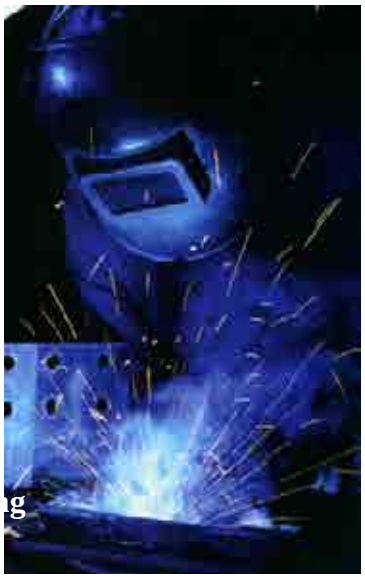
Phosphorus Flame Retardants for Textiles

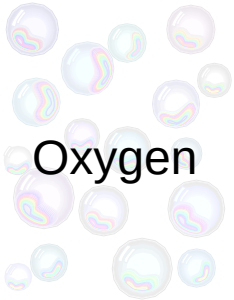
Summary

Introduction

- Flame retardants are prevalent in many aspects of our lives
- In upholstered furniture
- Curtaining
- Car seating
- The work place
- Transportation



How Do Textiles Burn?

Textile (fuel)  + Ignition source  +  Oxygen = Fire 

How Do Textiles Burn?

•Cellulose decomposes (in oxygen) to tarry depolymerization products, notably levoglucosan

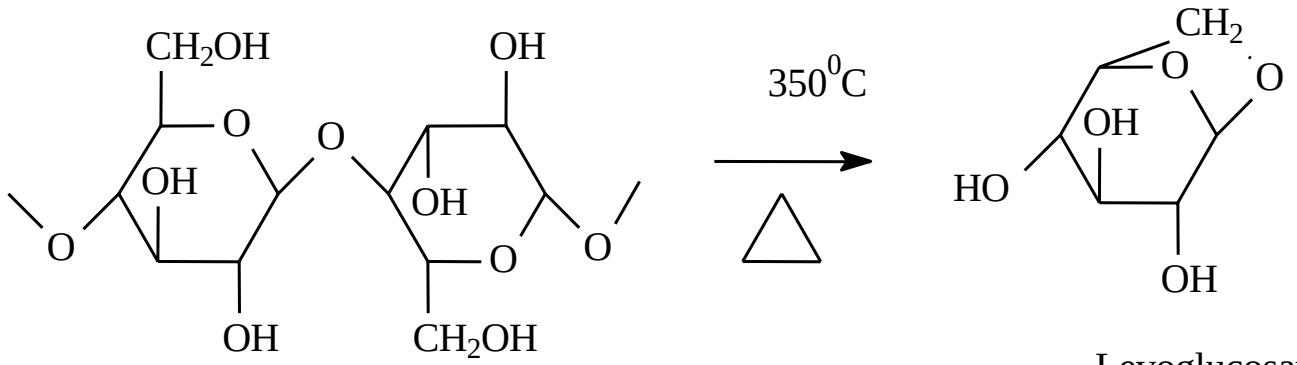
• Then to volatile combustible products such as alcohols, aldehydes, ketones and hydrocarbons

•Flammable gases ignite

•After flaming, the carbonised residue slowly oxidises (smoulders) until it has been consumed

How Do Textiles Burn?

Thermal degradation of Cellulose



Levoglucosan

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- How Do Textiles Burn?
- **The Action of a Phosphorus Flame Retardant**
- Flame Retardant Selection
- Classification of Textile Flame Retardants
- “Inherent” Flame Retardant Fibres
- Methods of Application
- Flammability Standards and Testing
- HSE Considerations
- Conclusions

The Action of a Phosphorus Flame Retardant

There are Potentially Four ways of Disrupting Combustion

- Removal of heat or application of cooling. Achieved by treating the material with heat absorbing materials.
- Increase in pyrolysis temperature i.e. glass fibre, aramids, carbon fibres
- Elimination of oxygen from combustion zone i.e. halogens
- **Prevent evaporation i.e. form char - Phosphorus**

