Institution: University of Leeds

Unit of Assessment: 15 – General Engineering

Title of case study: Case 5. Improved Safety of Fire Resistant Glasses

1. Summary of the impact (indicative maximum 100 words)

CGI International Ltd is an independent producer of fire resistant (FR) glass for the building industry. A Knowledge Transfer Partnership (KTP) with the University of Leeds resulted in the launch of three new high impact performance certified glass products, exhibiting improved fire resistance, twice that of previous products. CGI's business performance improved substantially, with the new products generating in excess of £5m of new business, within the eligible REF period, in a shrinking market thereby increasing market share. Product development time was reduced by 50% and fire test costs by £20k pa. A new research and development function was created employing 4 staff and this, together with an investment in equipment, has moved CGI from being a commodity manufacturer to a technically led solution provider.

2. Underpinning research (indicative maximum 500 words)

Pyroguard© FR glass is manufactured by CGI International Ltd, in Haydock (UK), and this has been the main revenue generator for the company for many years. In 2007 the company recognised the need to develop the product further in order to maintain and increase its international market share. This was a high profile and strategically important project central to the business plan and expected subsequent growth of CGI. However, CGI lacked the scientific understanding of the product and the know-how to improve it.

For this reason CGI approached **Dr HN Phylaktou** at the University of Leeds (UoL) for assistance, who has a distinguished track record on fire and combustion research and has provided consultancy and Continuing Professional Development courses to industry on this subject for a number of years to many companies. To facilitate the research, CGI and UoL successfully applied for a Knowledge Transfer Partnership (KTP6350, PI **HN Phylaktou**; £117.9k, November 2006 to January 2010). This provided funding for a Knowledge Transfer Associate (**Dr V Crook**) to be employed by the University to carry out the research.

Some of the challenges in developing the FR product were, (i) understanding the importance of the large number of variables involved during the testing procedure, (ii) the high cost and disruption to the business in producing and fire testing full scale samples, and (iii) the long timescales required to perform the test.

To address the challenge of understanding the behaviour of the FR glass under fire conditions it was critical to devise a method which did not rely on full scale fire testing. Developing such a testing method, at the bench scale, was an interesting academic challenge and would be of substantial commercial interest, being able to accurately predict the fire performance of large scale materials when exposed to real fire scenarios or full scale product certification tests. One small scale (sample sizes 10x10 cm^2) method identified by the researchers at the University of Leeds utilised a cone calorimeter to investigate the behaviour of FR glass products through collection of data such as heat release rates, critical heat fluxes, effective heats of combustion, smoke evolution rates and toxicity. Whilst some of the measurements are applicable to wider conditions, most depend on scale and scenario and care must be taken when attempting to correlate results from cone calorimeter tests with real fire performance or other fire tests.

In this work (2006-2010), CGI in partnership with the Leeds academic team - **Dr V Crook** (KTP associate), **Dr HN Phylaktou** (lead academic), **Dr JEJ Staggs** (academic advisor) - characterised the thermal performance of a commercial fire resisting glazing unit, constructed of a polymer layer sandwiched between two panes of 3 mm thick standard float glass. The aim was to use the cone calorimeter to guide improvements in the performance of the product in the full scale furnace test

by implementing changes in the physical set up and the chemical composition of the polymer formulation.

Analysis of the full scale tests showed that integrity failure was mainly due to the deterioration of the high temperature bonding properties with increasing temperature or the loss of internal cohesion of the polymer during the thermal decomposition. This indicated the need for an appropriate failure criterion for small scale tests [1].

Early tests demonstrated that the fixed heat flux cone calorimeter tests induced a temperature response at the cold face of the glass (and hence through the polymer) which was quite different from that induced by the furnace test. Also, thermogravimetric analyses of the polymer demonstrated the strong dependence of the residual quantity of polymer-char and the mass loss rate on the heating regime employed. Further, studies of the morphology and structure of the char showed it to be significantly influenced by the heating rate [1].

The above demonstrated the importance of the heating regime on performance. In a parallel programme [2] aimed at intumescent coating applications it was demonstrated that the cone calorimeter may be used to approximate furnace testing conditions, within certain limitations. It was shown that using the cellulosic heating curve, the temperature profiles of samples heated in both environments may remain accurate (to within 10%) for periods in excess of 40 minutes, which would be a sufficient time period for the procedure to be useable as a screening test method for full-scale gas fired furnace tests. This methodology was combined with a simultaneous constant shear stress test along the layer planes of the CGI glazing samples in an adapted specimen folder. Test failure occurred when the shear force caused a large movement of one of the layers as the sample temperature increased.

The team was able to correlate small scale test failure to the full scale test failure and also through the use of “design-of-experiments” methodology the effects of the large number of chemical and physical variables of the glazing unit were mapped in a multi-dimensional performance domain. This allowed product design optimisation with specific performance objectives and led to a number of improvements being quickly incorporated into the existing products and led to the development of new ones. This work made a significant step forward in the development of appropriate testing procedures for thermally reactive fire protection systems using the convenience and low cost of the cone calorimeter [2]. A cone calorimeter is now used as a quality control tool at CGI.

Key Researchers
HN Phylaktou (Lecturer, 01/11/1993 - 31/07/1999, Senior Lecturer, 01/08/1999 - present)
JEJ Staggs (Lecturer, 18/03/1996 - 31/07/2002, Senior Lecturer, 01/08/2002 - present)
V Crook (KTP Associate, 17/11/2006 - 08/01/2010)

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

[1]. **V Crook**, A Napier, **HN Phylaktou** and **JEJ Staggs** (2009) “Using a Modified Cone Calorimeter to Predict the Performance of a Thermally Reactive Glazing System in a Furnace Test”, *12th European Meeting on Fire Retardant Polymers*, Poznan, Poland, August 2009.

