Cabin Air Sampling Study

Functionality Test

Executive Summary
prepared for the Department for Transport

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November 2007

1. BACKGROUND

The Department for Transport (DfT), on behalf of the Government's Aviation Health Working Group (AHWG), commissioned Cranfield University to organise, manage and deliver a functionality test of a variety of air sampling devices capable of detecting a wide range of compounds in a cabin air environment including transient "fume events". The functionality test was to be the preliminary stage of a major monitoring study of the cabin air environment, which the Department intends to conduct.

2. METHODOLOGY

The initial design for the functionality test was based on the recommendations from the Government Committee on Toxicity (COT). This proposal had been to collect cabin air samples from a BAe146 and Boeing 757 (fitted with a RR535 engine) on the ground with and without the engines running in order to assess the suitability of the equipment for use in a major investigation into cabin air quality. The sampling equipment to be assessed was to be solid phase microextract fibre (SPMEs) and photoionization detectors (PIDs).

Two potential roles for the equipment were considered:

1. Monitoring of overall VOC and SVOC concentration across all phases of a flight
2. Detection of anomalous elevations of VOC and SVOC concentrations ("fume events").

Since the increased concentrations of VOC/SVOCs in a "fume event" were considered likely to be transient, consideration was also given to the feasibility of using a PID as a method for triggering other VOC/SVOC sampling methods such as pumped thermal desorbtion (TD) tubes, which might be expected to allow identification of specific VOC/SVOCs released during an incident.

The devices were placed and operated by a scientist from Cranfield and an occupational hygienist from an independent commercial laboratory. In addition to analysis by these two institutions of the samples they took, extra samples were sent to a further independent commercial laboratory.

The Building Research Establishment (BRE) have extensive experience and their own equipment and techniques for air sampling and analysis. They were also invited to take part in the cabin air sampling on the BAe 146 and Boeing 757 aircraft.

3. DATA COLLECTION

3.1 Stage 1

The first stage of the functionality test involved the collection of samples from the cabin air of a BAe 146 aircraft whilst parked in the hangar. Samples were taken with

and without the Auxiliary Power Unit (APU) and Air conditioning packs (ECS) running.

As an additional check of the sampling techniques used, an "unknown" solvent (prepared by Cranfield University) was released at a pre-determined time in the BAe 146 cabin, whilst the engines were running. This enabled information to be gained about the capability of the various types of sampling equipment to provide information on the identity of a substance and its concentration. The analysis of the samples indicated that:

- The compounds determined were all at low concentrations – less than 0.1mg/m^3 (apart from the test with the introduction of the unknown solvent), which is less than any of the workplace exposure levels for the compounds determined.
- Toluene was correctly identified as the unknown solvent introduced into the cabin. Other impurities of the Toluene test solvent were also determined.
- The results indicated that the most appropriate technique for determining accurately the compounds present within the cabin was the pumped thermal desorption methodology. This is especially the case for compounds that may only be present for short periods of time, such as those released during any "fume event".

Overall, the results from the tests in the BAe 146 had provided valuable information on the performance of the sampling equipment on the ground. Rather than replicate the same procedures on the ground with a B757, it was decided for Stage 2, that more could be gained from collecting samples using the equipment in flight.

3.2 Stage 2

The sampling equipment was the same as for the BAe 146, with the following two minor exceptions. The PID device was changed from a device which would register one part per million, to one part per billion. Two samples were collected from some of the test conditions in order that they could be analysed by two independent laboratories as a check on the analysis and findings.

A flight was planned which involved the test conditions during which samples were taken. These are summarised below:

1. Aircraft background
2. Aircraft background (APU and ECS on)
3. Taxi
4. Ascent/Climb
5. Cruise
6. Descent
7. Descent/Landing/Short Taxi
8. Stand (APU and ECS on)

All samples were collected on the flight deck of the aircraft, with the door to the cargo bay closed.

The procedure for the flight and data collection went entirely as planned with one exception. This was that at the top of the climb phase, a "fume event" occurred. The event was of very short duration but was noticeable to all in the cockpit (crew and scientists) as a distinct oily type odour, which persisted for less than one minute before completely dissipating. Although the BRE sampling equipment indicated an increase in the number concentration for particles measured during this period, their mass concentration would have been extremely small. The pumped sample taken for analysis during this flight phase (i.e. over 18 mins) did not significantly affect the results from the climb phase of flight. This means that although a "fume event" occurred on this flight, the samples taken cannot be regarded as an accurate measure of substances released during that event. As discussed in the Conclusions below, measurements will need to be taken over a much shorter period in the next phase of the study.

The sampling for volatile and semi-volatile compounds using thermal desorption tubes at various stages of the test flight resulted in the detection of; Benzene, Toluene, Xylene, 1,2,4-Trimethyl benzene, Naphthalene, Heptanal, C9-C15 Aliphatic hydrocarbons, Phenlo, 3-Carene, Phenylethyne, C17 Aliphatic hydrocarbons, Ethyl hexyl phthalate, C20-C30 Aliphatic hydrocarbons and Hexadeconoic acid. The results of the sampling highlight that none of the detected compounds were present at concentrations in excess of 0.2 mg/m^3 (200 $\mu g/m^3$). For all samples, Toluene was the predominant analyte detected.

It should be noted that in all instances the detected concentrations from the sampling using thermal desorption tubes were significantly below the relevant HSE specified WEL where applicable. It should also be noted that wherever possible, WELs are set at a level at which there is no evidence of adverse effects on human health.

The results from the analysis of the SPMEs and PD pumped samples sent to an independent laboratory for analysis, highlighted the practical challenges associated with using one organisation to collect the samples and another to perform the analysis. The results from the analysis performed by the independent company did confirm that the collection of data using PD pumped samples to be the most appropriate method.

4. CONCLUSIONS

1. The results from the tests on both a BAe 146 and the B757 indicated that equipment and analytical techniques are available to monitor and provide data on contaminant chemicals in the cabin.

2. The functionality tests led to the identification of two techniques with independent methods for data collection and analysis which can be performed by independent laboratories and which can potentially be used for a future data collection investigation of cabin air quality. The techniques allow quantification of the concentration of the contaminants present so as to allow direct comparison between the sets of results. One method has been developed by BRE and is their intellectual property. The other technique involves a combination of the use of pumped TD tubes to collect air samples over predetermined phases of flight and the potential use of a PID (ppb) to indicate when a "fume event" has occurred and to indicate that a pumped TD tube sample should be immediately collected within the following minute.

3. The techniques described can potentially be used for both background monitoring of cabin air in normal flight and for sudden "fume events". It is recommended that the Functionality Test is extended to finalise the methodology to be used for the collection of cabin air samples both during normal flight and immediately following a "fume event". It is suggested that the extended programme takes place during the first three months of 2008. This will enable samples to be collected and a preliminary data set established, during the winter weather, which is the time at which 'fume events' have an increased probability of occurrence.

4. Finally, it is recommended that in any future major data collection study, following any occurrence of a "fume event";

(i) the pilots and research scientists on the aircraft are required to complete a questionnaire about the event.

(ii) relevant information is obtained from the flight data recorder and aircraft maintenance reports for subsequent analysis.

5. The major data collection study will enable information to be gained on the substances which are released into the cabin air. Once this knowledge has been obtained, consideration should be given to a further study involving the collection of specimen samples from pilots following a "fume event". From these samples it will be possible to determine by laboratory testing, whether the substances released during a "fume event" and identified in the main data collection study, have been absorbed by the pilots.