CRANFIELD UNIVERSITY; INSTITUTE FOR ENVIRONMENT AND HEALTH

AIRCRAFT CABIN AIR SAMPLING STUDY:
PART 1 OF THE FINAL REPORT – DRAFT FOR REVIEW, NOVEMBER 2010

REVIEW OF DRAFT REPORT – PROFESSOR ROY M. HARRISON

This report describes in some detail a study involving measurements of air quality on the flight deck of commercial airliners. In all, measurements were made during 100 flights of five different aircraft, comprising four passenger planes and one cargo plane. The measurements were made in order to quantify pollutants including VOCs, SVOCs and other pyrolysis products released into the cabin air during an oil or hydraulic fluid smoke/fume incident. No such incidents were reported but nonetheless odours were encountered on a substantial proportion of flights. The air contaminants measured as part of the study were specific volatile organic compounds (toluene, m+p-xylene, limonene, tetrachloroethylene and undecane), organophosphate esters (tri-ortho-cresyl phosphate (TOCP), other tri-cresyl phosphate (TCP) isomers and tri-butyl phosphate (TBP)), total VOC by photoionisation detector, carbon monoxide by electrochemical cell and ultrafine particle count using a portable Condensation Particle Counter. There is little justification provided for this choice of analytes, and a greater explanation would be highly beneficial. The measured concentrations are compared both with measurements from indoor environments and with occupational and indoor air quality standards and guidelines.

It is clear from the report, and particularly the very detailed appendices, that certain aspects of the study were very carefully thought through, and for example especially designed documents produced in order to provide a proper record of the work conducted. Inter-laboratory analytical trials were carried out with apparently very satisfactory results.

Given the need to use portable instrumentation with very modest space requirements, the selection of sampling/monitoring instruments appears generally appropriate. There is, however, one issue which appears highly unsatisfactory. The method for sampling both volatile organic compounds and semi-volatile organic compounds (the organophosphate esters) involves pumping air through stainless steel sorbent tubes packed with quartz wool and Tenax TA. This is a fairly standard tube for sampling VOC and is likely to have proved reliable for this purpose. It is, however, wholly untested for the sampling of organophosphate esters, and for semi-volatile compounds more generally. There are two problems associated with its use for organophosphate (OP) esters. Firstly, the OP esters have rather high boiling points and are hence likely to be partitioned mainly onto airborne particles. The Tenax traps will not be efficient collectors of airborne particles and the

residence time is likely to be insufficient to ensure desorption to the Tenax. Secondly, the OP esters are rather polar compounds, in comparison to the hydrocarbons which are of low polarity. Consequently, for this reason also, the Tenax may not be an efficient collector of OP esters. In this context, it is surprising that the report gives no justification of the selection of this sampling method and more seriously gives no evidence of its efficiency for the collection of OP esters. In the paper by Bergh et al. (2010) cited within the report, those authors use SPE cartridges containing a more polar aminopropyl silica for the collection of OP esters. In an earlier paper from the same group (T. Staaf and C. Oestman, JEM, 7, 344-348, 2005) sampling efficiency tests are conducted on the SPE cartridges and are shown to be absorbant dependent. Consequently, there is every reason to believe that the Tenax tubes are likely to be markedly inefficient for the sampling of OP esters and consequently the lack of sampling efficiency studies conducted on airborne samples is a very serious deficiency. This is particularly so as some of the major concerns surrounding fume events in aircraft cabins focus upon the possible adverse effects of exposure to OP esters.

The other major omission from this report is any attempt to analyse the continuous measurement data as a single dataset. Continuous records were collected of total VOC by photoionisation detector, carbon monoxide by electrochemical cell and ultrafine particle number count by P-Trak detector. Although there will be differences in the response times of these instruments, they all give continuous records and much would be learnt from analysis of the three analytical time series as a single dataset. As currently presented, the report gives no perspective on whether excursions in these variables were always simultaneous, or whether individual contaminants were elevated individually or perhaps in pairs.

Other points of lesser importance are the following:

(a) The second sentence of the summary gets off to a bad start by referring to *principle* objectives rather than *principal* objectives.

(b) All of the calibration standards were prepared by injection of liquids onto the sorbent tubes rather than from sampling from the gas phase. It would be preferable to introduce standards from the gas phase or alternatively to establish that injected liquid standards give an equivalent response to the same amount of standard introduced from the gas phase.

(c) There is no mention of retention volumes of the sorbent tubes. These have presumably been established for individual VOCs at some stage and need to be cited in order to establish that they are not exceeded for any of the determinands.

(d) Page 19 lists five events which were omitted from the tabulated concentration data for a number of reasons. Two of these need elaboration, i.e. the sample that was taken using an incorrect type of tube (how on earth did this happen?) and IPA from the particle counter being sampled by the sorbent tube (was this tube analysed at all? If not, why not?).

(e) There seems to be no recognition of the fact that the ultrafine particle counts are extremely high. This may be because BS EN 4618:2009 indicates that concentrations of this magnitude are to be expected within an aircraft cabin, but compared to other environments, even alongside very busy roads, some of the measured concentrations are extremely high. Some explanation for the source of the ultrafine particles, and consideration of accompanying pollutants would be well worthwhile. An important issue, however, is the averaging time of these data which does not appear to be specified. The latter comment also applies more generally to the continuously collected data.

(f) Figure 4 contains no units on either axis.

(g) Page 27, Table 11 – what is the averaging time for these concentrations?

(h) Page 29, it would have been useful to examine in more depth the extent to which those people reporting odours are able to distinguish between them. From my own experience, the most common odour on aircraft is that of kerosene fuel vapour sampled during taxiing. This is an entirely different smell from a smell of oil or pyrolysed oil, yet, my interpretation of page 29 is that the respondents were not distinguishing these. This is an issue that ideally needed consideration in the design of the study with perhaps some investigation of the capabilities of the questionnaire respondents to distinguish such odours.

(i) Page 34, Table 17 – carbon monoxide now appears in units of $\mu g\ m^{-3}$ whereas previously the data were in ppm. It would be appropriate to unify the units used for carbon monoxide throughout the report.

(j) Page 35 – it would be useful to qualify the data in these tables with the averaging times of the measurements.

(k) Page 38 – preamble to the conclusions – this refers to the formal reporting of incidents. It would help to put the report into context if the frequency of formal reporting of fume incidents were to be listed.

(l) Appendix G – it is not clear why the inter-laboratory comparison was restricted to pre-prepared solutions introduced to sorbent tubes rather than a fuller comparison of co-located simultaneous samples collected from the atmosphere.

CONCLUSION

Overall, this is a report of very varying quality. Certain aspects of the study design and analytical work are of a very high standard. However, there are serious weaknesses both in the sampling of OP esters and in the analysis of continuous measurement data which substantially weaken the overall impact of the report. Otherwise, the points raised a relatively minor, but nonetheless should be given attention in drawing up the final version of this report. Despite the questions raised, it seems likely that the data for VOC (but not SVOC) are reliable, as well as those for TVOC, CO and particle number. These give some reassurance that during the periods of sampling, no major ingress of pollutants occurred.