COMMENTS ON AIRCRAFT AIR QUALITY

Submitted to the

Committee on Air Quality in Passenger Cabins of Commercial Aircraft

National Academy of Sciences/National Research Council

Commission on Life Sciences

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(Updated section on cabin altitude, November 2002)

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on behalf of the Association of Flight Attendants, AFL-CIO
This document is submitted on behalf of the Association of Flight Attendants (AFA), a labor union that represents more than 50,000 flight attendants at 27 different airlines. It is based on reports of problems with aircraft air quality submitted by flight attendants; AFA’s involvement in various investigative efforts and on various committees and working groups; conversations with mechanics and engineers; and in a few cases, information and reports that the airlines and the US Federal Aviation Administration (FAA) have provided.

What gives us reason to believe that there is a problem with aircraft air quality in the first place? First, there are few regulations, and the justification for the regulations that do exist is not always clear. Second, the design of the air supply systems facilitates some problems. Finally, we receive reports of problems with aircraft air quality from our members.

• **Sources of data that define the problem.**

The flight attendants that the AFA represents are stationed at approximately 75 bases and a union safety and health representative is assigned to each base. Each local safety representative is responsible for collecting incident reports from members, including reports of problems with air quality. These reports are not as useful as we would like because there is no guarantee that members will always report problems to their local union. Their priority is to file a report with the company if they think that their symptoms might be serious enough to file a workers’ compensation claim.

What about other sources of information? The airlines are required to collect and log reports of occupational illnesses and recordable injuries, but to date, they are not required to share that data with the flight attendants or their representatives. In most cases, the airlines do not share these reports, and in our experience, if they do, it is with the understanding that the information is confidential.
Unfortunately, logs of injuries and illnesses (OSHA 200 logs) maintained by the airlines are not always reliable. For example, a representative at one airline gave us a copy of their OSHA 200 log printed in June 1998. Seven months later, somebody else at the same airline gave us another copy of the OSHA 200 log printed in December 1998. Nineteen of the 27 occupational illnesses logged in the first six months of the year on the June log as "inhalation – unknown cause" or "inhalation-chemical" had been removed on the December log. Clearly there is some question as to how reliable these company records are, even if they are provided.

The FAA does not collect work-related illness reports from flight attendants, nor does the National Transportation Safety Board. A search of the FAA’s Service Difficulty Reporting System which is a reporting system for maintenance issues identified almost 8268 reports that mentioned "smell", "fume", "odor", "gas", "toxic fume", or "toxic gas" between January 1, 1986 and March 7, 2000. However, these are not illness reports.

In conclusion, in terms of data, the FAA does not collect reports on symptoms, the unions do not have access to company records and there is some question as to the validity of the records, and although union safety representatives receive reports of air quality problems from flight attendants, we do not have a reliable system that would allow us to report a rate of air quality incidents system-wide.

So what do the reports that we do receive tell us? The symptoms, whether reported to the company or the union, range from headaches, nausea, and fatigue, to fainting, neuromuscular damage, and memory loss. Here is an example of an excerpt from a more serious report:

"After the aircraft door closed for departure, a strong odor came into back of cabin; at 10,000 feet, flight attendant in aft jumpseat felt "weird", had difficulty focusing, metallic taste in mouth, body heavy, skin felt hot, nauseous; she went to cockpit to
“use their oxygen; when there, warning light went off; pilot said there was a hydraulic leak in the main system.”

There is concern among some parties as to whether these symptoms can be explained by problems with aircraft air quality or other factors such as jet lag, dehydration, fatigue, or simply "hysteria". Nobody could argue that being on duty for long flights, crossing time zones, and attending to the public are not stressors in and of themselves. However, the persistence and the patterns of the symptoms often indicate a strong correlation with air quality problems.

