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Research on Fires of Plastic Building Materials

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ABSTRACT

Research on fire, smoke, and toxic products generated in building fires carried out by QMC Industrial Research is described. The approach to real fire problems combines model studies by laboratory analysis or computer modeling with large-scale testing of components.

We are a contract research company, within the University of London, which specializes in industrial polymer problems. We work on fire, smoke, and toxic products generated in building fires by plastic building materials, furniture, and furnishings (fabrics and textiles). Because our work is conducted in confidence for industrial and Government clients, I will give only an overview of the achievements of my team, led by Dr. Green, Dr. Hume, Mr. Maries, and Dr. McRoberts.

Most people enter the fire testing field by intensifying the heat conditions used in heat ageing experiments, and also by using the higher temperatures involved in pyrolysis studies. However, for more than ten years we have been involved in the study of the ablative behavior of polymers used as lining materials for solid-fuelled rocket motors which are degraded at very high temperatures

indeed. Typical conditions would be exposure of a copolymer to propellant gases at high velocity, say at 3000°C, for 10 to 20 sec. The polymer surface temperature in the char stagnation zone reaches between 1600 and 1800°C.

A polymer such as PVC dehydrochlorinates and then decomposes at a lower temperature, usually between 350°C and 650°C, depending on heating rate, at some distance below the char surface. The gaseous diffusion products then diffuse out towards the propellant gas stream. During this diffusion, secondary reactions occur which have a fundamental influence on the composition of final smoke and toxic products produced as well as on the overall thermochemistry of the system. By scaling down to the lower temperatures of up to 1000°C which are typical of real fires, many of the techniques and approaches which have already been developed for the rocket system can be used.

Our approach to real fire problems combines model studies with large-scale testing of components. Model studies are of two types: laboratory analysis and computer modeling.

Laboratory analysis, usually by GLC-MS, computer-operated as described by Professor Einhorn [1], involves pyrolysis and smoke sampling. This has been reported by us previously, for instance, for polyesters at the Madrid IUPAC Macromolecular meeting in September 1974 [2].

Computer modeling of heat transfer through semi-infinite panels of plastic material, with comparison of the computer predictions from the basic material properties with the results from embedded thermocouple readings in special furnaces was reported in one paper published in 1974 [3, 4] and others are in press [5, 6].

We are involved also in larger-scale tests which have enabled the testing of whole structures, such as the wall section involved in the Summerland fire in the Isle of Man in 1974, and a scaled-down insulated fractionation column from a London brewery disaster. Recently we have extended our work to chairs in furniture stores, to PVC belting in a simulated mine gallery, and cables in a simulated underground railway fire situation, this last being for the new extension to the Glasgow underground railway.

The laboratory used for these large-scale tests, which looks rather like something out of Clochemerle, is the sort of building described by Dr. Woolley [7]. His experience was made use of by us at the design stage and we are grateful to him for his collaboration.

Our design is similar to his, except that we took the opportunity to put in an extra room, an "observation/instrument room," where we can house gas chromatography equipment, make cine films and stills, use other gas sampling techniques, house our potentiometric

temperature recorders for the thermocouples and optical density equipment, and so on. Unlike the Fire Research Station, we do not use a wood crib but, rather, propane gas ignition. The reason for this is that we are particularly concerned with analysis of detailed products and we are rather worried about possible interaction between the products of wood combustion—so menacingly described by Professor Einhorn—and the products of degradation of PVC itself. This possible interaction has not yet been investigated.

WHAT HAVE WE ACHIEVED ?

In the four or five years that we have been involved in this field, we have conducted laboratory pyrolysis studies, as described by Dr. O'Mara [8], over the temperature range from 600°C to 1100°C [9]. We now feel able to understand in outline the mechanisms of formation of smoke from hydrocarbon polymers, within which classification I include dehydrochlorinated PVC; in other words, I do not think there is a problem with the HCl because that is fairly well understood.

