HSE Research Report 222

HSE
Health & Safety Executive

Tests for the ignition and flame spread of clothing fabrics subjected to angle grinder sparks

Results from ten generic fabrics and variants

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RESEARCH REPORT 222

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Tests for the ignition and flame spread of clothing fabrics subjected to angle grinder sparks

Results from ten generic fabrics and variants

Peter Fardell, C.Chem. MRSC. MSc. and
Carol Rock, BSc.
Centre for Fire Performance and Suppression
Fire Division
Building Research Establishment Ltd
Garston
Watford
Herts WD25 9XX

Test methods for measuring the times to ignition and rates of flame spread of fabrics subjected to sparks from a hand angle grinder have been developed. Such tests are needed by the HSE as there is a regular incidence of burn injuries caused through workwear fabrics igniting and causing burns to the wearer through the use of angle grinders. Separate apparatus was used for measuring time-to-ignition and flame spread and development details have been previously reported. Ten generic fabric fabrics have been tested (sixteen, including variants) with the prototype apparatus, including synthetic, natural, synthetic/natural mixtures, Flame Retarded (FR), laundered FR and fabrics contaminated with grease and paint.

Many fabrics could ignite after less than a minute with one “FR” fabric igniting after ten seconds. Another FR fabric, checked for correct FR content was resistant to ignition and flame spread.. Examples of non-ignition were observed with both natural and synthetic fabrics but a different mechanism was apparent in each case. Natural fabrics tended to form a protective carbonaceous char whereas synthetic fabrics tended to melt and form a hole around the stream of sparks, preventing or reducing the likelihood of ignition.

Flame-spread rates were measured horizontally and at 25O to the horizontal. Most fabrics showed a well defined rate of flame spread which was usually significantly faster in the inclined position. Overall rates between 9mm/min and 891 mm/min were measured although in some cases flaming ceased before the whole length of sample had been consumed.

Two full scale tests using a manikin clothed in FR (Proban) cotton and a non FR cotton “boiler suits” confirmed the small scale test results and illustrated the value of FR fabrics in resisting ignition and flame spread from hand grinder sparks. The non FR boiler suit ignited after twenty seconds and burnt to completion. The FR boiler suit did not ignite after sustained continuous application of a stream of sparks over a five minute period.

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EXECUTIVE SUMMARY

Apparatus and procedures have been developed to measure the times to ignition and flame-spread rates of clothing fabrics subjected to angle grinder sparks. The development work has been separately reported in previous Milestone deliverables. This final report describes results obtained using the prototype apparatus and procedures on ten generic fabric samples and variants, chosen by the HSE.

The time-to-ignition apparatus utilised a proprietary, commonly available, 115mm disc angle grinder, retained in a proprietary stand. The work piece used was a hollow square section bar of mild steel, 50mm x 50mm x 7mm wall thickness, which enabled the apparatus to generate a steady and repeatable stream of sparks over periods in excess of 5 minutes.

For measurement of the time-to-ignition, the tested fabric was held in a vertical wire mesh holder which allowed the stream of grinder sparks to impinge at the base of the sample in a "U" shaped vertical channel. The sparks were allowed to impinge for various fixed time intervals after which the sample was inspected for self-propagating flames. Each time interval was repeated between 3 and 5 times. When every trial over a particular time period produced self-propagating flaming, this was recorded as the time-to-ignition.

For measurement of the flame spread rate procedure, it was not possible to utilise the same apparatus used for time-to-ignition. This was due to uncertainties in measuring the flame front and because the flame spread following ignition could be very variable depending on subtle folds developing and sections of the sample falling at random during flaming. It was therefore agreed to utilise a separate apparatus for the flame spread rate studies. This apparatus was based on an existing standard used to test the horizontal flame spread of fabrics used in the interior of vehicles in the USA. Each flame spread rate determination was repeated and the mean value used as the quoted flame spread rate.

Finally, two tests were carried out using a full size manikin dressed in an FR and then a non FR boiler suit,using the standard stream of angle grinder sparks used in the main study.

In summary the main findings were:

- Natural and synthetic fabrics were not particularly distinguishable by their ignition and flame spread performance – although the mechanisms were different in each case. Synthetic fabrics tended to melt, natural fabrics tended to char.
- A proprietary FR fabric ignited readily.
- A laundered FR cotton fabric had a reduced time to (partial) ignition compared with an unlaundered sample but remained resistant to flame spread.
- Grease contamination showed marginally reduced ignition times and a tendency to increased flame-spread rates over the uncontaminated samples.
- Paint contamination increased the ignition time and reduced the rate of flame spread with a cotton sample. With a contaminated polyester sample, time-to-ignition was reduced and flame-spread rates were marginally increased over the uncontaminated sample.

- The FR boiler suit resisted ignition and failed to ignite after 5 minutes of continuous application of a stream of sparks. The non-FR boiler suit ignited after approximately 20 seconds and continued to burn to completion.

A number of ancillary studies were also carried out to investigate particular observations. These were:

- Validation trials for a substitute fabric which had been discontinued during the study. (The substitute fabric was deemed equivalent).
- Investigation of the time-to-ignition changes occurring following a change of sample holder and operator. (The changes were ascribed to the change of sample holder and were not found to be significantly operator dependant).
- Obtaining elemental analysis of a substitute FR fabric following the ready ignition observed with an original FR fabric. (This "pedigree" fabric was shown by elemental analysis to contain the expected level of FR treatment and exhibited the expected ignition characteristics).

It is recommended that the apparatus and methodology developed in this study be adopted for use by the HSE as a basis for testing the ignition and rate of flame spread performance of work wear fabrics when subjected to sparks from an angle grinder. It is further recommended that some aspects of the study (e.g. fabric combinations, contaminated samples and development of performance criteria) should be carried out in future work.

1 INTRODUCTION

This study was undertaken for the HSE because of concerns over the incidence of injuries sustained in the workplace from fires caused by angle grinder sparks impinging on clothing. A simple but realistic test was required which could measure times to ignition and flame-spread rates from a range of fabrics which might be used in work wear.

Statistics gathered by the UK's Health and Safety Executive (HSE) as part of their "FIREX" database [1] have shown a continuing incidence of burn injuries caused by hand operated angle grinder sparks impinging on clothing. There have been at least ten such incidents over the last ten years including three serious injuries.

The Fire and Risk Sciences (FRS) division of the Building Research Establishment was invited to design, develop and establish standard test apparatus and procedures for measuring the time-to-ignition and rates of flame spread on clothing fabrics subjected to constant stream of angle grinder sparks.

The intention is to use the methods to determine the ignition and flame spread characteristics of fabrics which may be encountered in the workplace, both as normal and workwear clothing. There was no requirement to set criteria for hazard classification although this would form a logical next step.

This is the final milestone report and describes a study of the ignition and flame spread characteristics of ten generic work wear fabrics and variants, (chosen by the HSE following the development stages) subjected to angle grinder sparks. The methods used for measuring times to ignition and flame spread have been developed in previous work under this contract and have been separately reported [2,3].

Progress reports, visits by and to the HSE project officer and other communications have been made at regular intervals throughout the study.

