A DISCUSSION OF TOXICITY REQUIREMENTS FOR CABIN MATERIALS

C. P. SARKOS

The FAA has made a public commitment to the issuance of a Notice of Proposed Rule-making (NPRM) on cabin interior materials by late 1984. During Congressional testimony FAA has stated that the NPRM would cover flammability, smoke and toxicity considerations. How best to implement a toxicity requirement has become a major issue. There are two opposing schools of thought:

(1) Toxicity must be addressed by a test method incorporating toxic gases measurements (most preferable) or an animal model (less desirable)

(2) Toxicity can most effectively be addressed by an improved and validated flammability test method

Arguement for a Flammability Test Method

The arguement for an improved flammability test method to address toxicity is based on an analysis of full-scale cabin fire tests conducted in the C-133 test article. Under these realistic conditions, which provide the most accurate accounting of the growth and hazards of a cabin fire, the toxic hazard was always the result of flashover. What this means is that for every test conducted in the C-133 test article, the level of toxic gases measured before the onset of flashover, or the level of toxic gas measured if flashover did not occur, was always significantly below the estimated levels that would prevent passenger escape. Generally, flashover is dictated by flammability considerations (e.g., heat release, flame spread, ease of ignition, etc). Therefore, an improved flammability test method that requires materials that delay the onset of flashover will also provide a safety benefit against the toxic hazard associated with flashover; i.e., additional time available for escape.

The attached figure is a typical result obtained in the C-133 test article. Before flashover the carbon monoxide (CO) concentration was below the detection limit of the instrument. After flashover the CO concentration increased dramatically. The reason for the low CO concentration before flashover is because of the small amount of burning materials (the fire remains localized) and because the combustion gases are concentrated in the ceiling smoke layer, above the head level of standing passengers. The creation of hazardous CO concentrations by flashover is a result of rapid fire growth coupled with the rapid depletion of oxygen (O_2). Elevated carboxyhemoglobin arising from CO inhalation is often detected in blood samples taken from aircraft fire victims and is considered to be the main toxic hazard associated with a cabin fire. It is worth repeating that dangerous CO concentrations have never been measured in the C-133 test article without flashover.

Current C-133 testing is aimed at providing data to determine which small-scale test method gives the best correlation with large-scale test results. One material at a time is being tested and the test conditions (fuel loading) do not result in flashover. Nevertheless, the toxic gases levels that are measured do appear to correspond to the increase in cabin air temperature (amount of burning material). On a preliminary basis, the OSU Rate of Heat Release Apparatus correlates with the C-133 temperature data. Thus, an NPRM based on OSU Apparatus heat release requirements would implicitly reduce toxic gas levels before flashover and, more importantly, would serve to delay the onset of flashover and corresponding production of hazardous toxic gases. (Note: C-133 tests to confirm the latter will be initiated shortly).

As mandated by the SAFER Advisory Committee and the Cabin Fire Safety Program Plan (FAA-ED-18-7), the focus of C-133 testing has been on the postcrash external fuel fire scenario. A smaller number of tests under simulated in-flight conditions with fires out in the open (primarily seats as the initial material ignited) were also conducted. The nature of both types of scenarios studied, consisting of intense, relatively short duration, aerobic fires, does not tend toward the creation of a toxic environment before flashover (passengers would be exposed to fairly complete combustion products for a relatively short period of time). Of greater concern from a potential toxicity consideration, as prompted by the Air Canada DC-9 accident, is the uncontrolled, hidden in-flight fire scenario. In this case passengers may be exposed to more incomplete products of combustion from a smouldering fire for a longer period of time. At this time the FAA does not have the extensive characterization data base for the hidden, in-flight fire scenario that it has acquired over the last four years for the postcrash fire scenario. A comprehensive program to address the hidden in-flight fire scenario, to begin in 1985, has been proposed. Nevertheless, it can be argued and substantiated by some test data that material improvements resulting from postcrash fire considerations will produce benefits for in-flight fire scenarios, particularly where the materials effected are the target of the initial fire.