The Action of a Phosphorus Flame Retardant

- Application of ignition source
- Formation of phosphorus pentoxide and phosphoric acid
- Dehydration of cellulose occurs
- Dehydration reduces the temperature of decomposition (275-325°C as opposed to 375°C for untreated cotton)
- Evolution of levoglucosan inhibited
- Flammable tars and gases reduced, char increased
- Formation of protective layer of char

The Action of a Phosphorus Flame Retardant

Synergistic Effect of Nitrogen

- Nitrogen catalyzes the cellulose phosphorylation
- The retention of phosphorus in the char may be aided by nitrogen
- Release of nitrogen gas which dilutes the flammable gases and reduces flaming
- Higher levels of nitrogen may allow lower levels of phosphorus in the flame retardant

Summary

Flame Retardant Selection

- Application
- Application method
- Performance requirements
- Fabric composition
- Fabric construction, weight
- Fabric must still behave like untreated material

COST

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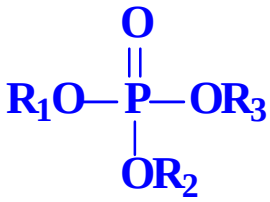
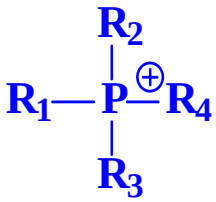
Classification of Textile Flame Retardants

- Phosphorus containing flame retardants

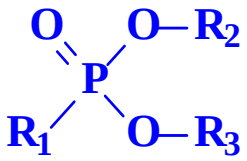
Phosphate

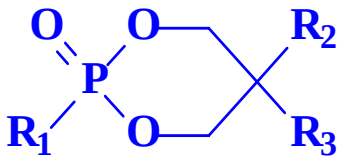


Phosphonium



Phosphonate





Cyclic

Classification of Textile Flame Retardants

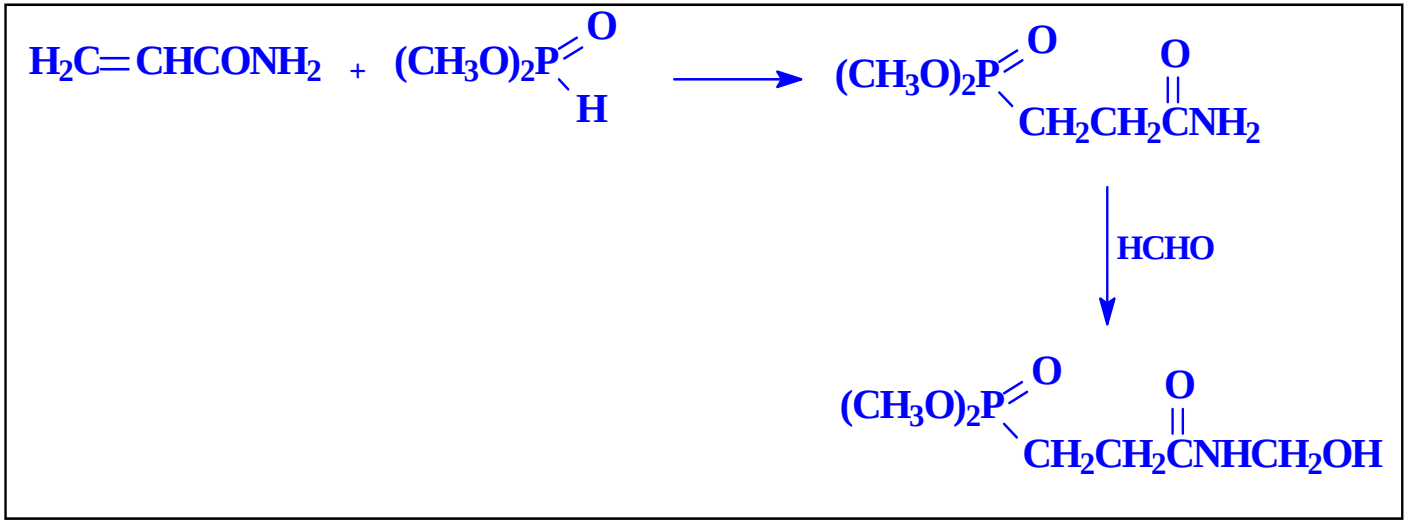
- Another method of classifying textile FRs is according to
- their *durability* to washing:

• Durable	Resistant to 50 or more washes
• Semi-Durable	Resistant to a water soak
• Non-Durable	Resistant to no washing

Classification of Textile Flame Retardants

Durable Flame Retardants (Top Treatments)

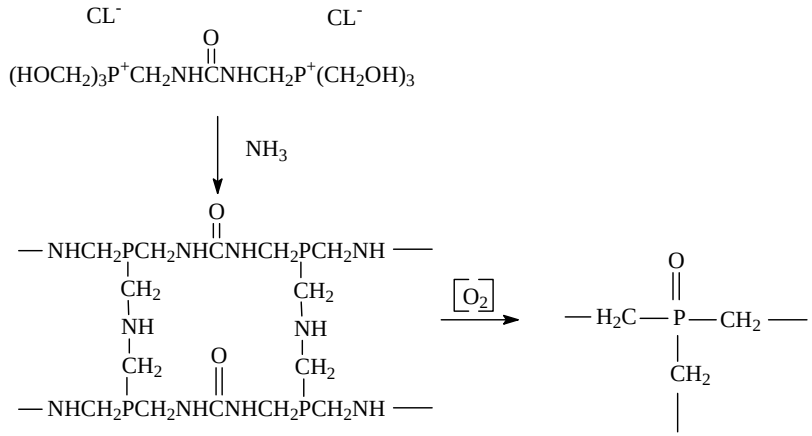
- Dialkylphosphonopropionamide
- Co-reacted with an amino resin and an acid curing catalyst
- Pad, dry, heat cure followed by alkali wash



Classification of Textile Flame Retardants

Durable Flame Retardants (Top Treatments)

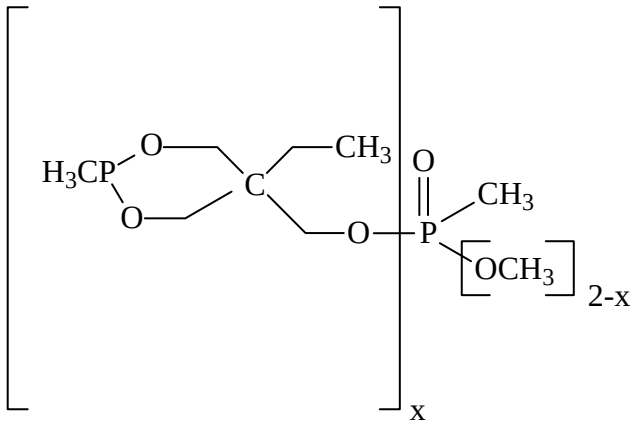
- Tetrakis(hydroxymethyl)phosphonium chloride marketed under the **PROBAN®** trademark by Rhodia and is available only under licence
- Applied to cotton and cotton synthetic blends by pad, dry, ammonia cure and hydrogen peroxide oxidation
- Durable to repeated washing



Classification of Textile Flame Retardants

Flame Retardants for Polyester fabrics (Top Treatments)

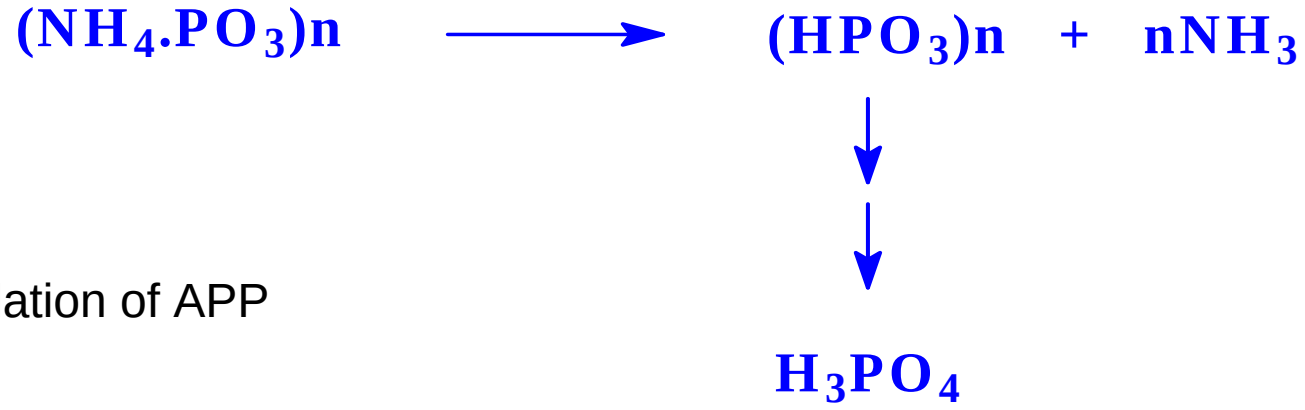
- Cyclic Phosphonate Ester based products may be used
- Applied by pad, dry, heat cure process
- Durable to washing
- Phosphorus FR's lower the melting point of polyester fabrics allowing the fabric to melt away from the ignition source more easily



