

Institution: University of Bolton		
Unit of Assessment: B12 - Engineering		
Title of case study: Fire safe materials – enabling fire risk evaluation and performance enhancement of materials		
Period when the underpinning research was undertaken: 1 Jan 2000 – 31 Dec 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Baljinder Kandola A. Richard Horrocks	Professor Professor	1994 - present 1972 - December 2020
Period when the claimed impact occurred: 2014 - 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact (indicative maximum 100 words)		
<p>Foci of 'Fire and Materials' research at Bolton for last forty years have been fire safety, fire standards and development of fire safe materials. Engagement with industry, key stakeholders and research impact exemplified are: (1) enhanced fire and safety standards and Consumer Protection Codes of Practice for children's fancy dress outfits, (2) expert witness evidence in a \$20 million international patent dispute resulting in saving a company of 325 employees from bankruptcy and (3) technical support to industry in product development thus enhancing profitability. The overall impact of this research is the saving of lives and assets across society.</p>		
2. Underpinning research (indicative maximum 500 words)		
<p>The need for stringent fire standards and research into improving the flame retardancy of clothing has been a Fire Materials Group (FMG) focus since the 1980s. In 2004, with support from the British Burns Society and charitable funding [G1] we undertook a retrospective analysis of clothing-related fires by collating published and unpublished statistics. The major findings echoed that of previous concerns in the UK and the US in that those most at risk were young children and the elderly, with females accounting for 55% of the incidences and loose-fitting garments posing the highest risk. The study concluded that the impact of the 1985 UK Nightwear (Safety) Regulations has been minimal in influencing the various clothing fire statistics and clothing fires are one of the major concerns amongst dwelling fires and that nightwear and flowing garments are still the most vulnerable garment categories [1]. Using cone calorimetry, we were able to quantify and rank for the first time in an objective manner, the relative flammabilities of a number of different apparel fabrics, each of which would pass the current UK regulations [2]. This work created the expertise base, which enabled members to be sought after by organisations such as the BBC to provide expert evidence on clothing burn incidents (Impact 1).</p> <p>To develop fire safe materials, the research strategies adopted by FMG include: incorporation of reactive flame retardants (FRs) by in-situ polymerisation; nano/microparticulate additives into polymers by melt blending; and surface treatments. One example of the FRs relevant to this case study is the use of intumescent, with cellulosic fibres [3], resinated matrices (unsaturated polyester and epoxy) within fibre-reinforced composites [4], and thermoplastic fibre-forming polymers (G2,G3). In parallel, we have been working with commercial intumescent coatings used for steel structures, to quantify their thermal barrier efficiencies when applied on flammable polymer composites [5] and also developing new coatings [6], (G4,G5, G6). The outcomes of these projects included a number of publications and establishment of FMG's' international standing in this area. This expertise formed the basis of Impact 2, an international patent dispute</p>		

where expert evidence was produced by Horrocks. The patent validity and infringement of the US patent was at the centre of the lawsuit (USP 8,796, 162B, Aug 5 2014), and the FMG's earlier patent USP 5,645,926 A, 1997 was cited as a reference and in the bibliography, and of the ten "other publications", six were authored works by Horrocks and Kandola.

The group has subsequently built upon this research avenue by utilizing the novel chemistries of intumescent and other FR materials to help industrial partners develop new products in both textiles and composite areas. We also developed, unique, small scale experimental systems, which mirror the rigorous testing that such products now undergo to meet necessary safety and environmental standards. Furthermore, by studying the effect of heat and fire on mechanical properties degradation of the FR composites [4,5], (G7-G10), the FMG has established Bolton as the only centre of UK expertise in this area, which forms basis of Impact 3.

3. References to the research (indicative maximum of six references)

- [1] A.R.Horrocks, S.Nazare and B.Kandola, 'The Particular Flammability Hazards of Nightwear', *Fire Safety Journal*, 39, 259 -276 (2004). <https://doi.org/10.1016/j.firesaf.2003.11.005>
- [2] S.Nazare, B.Kandola and A.R.Horrocks, 'Use of Cone Calorimetry to Quantify the Burning Hazard of Apparel Fabrics', *Fire and Materials*, 26 (4-5), 191- 200 (2002). <https://doi.org/10.1002/fam.796>.
- [3] B.K.Kandola and A.R.Horrocks, 'Complex Char Formation in Flame-Retarded Fibre Intumescent Combinations - IV. Mass Loss Calorimetric and Thermal Barrier Properties', *Fire and Materials*, 24, 265-275 (2000). [https://doi.org/10.1002/1099-1018\(200011/12\)24:6%3C265::aid-fam747%3E3.0.co;2-e](https://doi.org/10.1002/1099-1018(200011/12)24:6%3C265::aid-fam747%3E3.0.co;2-e); V. Exploring Different Fibre/Intumescent Combinations', *Fire and Materials*, 25, 153-160 (2001). <https://doi.org/10.1002/fam.765>
- [4] B.K.Kandola, A.R.Horrocks, P.Myler and D.Blair, 'The Effect of Intumescent on the Burning Behaviour of Polyester-Resin-Containing Composites', *Composites Part A*, 2002, 33, 805. [https://doi.org/10.1016/s1359-835x\(02\)00026-x](https://doi.org/10.1016/s1359-835x(02)00026-x)
- [5] B.K Kandola, P.Luangtriratana, S.Duquesne and S.Bourbigot. The Effects of Thermophysical Properties and Environmental Conditions on Fire Performance of Intumescent Coatings on Glass Fibre-Reinforced Epoxy Composites. *Materials* 2015, 8, 5216-5237. <https://doi.org/10.3390/ma8085216>
- [6] P. Luangtriratana, B.K. Kandola and J.R. Ebdon. UV-polymerisable, phosphorus-containing, flame-retardant surface coatings for glass fibre-reinforced epoxy composites. *Progress in Organic Coatings*, 78, 73-82 (2015). <https://doi.org/10.1016/j.porgcoat.2014.10.004>