Arguement Against an Explicit Toxicity Test Method

The above discussion presents a case for reducing the toxic hazards of a cabin fire by implementing an improved and validated flammability test method. This approach is based on a better understanding of the characteristics of a cabin fire obtained through full-scale (C-133) fire tests, and correlation studies to demonstrate the validity of improved test methods. Full-scale test results do not support the need for an explicit toxicity requirement for cabin materials, nor is their reasonable agreement amongst toxicologists as to what is an appropriate toxicity test method.

A need has been expressed for a toxicity requirement that would safeguard against the use of more toxic materials by industry in their quest to meet more stringent flammability requirements. The overall approach being proposed is to burn the material in a suitable device, such as the OSU Apparatus, and to measure the more "important" gases (CO, HCl, HF and HCN). Acceptance limits for the measured gas levels would match the performance of the "best" state-of-the-art panel (phenolic/fiberglass). By this supposedly fairly simple and reasonable requirement, it has been stated that FAA would prevent the use of more fire resistant materials that may create a toxic hazard in the pre-flashover period. Although appealing to some, this approach has the following serious drawbacks:

(1) The need for a separate toxicity requirement is contrary to the most reliable information available about the characteristics of a cabin fire; i.e., full-scale (C-133) fire test data. One may argue that realistic test data, acquired by the commitment of considerable resources, was being overriden by speculation about a hypothetical situation that may never happen.

(2) It is conceivable that the proposed toxicity requirement may prevent the use of more fire resistant materials that would improve safety in an actual cabin fire. As an example, take a material that produces 50% more than the "allowable" CO limit, but is extremely fire resistant and would delay the onset of flashover by 2 minutes. We know from full-scale test data that a 50% increase in the concentration of CO (a small number to begin with) would very likely not create a toxic hazard before flashover, whereas a 2 minute delay in the onset of flashover would provide a benefit of 2 minutes in additional time available for escape.

(3) Screening materials by measurement of simple toxic gases will not detect an unusually toxic material. This type of material exists - not because of the generation of high CO or HCL levels during combustion - but because of the creation of some type of neurotoxicant or other extremely toxic species whose existance cannot be predicted before hand. Detection of unusually toxic materials requires the use of an animal model (rodent).

(4) The accurate measurement of "simple" toxic gases (especially HCN, HF and HCL) in a combustion mixture is complex and labor intensive. A new test requirement containing toxic gas measurements would be significantly more difficult, expensive and time consuming than existing proposed or contemplated FAA flammability requirements.

(5) Validated predictive models for the toxicity of a gas mixture are not currently available (it is generally assumed that the effects are additive). Although estimates exist for human exposure limits for individual gases, based primarily on animal test data, the combined effects may be additive, antagonistic or synergistic (FAA has planned research on the toxicity of gas mixtures).

(6) A toxicity test method requirement, based on the measurement of a small number of simple toxic gases, is contrary to documented conclusions and statements by the scientific community. Several examples are as follows:

(a) "Relative toxicity of materials should be determined on the basis of dose-response relationships in animals". (Committee on Fire Toxicology, National Academy of Sciences)

(b) "It will be a least several years before scientifically-based, tested smoke/toxicity hazard assessment methods are available and widely used". (Advisory Committee on the Toxicity of the Products of Combustion, National Fire Protection Association, chaired by Dr. Jack Snell, Director of NBS Center for Fire Research).

(c) "What probably cannot (or should not) be done in the near future is to require that materials selection be regulated on the basis of the toxicity of smoke - the state of the art in evaluating relative toxicity hazards for humans is just not that sophisticated or reliable". (Dr. Charles Crane, FAA/CAMI)

Conclusions

At this time, on the basis of full-scale cabin fire test findings and the state-of-the-art of small-scale tests for materials, it is concluded that the most effective means of reducing the toxic hazard of burning cabin materials is to require improved flammability criteria (e.g., heat release in the OSU apparatus). Also, work should commence to study the toxic hazards of hidden in-flight fires, and the FAA-sponsored work at Southwest Research Institute to study escape impairment of baboons exposed to toxic gases, recognizing that the baboon is a surrogate of man, should be continued. The latter work is considered by many to be the most important research in this country in the field of combustion toxicity, and continued support by FAA would reflect its commitment toward understanding and controlling the toxic hazards associated with aircraft fires.