Safe Cable Technology

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Association of European Producers of Flame Retardant Olefinic Cable Compounds

Summary

The manufacture of zero halogen cable products is either carried out by cable companies themselves or alternatively a number of relatively small independent companies specialising in compound manufacture. The dispersed nature of this group makes effective promotion of these materials difficult and as a result the need for a trade association was highlighted. The result is the Association of European Producers of Flame Retardant Olefinic Cable Compounds (FROCC) which was formed in summer 2001.

Over the past 3 years it has been claimed in numerous publications (1, 2, 3) originating from the USA (or from work carried out within Europe but sponsored by companies of US parentage) that "Zero Halogen" cables exhibit excessive flame spread, self reignite, cause explosions and generate combustion fumes with significant toxicity. The purpose of this paper is to place on record a response to the alleged deficiencies of zero halogen cable technology and to confirm our belief in the continuing viability of these products.

Introduction.

Different perceptions of fire hazard exist within the USA and Europe. In the USA it has been noted that fire fatalities are due to carbon monoxide (CO) poisoning and that under flashover conditions CO is directly linked to heat release(4). Therefore if the heat release is controlled by whatever means the fatalities will correspondingly be reduced. In Europe the model is different. Fire fatalities are believed due to people failing to escape from the fire hazard. Smoke, irritancy and toxicity are factors inhibiting escape and it is to these factors that the greatest attention is given(5). The exclusion of halogenated materials is a strategy to improve escape potential as the combustion fumes arising from halogenated materials are known to cause significant smoke, irritancy and toxicity.

Considerable debate has been stimulated by the use of "prescriptive" description such as "zero halogen" in cable regulations. The combustion chemistry for halogenated products is extremely complex and published results indicate approximately twice the number of identifiable combustion fume components compared with the number arising from the combustion of zero halogen cable products. In addition many of these halogenated components have significant toxicity and/or irritancy. In comparison the principal toxic or irritant products arising from the combustion of zero halogen products are CO and the aromatic hydrocarbons (Formaldehyde and Acrolein). Thus by excluding halogens (a relatively straightforward test) and controlling CO, Formaldehyde and Acrolein the design engineer can go a long way towards risk reduction(6). Attempts to define better approaches using fire safety engineering have foundered due to the opposition of the very people who oppose prescriptive testing. The ISO standard 13571 is now at its 14th draft and has been watered down to a Draft Technical Standard. Our position is that until industry is able to accept adequate replacements (such as ISO 13571) the current acid gas and corrosivity regulations must remain in place.

Flamespread

There are two scenarios by which cables may become involved in fire situations. The first is due to propagation following an ignition due to an electrical deficiency. Typically this might involve a smouldering type ignition followed by combustion property controlled propagation. The second is the external fire where in effect the cables are simply providing fuel for an established fire. A good example of the second type is the plenum chamber work carried out in the UK where the cables were exposed to an established 1MW secondary fire(1).

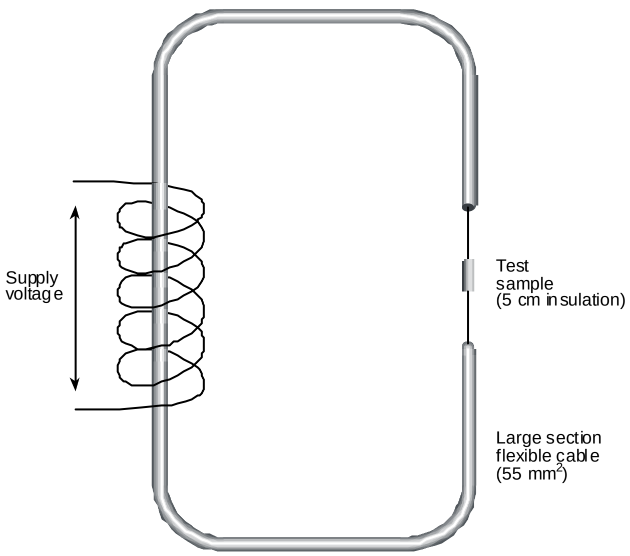

Fig 1. Circuit diagram for fire initiation test rig

Recent studies have attempted to define the factors which cause cable initiated fires to propagate. The results compared single 1.5 mm^2 insulated conductors. As a first step the current overload situation was explored. The test circuit involved one loop of cable passing through a HV transformer (Fig 1). It was calculated that the maximum available current in the loop would be 900 A at 10 Volts. Two cables were tested:

Zero halogen (hydrate filled)

Plasticised PVC

The results are shown Table 1. Under the conditions of test, neither cable ignited. Smouldering decomposition did occur with significant smoke release from the PVC cable.

