

THE ROLE OF TECHNICAL TEXTILES IN FIRE PROTECTION

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University of Bolton,

Bolton, BL3 5AB, UK



SCI Levinstein Lecture

19th October 2016

“Most significant inventions that drove the textile industry in the 18th, 19th and 20th Centuries were invented within a 20 mile radius of Bolton !”

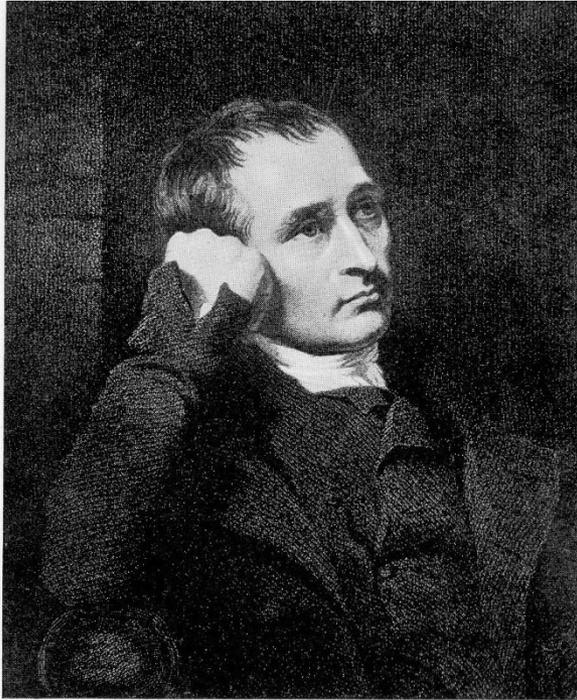
Bolton?

Textiles?

Technical Textiles?

Samuel Crompton?

(1753-1827)



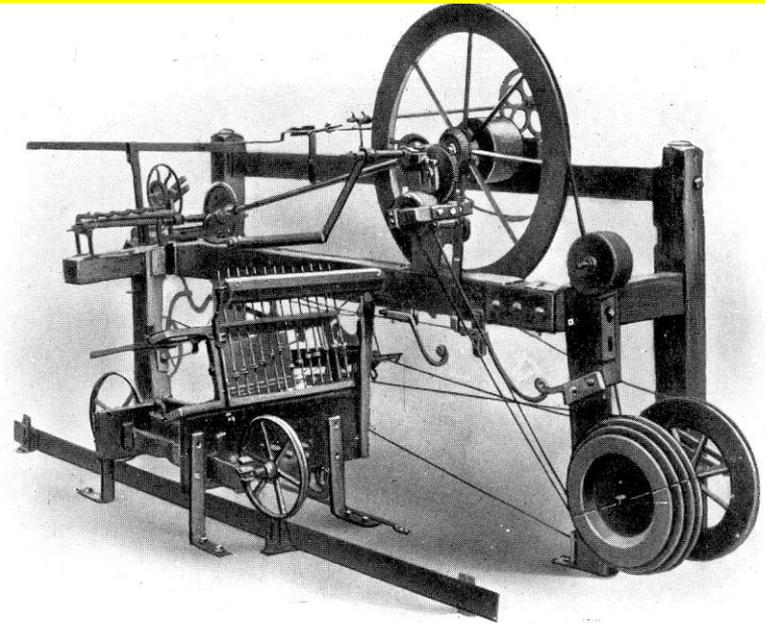
Sam. Crompton

1753-1827.

**Cotton mules were manufactured from
~1790 until the 1930s:**

Fine spinning mule makers of Bolton:

**Dobson and Barlow
Richard Threlfall**



CROMPTON'S SPINNING MULE.

THE MACHINE IS THE PROPERTY OF DOBSON AND BARLOW, LTD.

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

1918-1939

Post war boom
Depression
Nylon!

1970s – late 1990s

Patents expire
Industry moves East:
CHINA!

Industrial Textiles



Technical Textiles (including composites)

**Before
1750**
Cottage
Industry

1850 – 1914

Organic chemistry
Viscose fibre
Lancs Textile
Industry matures

1945 – 1970s

Synthetic fibre
monopoly
Consolidation of
traditional
textiles

1990s – present

Break up of
“majors”
**Technical
textiles!**

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



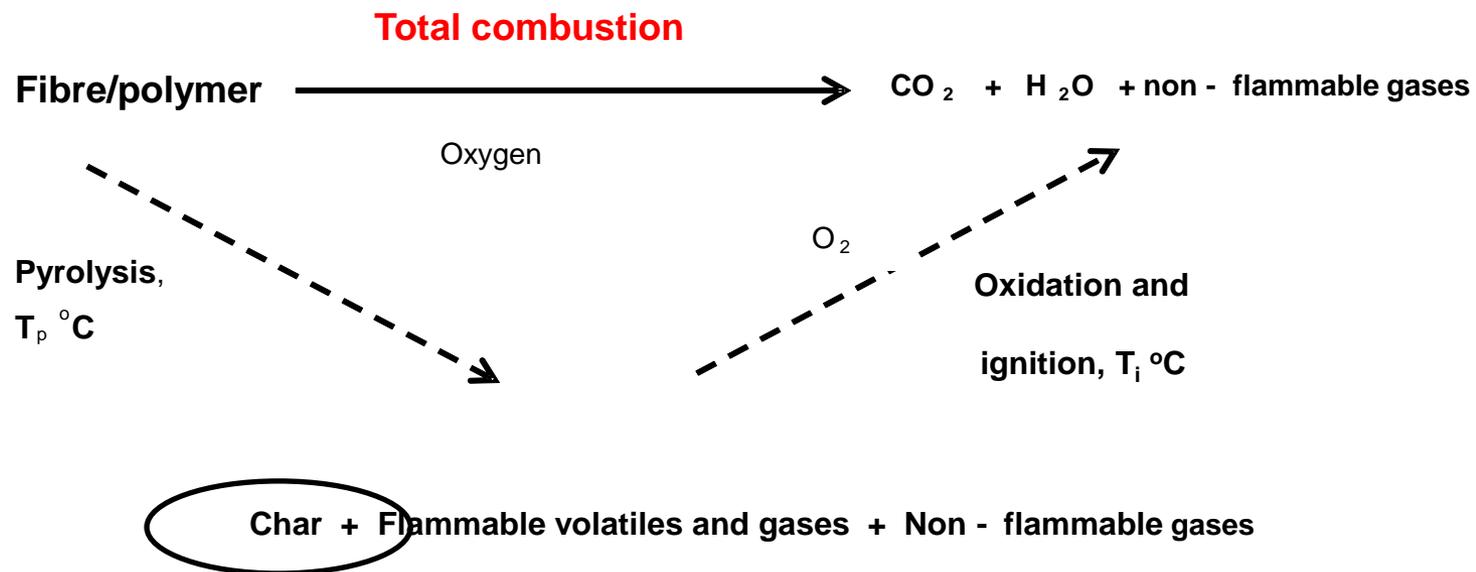
**Driven by Fire Safety
Regulation and/or
legislation**