2 DESCRIPTION OF THE PROJECT

2.1 General Background

Previous work on this project has been fully described in reports of meetings with the HSE project officer and two Milestone Reports [2,3] but in summary, the initial work involved setting up a proprietary hand angle grinder and stand and developing a technique for generating a standard continuous shower of sparks from a suitable work piece. This was followed by the development of a suitable fabric sample holder and technique for measuring time-to-ignition of tested fabrics. For flame spread measurements, an existing small-scale horizontal flame spread apparatus [4] was modified and used.

It had been hoped that the ignition and flame spread parameters would be measured on the same apparatus and during the same test. However it proved very difficult and subjective to measure flame-spread rates following ignition of a vertical sample with grinder sparks. The flame front was difficult to follow and although possibly the worst case for flame spread, (vertical orientation) the variations in flaming behaviour (e.g. through folds developing in a random manner and fabric dropping from the sample holder) it was decided to separate the testing for ignition and flame spread behaviour. This gave the opportunity to test flame spread in a much more controlled manner (using a modified existing standard test protocol [4]) and to investigate the effect of sample orientation on flame-spread rates.

A wide range of fabric types including pure natural, pure synthetic and natural/synthetic mixtures were studied in the development stages of the project.

2.2 Fabrics Used

Table 1 summarises the fabrics and their variants used over the entire study both during the development work (as previously reported [2,3]) and as reported here. The fabrics tested for this report, using the prototype apparatus and procedures, are shown in bold type in table 1. This includes the ten generic fabrics, fabric combinations, fabrics contaminated with grease or paint, and laundered and unlaundered FR cotton fabrics. All fabrics were conditioned for a minimum of 48 hours to Standard conditions (50%RH +/- 5% and $23^{O}C$ +/- $2^{O}C$) prior to testing.

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Table 1 – Summary of fabric fabrics used over the entire study (for this report in bold).

Fabric Number	*Description*	*Mass per unit area (kg/m^2)*	*Remarks*
1	**35% polyester/65% cotton**	**0.092**	
2	**100% cotton close weave**	**0.156**	**Replaced by 15.**
3	**100% cotton FR treated (interliner)**	**0.140**	
4	**100% polyester ("Charmeuse" satin)**	**0.091**	
5	100% cotton (open weave)	0.174	
6	81% acrylic/19% polyester	0.212	
7	59% cotton/41% modacrylic	0.402	
8	55% polyester/45% viscose FR treated	0.281	
9	**100% wool (suiting "dogtooth")**	**0.182**	
10	**100% cotton FR treated (corduroy)**	**0.599**	
11	**Stretch denim (cotton)**	**0.377**	
12	**Polyester fabric and wadding (Quilting)**	**0.219**	
13	**100% polyester (purple)**	**0.104**	
14	**100% polyester over 100% wool**	**N/A**	**Two layers of fabric**
15	Cotton close weave (replacement for 2, blue/white)	0.161	Checked for similarity with 2
16	**"Proban" treated cotton - unlaundered**	**N/A**	**CHNP (41.1%, 6.3%, 2.1%, 2.3%)**
17	**"Proban" treated cotton - laundered**	**N/A**	**To BS EN ISO 10528:1995**
18	**100% cotton with grease contaminant**	**-**	**Fabric 15 + grease**
19	**100% cotton with paint contaminant**	**-**	**Fabric 15 + paint**
20	**100% polyester with grease contaminant**	**-**	**Fabric 13 + grease**
21	**100% polyester with paint contaminant**	**-**	**Fabric 13 + paint**
22	**Boiler suit (cotton, non FR)**	**-**	
23	**Boiler suit (cotton FR)**	**-**	

2.3 Replacement for fabric 2.

Following the use of this fabric (a "close weave" cotton) for ignition and flame spread study, more fabric was needed for the "contamination" studies (see 2.4). Unfortunately it was discovered from the supplier that this was a discontinued line. Although there was an option for this fabric to be specially made by the manufacturer it was decided that due to the expense and time period required, a similar fabric would be selected which was likely to be in stock for an extended period. Fabric 15 was therefore obtained and used for the rest of the "contamination" study in place of fabric 2, following checks on the similarity of the new fabric to the old in terms of time-to-ignition and flame spread (horizontal sample only).

2.4 Contaminated samples

Two fabric types – one 100% synthetic (fabric 13) and one 100% natural (fabric 15 – the replacement for fabric 2) were chosen for study where the fabric had been contaminated with a petroleum-based workshop grease and an organic solvent paint. The contaminated fabrics were designated 18,19,20 and 21 (see table 1). The whole area of fabric was coated in each case for the ignition and flame spread tests, with an allowance made for the different sized specimens required for each test.

With the grease contaminant, application was attempted by smearing a weighed portion of grease on a spatula over the whole area of a fabric both for the time-to-ignition and flame spread samples. It was possible to obtain a reasonably uniform coating with this technique after several trials. The samples were tested within 2 hours of application to avoid any significant evaporation of any volatiles.

With the paint contaminant, application was attempted by simply brushing on the paint to the fabric surface as uniformly as possible, and allowing the paint to dry over a 24 hour period. The "loading" of paint was measured by weighing the fabric before and after application of the paint but it proved difficult to make the loadings identical for the two fabric types, and a fairly wide variation of loading had to be accepted.

Table 2 summarises the fabrics chosen, the contaminants used and the contaminant loading achieved.

Table 2: A summary of the contaminated tests fabrics tested

Fabric	*Description*	*Contaminant*	*Approximate mass applied.*	
			Ignition	*Flame Spread*
18	100% Cotton close weave	"Castrol Spherol L-EP2" petroleum based grease.	2g over an area 300mm x 100 mm	1g over an area 300mm x 35mm
20	100% polyester	"Castrol Spherol L-EP2" petroleum based grease.	2g over an area 300mm x 100 mm	1g over an area 300mm x 35mm
19	100% Cotton close weave	"Dulux Trade High Gloss" organic solvent based paint.	3.1g over an area of 300mm x 100mm	1.4g over an area of 300mm x 35mm
21	100% polyester	"Dulux Trade High Gloss" organic solvent based paint.	1.6g over an area of 300mm x 100mm	0.68g over an area of 300mm x 35 mm

2.5 Effect of changing the sample holder for the ignition studies.

During the development stages of this work, a simple variable "handy angle" sample holder was used for the measurement of times to ignition of fabric fabrics subjected to angle grinder sparks. [2]. This enabled various configurations of fabric to be presented to the stream of grinder sparks, to achieve a configuration which gave the most consistent and measurable ignition results.

However following the establishment of the optimum dimensions for the sample holder it was decided to use a more accurately constructed, fixed dimensions, open wire mesh sample holder for the final series of tests on the ten generic fabrics and variants. However early trials with this holder, with a different operator, showed significantly shorter times to ignition for the same fabric. A short series of tests was therefore performed on two of the fabrics (9 and 12) which showed the most variability in order to establish whether the effect was due to the change of sample holder or to the change of operator.