Classification of Textile Flame Retardants

Non-Durable Flame Retardants (Top Treatments)

- Non-durable APP's used
- End-uses include furnishings, filter fabrics, disposable protective clothing



Degradation of APP

Classification of Textile Flame Retardants

Non-Durable Flame Retardants (Top Treatments)

- Need for more sophisticated flame retardants for higher processing speeds and more demanding applications
- Phosphonates generally have higher thermal stability than APP's allowing higher processing speeds
- Flame Retardants capable of being processed at temperatures of over 130ºC have been developed by Rhodia and marketed under the **AMGARD®** trademark
- Some of the **AMGARD®** products are based on phosphonate chemistry which generally have higher thermal stability than APP's

Classification of Textile Flame Retardants

Semi-Durable Flame Retardants

- Used for items not normally washed but may be subjected to water soak or dry cleaning
- Ammonium polyphosphates may be used
- End uses include upholstery and curtains

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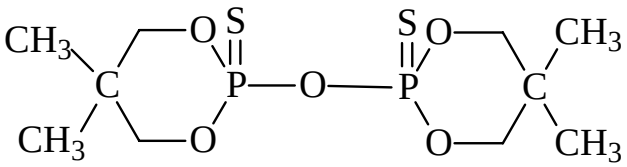
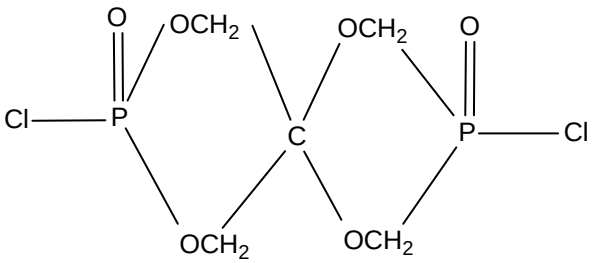
“Inherent” Flame Retardant Fibres

- Phosphorus containing FR additive can be incorporated into the spinning dope during manufacture of viscose fibres
- Polyester fibres can also be given FR properties by inclusion of phosphonic acid based derivative

“Inherent” Flame Retardant Fibres



Viscose spinning bath additive for flame retardant rayon



Spirocyclic pentaerythritol di(phosphate acid monochloride additive for polyester