**“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**



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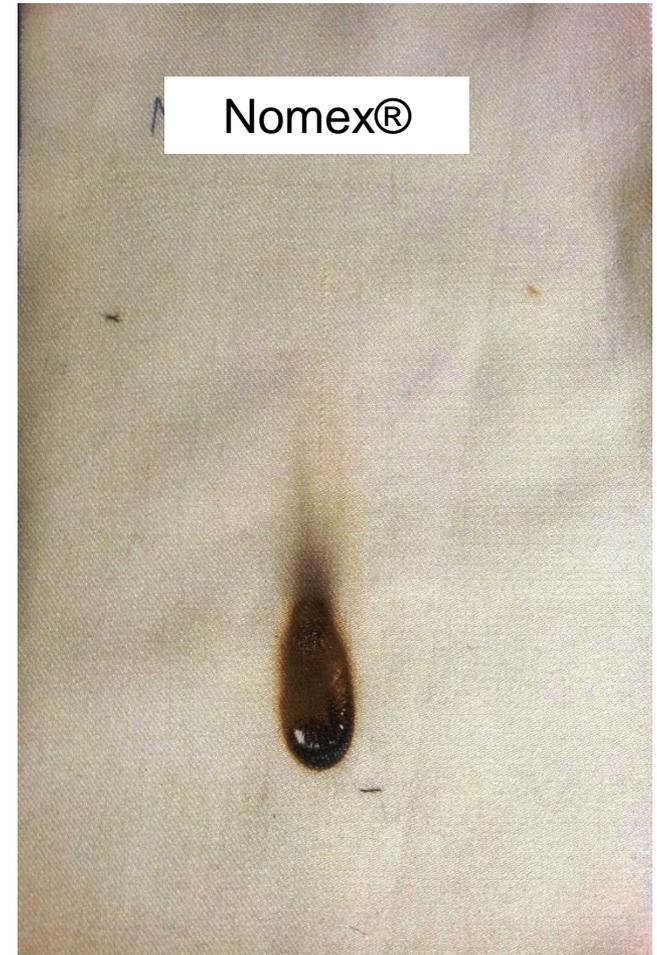
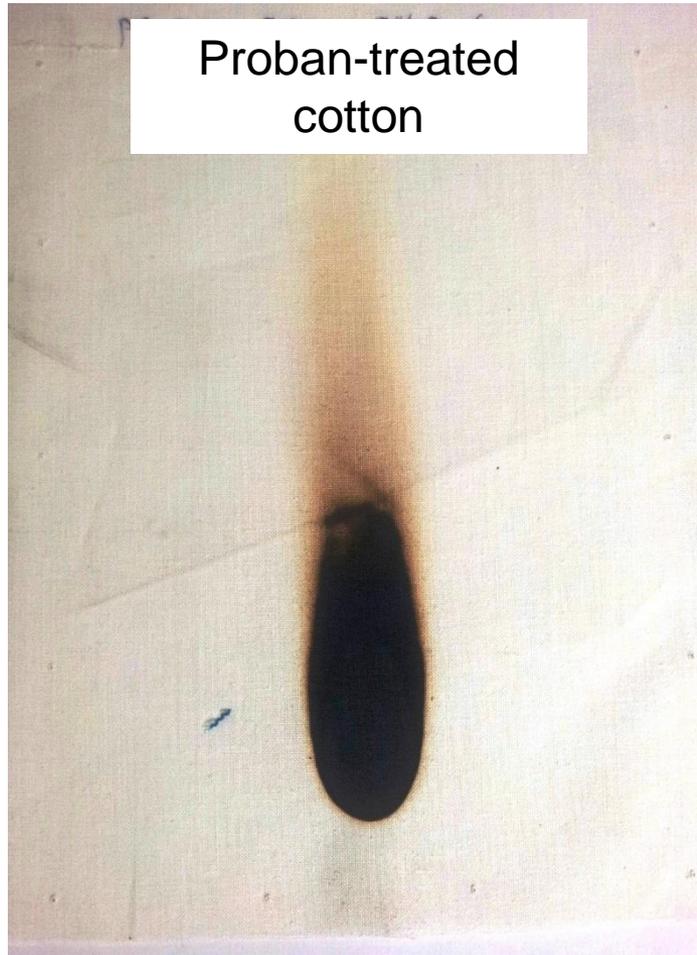
Major Fire & Heat Resistant Technical Textile Applications

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

Char formation: FR Cotton® vs Nomex®



BS5438: 10s
ignition



Flame and heat resistant Fibres!

PROBAN



 Lenzing FR[®]

 **Basofil**[™]
heat & flame resistant fiber

NOMEX^{*} III
aramid



PBI FABRICS
THAT BATTLE THE
HEAT AND FLAMES

TEIJINCONEX
ARAMID FIBER

Kevlar[®] Fibers

***Char-forming* Fire Retardant (FR) Fabrics for use upto 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



**Durable to
200+
laundering
cycles!!**

PROBAN®



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:

PROTECTION AGAINST HEAT AND FLAME

Compliance	Relevant countries
EN ISO 11612	International Standard.
ISO 6942	
EN ISO 14116	
AS/NZS ISO 2801:2008	Australia
CGSB 155.20	Canada
NFPA 2112	USA
ASTM F 1506	USA
GOST ISO 11612-2014	Russia
GOST 11209-85	Russia
GOST R 12.4.297-2013	Russia

PROTECTION AGAINST ELECTRIC ARC

Compliance	Relevant countries
RWE Eurotest	Customer Specific
IEC 614821	International Standard.
NFPA 70E	USA
AS/NZS 4836:2011	Australia
GOST 12.4.234-2012	Russia

Comply with all hazard risk categories.

- Lightweight woven garments with $>37\text{cal/cm}^2$ (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



HAINSWORTH
TECHNOLOGY

Firefighters' Clothing: A "System"



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

***Flame source
84kWm⁻²***

**Manikin torso records areas
experiencing 1st, 2nd & 3rd
degree burns**

(BS ISO 13506:2008)



Instrumented Manikin (eg DuPont Thermoman ®) for Testing Protective Clothing Fire Performance:

Flame source
 $84kWm^{-2}$

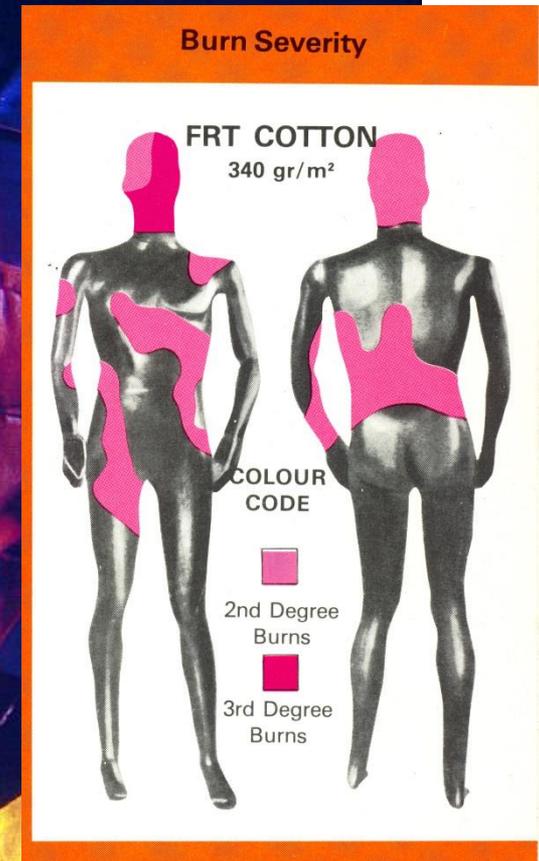
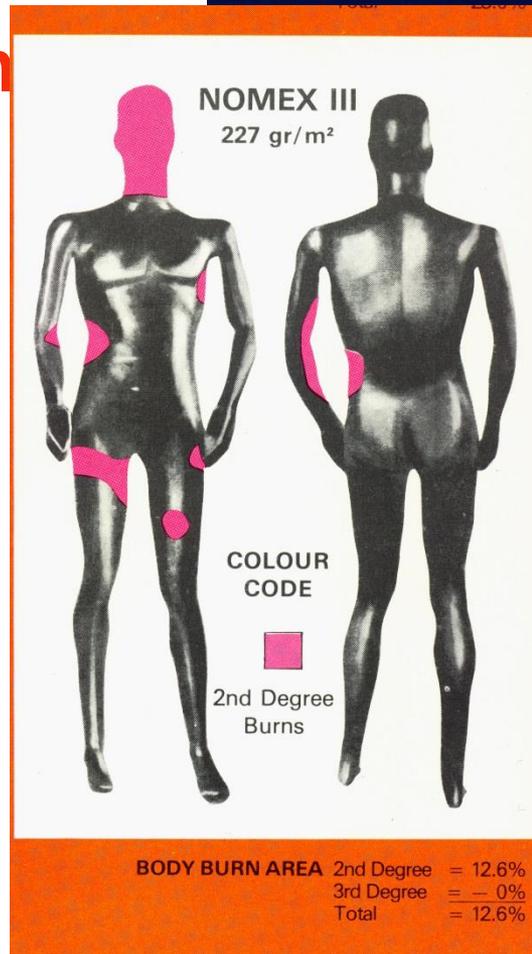
Manikin torso records areas
experiencing **1st, 2nd & 3rd**
degree burns



Instrumented Manikin (eg DuPont Thermoman[®]) for Testing Protective Clothing Fire Performance:

Flame source
84kWm⁻²

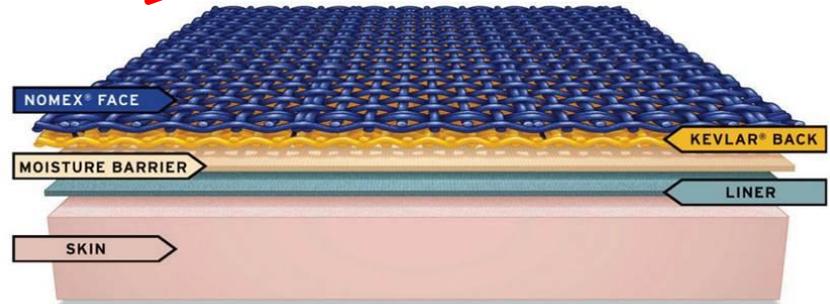
Manikin torso records areas experiencing **1st, 2nd & 3rd degree burns**



2005 Positioning Fibres



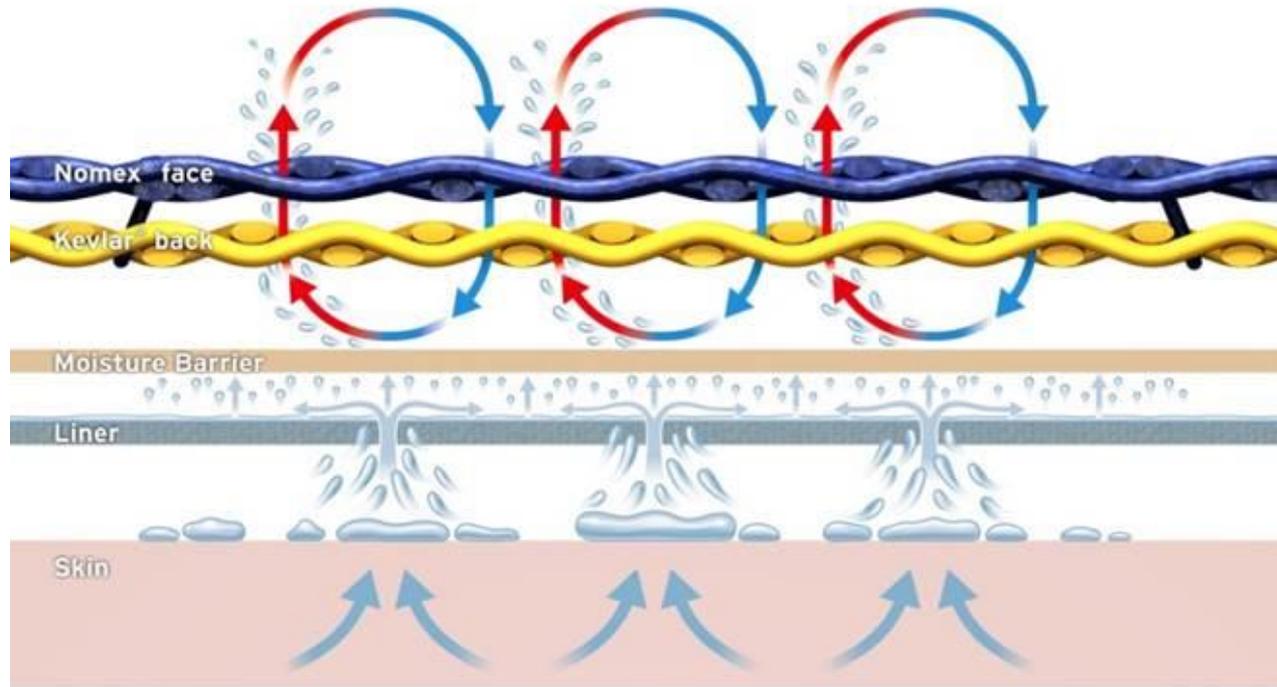
PATENTED
FABRIC DESIGN



Reduction of **Heat Stress**
by
moisture and **heat**
transfer

Reducing Heat Stress

Design That Saves



Open outershell layer optimises breathability, reducing the risk of heat stress



HAINSWORTH
TECHNOLOGY

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**

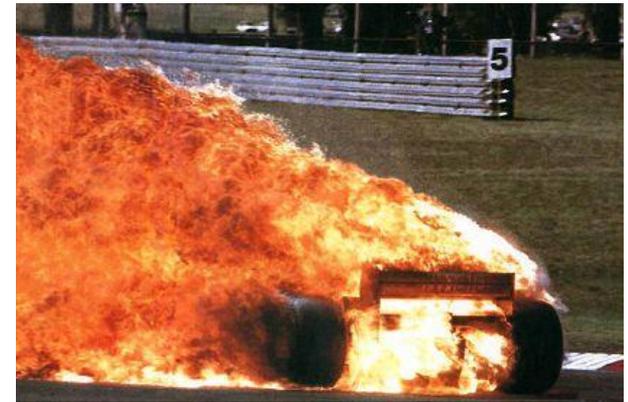
Racing Car Driver's Suit: the complete clothing system