Table 1. Propagation of electrically initiated fire

Current [Amp]	Time [s]	Hydrate filled	PVC
20		Not tested	No effect
50	30	No effect	Smoke
	60 – 180		Maximum smoke
	420	Signs of plastic deformation. No cracks. Good physical properties after test.	Stops smoking, insulation brittle and cracked
70	30	Slight smoke, insulation discolours	Heavy smoke, insulation falling away from conductor
	45	Wire red hot	Bare wire
	60	Smoke	
	90	Insulation still intact	Wire melts
	120	Insulation turns white	
	420	Stable white char	

Additional work explored the propagation of fire along a ladder comprising vertical and horizontal elements within a $3m^3$ test cell (Fig 2). The test was carried out with the door to the cell open which allowed some ventilation. Some results for data cable are being published (MIT Sept 2001). However the total programme involved many cable types and as a general conclusion it can be stated that horizontal propagation was difficult to provoke.

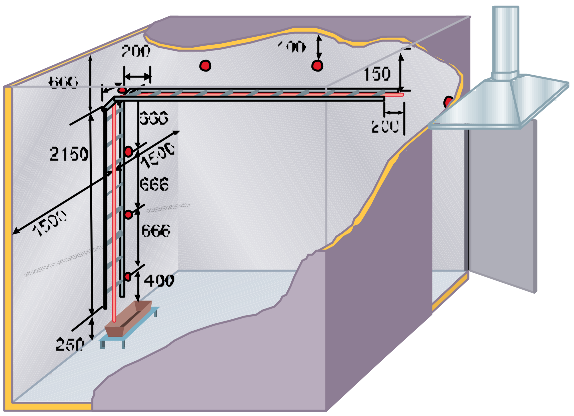

Fig 2. Flashover test cell

Given a different experimental set-up with sufficient source energy plus the correct (magnitude and direction) ventilation, the complete propagation along a horizontally installed cable is clearly possible. Tests using low fire performance cables have been carried out at BRE (7). The fire source was a 1MW gas crib which burned for 30 minutes. The test samples were German building cables NYM (PVC) and NHMH (Zero halogen). The cables were totally consumed during the test. Comparative Heat Release data is shown (Table 2). Concern is generally expressed for the delicate computer equipment being exposed to such conditions although it is a debatable point if the equipment would behave differently due to NYM or NHMH heat exposure.

Table 2. Heat release during large scale plenum fire tests

Cable	NYM	NHMH
Burner - HRR(average) MW	1.00	1.00
Cable - HRR(average) MW	0.22	0.38
Total HRR(average) MW	***1.22***	***1.38***
Burner - HRR(peak) MW	1.00	1.00
Cable - HRR(peak) MW	0.96	1.59
Total HRR(peak) MW	***1.96***	***2.59***

Explosive flamespread – "Flashover"

The definition of flashover is given in a British Standard (8) as: "a sudden transition to a state of total surface involvement in a fire of combustible materials within a compartment". The international Standard Organisation *(9)* gives a similar wording: "The rapid transition to a state of total surface involvement in a fire of combustible materials within an enclosure".

These definitions might be considered abstract. The following description, coming from the Home Office Fire Research and Development Group, provides further clarification (10). "In a compartment fire there can come a stage where the total thermal radiation from the fire plume, hot gases and hot compartment boundaries cause the radiative ignition of all exposed combustible surfaces within the compartment. This sudden and sustained transition of a growing fire to a developed fire is flashover". From experimental data, Thomas (11) has derived an expression for the minimum rate of energy release required for flashover. His expression assumes a sudden temperature change of 600 °C.

