	Yes	
Microguard CFR	0	0	0	0	No	No	Pass
	0		0		No	No	
	0		0		No	No	
Microguard FR	0	5	0	11	Yes	No	Fail
	0		0		No	No	
	15		33		Yes	No	
DuPont Temprow	9	4	51	39	Yes	No	Fail
	2		32		Yes	No	
	0		35		Yes	No	
*Pass criteria		≤ 2s		≤ 2s	No	No	

#### Tyvek, Microguard 2500, Microguard 1500 and Orex

Both layers of all the samples were entirely consumed. There was significant afterflame and afterglow in every case, and flaming debris formed. All of these samples were classed as “fail”.

#### Microguard CFR

A hole formed in the outer layer, but no hole formed in the inner layer, only a small area of charring. There was no afterflame or afterglow, and no debris of any kind. This sample was classed as a “pass”.

## Microguard FR and DuPont Tempro

A hole formed in the outer layer, and a smaller one in the inner layer, surrounded by a small area of charring. In some of the tests (Microguard FR tests 1&2, DuPont Tempro test 3), there was no afterflame or afterglow. In the other tests, there was both afterflame and afterglow. Both occurred in the lower layer, and in the case of afterflame, was a very small, muted flame contained between the two layers. There was no debris in any of the tests. This sample was classed as a “fail”.

### 3.2.2 Proban treated lower layer

A summary of the results of the dual-layer tests with a Proban-treated coverall as the lower layer is shown in Table 2. More detailed descriptions follow.

**Table 3** Summary of double layer tests using Proban-treated coverall

Material	Afterflame time (s)	Average afterflame time (s)	Afterglow time (s)	Average afterglow time (s)	Hole formed in inner layer?	Flaming debris?	Pass or fail?*
DuPont Tyvek	5	7	0	0	No	No	Fail
	0		0		No	No	
	17		0		No	No	
Microguard 2500	0	88	0	0	No	No	Fail
	67		0		No	Yes	
	197		0		No	Yes	
Microguard 1500	0	4	0	0	No	No	Fail
	12		0		No	Yes	
	0		0		No	No	
Orex Deluxe	54	76	0	0	No	Yes	Fail
	57		0		No	Yes	
	118		0		No	Yes	
Microguard CFR	0	0	0	0	No	No	Pass
	0		0		No	No	
	0		0		No	No	
Microguard FR	0	0	0	0	No	No	Pass
	0		0		No	No	
	0		0		No	No	
DuPont Tempro	0	0	0	0	No	No	Pass
	0		0		No	No	
	0		0		No	No	
*Pass criteria		≤ 2s		≤ 2s	No	No	

### DuPont Tyvek

A hole formed in the outer layer of all three samples, spreading across to the right hand side in the two cases where there was also afterflame. There was no afterglow, and no debris of any kind. This combination failed to meet the criteria for limited flame spread.

### **Microguard 2500**

In one of the samples, only a small hole formed in the outer layer, and there was no debris. In the other two, the outer layer was fully consumed, and flaming debris was formed. In one case, this debris dripped onto the inner layer, and continued to burn for a considerable length of time (197 s, see Table 3). Although no hole formed in the Proban-treated layer, and it did not itself catch light, considerable scorching was evident upon examination after the test. This combination failed to meet the criteria for limited flame spread.

### **Microguard 1500**

A hole formed in the outer layer of all samples. Afterflame was only seen in one case, where the hole spread to the right hand side of the sample. This sample also dripped flaming debris. The other samples did not. Some additional scorching to the inner layer was also noted in this case. This combination failed to meet the criteria for limited flame spread.

### **Orex**

In two of the samples, around two thirds of the outer layer was consumed. In the final case, all of it was. In all cases, the sample dripped flaming debris, and additional scorching was noted on the inner layer, although no hole was formed. This combination failed to meet the criteria for limited flame spread.

### **Microguard CFR, Microguard FR and DuPont Temprow**

In all cases, a charred area with discontinuous holes was formed in the disposable coverall, but no afterflame or afterglow was observed, nor was there any debris. A small charred area was found on the inner coverall, but no hole. All of these samples met the criteria for limited flame spread.

## 4 DISCUSSION

### 4.1 SINGLE LAYER TESTS

#### 4.1.1 Non disposable coveralls

Of the non-disposable coveralls, the Proban-treated coverall met the pass criteria. The cotton coverall was entirely consumed, and did not. This was the expected outcome in both cases.

#### 4.1.2 Non flame retardant disposable coveralls

The Microguard 2500, Microguard 1500 and Orex, all showed afterflame, and all dripped flaming debris. This flaming debris often continued to burn for a considerable length of time after hitting the filter paper. This is especially worrying, since it would likely do the same thing if it struck another item of clothing or skin.

The Tyvek coverall did not flame or drip flaming debris, but failed to meet the criteria because it formed a hole.

#### 4.1.3 Flame retardant disposable coveralls

All of the flame retardant coveralls used meet the requirements for EN533 Index 1; that is, they should not propagate flame, but they also offer no protection. This category of flame retardant clothing is designed to be the outer layer in an Index 2 or 3 assembly. It is therefore not surprising that none of these met the criteria set in this project for limited flame spread. In all cases, the failure was due to hole formation.