FR & HR
Properties
2-4 fabric
layers



NOMEX
DUPONT

“...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



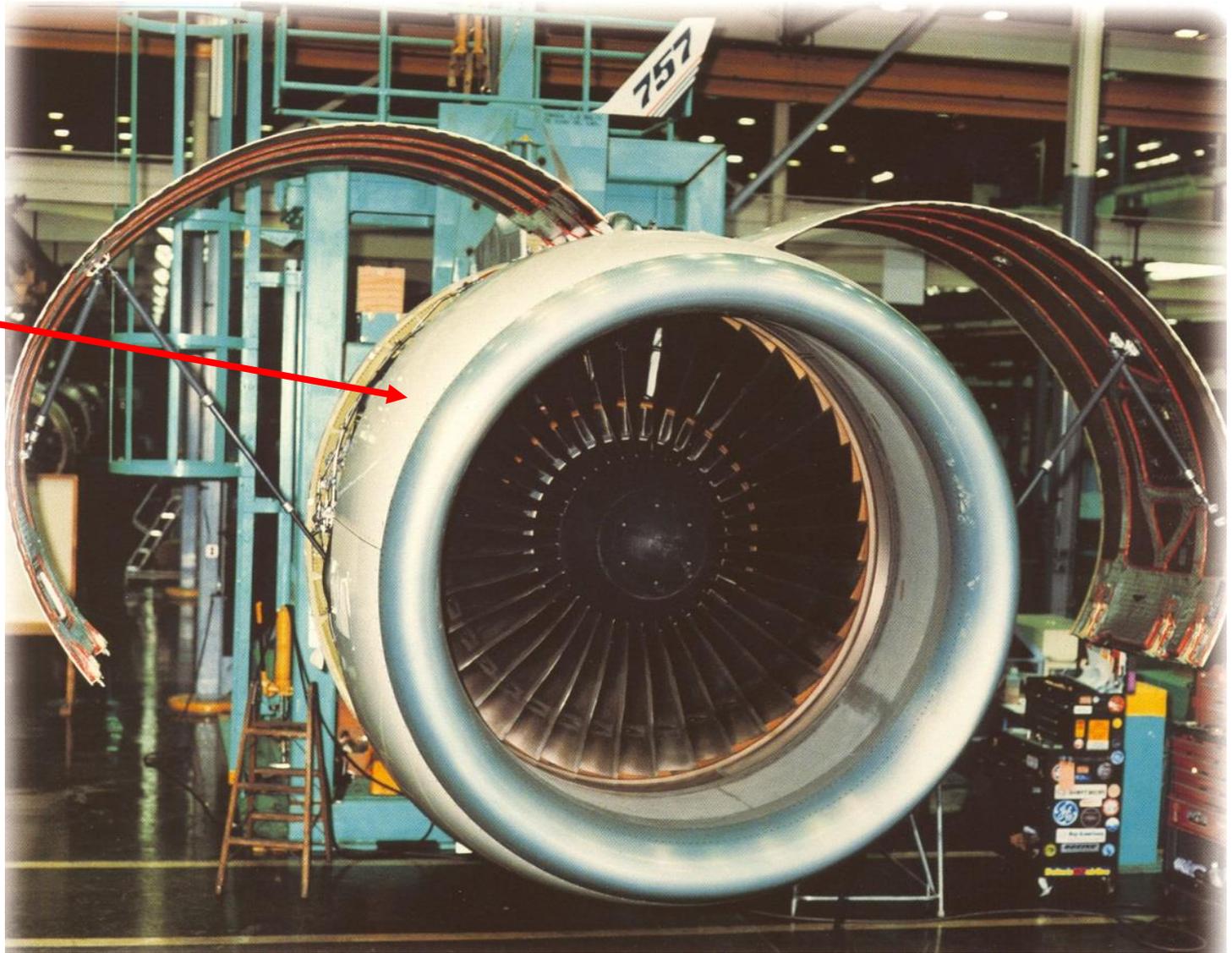
**Engine
insulation**

3M

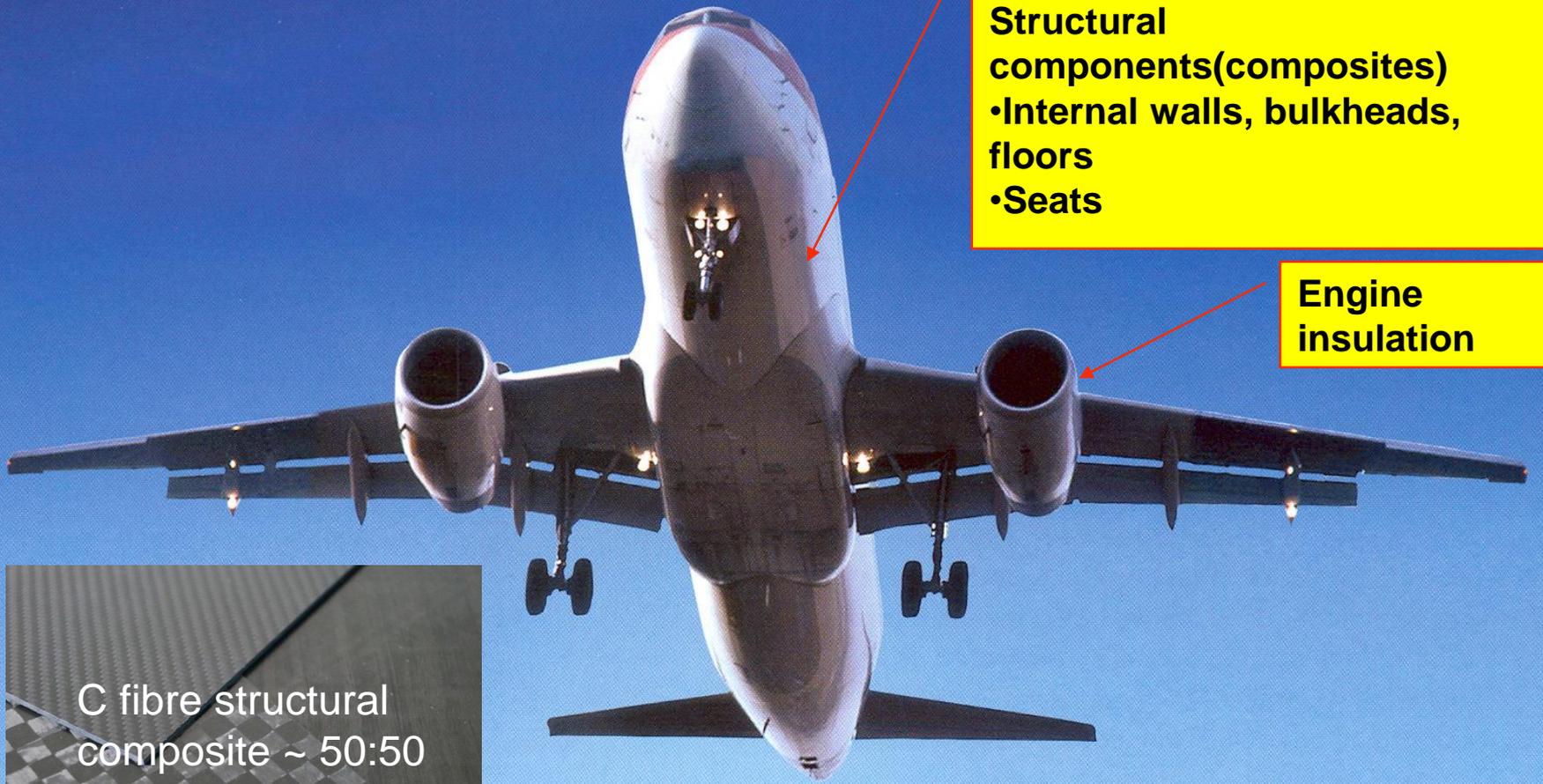
Nextel™ Ceramic Textiles

Products for high temperature applications





Insulation



- Main Structural components(composites)
- Internal walls, bulkheads, floors
- Seats

Engine insulation

C fibre structural composite ~ 50:50 fibre:resin

Air-frames

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



Air-frames



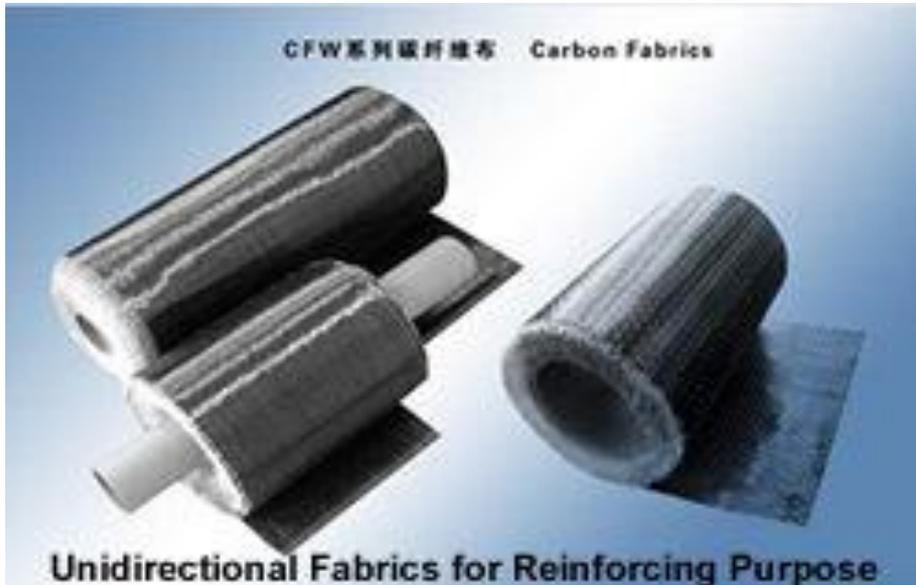
Boeing "Dreamliner" is ~50% carbon composite



25% textile!



C-fibre prepregs and composites



A380 waste tank

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))