For example, sometimes certain types of reports are concentrated on (but not restricted to) certain aircraft types, making them easier to define. At one airline ("Airline A"), almost half of the 68 air quality incidents logged by the company over seven months were reported on a single aircraft type, although that aircraft type only made up 5% of the fleet. Also, there was a definite pattern to the symptoms – most reports mentioned dizziness and fainting. Another airline ("Airline B") logged 760 incidents over a nine-year period that involved either a visible aerosol in the cabin and reported symptoms, or mechanical records that indicated contamination, or both. A single aircraft type was involved in three-quarters of these incidents, even though that aircraft type only made up about half of the fleet.

What follows is a description of some of the AFA's concerns with the reduced oxygen environment, the absence of a ventilation standard, the presence of particular contaminants in the aircraft cabin, and the design of the air supply systems on commercial aircraft.

- **Reduced oxygen content**

The aircraft cabin is pressurized because the oxygen content in unpressurized air at altitude is not adequate to sustain life. The introduction of compressed air into the aircraft cabin ensures that the internal cabin pressure (and the corresponding partial pressure of oxygen) is higher than
the outside air pressure at the flight altitude. The cabin pressure is usually referred to in terms of its corresponding altitude ("cabin altitude").

During the certification process, the FAA requires the manufacturer to demonstrate that the aircraft is "equipped to provide" a cabin altitude of not more than 8000 feet at the maximum operating altitude (14 CFR 25.841(a)).

The 8000 ft design standard for cabin altitude and the desired maximum flight altitude define the necessary pressure differential (PD) that the manufacturer must design the aircraft skin to withstand under normal operating conditions for the anticipated lifetime of the aircraft. In this way, maximum operating altitudes for normal conditions are established by the regulatory authority according to aircraft type (e.g., see FAA Type Certificate Data Sheets) and incorporated into the flight operations manuals (FOM).

On a new aircraft that is operated at or below its maximum certified flight altitude, the cabin altitude should be equal to or less than 8000 feet. On older aircraft, air leakage through the seals of the doors and cockpit windows can create a situation where the volume of air leaving the aircraft exceeds the volume of air that the air conditioning system provides to the cabin and cockpit. Manufacturers typically calculate and publish curves that define the inflow of outside air, as a function of flight altitude, necessary to maintain a cabin pressure at or below 8000 feet at the maximum flight altitude, both for new aircraft with tight door and window seals, and older aircraft with anticipated seal wear. However, if the air conditioning packs are operated on low-flow as a fuel-savings measure, such that the scheduled cabin pressure is not maintained, then the cabin altitude can exceed 8000 feet. The cabin altitude can also exceed 8000 feet if an aircraft has unusually high external leakage (i.e., outflow exceeds the cabin air inflow), or if it is operated above its maximum certified altitude.
This 8000 feet *design standard* for cabin altitude was first issued in 1957 by the US Civil Aeronautical Board (CAB)\(^1\) and adopted by the FAA in 1964. No regulatory authority has issued an explicit *operating standard* for cabin altitude, except that when the cabin altitude reaches 10,000 feet (essentially an emergency condition), the pilots must don oxygen masks, and at 14,000 feet, oxygen masks are automatically provided to the cabin occupants.

There is no apparent rationale for the 8000 feet design standard, probably because the FAA was not required to provide substantiating material when it recodified the CAB regulations as Federal Aviation Regulations in 1964. The FAA must now thoroughly justify any new standards but the pressurization standard has not been revisited, and an operating standard has never been proposed.

Because occupants' oxygen needs vary according to activity level, health status, and age, there is controversy over whether even the 8000 feet *design standard* is appropriate for the oxygen needs of the flying public. For example, a study of blood oxygen saturation among a group of 42 airline pilots (mean age of 46 years, +/- 9 years) measured an average blood oxygen saturation on the ground of 97% (95-99%) compared to 89% (80-91%) at altitude\(^2\). The problem is that heart and lung disease, being overweight, old(er), unfit, and taking certain medications will mean that one's body uses that aforementioned reduced amount of oxygen at altitude less efficiently than might be expected among fit pilots. The second part of the problem is that more than half of Americans are overweight\(^3\) and obesity is on the increase in Europe\(^4\). One in four Americans aged 18 and older smoke\(^5\), approximately 17 million have asthma\(^6\), and heart disease accounts for 40% of deaths of all Americans, making it the leading cause\(^7\). Finally,

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\(^1\) US Civil Aeronautical Regulation 4b.374 (Aug. 12, 1957); recodified as US Federal Aviation Regulation 25.841(a) (Nov. 3, 1964).