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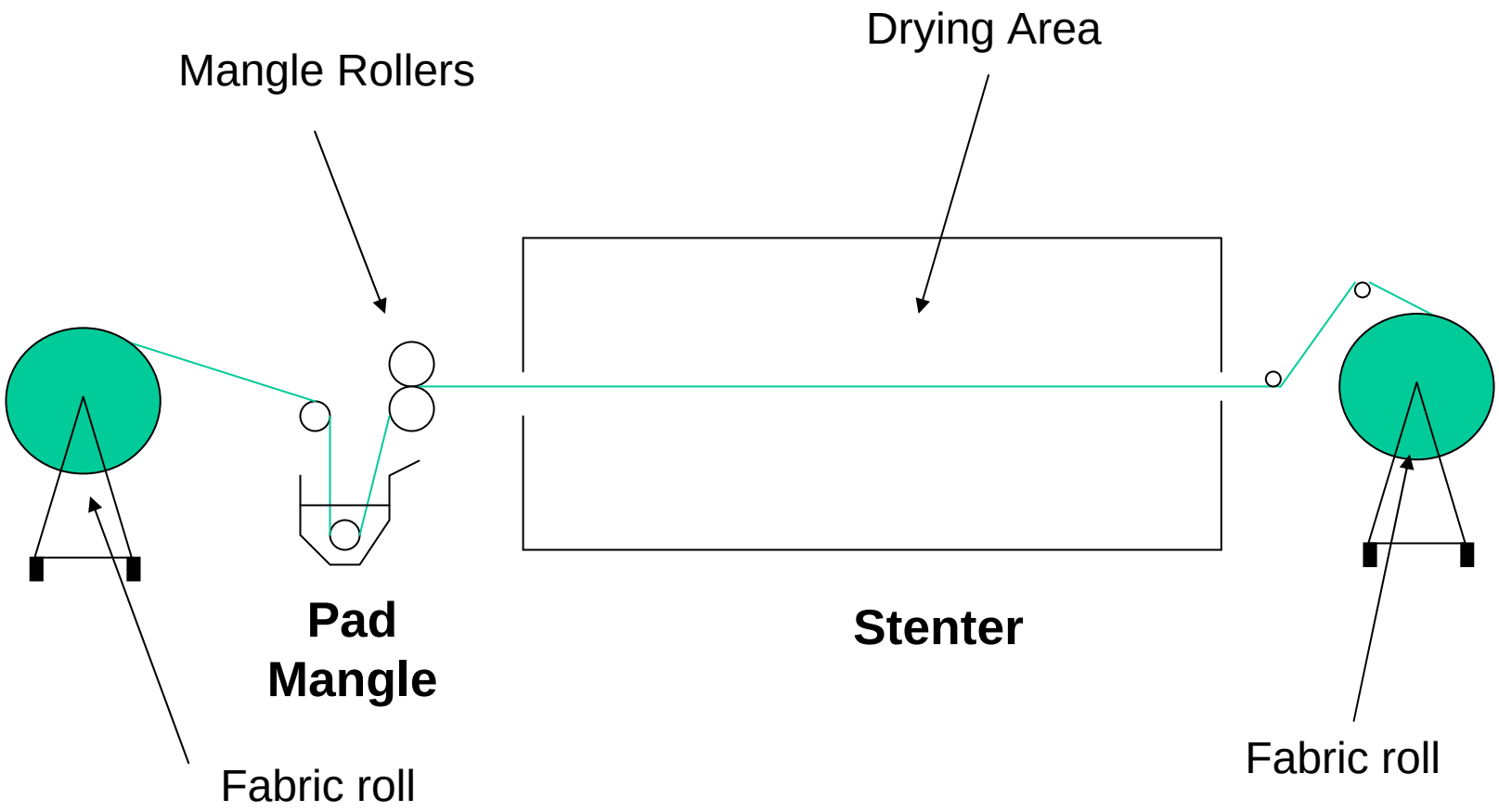
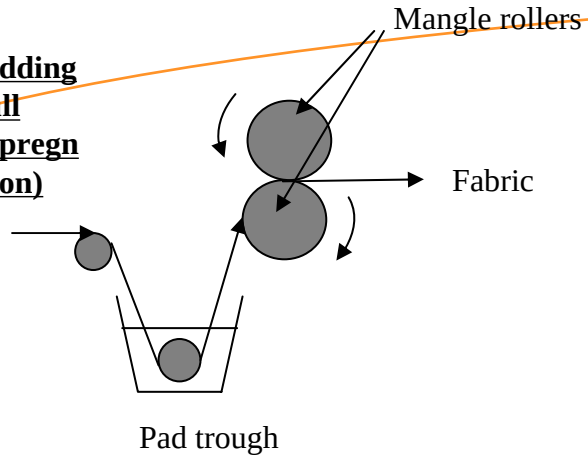
Methods of Application