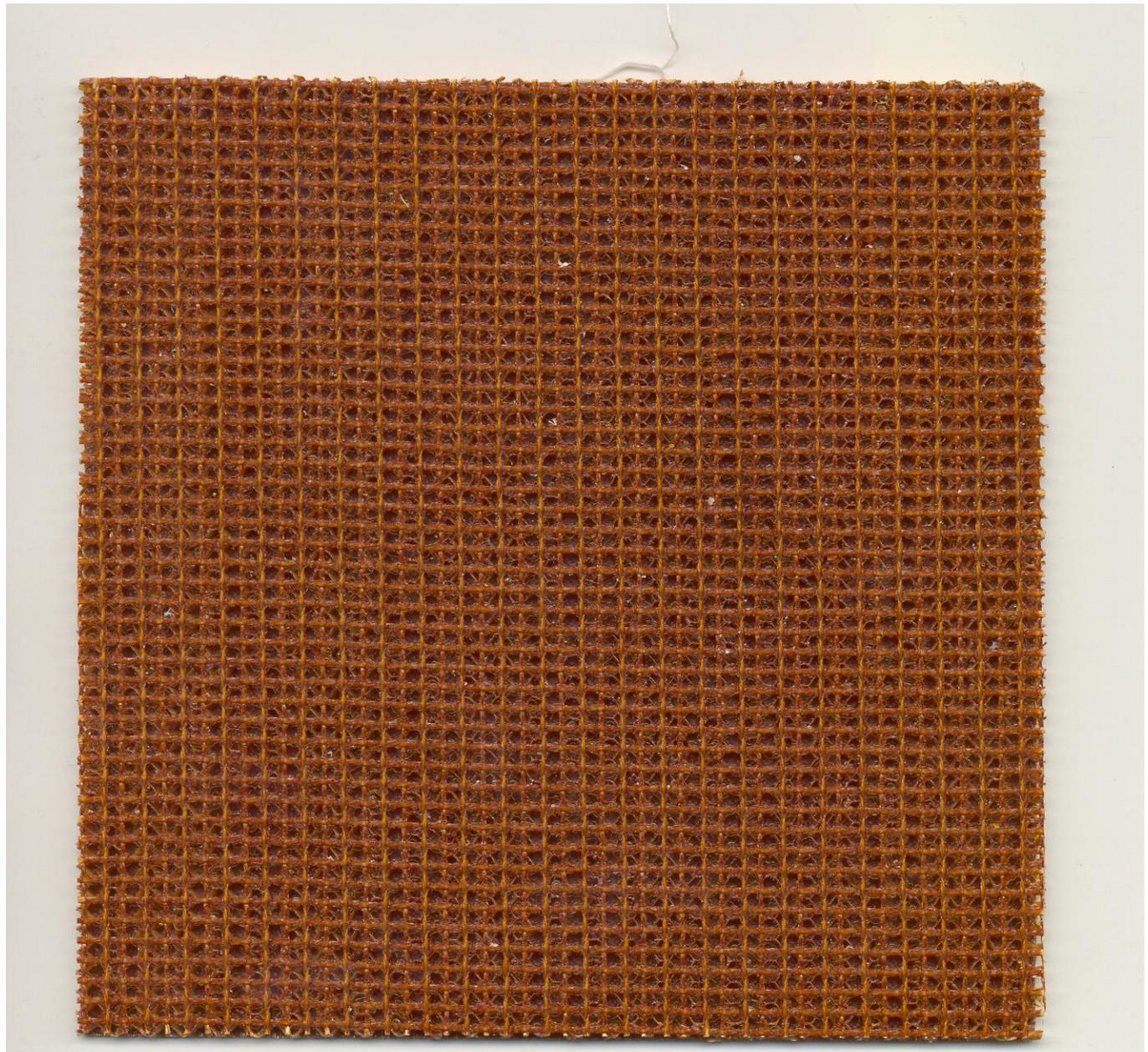


All internal panels including external décor (walls, flooring, ceilings, etc.,) must pass the “OSU 65/65 test (FAR 25.853 Pt IV, App F)”!!

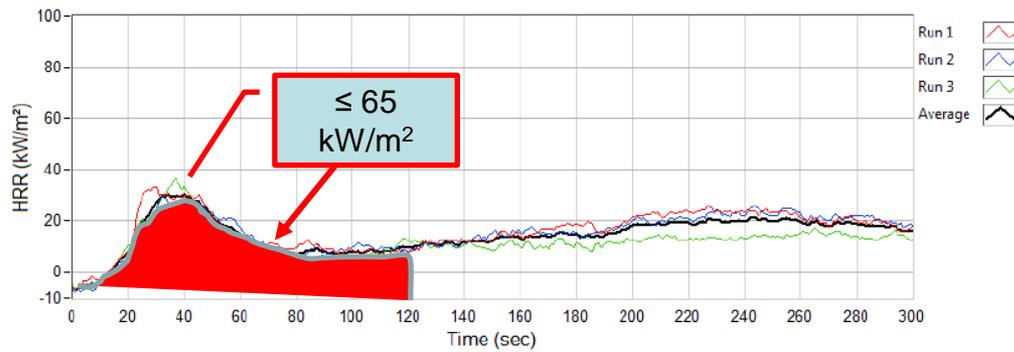


**Woven or knitted
fabric reinforced
“honeycomb”
panel for walls,
ceilings and
floors.**

**Eg. Glass
fibre/phenolic
or
Aramid
fibres/polyimide resin**



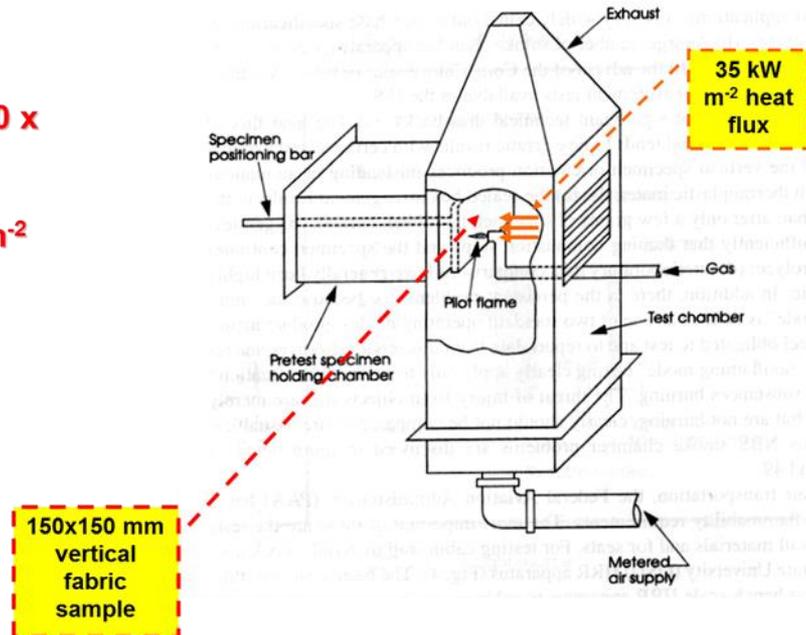
Heat release rate test for cabin materials: “The OSU calorimeter test” (FAR 25.853 Pt IV, App F)



Run	Peak (kW/m ²)	Peak Time (sec)	2 min Total (kW*min/m ²)	Initial Baseline (mV)
1	33.1	30	26.6	24.2
2	29.5	32	23.8	24.4
3	36.5	37	23.0	24.6
Average	33.0	33	24.5	24.4
Stdev	3.50		1.89	0.20



