Bolton?

Textiles?

Technical Textiles?

Samuel Crompton?

(1753-1827)

“Most significant inventions that drove the textile industry in the 18th, 19th and 20th Centuries were invented within a 20 mile radius of Bolton!”
Cotton mules were manufactured from ~1790 until the 1930s:

Fine spinning mule makers of Bolton:

Dobson and Barlow
Richard Threlfall
Industrial Synergies

• **Cotton textiles**
• Engineering/machinery manufacture
• Chemicals
• Transport

All required “industrial textiles”:
• Ropes
• Strappings/webbings
• Drive belts
• Filter fabrics
• Packaging (eg sackcloths)
• Industrial clothing
Timelines:

1750 – 1850
Textile inventions plus factory system; Industrial growth/complexity

1850 – 1914
Organic chemistry
Viscose fibre
Lancs Textile Industry matures

1918-1939
Post war boom
Depression
Nylon!

1945 – 1970s
Synthetic fibre monopoly
Consolidation of traditional textiles

1970s – late 1990s
Patents expire
Industry moves East: CHINA!

1990s – present
Break up of “majors”
Technical textiles!

Industrial Textiles → Technical Textiles (including composites)
Technical Textile Industry in NW England

- One of largest in World
- ~£1.5 billion pa

2nd editions 2015 & 2016
Technical textiles are present in most manufacturing supply chains:

- Construction
- Personal Protective Equipment (PPE)
- Chemical
- Automotive
- Aerospace
- Marine
- Rail

Many require Fire and Heat Resistant properties
Major Fire & Heat Resistant Technical Textile Applications

- Contract and Domestic Furnishings
- Protective Clothing
- Transport
  - Aircraft
  - Ships
  - Trains
  - Cars/coaches

Driven by Fire Safety Regulation and/or legislation
“9/11” – a textile-fuelled fire?
Flammability of Textiles (& hence fire loads) are determined by:

- Ease of ignition
- Rate of burning
- Energy (heat) release rate
- Production of protective layer (char)
- Toxicity of fire gases
- Smoke evolution
Total combustion

Fibre/polymer → CO₂ + H₂O + non-flammable gases

Pyrolysis, T_p °C

Oxidation and ignition, T_i °C

Char + Flammable volatiles and gases + Non-flammable gases
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Major Fire & Heat Resistant Technical Textile Applications

• Contract and Domestic Furnishings

• Protective Clothing

• Transport
  • Aircraft
  • Ships
  • Trains
  • Cars/coaches
Char formation: FR Cotton® vs Nomex®

BS5438: 10s ignition

Proban-treated cotton

Nomex®
Flame and heat resistant Fibres!

PROBAN
PYROVATEX
Lenzing FR
Basofil™
Nomex® III
PBI Fabrics
That battle the heat and flames
Teijinconex
Aramid Fiber
Kevlar® Fibers
Char-forming Fire Retardant (FR) Fabrics for use up to 100°C continuously

**Applications:**

- Protective clothing: eg workwear
- Barrier fabrics
- Furnishings & interior textiles

**Typical fabrics/textiles:**

- FR cotton (eg Proban®, Pyrovatex®)
- FR wool (eg Zirpro®)
- FR viscose (eg Lenzing FR)
- FR acrylic (eg Kanecaron)
**High Performance Fire & Heat Resistant (F&HR) fabrics for use above 150°C continuously**

**Applications:**

- High performance protective clothing: eg firefighters’ kit
- Defence and emergency textiles
- High performance barrier composites: aerospace, surface vessels, transport

**Typical fabrics/textiles:**

- Meta-aramids (eg Nomex®, Teijinconex®, Kermel ®)
- Para-aramids (eg Kevlar®, Twaron®)
- Arimid (eg P84®)
- Novoloid (eg Kynol®)
- PBI (eg PBI®)
- PBO (Zylon®)
- Semi-carbon (Panox®)
- Carbon
- Ceramics (eg glass, Nextel®)
Major F & HR Technical Textile Applications (1)

• Contract and Domestic Furnishings

• Protective Clothing
  – UK Health & Safety at Work Act 1947
  – EU PPE Directive 1989
    • Workwear/corporate wear
      – Industrial
      – Welding/molten metal
      – Off-shore
      – Wild-fire fighting
      – Defence wear
FR Corporate and work wear: *to be worn during the whole working period:*

- Comfortable
- relatively lightweight
- durable to multi-laundering

Courtesy Carrington Workwear Ltd., & Solvay
Globally Compliant
Flame retardant workwear