\(^7\) American Heart Association, 2000.
the flight attendant population has changed after the removal of age restrictions in 1968, and likely after the removal of weight restrictions in the early 1990s. Given all of this, it seems more appropriate to measure blood oxygen saturation of the general public, or at least the active flight attendants, at altitude, rather than pilots.

Probably the most-quoted position on the subject of cabin pressure is in the report issued by the NAS Committee on Airline Cabin Air Quality in 1986\(^8\) that said for normal, healthy individuals

\[\text{“...pressurization of the cabin to an equivalent altitude of 5,000 to 8,000 feet is physiologically safe.”}\]

However, the Committee also reported

\[\text{“... a 7-10% decrement in maximal performance at altitudes between 7,000 and 10,000 ft”}\]

and "various degrees of risk” for people with cardiopulmonary disease and some other ailments at 8000 feet.

It is not clear whether the Committee's conclusions were based on blood oxygen saturation measurements of pilots, but the justification deserves a review because some researchers have suggested that the 8000 foot limit was developed for the needs of fit military men\(^9\) and that a 6000 foot limit may be more appropriate for the general public\(^10\). It is also relevant to note, given the controversy over the definition of an appropriate altitude limit, that there are two cost incentives to pressurize the aircraft to the highest altitude (and therefore lowest absolute oxygen


\(^9\) McFarland, RA; Edwards, HT. “The effects of prolonged exposures at altitudes of 8,000 to 12,000 feet during trans-Pacific flights.” Journal of Aviation Medicine, 8: 156-177 (1937).

content) possible: first, flying at a lower altitude, all other things being equal, requires more fuel, and second, it is preferable to minimize the pressure differential between the inside and the outside of the aircraft to reduce the strain on the aircraft structure.

- **Contamination & ventilation**

The second issue to consider is that of contaminant levels inside the cabin (including biological contaminants), and the need to ensure that enough outside air is supplied, not only to pressurize the aircraft, but also to reduce or eliminate airborne contaminants. Ventilation is, of course, effectively independent of oxygen supply.

Through the 1980s, the US National Institute for Occupational Safety and Health (NIOSH) conducted approximately 500 indoor air quality investigations in buildings and concluded that inadequate ventilation was the primary source of indoor air quality problems (52%)\(^\text{11}\). This conclusion applies to buildings not aircraft, but it is an example of the important role that ventilation plays in maintaining the quality of indoor air.

Like a building, sources of contamination include cabin occupants and cabin interiors. Unlike a building, the aircraft envelope (the space between the cabin liner panels and the fuselage) is coated with a lubricant and changes temperature dramatically multiple times in a relatively short time span. Also unlike a building, the supply air is compressed in a number of engines.

One question is what do we know about how contaminant levels compare between buildings and aircraft? On aircraft, the bioeffluent load is higher than in buildings because it is a more densely populated space. The higher bioeffluent load on aircraft is really only an issue if the ventilation system is turned off because ventilation is provided in terms of volume of air per person. However, although equilibrium concentration of bioeffluents in the cabin will not

necessarily be higher than in a building, it will be reached more quickly given the relatively small volume of the cabin\textsuperscript{12}. Some parties have argued that despite this, the smaller unit surface area per person on an aircraft means that less outside air is required to control contaminants. However, to our knowledge, the relative contributions of the interior and envelope have not been properly quantified and compared to other settings, like buildings. What has been shown is that the envelope air can contain high levels of volatile organic carbons (VOCs), probably from the lining of oil and mold growth. These VOCs can leak into the cabin upon ascent when the cabin is being pressurized. In comparison, (with the exception of basement dwellings) high VOC concentrations in the building envelopes have apparently not been shown to be an issue, probably because the exterior cladding of a building permits some air exchange, unlike the skin of an aircraft which is at least intended to be airtight\textsuperscript{13}. Also, a building envelope is not coated with an anti-corrosion oil.