2.6 Effect of FR additive to the cotton fabric.

One of the ten generic fabrics chosen for study in this phase of the work was an FR cotton, (fabric 3). It was intended to use this fabric to determine the effects of a standard laundry cycle [5] on the flammability of an FR fabric but this particular fabric surprisingly proved to ignite readily from the grinder sparks (but showed little flame spread). It was therefore decided to include a "pedigree" FR cotton fabric treated with "Proban" (fabric16) in the programme with elemental analysis to determine the level of FR present, and check this level with the usually accepted level for an FR cotton fabric [6].

Accordingly a sample of a "Proban" treated cotton was purchased and an elemental analysis (C, H, N, and P) obtained.

2.7 Testing of the ten generic fabrics and variants

The testing apparatus and procedures used for the work carried out for this report was as previously described in detail [2,3]. In summary, for measurement of the time-to-ignition, the tested fabric was held in a vertical wire mesh holder which allowed the stream of grinder sparks to impinge at the base of the sample in a "U" shaped vertical channel. The sparks were allowed to impinge for various fixed time intervals after which the sample was inspected for self-propagating flames. Each time interval was repeated between 3 and 5 times. When every trial over a particular time period produced self-propagating flaming, this was recorded as the time-to-ignition. Appendix 1 contains the detailed results of the time-to-ignition study.

For measurement of the flame spread rate, it was not possible to utilise the same apparatus used for time-to-ignition. This was due to uncertainties in measuring the flame front and because the flame spread following ignition could be very variable depending on subtle folds developing and sections of the sample falling at random during flaming. It was therefore agreed to utilise a separate apparatus for the flame spread rate studies. This apparatus was based on an existing standard used to test the horizontal flame spread of fabrics used in the interior of vehicles in the USA. Each flame spread rate determination was repeated and the mean value used as the quoted flame spread rate. Appendix 2 contains the detailed results of the flame spread rate study.

2.8 Full scale dressed manikin tests

Two cotton "boiler suits" were obtained from a recognised supplier [7], one treated with "Proban" flame retardant, the other untreated. These boiler suits were used to clothe a manikin with mineral wool inserts to simulate the torso and arms and legs. Each dressed manikin was subjected to a stream of grinder sparks below the waistline and observations made of ignition and flame spread.

3 FINDINGS AND DISCUSSION

3.1 Summary of ignition and flame spread results

Table 3 summarises the ignition and flame spread data for the ten chosen fabrics and variants. For time-to-ignition, the results were obtained using the wire frame sample holder thus repeating several of the tests carried out in the development stages which used a “handy angle” sample holder. Three to five successful ignitions (i.e. flame propagating away from the influence of the grinder sparks) were used as the criteria for ignition over a given time interval. In some cases differences in times to ignition were observed, depending on the orientation (i.e. weft lengthwise or width wise). These are indicted in table 3 where the time-to-ignition was altered sufficiently to place the result in another time period.

For the flame spread rate trials, only the additional fabrics required for test following the development stages were tested. Flame-spread rates for the other fabrics are reported here as obtained during the development stages.

Table 3 – Summary of time-to-ignition and flame spread results for the ten generic fabrics and variants.

Fabric number	*Fabric description*	*Time-to-ignition (Seconds).*[1]	*Mean rate of flame spread (horizontal) (mm/min)*	*Mean rate of flame spread (25^{O}incline) (mm/min)*
1	35% polyester, 65% cotton	10	176	889
2	100% cotton (close weave)	20	131	891
3	100% cotton "FR" (interliner)	10	0	450
4	100% polyester	Not measurable (melted and formed hole).	0	85 (extinguished after 15 seconds)
9	100% wool (suiting)	45	0	0
10	100% cotton "FR" (corduroy)	Did not ignite.	0	143 (extinguished after 46 seconds)
11	Denim (cotton) stretch fabric	20 (lengthwise) 30 (widthwise)	84	407
12	Polyester fabric quilt over wadding	10	80	391
13	100% polyester	Not measurable (melted and formed hole).	0	248 (extinguished after 20 seconds)
14	100% polyester over 100% wool (two layers)	30	0	0
16	100% cotton with "Proban" FR treatment – unlaundered sample.	30 (only small flamelets observed for 2 seconds).	0	0
17	100% cotton with "Proban" FR treatment – laundered sample.	10 (only small flamelets observed for 2 seconds).	0	0
18	100% cotton (fabric 15) with grease contaminant.	15	140	728
19	100% cotton (fabric 15) with paint contaminant.	Ignited in only one trial at 60s on non painted area.	91	496
20	100% polyester (fabric 13) with grease contaminant.	Ignited in only one trial at 40s.	254 (extinguished after 10 secs)	9.4 (extinguished after 12 seconds)
21	100% polyester (fabric 13) with paint contaminant.	30	170	587

3.2 Natural and synthetic fabrics

Time-to-ignition results did not particularly distinguish between natural and synthetic fabrics. Flame-spread rates were generally significantly faster for the 25^{O} inclined sample, over the horizontal sample. In some cases no flame spread was observed with a horizontal orientation but was observed in the 25^{O} inclined orientation.

With the synthetic fabrics a hole was often punched through the fabric preventing further impingement of sparks onto the sample, which in some cases produced a "no-ignition" result. Flame-spread rates on these samples were however often measurable, particularly in the 25^{O} inclined orientation.

With natural fabrics a char tended to form which appeared to inhibit ignition. Wool was particularly resistant. A polyester covering over wool (fabric 14) ignited after 30 seconds but a flame spread rate could not be determined in either of the two orientations attempted for this double-layered fabric.

Fabrics consisting of synthetic/natural fibre mixes were not particularly distinguishable from their "pure" counterparts.

With fabric combinations (i.e. two layers) there was some evidence of intermediate behaviour from that measured with the individual components, but this was somewhat tenuous and needs further investigation.

3.3 FR treated fabrics and effects of laundering

One proprietary FR fabric (fabric 3) ignited readily (after 10 seconds). This required the inclusion of a "pedigree" fabric, analysed for FR content (fabric 16). The phosphorus content measured (2.3%) is consistent with the recognised correct loading of "Proban" cotton fabric in this application [6].

The unlaundered "Proban" treated cotton fabric (fabric 16) ignited after 30 seconds but produced small flamelets which extinguished after a few seconds.

After being subjected to a standard laundry cycle, the FR "pedigree" fabric (fabric 17) ignited after 10 seconds (but with small, barely propagating flames). No flame spread was observed with either the laundered or unlaundered samples.

3.4 Fabrics contaminated with grease or paint.

Grease contamination on a cotton fabric (fabric 18) reduced the time-to-ignition from 20 seconds on the uncontaminated sample to 15 seconds. Flame spread rate was slightly increased in a horizontal orientation and slightly decreased in the 25 degree inclined orientation compared to the uncontaminated sample. (However, note that a substitute fabric for fabric 2 had to be used for this "contamination" trial).

Paint contamination on a cotton fabric (fabric 19) increased the time-to-ignition from 20 seconds on the uncontaminated sample to over 60 seconds. Flame-spread rates were significantly reduced in both orientations, over the uncontaminated sample. (However, note that a substitute fabric for fabric 2 – fabric 15 - had to be used for these "contamination" trials).