Grants

- [G1] A.R.Horrocks and B.K.Kandola, 'Identification and Prediction of Factors in Children's Clothing Responsible for Increasing Burn Injury Severity' (1999-2002). Funder: 'Clothworkers Foundation' and 'Cotton Industry War Memorial Trust', £21K. Collaborating organisation: Burns Unit, Withington Hospital, Manchester.
- [G2] B K Kandola and A R Horrocks, 'Nanocomposite Fire Retardants for Synthetic Fibres' (2003 – 2006). EPSRC (GR/S24367/01) and DSTL, Ministry of Defence (Dstl/02/JGS/352.1), £150K.
- [G3] A.R. Horrocks, 'Developing the Next Generation of Flame Retardant Technical Polypropylene Yarns' (FLAMTECH), (2002 – 2005). DTI, UK, £ 229K.
- [G4] B K Kandola and A R Horrocks, 'Novel Polymerisable Flame Retardant Surface Coatings for Polymers' (2013 – 2016). Funder: Chemtura (LANXESS now), USA, \$97K.
- [G5] B K Kandola, 'Chemical Functionalization of Nylon Textile Surfaces to Impart Durable Fire Retardance' (2018 – 2020). Funder: Natick (US Army), \$100K.

- [G6] B K Kandola, 'Epoxy-based fire-resistant intumescent protective coatings' (2018 – 2020). Innovate UK, KTP 011026, £148K.
- [G7] B K Kandola, A R Horrocks and P Myler, 'Predictive Modelling of Combustion – Induced Mechanical Property Degradation of Flame-Retardant Structural Composites' (2006 – 2009). EPSRC (EP/D000734/1.) and DSTL, Ministry of Defence, £162K.
- [G8] B K Kandola, P Myler, A R Horrocks and J Ebdon, 'Novel co-blended polymer matrix systems for fire resistant structural marine composites' (2010 – 2013). EPSRC (EP/H020675/1), £427K.
- [G9] B K Kandola, 'Fire Retardant Bio-Composites for High Performance Applications' (FRBioComp), (2011 – 2015); TSB (Technology Strategy Board), Project No. 100982; TP No: 5680-44823, £203K.
- [G10] B K Kandola, 'Effects of impact and fire on aerospace and automotive composite materials containing nano and microparticulate additives' (2016 – 2020). Funder: DSTL, Ministry of Defence, £177K.

4. Details of the impact (indicative maximum 750 words)

We present three examples describing the impact of FMG's research across a number of key stakeholders:

1. Improved standard of consumer protection for children's fancy dress costumes in the UK

Based on FMG's expertise in textile flammability, the BBC approached Horrocks in March 2015 to test specimen fabrics from children's fancy dress costumes and present an opinion regarding their fire safety. This was prompted by the story of TV presenter Claudia Winkelmann after her daughter was badly burned at a Halloween party [S1]. Horrocks' views featured heavily in a special episode of BBC Watchdog (May 2015) as he performed numerous flammability tests, which showed the current failings of children's fancy dress costumes that had passed the EU Toy Directive EN 71-2 standard [S1]. Watchdog took on board Horrocks' recommendation that Halloween costumes should be tested against the well-established UK flammability standard (BS 5722) for children's nightwear. His recommendation was also echoed by the Chief Fire Officer of Bedfordshire Fire and Rescue Service in the same programme.

Almost immediately, Sainsbury issued a press release stating: '*From Halloween 2015, all children's dress-up sold by Sainsbury's will also meet the British nightwear flammability safety standard*' [S2].