PROBAN® workwear is available worldwide with accreditations to give protection against heat, flame and electric arc even against the toughest standards:

<table>
<thead>
<tr>
<th>PROTECTION AGAINST HEAT AND FLAME</th>
<th>PROTECTION AGAINST ELECTRIC ARC</th>
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</thead>
<tbody>
<tr>
<td><strong>Compliance</strong></td>
<td><strong>Compliance</strong></td>
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<tr>
<td>EN ISO 11612</td>
<td>RWE Eurotest</td>
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<td>EN ISO 14116</td>
<td>International Standard.</td>
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<td>NFPA 70E</td>
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<td>GOST 12.4.234-2012</td>
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<td>GOST 11209-85</td>
<td>Russia</td>
</tr>
<tr>
<td>GOST R 12.4.297-2013</td>
<td>Russia</td>
</tr>
</tbody>
</table>

Comply with all hazard risk categories.
- Lightweight woven garments with >37cal/cm² (HRC 3)
- 320gsm knitted garments with 25 EBT (HRC3)
Major F & HR Technical Textile Applications (2)

- Contract and Domestic Furnishings

- **Protective Clothing**
  - UK Health & Safety at Work Act 1947
  - EU PPE Directive 1989
    - Workwear/corporate wear
      - Industrial
      - Welding/molten metal
      - Off-shore
      - Wild-fire fighting
      - Defence wear
    - Emergency Services’ clothing systems
      - Air ambulance
      - Police
      - **Firefighter**
100 Years of Fabric Evolution
Firefighters’ Clothing: A “System”
Instrumented Manikin (eg DuPont Thermoman ®) for Testing Protective Clothing Fire Performance:

*Flame source*

$84kWm^{-2}$

Manikin torso records areas experiencing $1^{st}$, $2^{nd}$ & $3^{rd}$ degree burns

*(BS ISO 13506:2008)*
Instrumented Manikin (eg DuPont Thermoman ®) for Testing Protective Clothing Fire Performance:

*Flame source 84kWm$^{-2}$*

Manikin torso records areas experiencing $1^{st}$, $2^{nd}$ & $3^{rd}$ degree burns
Instrumented Manikin (eg DuPont Thermoman ®) for Testing Protective Clothing Fire Performance:

Flame source $84\text{kWm}^{-2}$

Manikin torso records areas experiencing $1^{\text{st}}$, $2^{\text{nd}}$ & $3^{\text{rd}}$ degree burns
Reduction of Heat Stress by moisture and heat transfer
Reducing Heat Stress

Design That Saves

Nomex face
Kevlar back
Moisture Barrier
Liner
Skin

Open outershell layer optimises breathability, reducing the risk of heat stress
Major F & HR Technical Textile Applications (3)

- Contract and Domestic Furnishings

- **Protective Clothing**
  - UK Health & Safety at Work Act 1947
  - EU PPE Directive 1989
    - Workwear/corporate wear
      - Industrial
      - Welding/molten metal
      - Off-shore
      - Wild-fire fighting
      - Defence wear
    - Emergency Services’ clothing systems
      - Air ambulance
      - Police
      - Firefighter
    - Specialist clothing
      - Motor sports
Racing Car Driver’s Suit: the complete clothing system

“…drivers in an overall made of Nomex® fibre can survive for 11 seconds in temperatures of 840 °C”
Major F & HR Technical Textile Applications (4)

- Contract and Domestic Furnishings
- Protective Clothing
- **Transport**
  - Aircraft
  - Ships
  - Trains
  - Cars/coaches
Engine insulation
Nextel™ Ceramic Textiles
Products for high temperature applications
Main Structural components (composites)
- Internal walls, bulkheads, floors
- Seats

C fibre structural composite ~ 50:50 fibre:resin

Engine insulation
Airframes

**Airbus 380**: the 25% Carbon-composite-framed aircraft for lightness; hence capacity and fuel efficiency
Air-frames

Boeing “Dreamliner” is ~50% carbon composite

25% textile!
C-fibre prepregs and composites

**NEWS: 19/01/2004 - LOS ANGELES, CA, USA**

HITCO Carbon Composites, Inc. (HITCO), an affiliate of SGL Carbon Group (NYSE: SGG - News), today celebrated the delivery of the first operational ship set of the carbon fiber tail structure parts for the vertical tail plane of the Airbus A380.
Aircraft Seatings & Interior Décor (FAR 25.853 (c))

120 kW/m² for 2 minutes
All internal panels including external décor (walls, flooring, ceilings, etc.,) must pass the “OSU 65/65 test (FAR 25.853 Pt IV, App F)”!!
Woven or knitted fabric reinforced “honeycomb” panel for **walls, ceilings and floors**.