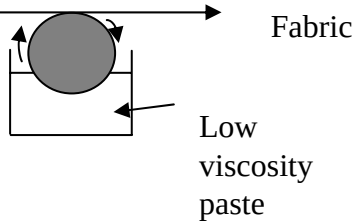


Methods of Application

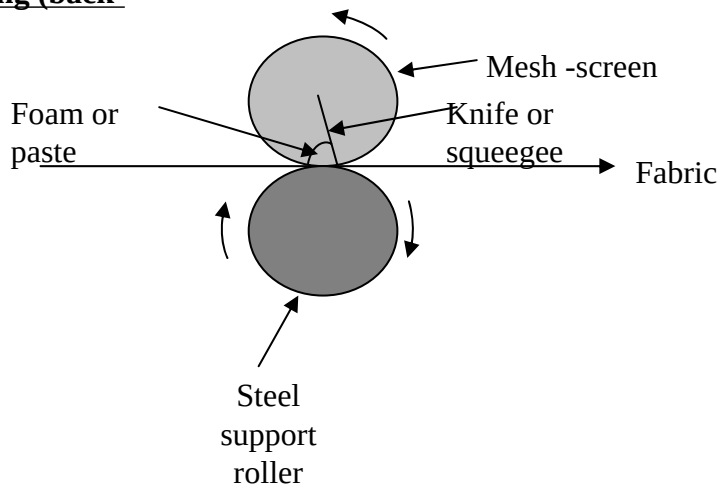
Padding (full impregnation)



Lick Roll



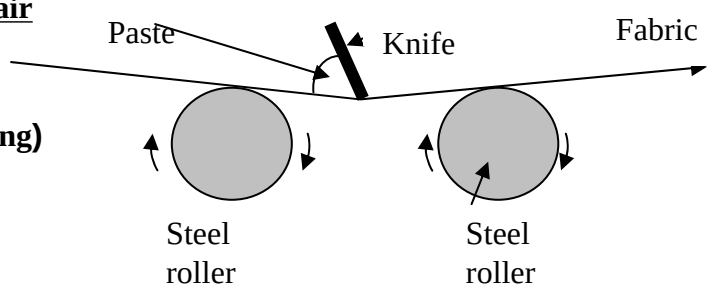
Screen coating (back-coating)



Methods of Application

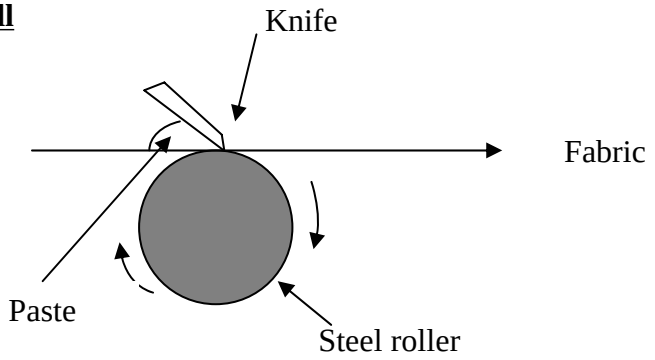
Knife over air

(Back-coating)



Knife over roll

(Back-coating)



Methods of Application

Pad Mangles

Methods of Application

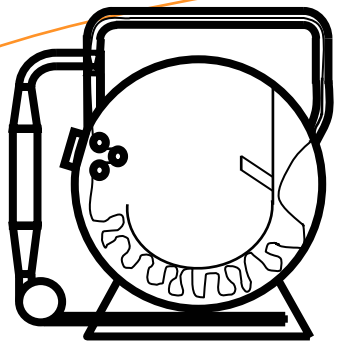
Stenter Drying

Methods of Application

Textile Coating Machines

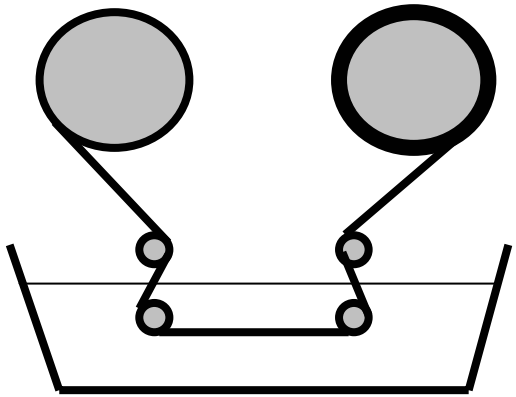
Methods of Application

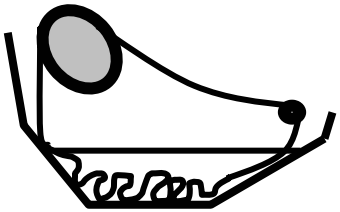
Wet Processing (Dyeing) machines



Jet Dyeing Machine

Jig Dyeing machine





Winch Dyeing Machine

Methods of Application

Wet Processing (Dyeing) machines

Continuous Wash Ranges

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Flammability Standards and Testing

