Air Distribution in Rooms, (ROOMVENT 2000)
Editor: H.B. Awbi

INVESTIGATION OF CABIN AIR QUALITY IN COMMERCIAL AIRCRAFTS

Shun-Cheng Lee[1], Sanches Lam[1] and Fred Luk[2]

[1]Environmental Engineering Unit,
Hong Kong Polytechnic University, Hong Kong
[2] Cathay Pacific Airways, Hong Kong

ABSTRACT

This project covered 16 aircrafts including both smoking and non-smoking flights from June 1996 to August 1997. The parameters concerned were carbon dioxide (CO_2), humidity, temperature, carbon monoxide (CO), ozone (O_3), bacteria, fungus, and respirable suspended particulate (RSP). Compared with the Federal Aviation Administration (FAA) standard, CO_2, CO and ozone levels on all flights were within such standards. Peak levels of CO_2 and particulate were observed during both boarding and de-boarding periods. For the smoking flights, the average particulate level (138$\mu g/m^3$) was much higher comparing with the non-smoking flights (7.6 $\mu g/m^3$). Low humidity in long haul flights caused uncomfortable conditions to the cabin crews. The average temperature was within the range of 23+/-2°C.

KEY WORDS

Cathay Pacific, Aircraft; Cabin air quality; Hong Kong; Cabin crew, Humidity

INTRODUCTION

Air travel has become an essential form of transportation in modern society. The health and comfort of air travellers depends on the complex interplay of several factors such as the adequacy of the ventilation system to allow fresh air in the occupied zone; the concentration of contaminants; the temperature; and relative humidity. (O'Donnell et al, 1991). For years, flight attendants have reported various health

problems - from chronic bronchitis to difficulties in pregnancy(Nagda et al, 1992). Environmental engineers have become aware of the effects of pollution in confined spaces and have revised ventilation. Spengler (1994) stated in his report that reduced amounts of outdoor air do not necessarily translate to poor air quality and increased risk of disease. Air cleaning and removal of pollutant sources mitigate some of the effects of decreasing dilution air. This was the first intensive study for aircraft air quality in Hong Kong. The detailed objectives of this paper are: **1)** To assess the indoor air quality on 16 Cathay Pacific Airways commercial aircrafts; **2)** To compare the Indoor Air Quality (IAQ) levels with existing regulations and standards including FAA, American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), International Standard Organisation (ISO), etc; and **3)** To provide and evaluate different remedial measures for IAQ improvement in the aircraft for CPA.

METHODOLOGY

The sampling size covered three different types of aircrafts including Boeing 747-400, Airbus 330 and Airbus 340 both smoking and non-smoking flights. Details of flight information is listed in Table 1 below. The sampling strategy and methodology employed are summarized in Table 2.

TABLE 1
FLIGHT INFORMATION

Flight	Date	Duration (hour:minute)	Occupancy (%)	Flight	Date	Duration (hour:minute)	Occupancy (%)
1	Sept 2, 96	11:29	-	9	Feb 28, 97	3:20	100
2	Sept 5, 96	13:05	-	10	Mar 2, 97	3:11	69
3	Sept 19, 96	12:52	-	11*	May 8, 97	1:25-stopover-3:00	60
4	Sept24, 96	11:30	-	12*	May 13, 97	5:00	67
5	Jan 13, 97	12:35	93	13	Jun 8, 97	14:15	34
6	Jan 15, 97	11:35	88	14	Jun 12, 97	6:55-stopover-12:50	-
7	Jan 24, 97	13:15-stopover-1:20	83-stopover-33	15*	Jun 28, 97	1:25	91
8	Jan 28, 97	1:20-stopover-11:50	32-stopover-78	16	Jun 28, 97	1:25	-