Eg. Glass fibre/phenolic or Aramid fibres/polyimide resin
Heat release rate test for cabin materials: “The OSU calorimeter test” (FAR 25.853 Pt IV, App F)

- Vertical specimen, 150 x 150 mm
- Fixed Heat Flux: 35 kW m⁻²
- Gas flame ignition of volatiles

<table>
<thead>
<tr>
<th>Run</th>
<th>Peak (kW/m²)</th>
<th>Peak Time (sec)</th>
<th>2 min Total (kW*min/m²)</th>
<th>Initial Baseline (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33.1</td>
<td>30</td>
<td>26.6</td>
<td>24.2</td>
</tr>
<tr>
<td>2</td>
<td>29.5</td>
<td>32</td>
<td>23.8</td>
<td>24.4</td>
</tr>
<tr>
<td>3</td>
<td>36.5</td>
<td>37</td>
<td>23.0</td>
<td>24.6</td>
</tr>
<tr>
<td>Average</td>
<td>33.0</td>
<td>33</td>
<td>24.8</td>
<td>24.4</td>
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<tr>
<td>Stdev</td>
<td>3.50</td>
<td></td>
<td>1.89</td>
<td>0.20</td>
</tr>
</tbody>
</table>

≤ 65 kW/m²
Fuselage insulation

Manchester Airport 1985
Fuselage Insulation: Acoustic & Fire

Fibrous structure-bag composite
Fuselage Insulation: Acoustic & Fire
(FAR 25.856(b) Appendix F, Part VII)

Burner heat flux
= 180 kW m\(^{-2}\)

Cal’r Output:
< 23 kW m\(^{-2}\) in less than 240s

Fabric/bag assembly
Burner heat flux = 180 kW m$^{-2}$
240 s

≤ 23 kW/m²
Major F & HR Technical Textile Applications (3)

- Contract and Domestic Furnishings
- Protective Clothing
- Transport
  - Aircraft
  - Ships
Ships, commercial, naval and pleasure:

- Similar textile solutions as seen in aircraft
  - Fibre-reinforced composite hulls
  - Fibre-reinforced composite bulkheads
  - Fibre-reinforced composite superstructures
- Flame resistance requirements defined by International Maritime Organisation (IMO)
- Internal structures and furnishings require defined levels of flame retardancy
Norwegian Navy All-composite Corvette
Vosper Thornycroft’s new generation of patrol vessels
Welcome Aboard! – but level of hazard increases with number of passengers!!!

“Queen Mary 2” & “Mariner of the Seas”

UK Brinton’s Carpets Ahoy!
Hazards of cruising!

MS Nordlys, 15 September 2011

Royal Carribean (Freedom of the Seas) fire: 22 July 2015
Major F & HR Technical Textile Applications (3)

• Contract and Domestic Furnishings
• Protective Clothing

• Transport
  • Aircraft
  • Ships
  • Trains

3rd Jan 2013, Schiphol Airport
Trains

• Innovations in aerospace are taken up by modern railway authorities:
  – Composite rolling stock structures
  – Seating and furnishings
  – Barrier & insulation fabrics
Virgin’s Pendolino UK train sets

Tech Textile Presence:
• Composite body parts
• Insulation
• Seatings
• Floorcoverings

• Glass / Unsaturated polyester or Vinyl ester
• Thick laminates
Major F & HR Technical Textile Applications

• Contract and Domestic Furnishings
• Protective Clothing
• **Transport**
  • Aircraft
  • Ships
  • Trains
• **Cars/coaches**
Textiles in cars

Cars: Typical textile composite assemblies

- **Seating fabrics**: polyester
- **Carpet surface fabric**: polypropylene or polyester
- **Roofliners**: polyester
- **Floor composites**: PP or PA6 surface tuft on PP scrim, resin (LDPE)-bonded to underlying nonwoven fibrous acoustic layer

All interior textiles must pass a basic flammability test: FMVSS302
Major **Fire & Heat Resistant** Technical Textile Applications

- Contract and Domestic Furnishings
- Protective Clothing
- Transport
  - Aircraft
  - Ships
  - Trains
  - Cars/coaches

**plus many more!**