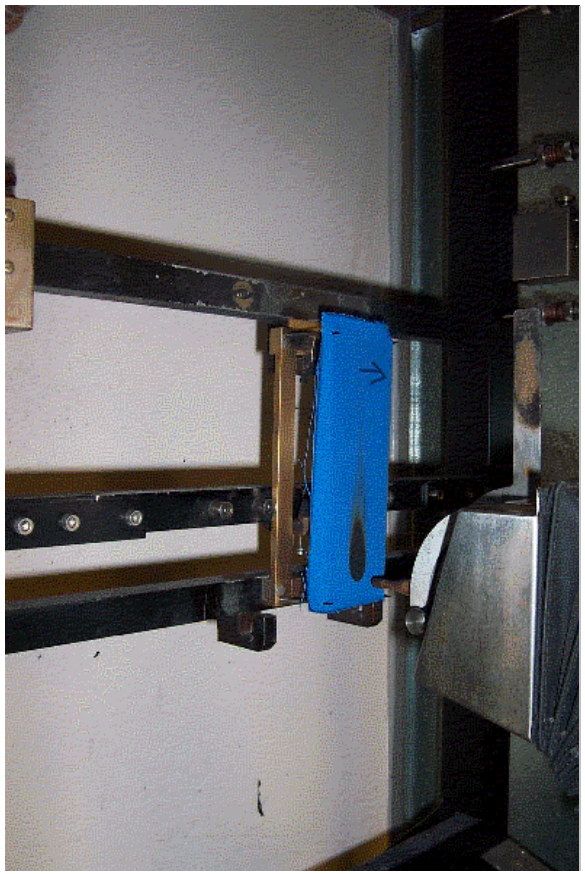
- Standards and testing are vital in ensuring that the flammability performance of a fabric is satisfactory for a specific end-use
- Flammability testing must be carried out in accredited test laboratories using recognised flammability test methods
- There are a range of national and international flammability standards

Flammability Standards and Testing

Protective Clothing (woven & or knitted) for use in the European Community
EN 533: 1997 Index 3, EN 531: 1995 para 6.2.2 EN 470: Part 1: 1995 para 6.1 after 50 washes at 75°C (according to EN 10528 Standard wash).
UK Sheeting & Blankets
BS7175 Ignition sources 0, 1 & or 5 when tested on top of & or below the test fabric, after 200 washes at 74°C.
UK Curtaining
BS 5867 Part 2 Type B after 50 washes at 74°C.
Mattress Ticking
BS 7175 Ignition sources 0, 1& or 5 when tested on top of & or below the test fabric, after 3 washes at 74°C.
UK Upholstery
BS 5852 Part 1 Ignition sources 0 & 1 after a water soak treatment BS 5651.