Carbon dioxide (CO\textsubscript{2}) concentration - in buildings and aircraft - is another controversial issue. CO\textsubscript{2} has generally been accepted as an indicator of ventilation rate, which can be an indicator of overall air quality, even if not health and comfort. For example, a review of almost 800 air quality surveys in "problem-free" buildings indicated that only 2.5\% of the CO\textsubscript{2} measurements were higher than the 700 ppm maximal difference between outside and inside air recommended by American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard 62-99\textsuperscript{14}. A number of aircraft studies indicate that CO\textsubscript{2} measurements collected on aircraft tend to be higher than in buildings. For example, in one study, CO\textsubscript{2} levels in the cabin

\textsuperscript{12} Walkinshaw, D. "Investigating the impacts of occupancy density and ventilation on indoor air quality of offices, classrooms, and aircraft." Indoor Air Technologies Inc. (November 2000).

\textsuperscript{13} Personal correspondence with D. Walkinshaw, PhD, PEng. (December 2000).

\textsuperscript{14} Springston, J. Abstract presented at the American Industrial Hygiene Conference & Exhibition, Orlando, FL (May 2000).
averaged approximately 1500 ppm\textsuperscript{15}. More recent air monitoring on eight B-777s measured mean CO\textsubscript{2} levels that ranged from 1252 ppm to 1758 ppm\textsuperscript{16}.

In addition to ventilation rate, two issues that are often discussed in the context of aircraft air quality are "ventilation effectiveness" and filters. Ventilation effectiveness is essentially the degree to which the ventilation system is designed to effectively deliver supply air to a person's breathing zone and deliver the "used" air to the return air ducts where a portion can be filtered and recirculated. Pollutant removal efficiency is one indicator that has been used to measure ventilation effectiveness. In terms of filtration, there is no requirement to install high efficiency particulate filters (HEPA) on aircraft but some of the major US airlines report that they have done so. Assuming that they are installed and maintained properly, HEPA filters (at least in theory) should be effective at removing the bulk of small particulate, including bacteria and most viruses. However, HEPA filters will not remove gases, and we are not aware of any comprehensive surveys that address whether HEPA filters improve air quality and reduce the transmission of disease in the aircraft cabin.

There is no minimum operating standard for ventilation systems on aircraft to control contaminant levels. The FAA has set a design for ventilation systems on new aircraft types, but the design standard does not apply to any aircraft in the sky to date, and even if it did, the airlines can operate the systems at any level, so long as they maintain cabin pressure which requires about 3 cubic feet per minute of outside air per person (CFM/p). Some parties have shown support for establishing a minimum standard of 5 CFM/p on aircraft. It is not clear whether the proposal is for 5 CFM/p sea level equivalent or 8000 feet equivalent (about 3 CFM/p at sea level) but a major proponent of this proposal has cited the three papers discussed below (attached in Appendix A) as the "foundation".


The first two references (Cain, W.S. et al., 1983; Leaderer, B.P. et al., 1983) characterize the ventilation rate at which 80% of occupants and visitors in a test chamber deem the odor to be acceptable under smoking and non-smoking conditions. It is difficult to follow the logic of applying the results to aircraft because the test chamber was aluminum-lined, the supply air was delivered through 14,000 holes in the floor which allowed perfect mixing, there was no envelope with an anti-corrosion coating or mold growth, the relative humidity was considerably higher than on an aircraft, and the tests were conducted at atmospheric pressure. Especially important is that aircraft do not have visitors, and occupants' perception of odor is not a reliable indicator of air quality. This last point was affirmed in the third paper (Berg-Munch B, Clausen G, and Fanger, PO, 1986) cited apparently in support of a 5 CFM/p standard. It concluded that, "the percentage of dissatisfied occupants is independent of ventilation rate."

