Development of Fire Retarded Materials – The Use of the Cone Calorimeter and the Pyrolysis Combustion Flow Calorimeter

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Most fire testing is focussed on specific protection goals, such as preventing sustained ignition, limiting the contribution to fire propagation, or acting as a fire barrier. In general, fire tests try to simulate a specific realistic fire scenario and monitor specific fire risks, rather than to determine the material's properties. Furthermore, the way a specimen responds, make a significant contribution to the fire scenario. Hence, interactions between properties of components and intrinsic material properties are complex and variable; comparing the fire behaviour in different fire tests and scaling up and down is difficult.

However, there is a significant need to screen new flammability modified polymeric materials using bench scale performance based methods. Further, in last decades the heat release rate (HRR) has increasingly discussed as the single most important variable in fire hazard and is nowadays usually determined by measurement of oxygen consumption. In this content, it is the aim of this contribution to introduce the *Cone Calorimeter* and the *Pyrolysis Combustion Flow Calorimeter (PCFC)*. The cone calorimeter has become one of the most important and widely used instruments for the research and development of fire retarded polymeric materials since the 80s. The PCFC, which is also called microscale combustion calorimeter, was recently proposed as method for flammability screening of plastics in the last years.

After ignition, the cone calorimeter represents a well defined flaming condition, forced by external radiation, typical for a developing fire scenario. The ignition parameter measured is the time to ignition, which depends on critical heat flux (or critical surface temperature) and critical mass loss for ignition. Fire response parameters measured in the cone calorimeter include HRR, total heat release, smoke production, CO production and mass loss. The specimen size is 100 mm x 100 mm with a thickness of 50 mm or less. Hence, the length-scale corresponds to the upper limit of typical flammability tests (performance in ignition scenarios). Using the typically applied heat fluxes ≥ 35 kW m^{-2}, it aims to replicate the performance in developing fires on a very small length-scale. It is one of the key features of cone calorimeter that a reasonable insight into the developing fire behaviour of a material can be obtained from a small specimen, reducing development time and cost. Although this is a significant advantage of the cone calorimeter, it is not without some important limitations. However, there are probably main uses of cone calorimeter data:

- To compare the fire response of materials to assess their fire performance, both with regard to materials development.
- To determine data for input to develop pyrolysis and burning models or to simulations or predictions of full-scale fire behaviour.
- To determine characteristic parameters such as peak HRR, fire growth rate index (FIGRA), total heat evolved (THE) etc., for regulatory purposes.

PCFC is a method for measuring the heat release rate of milligram-sized samples. It separately reproduces the solid-state and gas phase processes of flaming combustion in a nonflaming test by rapid controlled pyrolysis in an inert gas stream followed by high-temperature oxidation (combustion) of the volatile pyrolysis products in excess oxygen. Of course, PCFC does not cover dripping, thermal insulation, etc that also control the performance of components under fire. Further, it does not capture incomplete combustion (flame inhibition) or incomplete pyrolysis. However, it is probably the best single method with regard to fire behaviour using milligram sample.