Grease contamination on a polyester fabric (fabric 20) did produce a marginal ignition at 40 seconds. The uncontaminated sample (fabric 13), melted and developed a hole, preventing further impact from sparks. A flame-spread rate for the contaminated sample was observed in the horizontal orientation with (atypically) a much lower rate in the 25^{O} orientation, but in both tests the flame extinguished well before complete combustion. No spread was observed with the uncontaminated sample when horizontal but the 25^{O} orientation uncontaminated sample did produce a measurable flame spread but again flaming extinguished well before the sample had been consumed.

Paint contamination on a polyester fabric (fabric 21), produced a reliable ignition after 30 seconds. The uncontaminated sample (fabric 13) melted and developed a hole, preventing further impact from sparks. Flame-spread rates of the contaminated sample were measured with both sample orientations with complete combustion of the sample in each case. The flame spread rate was much faster with the 25^{O} orientation.

These variable results must be considered to be due in part to the difficulties experienced in applying a uniform and consistent level of contamination on the fabrics and to the variable flammability nature of the base materials, particularly the polyester fabric. Further work is needed on this aspect to confirm (or refute) the findings from this limited study.

3.5 Manikin fire test

The FR treated boiler suit resisted ignition and did not produce any signs of self-propagating flames after exposing the fabric to a sustained stream of sparks over a five minute period. The fabric glowed, smouldered and fumed during application of the sparks but this ceased shortly after the stream of sparks was stopped.

The non FR boiler suit ignited readily after approximately 20 seconds when the stream of sparks was stopped. It continued to burn to completion.

Figures 1 and 2 illustrate the behaviour of the FR and non FR boiler suit in the manikin tests:

Figure 1. Grinder sparks being applied to manikin (FR "Proban" cotton boiler suit). No ignition occurred after five minutes of sustained application of the sparks

Figure 2. Grinder sparks have been applied to a manikin (non-FR boiler suit). The result after approximately 45 seconds (ignition occurred at approximately 20 seconds).

3.6 Detailed test results

Appendices 1 and 2 provide details and results of the all trials carried out to obtain these data for ignition times and flame-spread rates respectively.

Appendix 3 provides details and results of the ancillary measures carried out during this project

i.e.

- Trials for a substitute for fabric 2.
- Establishing the degree of operator dependence for the ignition study
- Elemental analysis of a “Proban” flame retarded cotton fabric.

4 CONCLUSIONS AND RECOMMENDATIONS

1. Following extensive development in earlier reported studies, [2,3] an apparatus for measuring the time-to-ignition and an apparatus for measuring rate of flame spread has been developed for work wear fabrics exposed to angle grinder sparks.

2. Ten generic fabrics and variants were chosen by the HSE to use in these tests with the two sets of apparatus. The ten fabrics and variants included pure synthetic fabrics, pure natural fabrics, synthetic/natural fibre mixtures, fabric combinations, FR fabrics (in one case laundered and unlaundered) and a natural and synthetic fabric both contaminated with paint and grease. In summary, main conclusions were:

   - The range of synthetic and natural fabrics tested showed ignition times and flame-spread rates covering a wide range but there was no particular distinction between values obtained for the two types.

   - Synthetic fabrics tended to melt and natural fabrics tended to form a surface char, both effects having a strong influence on performance in the ignition and flame spread tests.

   - Natural/synthetic fibre mixes were not particularly distinguishable from their "pure" counterparts.

   - Combinations (i.e. two layers) of synthetic and natural fabrics showed some evidence of intermediate performance between the two components.

   - A cotton fabric marked as "FR interliner" ignited readily.

   - A cotton fabric purchased as "FR" and checked for acceptable FR content by elemental analysis did exhibit very limited ignition and flame spread behaviour, both before and after being subjected to a single standard laundry cycle.[5].

   - Synthetic and natural fabrics contaminated (separately) with grease and paint did not show a particularly degraded performance – in some cases a marginal improvement was observed. However these results must be considered as provisional (and subject to further confirmation) due to problems with ensuring a uniform application of contaminant to the samples and the variability in behaviour of the base fabrics.

   - Tests on a full sized manikin clothed in separate tests with an FR and non FR "boiler suit" demonstrated the value of FR treated materials when subjected to sparks from an angle grinder. The FR boiler suit did not ignite after 5 minutes of sustained spark impingement whereas the non FR boiler suit ignited after approximately 20 seconds and burnt to completion.

3. It is recommended that the test apparatus and methodologies as developed in this study should be used as the basis for a Standard test method for determining the times to ignition and rates of flame spread of fabrics likely to be encountered in the workplace, when subjected to a stream of sparks from an angle grinder.

4. Further development work is recommended, particularly in the areas of fabric combinations, contaminated fabrics and to develop performance criteria.

APPENDIX 1 - Test data obtained from the "time-to-ignition" study of the ten generic fabrics and variants.

(Note – "Width" and "Length" terms relate to the direction of the warp threads of the fabric in the sample holder.

Fabric: 1. 35%polyester/65%cotton. Orientation: Width (Length)						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	N (Y)	N (Y)	Y (Y)	Y (Y)	Y (Y)	
10	Y	Y	Y	Y	Y	
15	-	-	-	-	-	
20	-	-	-	-	-	
30	-	-	-	-	-	
40	-	-	-	-	-	
Other	-	-	-	-	-	

Fabric: 2. Cotton close weave. (note – replaced by fabric 15 for "contamination" studies). Orientation: Width (Length)						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	-	-	-	-	-	
10	N	N	N	-	-	
15	N (N)	N (N)	N (N)	-	-	
20	Y (Y)	Y (Y)	Y (Y)	-	-	
30	-	-	-	-	-	
40	-	-	-	-	-	
Other	-	-	-	-	-	

Fabric: 3. 100% cotton FR treated (interliner). Orientation: Width (Length)						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	N (N)	N (N)	N (N)	N (N)	N (N)	Slight scorching
10	Y (Y)	Y (Y)	Y (Y)	Y (Y)	Y (Y)	Surprising for an FR product
15	-	-	-	-	-	
20	(Y)	(Y)	(Y)	(Y)	(Y)	Surprising for an FR product
30	-	-	-	-	-	
40	-	-	-	-	-	
Other	-	-	-	-	-	

Fabric: 4. 100% polyester. Orientation: Width						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	N	N	N	-	-	No sign of ignition/fumes
10	N	N	N	-	-	Slight melting
15	N	N	N	N	N	Slight melting
20	N	N	N	-	-	Melted, punched hole.
30	-	-	-	-	-	
40	N	N	N	-	-	Melted, punched hole
Other 120	N	N	N	-	-	Melted, punched hole

Fabric: 9. 100% wool (suiting). Orientation: Width (Length)						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	N	N	-	-	-	No sign of scorching
10	N	N	-	-	-	No sign of scorching
15	N	N	N	-	-	Slight scorching
20	N (N)	N (N)	N (N)	-	-	More scorching, light fuming
30	N (N)	N (N)	N (N)	-	-	Scorching and moderate fuming
40	Y (N)	N (Y)	N (Y)	Y (N)	- (Y)	Transient flames for approx. three seconds.
45	Y (Y)	Y (Y)	Y (Y)	-	-	

Fabric: 10. 100% cotton FR treated (corduroy). Orientation: Length						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	N	N	-	-	-	No signs of fumes/scorching
10	N	N	-	-	-	No signs of fumes/scorching
15	N	N	-	-	-	No signs of fumes/scorching
20	N	N	N	-	-	Some scorching, hole developed
30	-	-	-	-	-	
40	N	N	N	-	-	Some scorching, punched hole
Other 120	N	N	N	N	N	Some scorching, punched hole. Expected from FR?