In parallel with the thermal process, there are also chemical processes. These chemical processes in the hot gas layer are often the reason for the sudden and dramatic increase in radiation to the fuel, resulting in flashover. These processes have not been greatly investigated. Measurement of certain parameters like mass loss rate, O_2, CO and C O_2 concentration makes it possible to determine the equivalence ratio, which is the ratio between fuel and air, normalised to the stochiometric fuel air ratio. This can also be used to identify flashover.

A principal objective of the $3m^3$ work programme described above (Fig 2) was an attempt to provoke a flashover fire propagation in a cable installation. Previous work had shown that fire propagation is very dependent on cable installation. It was hoped that by combining all the most adverse factors, the fire growth would become so rapid that flashover would be provoked. From previous studies, the worst case scenario was found to be a single layer of cable in a tray installation. The addition of a cover to the vertical part of the installation provokes a chimney effect and extremely rapid vertical propagation. Different cables have been used for this work but in only one out of 40 tests did propagation occur along the full length of the horizontal ladder. This was despite significant fires approaching 400kw being provoked in the vertical part of the test assembly.

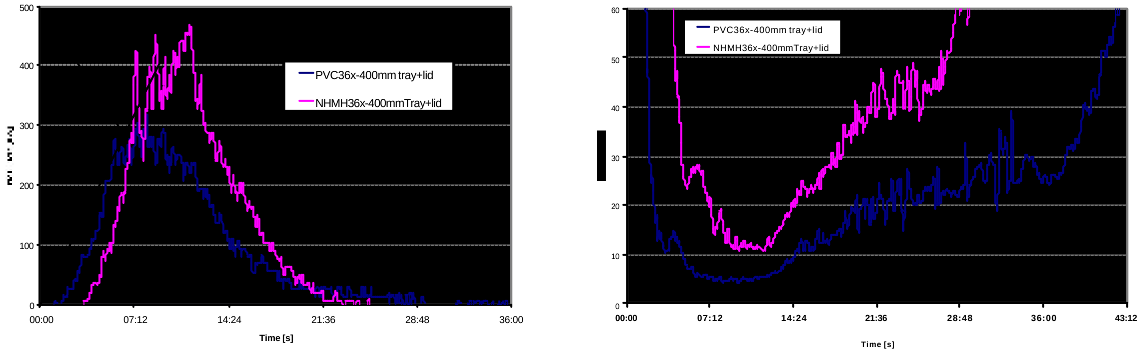

Fig 3. Flashover study – Heat release data + Vitiation

The gradient of the growth of heat release is defined as fire growth rate (FIGRA) and is seen to be +/-800 W/s. This is a value typically associated with a flashover fire. However only the NYM cable propagated along its full length. The CO2/CO ratio of below 10 indicates severe vitiation. Due to the heavy smoke it was impossible to observe the fire development and so we remain uncertain if flashover occurred. Horizontal fire propagation for the NHMH cable was < 2000 mm and so in this case flashover had certainly not occurred.

It should be emphasised that these of installations were designed to provoke severe fire growth and should never be encountered in practice. It may be concluded that correctly installed cables are by themselves unlikely to cause flashover.

Re-ignition

The reported re-ignition experiment (2) was carried out as part of the PIT funded research using the BRE plenum rig. The test was carried out using zero halogen cable. There was no ventilation. During the period where the burner was alight limited flame propagation was observed which ceased a short time into the test. However the cable assembly and plenum space clearly became very hot. After the fire was extinguished air entered the plenum and the fire reignited and propagated until all the air was consumed when it self extinguished again. This cycle was slowly repeated until the total cable length had been consumed.

Our view is that this experiment says more about post fire management than cable technology. The risk of re-ignition following a fire is well established and is not particular to zero halogen cables.

Toxicity Studies.

It is always possible to find a particular combustion process which gives a particular combustion chemistry with particular combustion fume composition. Literature surveys for general combustion fume toxicity reveal a consistent picture - PE less toxic than PVC which is less toxic than FEP, Fig 4.