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

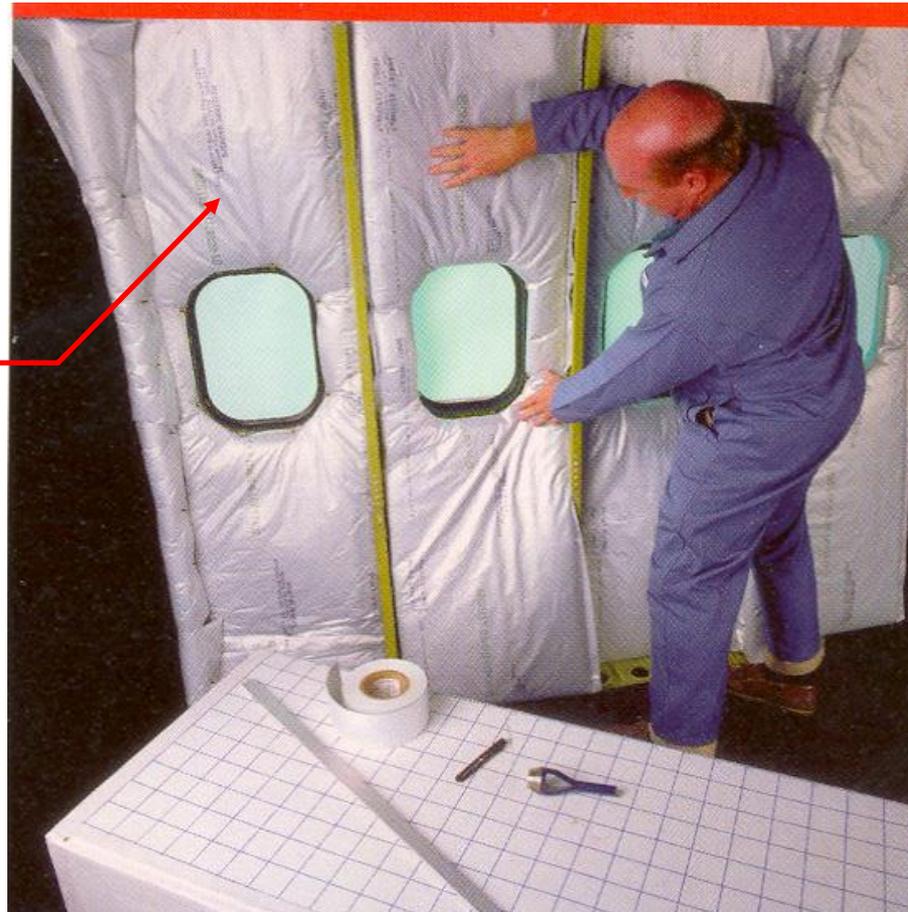


**Fuselage
insulation**

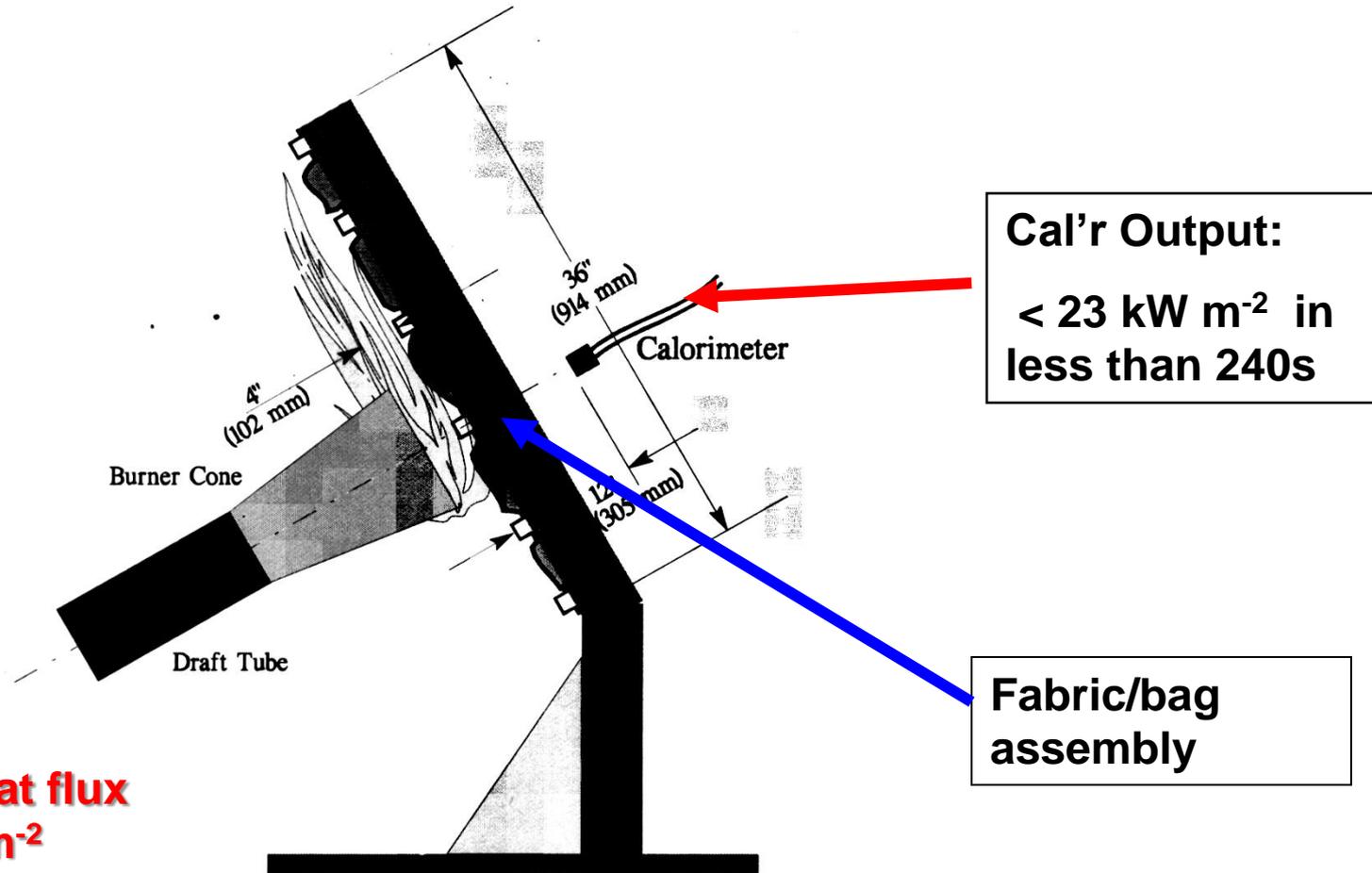


Fuselage Insulation: Acoustic & Fire

**Fibrous
structure-bag
composite**



Fuselage Insulation: Acoustic & Fire (FAR 25.856(b) Appendix F, Part VII)

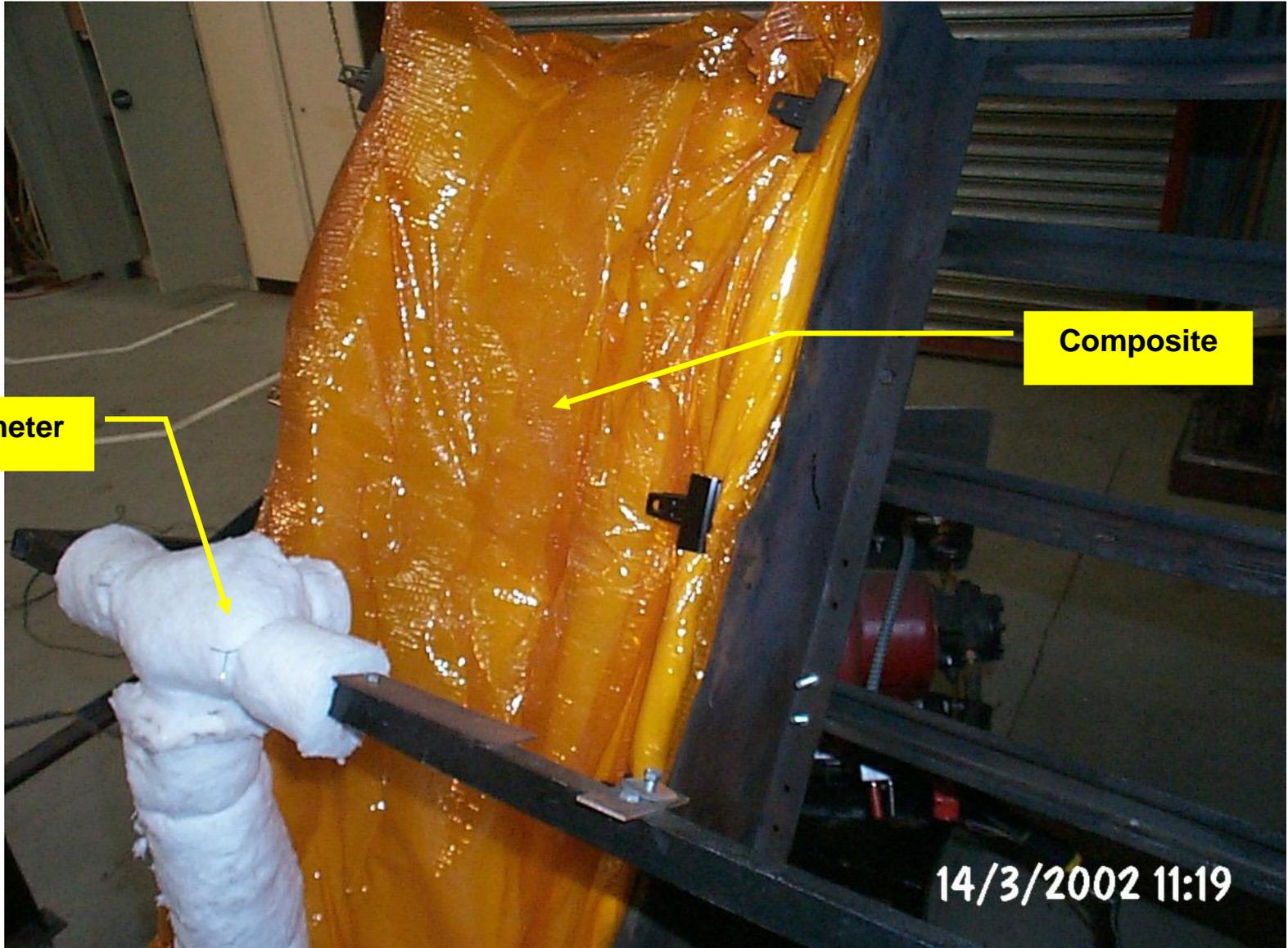


**Burner heat flux
 $\approx 180 \text{ kW m}^{-2}$**

Cal'r Output:

**$< 23 \text{ kW m}^{-2}$ in
less than 240s**

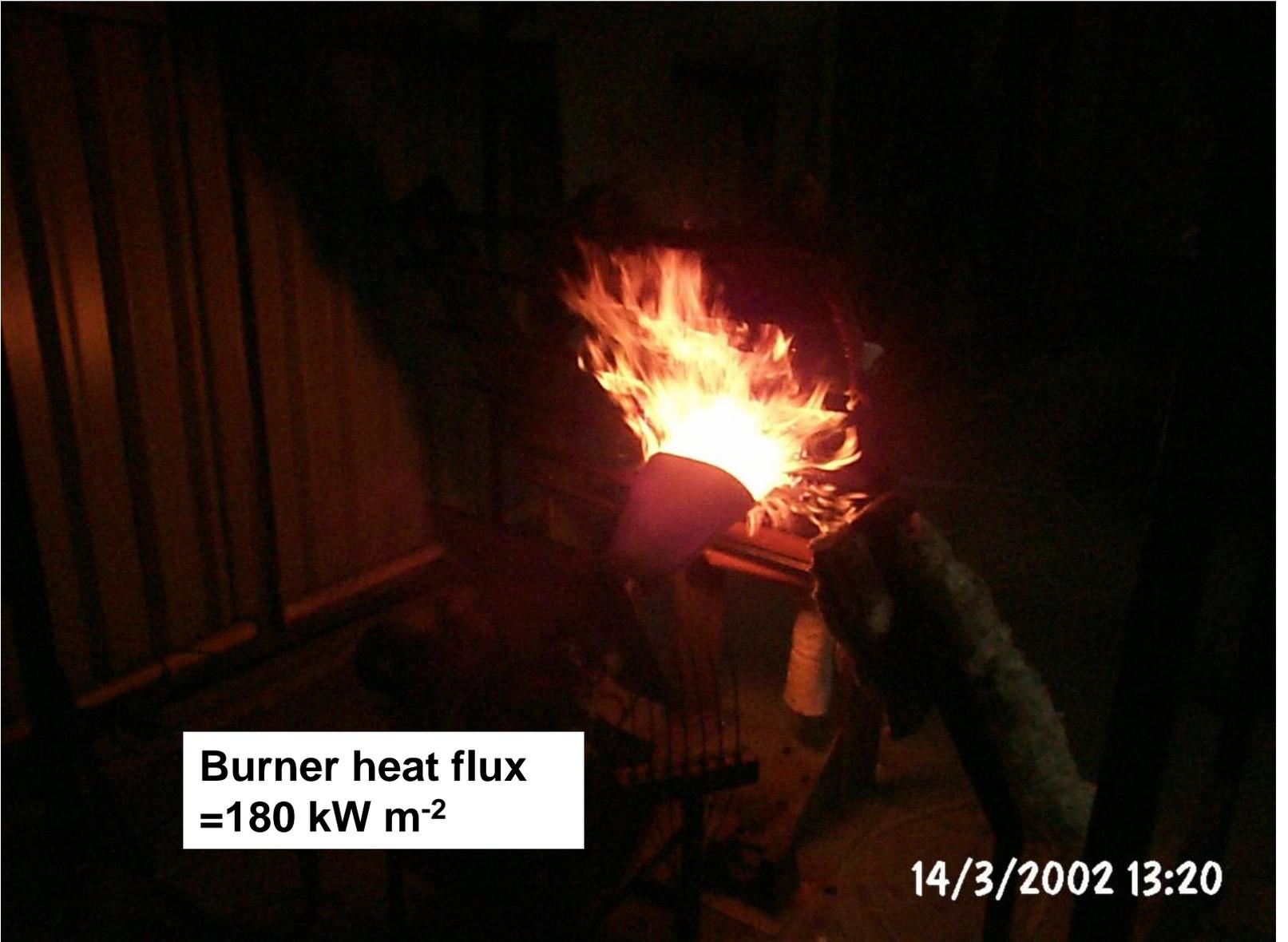
**Fabric/bag
assembly**



Calorimeter

Composite

14/3/2002 11:19

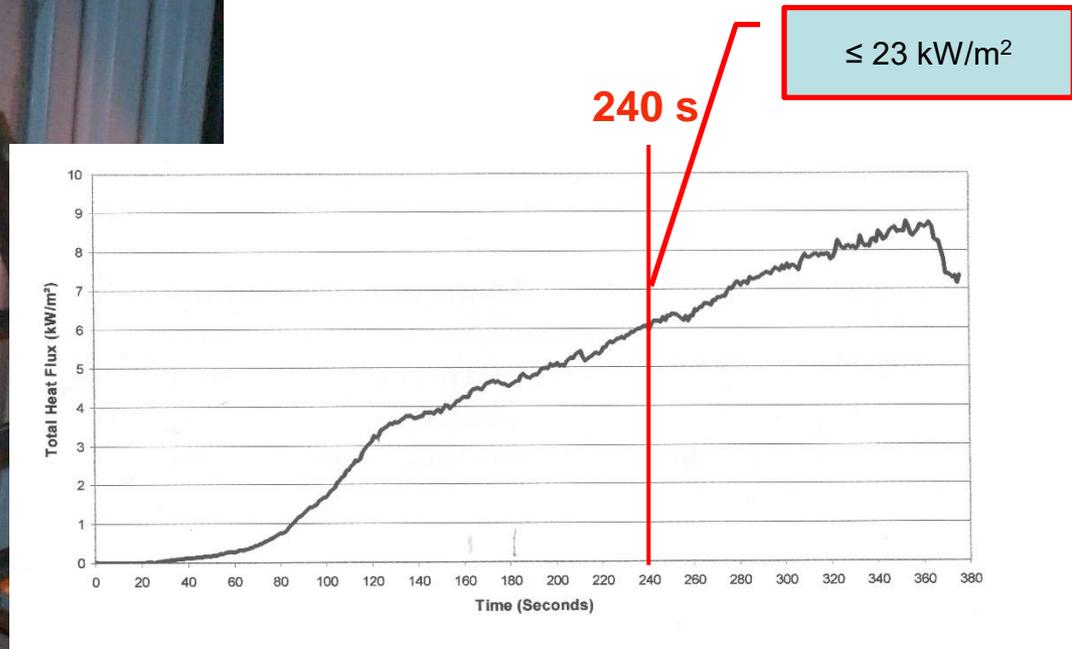
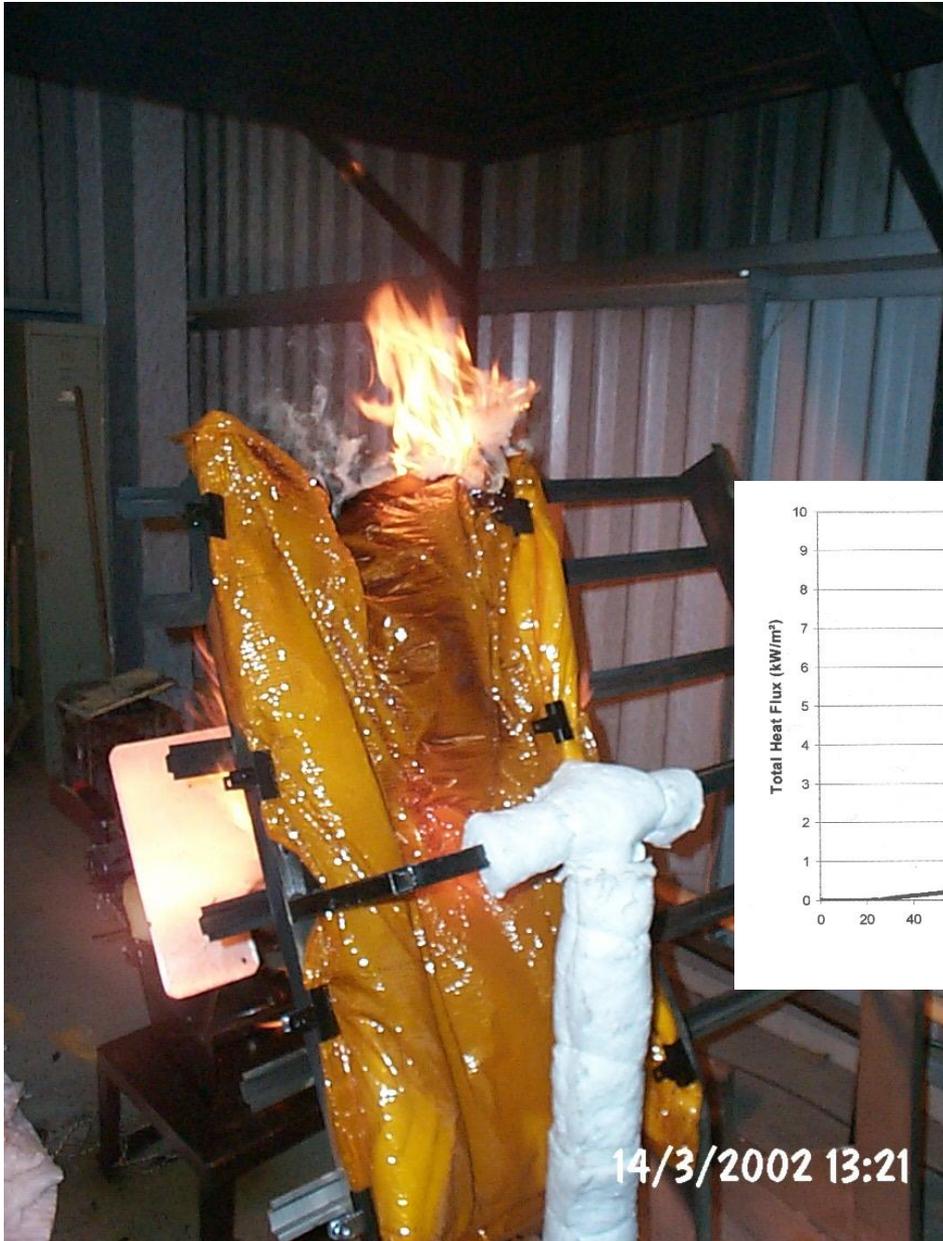
A photograph showing a burner with a large, bright orange and yellow flame. The burner is positioned in a dark room, and the flame is the primary light source. The burner itself is a dark, cylindrical object. The background is mostly black, with some faint vertical lines on the left side, possibly from a window or a wall panel. The overall scene is dimly lit, with the flame providing the main illumination.