Fabric: 11. Stretch denim (cotton). Orientation : Width (Length)						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	N	N	-	-	-	No sign of fumes or scorching
10	N(N)	N(N)	N(N)	-	-	Slight scorching
15	Y(N)	Y(Y)	Y(Y)	N(Y)	N	Heavy scorching before flame
20	N(Y)	Y(Y)	Y(Y)	N(Y)	Y(Y)	Heavy scorching before flame
30	Y	Y	Y	Y	Y	

Fabric: 12. Polyester fabric and wadding. Width (Length)						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	N (N)	N (N)	N (N)	-	-	Some scorching
10	Y (Y)	Y (N)	Y (N)	-	-	
15	-	-	-	-	-	
20	-	-	-	-	-	
30	-	-	-	-	-	
40	-	-	-	-	-	
Other	-	-	-	-	-	

Fabric: 13. 100% polyester. Orientation: Width (Length)						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	N	N	-	-	-	Small holes from sparks
10	N	N	-	-	-	Small holes from sparks
15	N	N	-	-	-	Scorching and small hole
20	N (N)	N (N)	N (N)	-	-	Scorching and larger hole
30	N	N	-	-	-	Scorching and larger hole
40	N (N)	N (N)	N (N)	-	-	Scorching and larger hole
Other (120)	N	N	N	-	-	Scorching large hole punched. Sparks not contacting fabric.

Fabric: 14. 100% polyester over 100% wool (two fabrics). Orientation: Width (Length)						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	-	-	-	-	-	
10	-	-	-	-	-	
15	-	-	-	-	-	
20	N (N)	N (N)	N (N)	-	-	Scorching, melted hole.
30	Y (N)	Y (Y)	Y (Y)	(N)	(Y)	
40	-	-	-	-	-	
Other	-	-	-	-	-	

Fabric: 16. "Proban" treated cotton. Unlaundered						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	-	-	-	-	-	
10	N	N	N	-	-	Slight scorching
15	N	N	N	-	-	
20	N	Y	Y	Y	-	Fuming and charring, flaming for 2 seconds only.
30	Y	Y	Y	Y	Y	Fuming, charring, flaming for 2 seconds only.
40	Y	Y	Y	Y	Y	Fuming, scorching, flaming for 2 seconds only.
Other	-	-	-	-	-	

Fabric: 17. "Proban" treated cotton. Laundered						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	N	N	N	-	-	
10	Y	Y	Y	-	-	Flaming stopped after 2 seconds
15	Y	Y	Y	-	-	Flaming stopped after 2 seconds
20	-	-	-	-	-	
30	-	-	-	-	-	
40	-	-	-	-	-	
Other	-	-	-	-	-	

Fabric: 18. 100% cotton (fabric 15) with grease contaminant.						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	-	-	-	-	-	
10	N	N	N	-	-	
15	Y	Y	Y	-	-	
20	-	-	-	-	-	
30	-	-	-	-	-	
40	-	-	-	-	-	
Other	-	-	-	-	-	

Fabric: 19. 100% cotton (fabric 15) with paint contaminant.						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	-	-	-	-	-	
10	-	-	-	-	-	
15	-	-	-	-	-	
20	N	N	N	-	-	
30	-	-	-	-	-	
40	N	N	N	-	-	
Other 60	N	N	Y	-	-	Flaming only on non painted area.

Fabric: 20. 100% polyester (fabric 13) with grease contaminant.						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	-	-	-	-	-	
10	-	-	-	-	-	
15	-	-	-	-	-	
20	N	N	N	-	-	Scorching and hole punched through
30	-	-	-	-	-	
40	N	N	Y	-	-	Scorching, hole punched flaming in one test.
Other (60)	N	N	-	-	-	

Fabric: 21. 100% polyester with paint contaminant.						
Time sparks applied (seconds)	***Trial 1***	***Trial 2***	***Trial 3***	***Trial 4***	***Trial 5***	***Remarks***
5	-	-	-	-	-	
10	-	-	-	-	-	
15	N	N	N	-	-	Slight hole and light fumes
20	N	Y	Y	Y	Y	Hole but continued flaming
30	Y	Y	Y	Y	Y	Holed but continued flaming.
40	-	-	-	-	-	
Other	-	-	-	-	-	

APPENDIX 2 – Test data obtained from the "flame-spread rates" study of the ten generic fabrics and variants.

Fabric Reference Number (Table 1) and repeat number	*Time in seconds to reach indicated flame spread distance in mm and (inches) – Horizontal Sample.*										
	0 (0)	***25.4 (1)***	***50.8 (2)***	***76.2 (3)***	***101.6 (4)***	***127.0 (5)***	***152.4 (6)***	***177.8 (7)***	***203.2 (8)***	***228.6 (9)***	***254.0 (10)#***
1.1	16	28	31	40	52	59	67	77	84	95	108
1.2	13	20	29	36	44	52	60	69	77	85	95
2.1	20	32	43	54	68	79	91	101	110	121	134
2.2	17	30	38	51	64	75	84	98	108	120	136
3.1	0	No flame spread									
3.2	0										
4.1	0										
4.2	0										
9.1	0	No flame spread									
9.2	0										
10.1	0										
10.2	0										
11.1	44	67	88	108	128	145	163	183	199	217	235
11.2	43	64	83	101	119	136	152	168	186	202	218
12.1	23	45	67	92	111	135	150	170	183	201	222
12.2	25	44	64	85	105	122	142	160	175	192	210
13.1	2	No further flame spread									
13.2	3										
14.1	No flame spread										
14.2											
16.1	0	No flame spread from ignition source									
16.2	0										

17.1	0	No flame spread from ignition source									
17.2	0										
18.1	25	35	47	56	66	76	85	95	105	117	131
18.2	25	36	49	61	72	85	93	102	115	125	137
19.1	25	42	60	75	90	107	125	141	157	178	197
19.2	26	42	61	77	95	110	126	141	158	174	192
20.1	7	13									
20.2	Very slight propagation from source (few mm) before extinguishing										
21.1	6	16	27	43	52	60	67	75	86	94	98
21.2	6	12	20	27	34	48	58	70	82	89	94