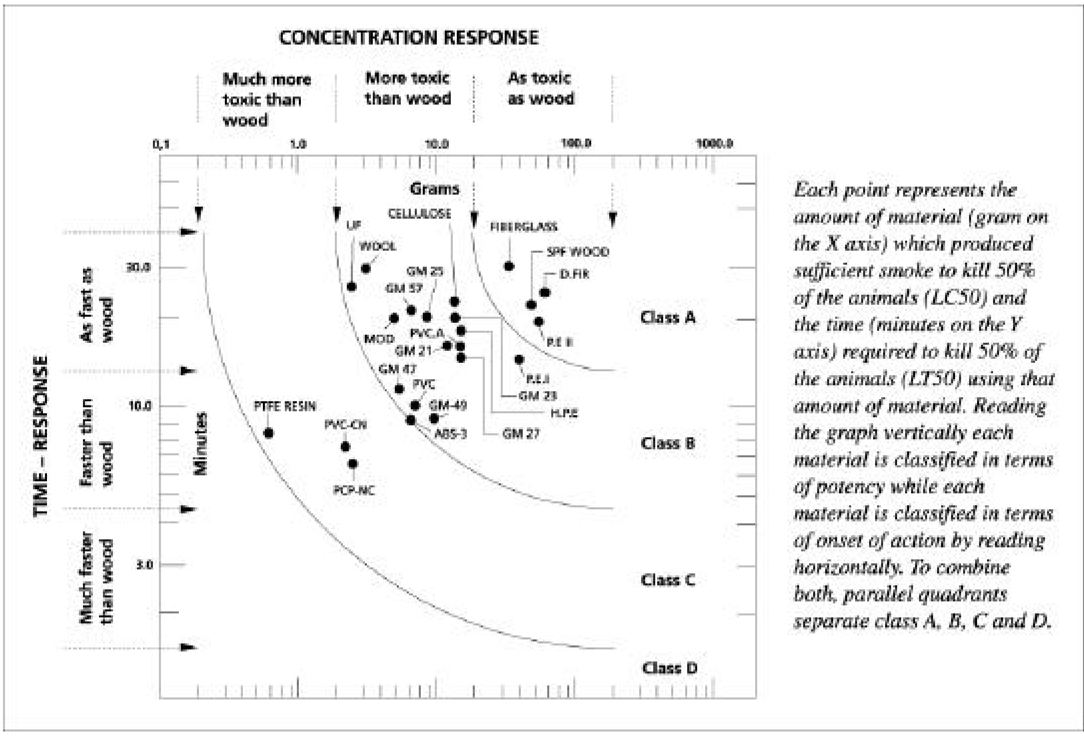

Fig.4 Concentration time response plot for classifying the potency of combustion products by plastics. (after A.H. Landrock,"Handbook of Plastics Flammability and combustion Toxicology")

The results of the cable toxicity tests such as IMO MSc. 41 or NES 713 do not always correspond with these findings. Identification of specific products requires the definition of decomposition reactions which must then be proven by practical experiments. Potential combustion reactions for PE, PVC and FEP are shown in figures 5, 6 and 7. It is clear from the reaction schemes presented that some of the most toxic substances such as benzene, carbonyl fluoride, octa fluoro isobutylene etc. are not taken into account in these methods. It comes as no surprise that a non-hydro carbon polymer like FEP gives totally different decomposition products than a hydrocarbon one and it is clear that this fact has not been taking into account in the referred methods.

