U.S. Department of Transportation

Study of Airliner Cabin Air Quality

Summary

BACKGROUND

In December 1989, an independent contractor for the U.S. Department of Transportation (DOT) completed its year long study of the air quality in airliner cabins. The purpose of this work was to develop information on exposure to various pollutants that were suspected of representing a health risk for airliner cabin occupants. These pollutants included tobacco smoke, carbon dioxide, microbial aerosols, ozone, and cosmic radiation. The study was conducted during the period when smoking was banned on scheduled commercial flights having durations of two hours or less, pursuant to Public Law 100-202, and preceded passage of Public Law 101-164, which bans smoking on practically all scheduled domestic flights. Geomet Technologies, Inc., of Germantown MD, performed the study for the Department.

MEASUREMENT

Overall Procedure - In order to assure that the conditions sampled were fully representative of the in-flight conditions that the public actually experiences, yet not cause undue alarm to passengers, measurements were taken using small, unobtrusive instruments, packaged in compact carry-on bags--of the type typically carried because they can be stowed under airliner seats. Technicians booked passage as ordinary revenue passengers on a total of 92 flights between April and June of 1989: 23 nonsmoking and 69 smoking flights, including eight on international routes. Flights were selected randomly out of the schedule for all flights between the nation's 70 largest airports, in such a way as to be statistically representative of the airlines, types of aircraft, flight durations, and times-of-day for departures.

On smoking flights, four technicians were positioned in coach, one each in the smoking section, the no-smoking boundary region (the three nonsmoking rows nearest the smoking section), the middle of the no-smoking section, and the part of the no-smoking section that was the most remote from the smoking section. On nonsmoking flights, technicians were placed at two locations, the middle and the rear of the plane. The instrument package was typically placed on the technician's lap or lap tray to obtain measurements of contaminants most representative of passenger breathing levels.

Measurement of Smoking By-products - There are literally hundreds of by-products left in the air after smoking, in the form of gases and suspended particles, which are collectively termed environmental tobacco smoke (ETS). To establish the levels of ETS in

airliner cabins, three of these by-products were sampled: nicotine and carbon monoxide in their gaseous form, and respirable suspended particles (RSP). RSP was measured using two different types of instruments--optical, and gravimetric--of which the optical is more accurate when concentrations are low. In the case of RSP, because the instruments measure suspended particles from all sources, including sources other than ETS, it was necessary to use RSP levels measured on non-smoking flights to establish a base line from which to compare the higher levels attained when smoking was permitted. Counts of people smoking and of cigarette butts left in ashtrays were also maintained concurrently.

Other Measurements - Levels of carbon dioxide (CO_2) and ozone were measured throughout the flight. Temperature, relative humidity, and cabin air pressure were also monitored. There was no need to sample cosmic radiation, since there are already well-based methods for forecasting its levels (risk analyses were conducted, however, and are described below). Samples of microbial aerosols (bacteria and fungi) were taken near the end of each flight, prior to descent, and later analyzed.

FINDINGS

Environmental Tobacco Smoke - The findings regarding levels of ETS contaminants are summarized in Exhibit 1. It may be seen that concentrations of RSP were highest in the smoking section, averaging near 175 micrograms per cubic meter ($\mu g/m^3$) compared to a background level of 35 to 40 $\mu g/m^3$ on nonsmoking flights. The differences between the no-smoking sections of aircraft where smoking was allowed versus nonsmoking flights, were small, except that levels of smoke in the boundary section were found to be about 35 to 50% higher than levels on nonsmoking flights. It may be seen that this migration of ETS contaminants into the boundary region was even more pronounced when considered in terms of one-minute peak RSP concentrations. Measured nicotine levels also show some penetration but are less conclusive because the levels of nicotine were frequently too low to be measured by the miniaturized instruments used.

Carbon Dioxide - The relatively high CO_2 levels found are indicated in Exhibit 2. On 87 percent of the flights they averaged over 1,500 parts per million (ppm), substantially higher than the 1,000 ppm level that the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) associates with satisfaction or comfort.