Fabric Reference Number (Table 1) and repeat number	***Time in seconds to reach indicated flame spread distance in mm and (inches) – Angled Sample (25^{O})***										
	*0 (0)***	*25.4 (1)*	*50.8 (2)*	*76.2 (3)*	*101.6 (4)*	*127.0 (5)*	*152.4 (6)*	*177.8 (7)*	*203.2 (8)*	*228.6 (9)*	*254.0 (10)#*
1.1	4	7	9	11	13						24
1.2	4										19
2.1	3										17
2.2	5										27
3.1	4	6									36
3.2	4	9									40
4.1	6		No further flame spread								
4.2	6	15	No further flame spread								
9.1	0	No flame spread									
9.2	0										
10.1	12	28	37	46	No further flame spread						
10.2	10	20	No further flame spread								
11.1	12	18	23	27	31	34	36	40	43	47	50
11.2	13	19	24	28	32	35	39	41	45	48	50
12.1	10	13	18	20	23	26	30	-	-	-	48
12.2	10	15	20	22	25	-	-	-	-	-	50
13.1	12	20	No further flame spread								
13.2	15	20									
14.1	No flame spread										
14.2											
16.1	13	No further flame spread									
16.2	12										
17.1	13	No further flame spread									
17.2	13										
18.1	10	-	-	15	16	-	-	26	-	-	30

18.2	7	10	13	15	-	-	-	22	-	-	29
19.1	8	-	-	15	-	20	-	30	-	-	36
19.2	10	14	17	20	24	26	-	35	40	-	44
20.1	Very slight flame spread before extinguishing										
20.2	6	10	No further flame spread								
21.1	3	7	-	10	-	15	-	20	-	25	28
21.2	3	-	-	12	-	14	-	21	23	-	30

APPENDIX 3 – Ancillary measurements

During the study a number of ancillary measurements were made to investigate various observations connected with the procedures. For completeness these are presented here.

Trials for a substitute for fabric 2

The new fabric (15) was required as the original (fabric 2) was discontinued before the contamination trials (which required fabric 2), could take place. Table A3.1 shows the comparative data obtained for these two fabrics.

Table A3.1 - Comparative data for an original and replacement cotton fabric

Fabric	*Mass/unit area* *(kg/m^2)*	*Time-to-ignition* *(seconds)*	*Mean horizontal flame spread* *(mm/min)*	*Mean horizontal flame spread (repeat)* *(mm/min)*
2	0.156	20	134	128
15	0.161	20	98.7	101

Although fabric 15 showed some difference in flame spread rate, the difference was considered small enough (in the context of the range of flame-spread rates observed throughout the whole study) to enable the fabric to be used as a substitute for the discontinued fabric 2 for the "contamination" trials in this study.

Establishing operator dependence for the ignition study

The development work for subjecting fabric samples to a consistent shower of sparks from an angle grinder, initially utilised a sample holder made from "handy angle". This was to enable a variety of configurations of fabric to be readily trialled to ensure the final design gave the most repeatable and reliable results. On completion of the development work, a final design was constructed from an open mesh wire sheet to the final required dimensions. However, early trials with the new sample holder, and with a different test operator showed significant differences in times-to-ignition; i.e. giving shorter times with the new sample holder. In order to check whether this was due to the change of sample holder or operator, two fabrics were chosen and trialled by both operators with both types of sample holder.

Table A3.2 below summarises the results:

Table A3.2: Results from test using different operators and the two different fabric sample holders

Sample holder	*Operator*	*Fabric*	*Run 1 (time/ignition)*	*Run 2 (time/ignition)*	*Run 3 (time/ignition)*
Handy angle	JC	9	60sec/no	60sec/no	60sec/no
Open wire	JC	9	30sec/no 40s/yes	40sec/no 45s/yes	40sec/no 45s/yes
Handy angle	JC	12	5sec/no 10sec/yes	10sec/no 20sec/yes	5sec/no 10sec/yes
Open wire	JC	12	5sec/no 10sec/yes	5sec/no 10sec/yes	5sec/no 10sec/yes
Handy angle	PJF	9	60sec/no	60sec/no	60sec/no
Open wire	PJF	9	30sec/no 45sec/yes	40 sec/no 45sec/yes	40sec/no 45sec/yes
Handy angle	PJF	12	5se/no 10sec/yes	5sec/no 10sec/yes	5sec/no 10sec/yes
Open wire	PJF	12	5sec/no 10sec/yes	5sec/no 10sec/yes	5sec/no 10sec/yes

As shown, the differences appear to be due to the different sample holder rather than the different operator, although the differences with sample 12 between handy angle and open wire holder were small. The differences are tentatively ascribed to the larger "heat sink" properties of the handy angle holder, over the open wire mesh holder, resulting in somewhat longer ignition times (where indeed ignition did actually occur) with the handy angle holder.

Elemental analysis of a flame retarded fabric

Due to the surprising result with one FR fabric (3) which ignited in 10 seconds (although it possessed a low flame spread) it was considered desirable to obtain a "Proban" treated cotton fabric (fabric 16) and subject this to elemental analysis to ensure the loading of FR treatment appeared consistent with correct "Proban" treatment.

Table A3.3 gives the result of a C, H, N and P analysis fabric 16 (“Proban” treated cotton).

Table A3.3

% carbon expressed as C	41.13 41.12
% hydrogen expressed as H	6.29 6.36
% nitrogen expressed as N	2.12 2.02
% phosphorus expressed as P	2.33 2.28

Through discussions with a major supplier manufacturer of “Proban” treated fabrics an elemental phosphorus content of 2.3% to 3% was considered a satisfactory “loading” in this application [6].

REFERENCES

1. *"FIREX" – HSE Technology Division's Database.*

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3. *"Hand grinder sparks: Development of a test for ignition and flame spread on work wear. An apparatus and procedure to compare flame-spread rates*. August 2002. Fardell P.J. BRE Client Report 206551.

4. Title 49 – Transportation #571.302 Federal Motor Vehicle Safety Standard (FMVSS) *"Standard 302: Flammability of interior fabrics"* US Federal Register Vol. 36.N0 232.

5. *"Textiles. Commercial laundering procedure for textile fabrics prior to flammability testing. (reduced procedure)*"BS EN ISO 10528 :1995.

6. *Phosphorus levels in "Proban" treated textiles. Northenden Textiles Ltd.,* Rengate House, 221 Palatine Road, Didsbury, Manchester M20 2EE. Mr. Tony Purcell (Private Communication).

7. Portwest Clothing Ltd. Market Street, Goldthorpe, Rotherham S. Yorkshire S63 9HB

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MERCHANT SHIPPING NOTICE

MSN 1731 (M+F)

Maritime and Coastguard Agency

The Merchant Shipping and Fishing Vessels Personal Protective Equipment Regulations 1999

This Merchant Shipping Notice is an integral part of the Merchant Shipping and Fishing Vessels (Personal Protective Equipment) Regulations 1999.

Notice to employers of crew, masters, safety officers and safety representatives.

This Notice supersedes Merchant Shipping Notices No. M1195 and M1358.

Summary

- This Notice gives notice of new regulations governing the provision of personal protective equipment, the Merchant Shipping and Fishing Vessels (Personal Protective Equipment) Regulations 1999. These Regulations supersede the Merchant Shipping (Protective Clothing and Equipment) Regulations 1985 (S.I. No. 1664), and come into force on 25 October 1999

- Annex 1 gives the design standards for personal protective equipment in use on board ships, for specified work activities and situations, in order to comply with regulation 5(2)(a) of the new Regulations.

Introduction

1. The Regulations require employers to ensure that personal protective equipment (PPE) is provided for their workers who are engaged in, or at risk from, a hazardous work activity on board a United Kingdom ship[1].