We believe that the key intermediates are benzene, styrene, and, in particular, the polycyclic aromatic hydrocarbons, many of which contribute to smoke obscuration—for instance, directly by physical condensation, and by chemical condensation to partially hydrogenated carbon particles. Others of these polycyclic aromatic hydrocarbons may be equally dangerous because they may be chronically toxic, for instance, carcinogenic, in relatively low concentrations, which is naturally of importance to the sapeurs/pompiers.

Experiments can be controlled to simulate real fire heat flux and atmosphere conditions. We are, therefore, in a position to criticize, however gently, current thinking of ISO (International Standards Organisation) which is strongly based on the (U. S.) National Bureau of Standards (NBS) smoke chamber. We criticize it because of the choice of single point conditions on what I think would now be generally agreed by the people at this meeting to be a multipoint surface.

As far as the computer heat transfer model is concerned, we have adequately—but not yet elegantly—described polystyrene and polyesters, including fiber-reinforced materials. However, for PVC, the model is less than adequate at present because of boundary definition problems associated with gas expansion and lifting of the carbonaceous char layer referred to earlier in this symposium. We think the model can be modified, and this work is in progress.

In the larger-scale tests, we are now able to do two things: first, we can study the important combination of design with materials and,

secondly, compare the composition of combustion products and smoke obscuration with results obtained over the years in a specially developed small-scale laboratory furnace, details of which we have published [3]. Unfortunately, our industrial clients are often willing to sponsor only large-scale burns according to existing specification tests, some of which are not very good. Thus, we have to take the opportunity to make all sorts of additional scientific measurements for this correlation purpose, with the agreement of the clients but extra to the basic tests carried out for them. A test for cables has been developed by London Transport, who recently had a spectacular smoke problem on the Piccadilly Line of the London underground system. Their test involves burning methanol in a tray. As the test progresses, we can see how the cable is performing over a period of time. At 1 min, nothing much has yet happened to the cable. At 5 min, the cable is now beginning to catch a little on the outer surface, but not much. At 10 min, the cable is virtually self-extinguished. The reason for this good performance has nothing to do with the PVC, which is bubbling furiously inside the cable; there is a tape of special design and impregnated with a special material which we applied to the surface and this has effectively made a PVC-insulated cable suitable for passing this fairly stringent test.

WHAT ARE OUR IMMEDIATE FUTURE OBJECTIVES?

We wish to control our laboratory test parameters rather better. First, heat flux level and uniformity of distribution of heat flux. Secondly, more precise control of atmosphere, from 20% down to zero oxygen in oxygen/nitrogen mixtures, corresponding to free combustion and starved combustion conditions. We want to carry out our tests over a fairly wide range of such conditions and we feel increasingly that single-point results are virtually useless.

Better instrumentation of our large-scale tests is needed to obtain more accurate temperature profiles, both over the area of the test specimen and also through its thickness. Again, atmosphere control in large-scale tests needs improving. We are working on obscuration/recognition because mere optical density measurements using light path measurements with photocells on, for instance, PVC smoke are no substitute for recognition tests. In the view of the firemen—and I think they are right—people need to be able to see an "Exit" sign. The physiology and psychology of seeing an "Exit" sign when panicked by fire and smoke has not been studied scientifically. We are already

monitoring evolved gases in large-scale tests—up to ten gases at once. For instance, routinely, we would always include carbon monoxide, carbon dioxide, HCl, and HCN in compounded PVC compositions. We want to extend this, certainly to include aldehydes, to which reference has been made earlier, probably also to direct measurement of benzene and higher aromatic compounds. Of course, we already do our work under both flaming and smouldering conditions where this is required but we need to persuade more of our clients to agree that this be done as a matter of routine.

Finally, our long-term objectives for the whole program would, I think, be twofold: first, the correlation of large-scale burn results with small-scale laboratory tests on the material, with the idea of reducing several-fold the present rather high cost of fire testing of plastics products; secondly, modification of the chemistry of smoke formation by the use of additives. This, of course, already takes us into the difficult patent field, and I must say no more.

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