Following intense media scrutiny, on 4th June 2015, Labour MP Teresa Pearce tabled a Parliamentary early day motion, calling on HMG to review fire safety standards for such costumes [S3] and subsequently on 1st December, Conservative MP Anne Main sought leave to table a Bill regarding standards of fire resistance and relevant labelling for children's fancy dress and play costumes [S4]. Within the motion Professor Horrocks' research and that of the FMG were directly referenced twice, for being instrumental in ensuring that such costumes are fit for purpose in England and Wales. In October 2017 the British Retail Consortium announced a new voluntary standard that mimics the nightwear rule [S5].

2. Expert witness in an industrial law suit

In 2015 Horrocks was contacted to act as a consultant where his expertise in intumescent materials would be used as evidence in an ongoing case in the US. Tietex International was being sued by a rival firm, PFG, regarding use of a FR chemical in a coating material sold to US mattress manufacturers. PFG claimed that the Tietex system was an intumescent and so infringed their patent. Horrocks, acting as expert witness for Tietex, experimentally modelled the behaviour of their formulation and explained to the court that the principal FR components under dispute -- ammonium polyphosphate and aluminium trihydrate - did not promote intumescent activity. Furthermore, he convincingly showed that the PFG expert misunderstood how to distinguish between FR and intumescent activity. In March 2018 a jury agreed and found Tietex not guilty of

patent infringement [S6]. The firm could have faced damages of \$60m had they lost, jeopardising the futures of 325 employees [S7]. Martin Wildeman, CEO, says: *“It was Dick Horrocks’ testimony that provided complete devastation to the plaintiff’s case”* [S7].

3. Technical support to industry

FMG continues to work with major UK manufactures of FR materials, coatings and composites. In composites, active collaboration with Hexcel Composites and Scott-Bader has been as collaborative projects to support product development activities, technology mapping and strategic opportunity reviews [S8, S9]. Through Composites UK, the trade association for the UK composites industry, with 377 members in all sectors and across the supply chain, FMG have offered technical advice and fire testing to many companies [S10].

Here are a few statements from leading companies:

“Collaboration with the FMG at Bolton over the last two decades has helped Hexcel in establishing building blocks that contributed towards new products in new markets, with potential sales value of millions of pounds..... Fire Group’s expertisehas supported Hexcel’s strategy by providing interpretation and technical support through prototype material sampling.” – R&T Manager, Hexcel Composites [S8].

“They have helped us to write our company’s technology roadmap for fire protection in a number of market areas where composites are used including, land transport, marine and construction. Their expertise in the chemistry, testing and technology of fire retardant systems has and will continue to help our company to grow our business in the fire protection area in the future.” – FMD Manager, Scott-Bader [S9].

“We have very much valued your support and advice. We are not aware of another university group with comparable knowledge in fire retardance of polymers and composites, so we see Bolton Fire Group’s role as critical in an area of increasing need” – Sustainability Manager, Composites UK [S10].

5. Sources to corroborate the impact (indicative maximum of 10 references)

- [S1] Watchdog programme aired on 14 May, 2015; Series 35, Episode 2; <http://www.bbc.co.uk/programmes/b006mg74>; <https://www.youtube.com/watch?v=DQiRej1ReUQ&t=138s>
- [S2] <http://www.pressat.co.uk/releases/sainsburys-to-introduce-enhanced-safety-standard-for-childrens-dress-up-2ad7353261934772a9ba650917231c73/> (May 28 but first announced May 22, see: <http://www.cfoa.org.uk/19812>)
- [S3] <https://edm.parliament.uk/early-day-motion/47857>
- [S4] [https://hansard.parliament.uk/Commons/2015-12-01/debates/1512014100001/ConsumerProtection\(StandardsOfFireResistanceOfChildren%E2%80%99SFancyDressAndPlayCostumesEtc\)?highlight=horrocks#contribution-15120141000300](https://hansard.parliament.uk/Commons/2015-12-01/debates/1512014100001/ConsumerProtection(StandardsOfFireResistanceOfChildren%E2%80%99SFancyDressAndPlayCostumesEtc)?highlight=horrocks#contribution-15120141000300)
- [S5] <https://brc.org.uk/news/2017/retailers-set-the-safety-standard-for-children-s-halloween-costumes>; <https://uobimpact.co.uk/childrens-fancy-dress-costumes/>
- [S6] Precision Fabrics Group, Inc v. Tietex International Ltd. Nos. 7:17-cv-3037, 7:17-cv-3038. United States District Court, D. South Carolina. <https://www.leagle.com/decision/infdc020180322g82>
- [S7] Chairman/CEO, Tietex International, USA. *Confirms Horrocks’ contribution in successful outcome of the patent dispute law suit.*
- [S8] R & T Manager, Hexcel Composites Ltd, UK. *Confirms Fire Material Group’s technical advice to industry.*
- [S9] Formulated Materials Development Manager, Scott Bader Company Ltd., UK. *Confirms Fire Material Group’s technical advice to industry.*

[S10] Sustainability Manager, Composites UK Ltd. *Confirms Fire Material Group's technical advice to industry.*