2. The Regulations are subject to the general rule that use of PPE is always a last resort, where risks cannot be avoided or reduced to a safe level by means of collective protection, or safe systems of work.

3. PPE must be provided free of charge to the workers, except that, where use of the equipment is not exclusive to the work place, workers may be required to contribute towards the cost.

[1] "worker" includes trainees and apprentices, but does not include persons who are training in a sail training vessel.

4. Where, traditionally, workers provide their own PPE, the employer remains responsible for ensuring that workers are equipped with appropriate PPE, and that they use it when engaged in work of the types outlined in Annex 1.

5. The equipment issued must be "suitable", which is defined as :

(a) in relation to any work process described in [this] Merchant Shipping Notice MSN 1731 (M+F), of the kind and to the standard specified [in that Merchant Shipping Notice], in relation to that work process;

(b) appropriate for the risks to which he worker is exposed and to the task which he is performing, without itself leading to any increased risk;

(c) correctly fitting the worker, or capable of being adjusted to fit;

(d) taking into account ergonomic requirements and the worker's state of health; and

(e) compatible with any other equipment the worker has to use at the same time, so that it continues to be effective against the risk"

6. In addition, the employer must ensure that the PPE supplied is easily accessible, and properly stored and maintained, and that where appropriate, instructions are available to the workers who are required to carry out any maintenance. The equipment must be regularly inspected, in accordance with the manufacturers instructions, and its operation checked. Respiratory protective equipment must be always be checked before and after use.

7. The employer must ensure, so far as is reasonably practicable, that PPE issued under the regulations is used as instructed - eg that workers do not use it for a purpose for which it is not designed, and that it is put on and worn correctly.

8. Workers must receive adequate and appropriate training so that they are aware of the risks against which the PPE is designed to protect them, and of when and how to use it and look after it correctly. This may include demonstrations of the wearing of PPE, where appropriate.

9. Workers are required to wear and use the PPE which has been issued to them when appropriate, and to comply with any training and instruction provided.

Standards of design and manufacture

10. The specifications for PPE are set out in the Annex. The list covers the PPE most commonly used on ships, but is not exclusive.

11. The letters "EN" stand for "European Norm". Where no "EN" standard is available, a BS standard is quoted. The letters "BS" refer to a British Standard. The standards are those to which the clothing and equipment should comply and the date which appears will be the date on which the latest revision of the relevant Standard was published, including all amendments at the date of this Merchant Shipping Notice.

12. Any reference to an EN or BS standard contained in the annex means that standard or an alternative Standard which provides, in use, equivalent levels of safety, suitability and fitness for purpose.

13. The standards of equipment given in this Merchant Shipping Notice do not apply to life saving appliances or other equipment which is subject to the Merchant Shipping (Marine Equipment) Regulations. (S.I. 1999/1957).

14. Publications mentioned in Annex 1 are available from:

"BS" and "EN" Specifications:

The British Standards Institution
389 Chiswick High Road
London
W4 4AL

The Code of Practice, **"Noise Levels in Ships"** is available from The Stationery Office.

MSPP3 (Seafarers Health and Safety)
The Maritime and Coastguard Agency
Bay 2/1
Spring Place
105 Commercial Road
Southampton
SO15 1EG

Tel: 01703 329390
Fax: 01703 329251

August 1999

[MC 122/6/053]

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ANNEX 1

STANDARDS OF PERSONAL PROTECTIVE EQUIPMENT

Note: all protective clothing should conform to EN 340 : 1993 - 'Protective clothing. General requirements.'

	Work activity	Protective clothing and equipment to be provided	Full title of Standard
1	Any process or activity involving a reasonably foreseeable risk to the head from falling or moving objects.	Head protection EN 397 : 1995	Specification for industrial safety helmets.
2.	When working in areas where the circumstances involve a reasonably foreseeable risk to the head from bruising or abrasion.	Scalp protection to EN 812 : 1997	Industrial bump caps.
3.	When entering or working in a space or working with machinery or equipment where the noise level exceeds 85dB(A).	Hearing protection complying with section 10 and appendix 3 of the Code of Practice for Noise Levels in Ships published by the Department of Transport (1990):	
		EN 352-1 : 1993	Ear muffs.
		EN 352- 2 : 1993	Ear plugs.
		EN 352- 3 : 1996	Ear muffs attached to an industrial safety helmet.
		EN 458 : 1994	Hearing protectors. Recommendations for selection, use, care and maintenance.
4.	Welding and gas cutting.	Eye and face protection to EN 175 : 1997	Personal protection. Equipment for eye and face protection during welding and allied processes.
		EN 166 : 1995	Personal eye protection. Specifications.
		EN 379 : 1994	Specification for filters with switchable or dual luminous transmittance for personal eye protectors used in welding and similar operations.
		EN 169 : 1992	Specification for filters for personal eye protection equipment used in welding and similar operations.

Work activity		Protective clothing and equipment to be provided	Full title of Standard
		Body protection to EN 470-1 : 1995 Additional protection may be required in some situations (eg for particularly intense welding/cutting operations)	Protective clothing for use in welding and allied processes. General requirements.
	Electric arc welding (in addition to above)	Safety footwear to BS 7193	Specification for lined lightweight rubber overshoes and overboots
5.	Any work activity in which there is a reasonably foreseeable risk of injury to the eye from particles, fragments or injurious substances.	Eye protection to EN 166	As above.
6.	Any work activity involving working in an atmosphere which is likely to be hazardous to health.	Note - The following items should be selected and maintained according to BS 4275 : 1997	Guide to implementing an effective respiratory protective device programme.
a)	Protection against nuisance dust mist, particles and dust of low toxicity.	Disposable dust respirators conforming to EN 149 : 1991	Specification for filtering half-masks to protect against particles.
		General purpose dust respirators conforming as appropriate to one of the following:	
		EN 136 : 1998	Respiratory protective devices: Full face masks.
		EN 140 : 1998	Respiratory protective devices: Half masks and quarter masks
		EN 141 : 1990	Respiratory protective equipment: Gas filters and combined.
		EN 143 : 1990	Specification for particle filters used in respiratory protective equipment.
		EN 371 : 1992	Specification for AX gas filters and combined filters against low boiling organic compounds used in respiratory protective equipment.
		EN 372 : 1992	Specification for SX gas filters and combined filters against specific named compounds used in respiratory protective equipment.
		EN 1827: 1999	Half masks without inhalation valves, with separate filters to protect against gases or gases and particles or particles only.