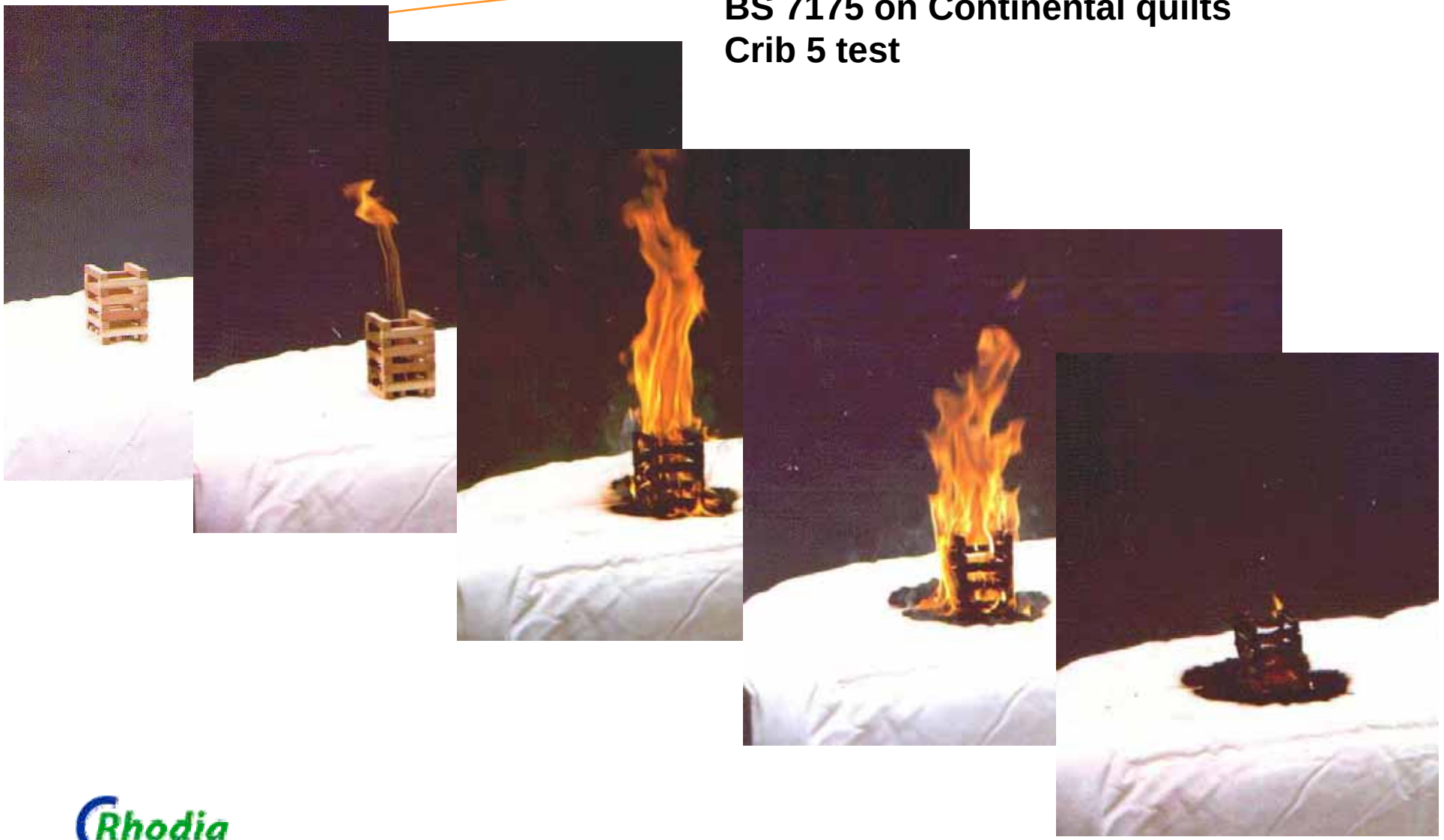
Flammability Standards and Testing

EN 532 standard for work wear



Flammability Standards and Testing

BS 7175 on Continental quilts
Crib 5 test



Flammability Standards and Testing

EN 348 standard for work wear

Flammability Standards and Testing

DOC FF3-71 standard for children's sleepwear

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HSE Considerations

- In recent years all chemicals are coming under increased scrutiny, especially halogen containing flame retardants
- Further pressure from REACH proposals (the **R**egistration, **E**valuation and **A**uthorisation of **Ch**emicals) in the EU due to become operational in spring 2007
- High customer expectation in terms of safety of chemical finishes
- Ecolabels such as Öko-Tex (or Blue Angel) whereby the endorsement confers safe toxicological and environmental profiles of the relevant chemicals

Conclusions

- Ever increasing pressure on chemical manufacturers to produce finishes which have a good tox and environment profile, and are cost and performance effective
- General move away from halogen containing flame retardants
- Challenge for the future will be to develop more efficient flame retardant finishes in terms of application and also performance
- Also multi-function finishes for textiles where flame retardant performance is imparted along with other properties, e.g. antimicrobial, soil/stain resist

- Reference: R Padda and G Lenotte, General Trends in Textile Flame Retardants, Speciality Chemicals Magazine, 2005, 43-44.

The End