**Burner heat flux
=180 kW m⁻²**

14/3/2002 13:20



14/3/2002 13:25



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

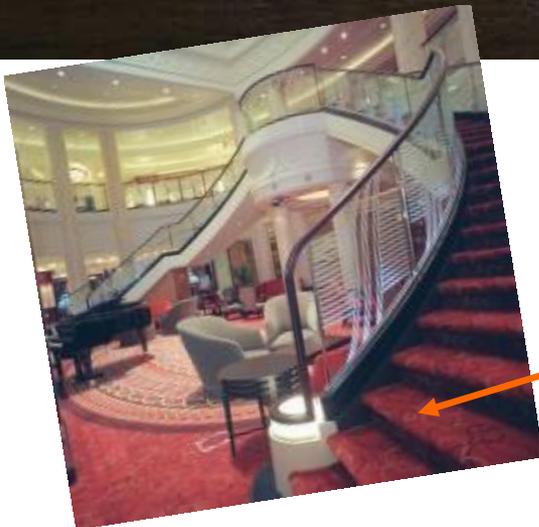
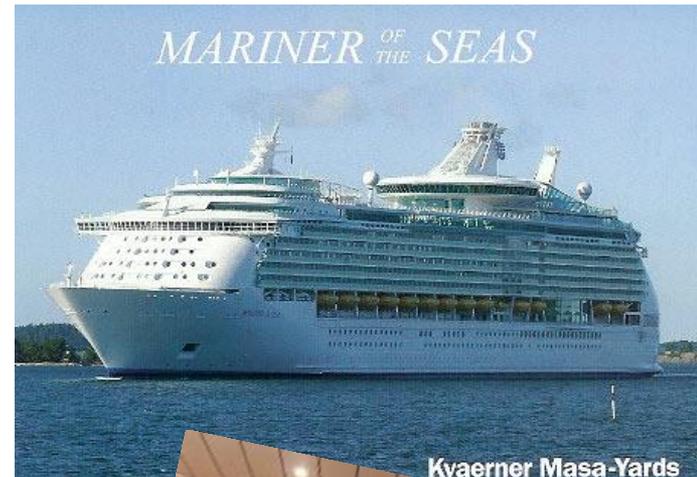


Welcome Aboard! – but level of hazard increases with number of passengers!!!

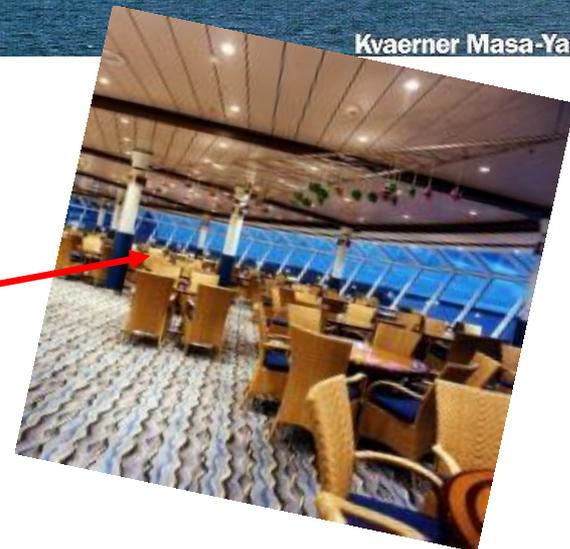
“Queen Mary 2”

&

“Mariner of the Seas”



UK
Brinton's
Carpets
Ahoy!





Hazards of cruising!

MS Nordlys, 15 September 2011



**Royal Caribbean
(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



Copyright : Phantasrail Galleries 2003



- Glass / Unsaturated polyester or Vinyl ester
- Thick laminates

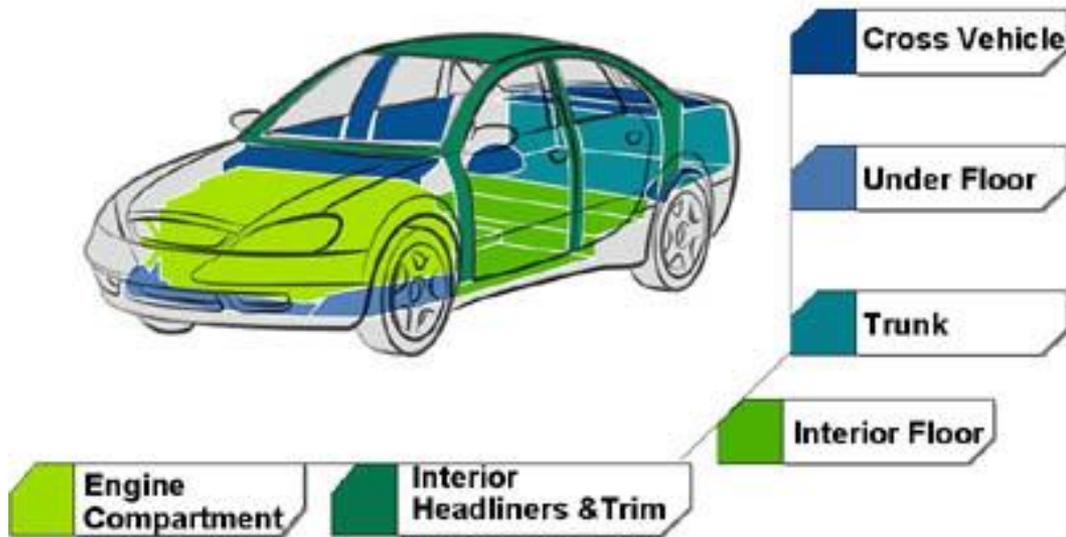
Major F & HR Technical Textile Applications

- 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!