**Smoking flight, Fight 3 & 16 are Airbus 340, Flight 9 is Airbus 33*

TABLE 2

SUMMARY OF SAMPLING METHODOLOGY AND STRATEGY

Parameters	Measurement Technique	Sampling interval	Flight(s) measured
Carbon monoxide	Electro-chemical	Every5 minute	9, 10, 11, 12, 13, 14, 15, 16
Carbon dioxide	Non Dispersive Infrared	Every5 minute	All
Temperature	Thermistor	Every 5 minute	All
Relative humidity	Thin-film capacitive	Every 5 minute	All
Ozone	Passive ozone badges or Bio-check enzyme	Integrated sample taken in the test flight.	6, 8, 10, 11, 16
Respirable Suspended Particulate	Light-scattering	Every 5 minute	5, 6, 11, 12, 13, 14, 15, 16
Microbiological Organisms	Burkard air sampler with agar plates	Up to twice per flight	8, 10, 12

Air from the cabin was sampled at a specific sampling frequency (Table 2) during the entire flight and its contents of NO, SO_2, NO_2 , and CO were measured. Humidity, temperature, CO_2, and RSP were continuously monitored. The sampling and analysis of the chemical and gaseous contaminants were performed according to the standard methods acquired from American Public health association, American conference Governmental Industrial Hygienists, American Society for Testing Materials, and National Institute for Occupational Safety and Health.

RESULTS AND DISCUSSION

The average CO_2 and CO levels measured were below FAA standard of 30,000(Table 3). Overall average bacteria counts(75 CFU/m^3) were very low. The average temperature was 21.9°C, which was within the ASHRAE range (23±2°C), and were stable during cruise. All of the measured RSP, CO_2, and CO concentrations were higher in smoking flights than non-smoking flights. (Fig 1)

TABLE 3

HEALTH REGULATIONS AND COMFORT STANDARDS FOR AIRCRAFT

Contaminant	Federal Aviation Administration	ASHRAE, 62-1988, 55-1989
Carbon dioxide (ppm)	30,000 continuous	1,000 continuous
Carbon monoxide (ppm)	50 continuous	
Ozone (ug/m3)	20 above 27,000ft	
Relative humidity (%)		20 minimum
Temperature (°C)		19-23, winter 23-26, summer

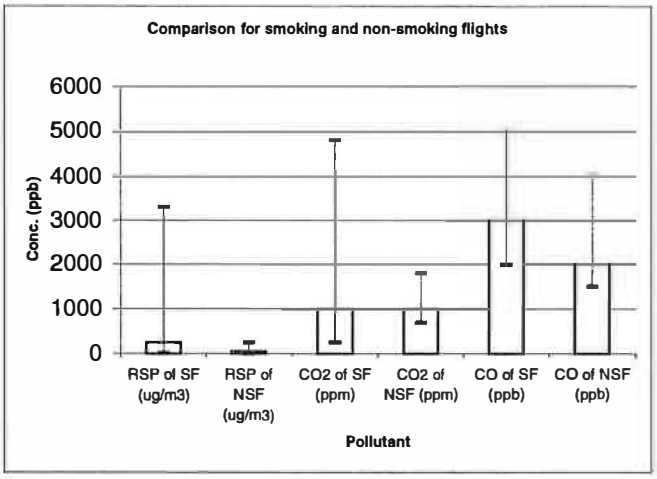

Fig 1 Comparison of smoking with non-smoking flight

The higher CO levels (3-5 ppm) in smoking flights did not exceed any relevant standards. However, the RSP levels were high for the smoking flights (71-264μg/m3). And given the low relative humidity and high ozone concentration, irritation and discomfort were likely to be important for occupants of the smoking and nearby sections. A similar temporal variation pattern of CO_2, RSP, bacteria, and fungi concentrations was dominated by the occurrence of boarding and de-boarding periods. Lower fresh air supply and the exhaust gases from the airport resulted higher CO_2 levels during boarding and de-

boarding. Also, peak RSP, bacterial and fungi counts were occurred during active pre-boarding and de-boarding as passengers were retrieving luggage and leaving. There was significant difference on minimum and average humidity on long-haul, medium-haul, and short-haul flights. Both average humidity and minimum humidity dropped as flight time increased. For short-haul flight, the minimum humidity was 16.3% compared with the long-haul flights at 6.7%. (Figure 2)