[2]. RJ Crewe, **JEJ Staggs** and **HN Phylaktou** (2011) “The Temperature-dependent Cone Calorimeter: An Approximate Alternative to Furnace Testing”, *Journal of Fire Sciences*, 29(2):131-151, DOI: 10.1177/0734904110382223.

Reference [2] above best represents the quality of the research within this Case Study and details the critical step of correlating cost-effective small scale testing with large scale standard furnace tests. This paper describes how a modified (variable heat flux) Cone Calorimeter can be used to approximately replicate heating regimes in standard furnace testing and highlights where one must take account of physical differences between the two systems, such as delivery of sufficient heat

flux to replicate aggressive furnace environments.

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

Context

Prior to the KTP, which completed in January 2010, CGI International Ltd was a commodity product manufacturer and supplier, operating without an R&D function with product improvements achieved empirically by tweaking the manufacturing process on a "trial and error" basis [A]. It was this lack of technical capability combined with external pressures and trends, in particular more stringent European fire standards, competition from toughened glass products, a sales plateau in The Netherlands and market demands for larger sizes of flame resistant (FR) glass, that led to CGI undertaking the KTP with the University of Leeds [B]. Research at the University of Leeds into the fire performance of glass laminates with resin interlayers provided CGI with the ability to model and accurately predict the performance of its Pyroguard product in full-scale fire tests using data from the cone calorimeter. The KTP project achieved the highest grade of 'Outstanding' and was shortlisted along with seven others (out of approximately 800 KTP projects) for the Best Partnership Award 2012 [C, D].

Impact

The commercial adoption by CGI of this new technical knowledge had a wide range of significant impacts on the Company, and also benefited users of its products.

Impact on CGI

During the eligible period CGI has:

- Developed and launched three new high performance products
- Generated **£5m of new business** in a shrinking market thereby increasing market share
- **Reduced product development time by 50%** and fire test costs by £20,000 pa
- Created a new R&D function, recruiting 4 staff and investing £120,000 in equipment
- Moved from being a commodity manufacturer to a technically-led solution provider

Development and commercialisation of new products

Formulation improvements to the resin interlayer have been incorporated in all products manufactured in-house by CGI. This includes three new premium Pyroguard products with improved fire and impact performance (EW 30 Impact, Maxi 30 and FD 60). EW 30 Impact was launched in September 2012 and represented the most significant innovative step, it being "*the first cut-to-size FR product in the market to achieve a 2B2 impact rating at 7mm* (pane thickness)". [B]

Increased sales and market share in a shrinking market

CGI has derived significant commercial benefit from these new products at the same time as the construction market, to which the performance of the FR glazing market is tied, has shrunk by 18.9% since the first quarter of 2008. [E] The addition of £5m of new business from sales of EW 30 Impact means that in effect CGI has increased its market share [B]. The higher margin premium products have increased the Company's profitability.

Reduction in development costs and shorter time-to-market

Accurate prediction of fire performance has enabled CGI to significantly reduce fire test costs, estimated at £20,000 pa, and shorten product development time by approximately 50%. [B]

Creation and resourcing of a brand new R&D function

In January 2010 CGI established a new R&D function, employing Dr Crook (the KTP associate) as Head of R&D and followed this with the recruitment of three additional staff. Investment in equipment, including a cone calorimeter, and facilities over the eligible period totalled £120,000. *"Having an R&D capability enables us to get closer to the market, identify trends and capture customer needs to ensure that we continue to innovate."* [B]. CGI has invested in two more KTPs with Leeds during the eligible period [B, D]. The topics of these were process improvement and the development of new product to replace the third party product representing 15% (and growing) of CGI sales. Implementation of the results of the first of these KTPs, which completed in March

2012, are at planning stage; the second, finishing in March 2013, has resulted in a new product specification that CGI will manufacture at its newly acquired French manufacturing facility. [B]

Fundamental change in culture and strategic direction
According to CGI, as a result of the KTP: *"A fundamental change in company culture has occurred, from a commodity manufacturer and supplier to a technically-led provider of innovative solutions for fire engineering problems in the construction industry."* [A]

Impact on users
The innovations underpinned by research from Leeds have also had an impact on CGI's customer base of glazing installation companies. The availability of an EW 30 product with a 2B2 rating at 7mm as opposed to 11mm thickness means that installers can cut-to-size on site. *"At 7mm thick we are able to process and cut Pyroguard ourselves, which saves a significant amount of time when fulfilling orders against short lead times."* [F]

Sustainable impact
Leeds' research is applicable in other thermally reactive fire protection systems such as intumescent paints for the protection of steel structures and industrial plant.

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

A. KTP "Best Knowledge Transfer Partnerships" nomination form, paragraph 'a', page 1.
B. Letter from CGI MD, dated 31st July 2013
C. KTP Awards "Best of the Best", TSB brochure, page 6
D. Best of the best, KTP awards 2012, video of Dr V Crook, www.ktponline.org.uk/ktp-best-of-the-best-2012-best-partnership-finalists/
E. '*UK construction data disappoints*', The Guardian, news article posted 12th July 2013, www.theguardian.com/business/2013/jul/12/uk-construction-data-flat-economic-growth
F. '*EW30 Impact Delivers First Class Fire Protection for Center Parc Marina*', Pyroguard press release August 2012, www.pyroguard.eu/ew30-impact-delivers-first-class-fire-protection-center-parc-marina/

Websites accessed successfully on 23rd October 2013