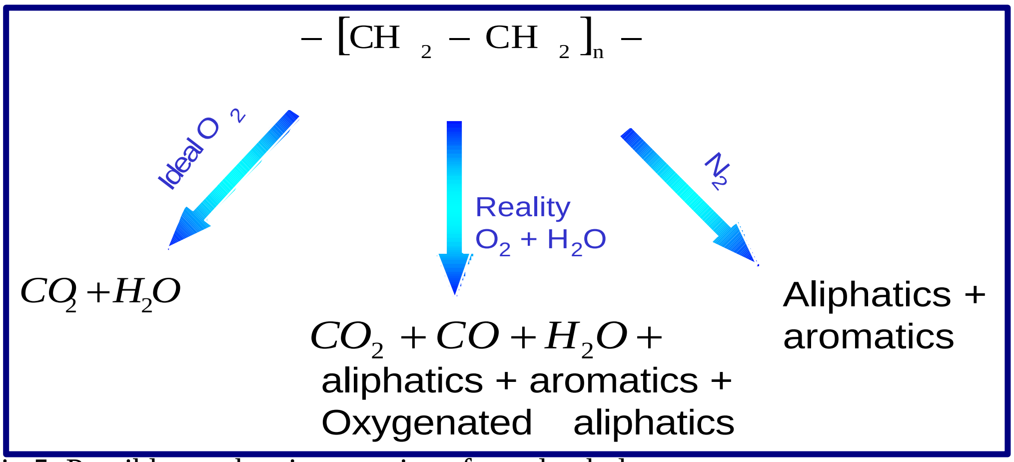

Fig.5. Possible combustion reactions for polyethylene.

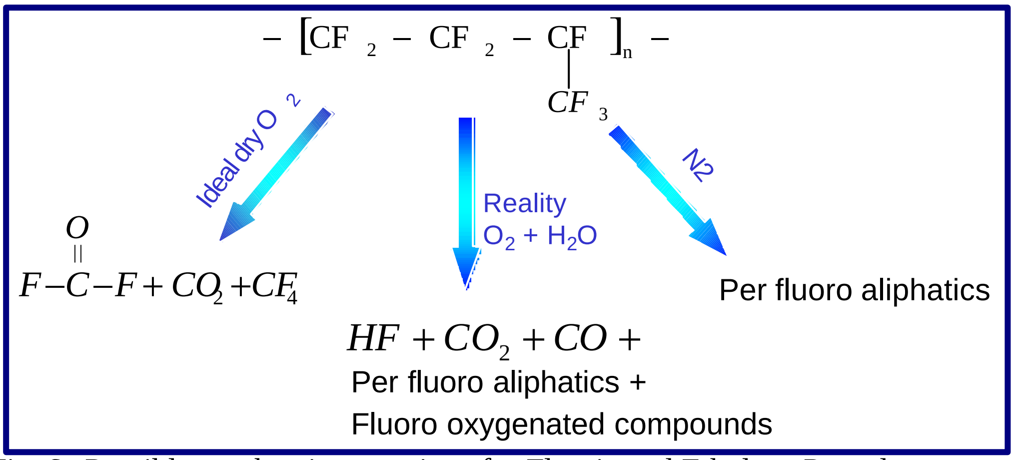

Fig. 6. Possible combustion reactions for Fluorinated Ethylene Propylene.