Ozone - Ozone levels were relatively low--an order of magnitude below the FAA three-hour standard of 0.10 ppm and never exceeded this level.

Microbial Aerosols - Measured bacteria and fungi levels were in all cases below the levels generally thought to pose a risk of illness.

RISK ASSESSMENT

ETS - Estimates of lifetime lung cancer risk for nonsmoking flight attendants and passengers were developed by applying the measured RSP concentrations to well-known health-effects models from the scientific literature. Two such models were used, one which assumes that risk is linearly related to exposure (phenomenological model) and one which assumes that the development of cancer occurs in stages, and takes into account the age at which exposure begins (multistage model).

To translate the results of these models into cancer risk, it was necessary to make certain assumptions about the numbers of hours flown by passengers and crew, and the duration of their careers. For flight attendants a typical career was assumed to start at age 25 and consist of 960 hours per year for 20 years, in airliner cabins where smoking was permitted. A frequent flying business passenger was assumed to fly for 480 hours per year for 30 years, starting at age 35.

Resultant estimates of lifetime lung cancer risk (i.e., premature deaths per 100,000 persons at risk) for nonsmokers exposed to ETS are summarized in Exhibit 3. The estimated risks were highest for cabin crew members, who fly more frequently, spend a larger fraction of their time in the smoking section, and because of their physical activity, exhibit a higher respiratory rate than nonsmoking passengers. Estimates from the two models were quite consistent except in the case of business passengers; for this group, the assumption that frequent flying begins at a later age resulted in lower estimates using the multistage model.

As may be seen in Exhibit 3, estimated lifetime lung cancer risks for nonsmoking cabin crew members ascribable to ETS exposure ranges from 12 to 17 premature deaths per 100,000 individuals. Were smoking unrestricted, 13 premature deaths due to cancer would be expected over the 85,000 flight attendant population. The forth-coming Congressional ban, however, has ruled out smoking on 99.8% of the domestic flights and 93.8% of all flights by U.S. carriers (including international), which reduces this risk to about 3 premature deaths over 20 years. Risk for nonsmoking frequent fliers is about 1/10 of these magnitudes, and for casual passengers is slight.

Cosmic Radiation - Exposure to cosmic radiation depends on the altitude and latitude of each flight taken; data defining this exposure has been widely published. The estimated lifetime cancer risks for a set of typical flights may be seen in Exhibit 4. Risk for cabin crew members range from 5 to 61 premature deaths due to cancer per 100,000 individuals flying for 20 years on domestic flights and from 13 to 30 premature deaths per 100,000 individuals

flying for 10 years on international flights. Comparable figures for passengers flying 480 hours per year range from 3 to 30 premature deaths for flying 20 years on domestic flights and from 7 to 15 deaths for flying 10 years on international flights. In addition, there is particular risk to the unborn--fetal exposure during weeks 8-15 of gestation greatly elevates the risk of retardation.

Conclusions - Of the contaminants studied, only the levels of ETS and cosmic radiation were sufficient to pose a health hazard and this hazard was principally confined to cabin crew and very frequent flyers. The other pollutants pose no health problem although levels of CO_2, a by-product of respiration, exceed comfort criteria.

MITIGATION MEASURES

With regard to mitigation of ETS, procedural options such as restriction of smoking and technological options such as increased ventilation were assessed. Of these options, a total ban on smoking was estimated to provide the greatest benefit at least cost (this has essentially been realized for domestic flights with passage of P.L. 101-164).

Exposure management strategies are considered the only viable option for reducing exposures of cabin crewmembers and passengers to cosmic radiation. This would involve careful scheduling of personnel to avoid persistent exposure to higher cosmic radiation levels generally associated with high-altitude flights and flight paths crossing extreme northern or southern latitudes.

Strategies to reduce CO_2 could include removal by sorption, or increased ventilation, the latter involving some fuel penalty.