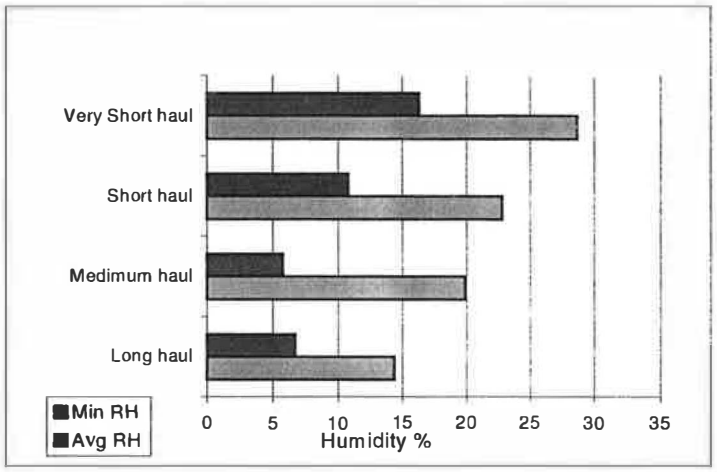

Figure 2 The impact of flight time on Humidity

The distribution of pollutants in the aircraft was not uniform. The concentration measured in any area would depend on location of the sampler in relation to the pollution source. The CO_2 levels in the rear of Economy Class was higher, suggesting a front to rear movement of the air. The humidity levels in toilet and galley area were the highest, suggesting the main sources of humidity in the aircraft were from the food preparation.

The CO_2 level was reduced by 29% due to the increase in the total cabin airflow when the ventilation was switched to high mode. But higher outside-air ventilation rates lowered humidity by 27% due to the relatively dry outside air. Temperature was not affected by the high mode ventilation.

CONCLUSION

A total of 16 flight audits on CPA aircraft were investigated in this project. In general, the aircraft air quality on CPA aircraft was satisfactory. The CO_2 levels on all flights were below the FAA standard. The relative humidity was low, with minimum 4.9% especially for long haul fights. The minimum relative humidity level recorded was below the ASHRAS standard, and was not uniform with the highest in first class and the lowest in economy class. Average particulate concentration on a smoking

flight was 1,815% higher than that of non-smoking fight. CO_2 and relative humidity levels were both reduced by 29% and 27.6%, respectively, by switching ventilation from low mode to high mode. The bacteria levels on CPA flights were generally low.

ACKNOWLEDGEMENTS

This project is supported by the Environmental Office of Cathay Pacific Airways Limited and the Hong Kong Polytechnic University.

REFERENCES

Aerospace Industries Association of America, Inc. Airplane Air Conditioning System Configuration and Air Flow Data for Selected Boeing, Douglas, and Lockheed Aircraft. (unpublished document, September 17, 1985)

American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. ASHRAE Standard: Ventilation for Acceptable Air Quality. ASHRAE 62-1981. Atlanta, Gal: American Society of Heat, Refrigerating, and Air-Conditioning Engineers, Inc., 1981.

Malmfors, T., Thorburn D., and Westlin A. (1989). Air Quality in Passenger Cabin of DC-9 and MD-80 Aricraft. *Environmental Technology Letters*, **10**, 613-628

Nagda, N.L., Koontz, M. D., Konheim, A. G and Hammond, S. K (1992). Measurement of cabin air quality aboard commercial airliners. *Atmospheric Environment*, **12**, 2203-2210

O'Donnell,A., Donnini, G. and Nguyen, V.H (1991). Air Quality, Ventilation, Temperature and Humidity in Aircraft. *ASHRAE Journal*, April, 42-46

Spengler, J., Burge, H., Dumyahn, T., Dalhstrom, C., Muilenberg, M., Milton, D., Ludwig, and Weker, R. (1994). Harvard Aircraft Cabin Environmental Survey. Department of Environmental Health, Harvard University School of Public Health, Boston, MA, USA.

U.S. Federal Aviation Administration. FAA Aviation Forecasts, Fiscal Year–1985-1996. FAA-APO-85-2. Washington, DC.: U.S. Federal Aviation Administration, 1985

U.S. Federal Aviation Administration. Transport Category Airplanes Cabin Ozone Concentrations. Advisory Circular 120-38. Washington, D.C. U.S federal Aviation Administration, 1980.