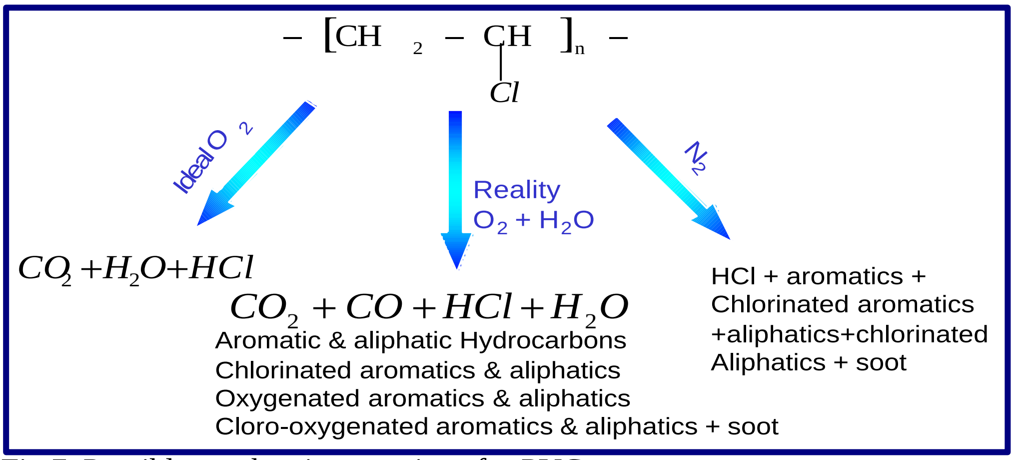

Fig.7. Possible combustion reactions for PVC

Extensive work comparing the toxicity of fumes arising from the combustion of chalk filled polyolefins, chalk filled polyolefins, PVC and FEP and cables produced from these materials has been previously published (12, 13). The key point is that the combustion of zero halogen products is largely a function of fire temperature plus the available oxygen. During the initial stages when oxygen is plentiful the combustion is clean with little smoke and very low toxicity. As the fire progresses the oxygen depletes, combustion slows and temperature decreases with resulting increases in smoke and toxic gases such as Acrolein and Formaldehyde. The combustion of halogenated materials is different. Smoke and gas analysis are largely independent of the available oxygen and the fire behaves as if vitiated, irrespective of the actual fire conditions. The result is a very rapid increase in both smoke and irritancy/toxicity during the early stages of the fire.

Euroclassification

At the time of preparation of this paper the debate regarding the Euroclassification of cables is by no means closed. (CONSTRUCT 00/430 Rev 2).

Table 3. EC proposal for the classification of cables

Class	Test	Classification	Additional
A	Not applicable		
B	Bunch vertical Single vertical Fumes	Flame spread FIGRA or peak RHR Flamespread	Dynamic Smoke Dripping Acidity
C	Bunch vertical Single vertical Fumes	Flame spread FIGRA or peak RHR Flamespread	Dynamic Smoke Dripping Acidity
D	Bunch vertical Single vertical Fumes	Flame spread FIGRA or peak RHR Flamespread	Dynamic Smoke Dripping Acidity
E	Single Vertical Fumes	Flamespread	Dripping Acidity
F	No performance		

The current document clearly separates the application of Zero Halogen products from PVC (Table 3). Without going into details of the limits proposed, the overall approach seems correct and will allow Zero Halogen products to compete in all classes. Where smoke and corrosivity are less important PVC will dominate – thus maintaining the status quo. Product selection will correctly be a matter of debate between the building designer and the National Fire Regulators.

Probably the most important outcome of the Euroclassification debate is the introduction of a time element to the definition of fire performance with FIGRA (Peak Heat Release/Time) and SMOGRA (Peak Smoke/time) defined as a key safety parameters. Comparative cone data is shown for Zero Halogen and a PVC products Fig 8.