### 4.2 DOUBLE LAYER TESTS

#### 4.2.1 Plain cotton inner layer and non flame-retardant outer layer

None of the specimens using a plain cotton inner layer and non flame-retardant disposable outer layer passed the criteria listed in section 2.2. This is not surprising, but the combination appears to be worse than either coverall when tested individually. The plain cotton coverall propagated the flame very well, and ensured that the entirety of the disposable coverall burned, which then produced considerable amounts of flaming debris. As an example, in the individual tests, the DuPont Tyvek coverall did not burn, but when tested in conjunction with the plain cotton coverall, it was entirely consumed.

None of these combinations are suitable for work in areas requiring flame retardant clothing.

#### 4.2.2 Plain cotton inner layer and flame-retardant outer layer

Where a flame-retardant disposable layer was used, significant reduction in flame spread was seen, but only in one case (Microguard CFR) were the criteria for limited flame spread met. This combination should still be treated with caution, however, since the manufacturer states that the disposable coverall should only be worn with EN533 Index 2 or 3 clothing underneath.

The other combinations produced a small hole in the cotton coverall. These combinations did not prolong burning, but neither did they offer protection from it.

None of the combinations in this category are suitable for work in areas requiring flame retardant clothing.

#### **4.2.3 Proban-treated inner layer and non flame retardant disposable outer layer**

The Proban-treated coverall met the pass criteria when tested alone. When tested with a non flame retardant disposable outer layer, this was no longer the case. The mean afterflame times are greater than 2 seconds for every type of outer layer coverall, and at least one sample of each coverall dripped flaming debris.

Although the inner layer was not seen to burn at any time (that is, afterflame was restricted entirely to the disposable outer layer), scorching and charring of the Proban-treated coverall was still evident.

An additional, and more concerning, problem is the possibility of the disposable layer melting onto the inner coverall. This was seen in only one sample, but it caused flaming to continue for a very long time (see Table 3, Microguard 2500, third sample). The charring on the inner layer after the test had been completed was significantly worse than the other two samples of this coverall.

The method of test used, with the two layers suspended vertically, does not encourage dripping from one layer onto the other. In a real-life situation, where some parts of the coveralls would be aligned horizontally, this is a far more probable scenario.

None of these combinations meet the criteria for limited flame spread, and none should be used in areas requiring flame retardant clothing.

#### **4.2.4 Proban-treated inner layer and flame retardant disposable outer layer**

All of these samples met the pass criteria. In each case, a hole formed in the outer layer, and a small charred area was visible in the inner layer. This is the configuration in which the disposable coveralls are intended to be used, and the testing supports this use.

#### **4.2.5 Certification of coveralls**

Neither the Microguard FR nor the Microguard CFR indicate that they meet the requirements for “Type 5” particle protection, only being rated for use against liquid chemicals for specific types of exposure. In terms of garment design, there is little difference between Type 4, 5 and 6. For a modest investment in testing, the manufacturer may be able to demonstrate wider applicability for these garments, for example, use in asbestos stripping applications.

The Tempro coverall makes no protective claims whatsoever, and does not currently carry even a CE mark, despite being made from material which meets Index 1 flame retardance requirements. Technically, provision of this non-CE marked garment to employees may contravene the PPE at Work Regulations, if it is intended to provide any form of protective function.

## 5 CONCLUSIONS

The only single-layer sample to pass the criteria for limited flame spread listed in BS EN 531:1995 was the Proban-treated flame retardant coverall. Therefore, none of the other coveralls should be worn singly in areas where there is a risk of fire. Reduction of heat stress potential by moving from the use of conventional, reusable coveralls to disposables does not seem to be practicable.

Using a disposable flame retardant garment to protect and prevent soiling of a reusable FR coverall appears practicable and safe in terms of limiting flame spread. However, this configuration may significantly increase the potential for wearers to suffer thermal stress.

Of the other dual-layer tests, all but one failed to meet the criteria for limited flame spread. The exception was the plain cotton coverall under a Microguard CFR. This combination should be treated with caution, however, since the manufacturer's instructions state that this coverall should only be worn over an EN533 Index 2 or 3 garment, if exposure to flame is possible.

### **Recommendations**

Dual layers of coveralls (disposable worn over non-disposable) should not be worn in areas where flame retardant clothing is required unless BOTH coveralls are flame retardant.

The manufacturer's instructions on how coveralls should be deployed should be followed at all times.

Manufacturers of the Microguard FR/CFR and Tempro coveralls should be invited to consider broadening the scope of certification of their products. This would assist users in identifying potentially useful garments for the type of application considered here, and legalise their use.

## 6 REFERENCES

ISO 15025:2002 *Protective clothing – Protection against heat and flame – Test method for limited flame spread*

EN531:1995 *Protective clothing for workers exposed to heat*

EN533:1997 *Protective clothing – Protection against heat and flame – Limited flame spread materials and material assemblies*

*The Personal Protective Equipment at Work Regulations (as amended) – see L25 Personal Protective Equipment at Work (second edition) HSE Books ISBN 0-7176-6139-3*