Work activity		Protective clothing and equipment to be provided	Full title of Standard
b)	Protection against toxic dusts and gases of low toxicity.	Respirators conforming as appropriate to one of the following:	
		BS 7355 (EN 136)	As above.
		BS 7356 (EN 140)	As above.
		EN 141	As above.
		EN 143	As above.
		EN 371	As above.
		EN 372	As above.
		EN 405 : 1992 Note: particulate filters may be incorporated for some applications.	Valved filtering half masks for gases or gases and particles.
		EN 1827: 1999	Half masks without inhalation valves, with separate filters to protect against gases or gases and particles or particles only.
c)	Protection against toxic dust.	Powered dust respirators, powered dust hoods and blouses conforming as appropriate to one of the following:	
		EN 136	As above (note: this only applies to the mask).
		EN 143	As above.
		EN 12942: 1998	Specification for power assisted particle filtering devices incorporating full face masks, half masks or quarter masks.
		EN 12941: 1998	Respiratory protective devices. Specification for powered particle filtering devices incorporating helmets or hoods.
d)	Protection against highly toxic atmospheres; or where there is oxygen deficiency; or as an alternative to the items above, where suitable.	Breathing apparatus conforming to: EN 1146 : 1997 (for self-rescue only) "Escape sets"	Respiratory protective devices for self rescue. Self contained open-circuit compressed air breathing apparatus incorporating a hood (compressed air apparatus with hood). Requirements, testing, marking.

Work activity		Protective clothing and equipment to be provided	Full title of Standard
		EN 137 : 1993	Specification for respiratory protective devices: self contained open-circuit compressed air breathing apparatus.
		EN 138 : 1994	Respiratory protective devices. Fresh air hose breathing apparatus for use with full face mask, half mask or mouthpiece assembly.
		EN 139 : 1994	Respiratory protective devices. Compressed air line breathing apparatus for use with a full face mask, half mask or mouthpiece assembly. Requirements, testing, marking.
		EN 269 : 1994	Respiratory protective devices. Powered fresh air hose breathing apparatus incorporating a hood.
		EN 270 : 1994	Respiratory protective devices. Compressed air line breathing apparatus incorporating a hood. Requirements, testing, marking.
		EN 271 : 1995	Respiratory protective devices: Compressed air line or powered fresh air hose breathing apparatus incorporating a hood for use in abrasive blasting operations.
		EN 402 : 1993	Respiratory protective devices for escape. Self contained open-circuit compressed air breathing apparatus with full face mask or mouthpiece assembly.
7.	Any process or activity involving working in an area where there is a reasonably foreseeable risk of injury from substances which are corrosive or likely to be absorbed through the skin.	Protective overalls, gloves or head gear, whichever is appropriate:	
		EN 340 : 1993	Protective clothing: General requirements.
		EN 465 : 1995	Protective clothing. Protection against liquid chemicals. Performance requirements for chemical protective clothing with spray-tight connections between different parts of the clothing (Type 4 equivalent).

Work activity		Protective clothing and equipment to be provided	Full title of Standard
		EN 466 : 1995	Protective clothing. Protection against liquid chemicals. Performance requirements for chemical protective clothing with liquid-tight connections between different parts of the clothing (Type 3 equivalent).
		EN 467 : 1995	Protective clothing. Protection against liquid chemicals. Performance requirements for garments providing protection to parts of the body.
8.	Any process or activity involving a reasonably foreseeable risk of injury to the hands unless the use of hand protection would increase the risk.	Hand protection conforming as appropriate to :	
		EN 374	Protective gloves against chemicals and micro-organisms.
		EN 374-1 : 1994	Terminology and performance requirements.
		EN 374- 2 : 1994	Determination of resistance to penetration.
		EN 374- 3 : 1994	Determination of resistance to permeation by chemicals.
		EN 388 : 1994	Protective gloves against mechanical risks.
		EN 407 : 1994	Protective gloves against thermal risks
		EN 420 : 1994	General requirements for gloves.
		EN 511 : 1994	Protective gloves against cold.
9.	Any process or activity involving particular risk of injury to the feet.	Foot protection conforming to : EN 345 ; or	Safety footwear for professional use.
		EN 346, whichever is appropriate:	Protective footwear for professional use.
		EN 345- 1 : 1992	Specification.
		EN 345- 2 : 1996	Additional specifications.
		EN 346- 1 : 1992	Specification.
		EN 346-2 : 1996	Additional specifications.
		EN 347-1 : 1992	Occupational footwear for professional use.
		EN 347-2 : 1996	Additional specifications.

Work activity		Protective clothing and equipment to be provided	Full title of Standard
10.	Work aloft or in any other area where there is a reasonably foreseeable risk of falling a distance of more than 2 metres.	Safety belt or harness and associated lanyard conforming to the following:	
		EN 353-1 : 1992	Specification for guided type fall arresters on a rigid anchorage line.
		EN 353- 2 : 1992	Specification for guided type fall arresters on a flexible anchorage line.
		EN 354 : 1992	Personal protective equipment against falls from a height. Lanyards.
		EN 355 : 1992	Personal protective equipment against falls from a height. Energy absorbers.
		EN 360 : 1992	Personal protective equipment against falls from a height. Retractable fall arrangements.
		EN 361 : 1992	Personal protective equipment against falls from a height. Full body harnesses.
		EN 362 : 1992	Personal protective equipment against falls from a height. Connectors.
		EN 363 : 1992	Personal protective equipment against falls from a height. Fall arrest systems.
		- or where the use of portable ladders is necessary, such ladders to be used in accordance with Chapter 15 of the Code of Safe Working Practices for Merchant Seamen.	
11.	Any work carried out from an overside position or in an exposed position where there is reasonably foreseeable risk of falling or being washed overboard or any work carried out in or from a ship's boat.	A lifebuoy with sufficient line attached ready for immediate use and either a Maritime and Coastguard Agency approved lifejacket or a lifejacket conforming as appropriate to one of the following, taking into account the area of operation:	
		EN 394 : 1994	Life jackets and personal buoyancy aids. Additional items.
		EN 396 : 1993	Life jackets and personal buoyancy aids. Life jacket 150.

Work activity		Protective clothing and equipment to be provided	Full title of Standard
		EN 399 : 1993 Partially inherent lifejackets must have at least 89 N of inherent buoyancy; and with the inflatable sections relying on automatic inflation.	Life jackets and personal buoyancy aids. Life jacket 275.
12.	Any work activity where it is necessary to carry out repair or maintenance work on or near exposed live electrical equipment and there is a reasonably foreseeable risk of injury.	Rubber gloves conforming to: BS 697 : 1986 EN 60903 : 1992 Protective sleeves conforming to EN 60984 : 1993 An insulating mat (except where specially insulated flooring is installed) conforming to BS 921 : 1976 Rubber soled footwear (no standard necessary). Note - gloves, sleeves and mats should protect against the appropriate voltage.	Specification for rubber gloves for electrical purposes *[4 classes of gloves rated at 650v and above]* Gloves and mitts of insulating material for live working. Sleeves of insulating material for live working. Specification. Rubber mats for electrical purposes.
13.	Any work activity involving a reasonably foreseeable risk of injury from vehicle movement eg during ro-ro operations.	Suitable high-visibility garment conforming to EN 471 : 1994	Specification for high-visibility warning clothing.
14.	Any work process involving exposure to heat	EN 531 : 1995	Protective clothing for industrial workers exposed to heat (excluding fire-fighters' and welders' clothing).
15.	Work in engine rooms or any area where there is a risk of fire.	Overalls made of fabric of low flammability - eg - natural fibre, high cotton content; - non-flammable clothing as appropriate	Cotton or cotton and polyester clothing with flame-retardant finishes are available to protect against sparks and flame.