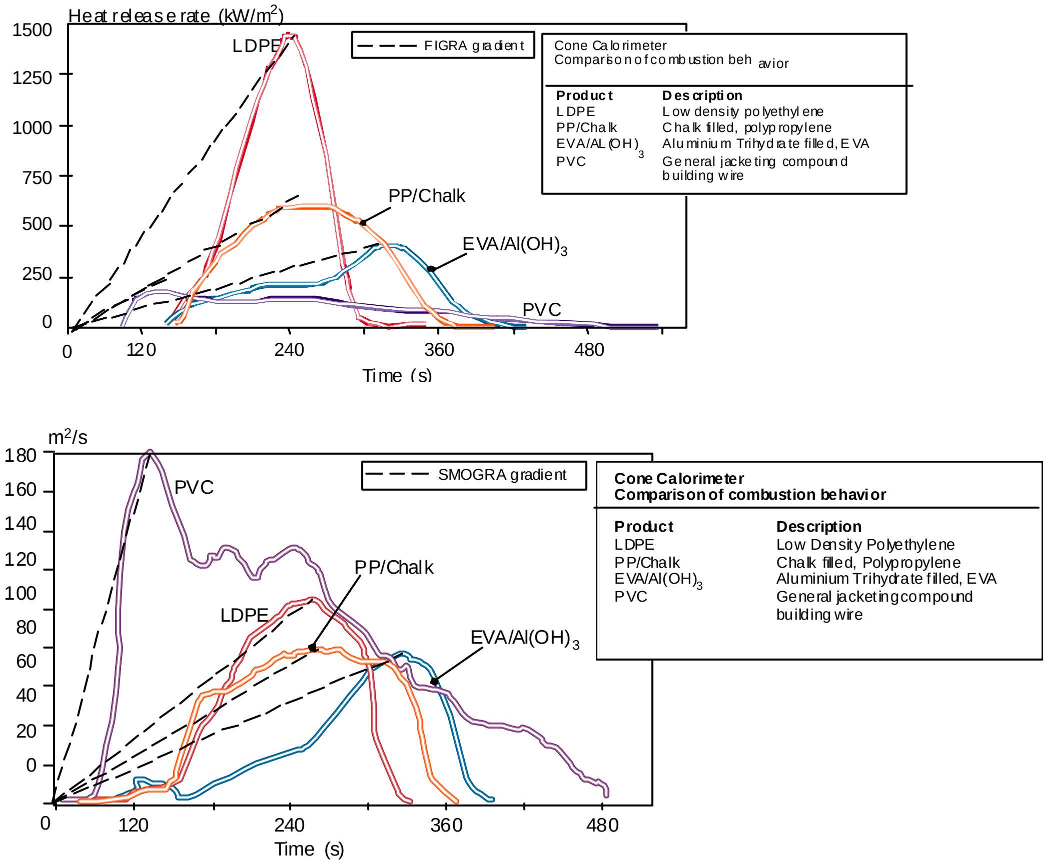

Fig 8. Typical FIGRA and SMOGRA data

The fire performance of these products has been explored by means of large-scale tests using the BRE plenum rig (7). Results correlate perfectly with the cone data with the PVC cable exhibiting rapid growth of both flamespread and smoke whereas the fire growth for the zero halogen cable was much slower. In the latter stages of the fire the zero halogen cable burned more strongly whereas the PVC cable was more subdued.

Discussion

In the introduction we described the basic fire safety philosophy in the USA of being totally concerned with Heat Release on the basis that after flashover the quantity of CO produced is directly related to the heat release. This approach gives problems. It is claimed that life is not tenable in the proximity of a flashover fire. The problem therefore is for the building occupants to effect an escape before flashover. This is recognised in Euroclassification legislation where FIGRA (Heat Release/Time) is defined as the key safety parameter.

The limited work reported on fire growth following cable electrical breakdown indicates that this mechanism is an unlikely source of a fire. This conclusion is supported by statistical data on fires. The research in this area is ongoing and it is hoped will form part of a European Community sponsored project on Life Cycle – Risk Analysis. However on the basis of the available evidence it may be assumed that the principal cable contribution is to provide fuel to a secondary fire source.

In any risk analysis consideration must be given to the size and nature of the fire source. If the fire is large adding zero halogen fuel will simply increase the fire load. There will be little change in smoke or toxicity/irritancy. Adding halogen containing fuel to an established fire is far more complex. There is a strong possibility of an immediate increase in smoke. Toxicity/irritancy will certainly increase and under certain circumstances it is reported that there is a possibility of the formation of extremely hazardous super toxic materials.

The ISO 13571 approach is to consider hazard in terms of Fractional Effective Concentration (FEC) which correlates with irritancy and Fractional Effective Dose (FED) correlating with toxicity. Currently FED and FEC values are established based on rather few of the possible combustion products. Recent work has shown that approximately 1/3 of the combustion products require GCMS procedures for their identification and are ignored using current protocols. The key here is the use of a mass balance in order to identify the scale of any problem.

The description “zero halogen cable compound” covers a range of products and technologies from simple mineral filled products to sophisticated intumescent systems. These products, especially those based on Hydrate technology, have an excellent record of safe use in building applications. We recognise that requirements change but believe strongly that the future lies in fire safety engineering as a means to design cost effective cable installations within the built environment. To that end FROCC supports:

1) Euroclassification (although with the proviso that the protracted gestation may render the result obsolete at birth!)
2) The application of FSE for building design
3) Improved toxicity assessment methods
4) Definition of strategies for Life Cycle Analysis/Risk Assessment

FROCC intends to participate fully in the ongoing debate on safe cable technology. The organisation is new and it is hoped will develop quickly. Our progress can be monitored on our web-site (www.frocc.org) which also contains full contact details.

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