In theory, air monitoring results could be used to determine an appropriate minimum ventilation rate on aircraft. For example, ASHRAE Standard 62-89 was partly based on field experience with "sick building syndrome" reports, air monitoring, and ventilation rates. The problem is that the majority of air monitoring efforts to date in aircraft has been conducted with the knowledge of the airline in question, and there is no guarantee that conditions on these flights are representative. Some studies have relied on stealth monitoring, but with few exceptions, stealth monitoring is usually conducted from one's seat, and may not represent the air in the aft galley or the supply ducts, for example. In some cases, studies have compared air quality parameters in aircraft to those in other environments, such as buses and trains. However, any comparison must be qualified given that the occupants on an aircraft, particularly flight attendants, spend longer uninterrupted periods of time in an airplane than people spend on a bus or train, and the aircraft is a reduced oxygen environment which could alter the acceptable level of certain contaminants.

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Aircraft disinsection

A special case of exposure to contaminants in the aircraft cabin involves the aircraft disinsection laws of 12 countries\(^{18}\), including Australia and New Zealand where AFA members are assigned to fly. In most cases, the pesticides are applied on the ground in Australia, before flight attendants and passengers board, with a solution that (according to the Australian Quarantine & Inspection Service) must contain 2% permethrin (by weight) and be chemically active for eight weeks ("residual treatment"). Sometimes, if the residual spray has "expired" before an aircraft makes it back to Australia for treatment, then the aircraft must be sprayed "in-flight" with a solution that must contain 2% fenothrin (by weight) while the passengers and flight attendants are still on board.

The World Health Organization approves these pesticides for "aircraft disinsection" because they are apparently effective at controlling vector borne disease. However, the US Environmental Protection Agency (EPA) will not permit either permethrin or fenothrin to be applied in passenger cabins in the US. The EPA has said that they doubt the benefit of spraying fenothrin in an occupied cabin exceeds the risks\(^{19}\). Also, the EPA is reviewing the toxicity of permethrin because of evidence that it can damage the brain development of infants and fetuses.

It is true that the EPA has approved permethrin for some other uses, such as lice shampoo and cargo hold disinsection, in the US. However, the potential for exposure to permethrin from using lice shampoo once every few years is quite different from the potential exposure while working a 15 hour shift on an aircraft that has been sprayed and not vented properly.

\(^{18}\) Australia, Barbados, Fiji, Jamaica, New Zealand, Panama accept residual treatment and Grenada, India, Kiribati, Madagascar, Trinidad & Tobago, and Uruguay require in-flight treatment. Brazil, Czech Republic, Indonesia, South Africa, Switzerland, and United Kingdom require spraying on selected flights.

The neurotoxic effects of permethrin have been documented both in animals\textsuperscript{20} and humans\textsuperscript{21}. Some of the typical effects observed following pyrethroid exposure (tingling, burning, numbness) are felt to be caused by the action on nerve endings in the skin. Therefore by definition, pyrethroids cause transient effects on the peripheral nervous system. Documented cases of acute, severe, neurologic effects (seizures, loss of consciousness) typically follow heavy exposures\textsuperscript{22}. It is unclear how these documented exposures compare to conditions in an aircraft. One would think that the typical exposure pattern for a flight attendant is chronic and lower-level; however, reports submitted by our members indicate that ambient exposures and surface contamination can be significant, particularly in the crew rest area.

In addition to its neurotoxic properties, permethrin has been recognized as an irritant (both to eyes and skin) by the World Health Organization (WHO, 1993), and has been shown to act as an endocrine disrupter, suggesting an adverse effect on the reproductive system\textsuperscript{23-24}. Further, of 64 cases of chronic pyrethroid intoxication reported to the Federal Health Office in Germany in 1993, eight presented symptoms classified as "multiple chemical sensitivity syndrome" (MCS)\textsuperscript{25}. The symptoms of MCS suggest immune system involvement, whether related to the pyrethroids or other elements of the pesticide products. Finally, there is some concern that pyrethroids may be sensitizing agents; that is, they may produce skin and respiratory allergies.

\textsuperscript{21} Altenkirch, H; Hopmann, D; Brockmeier, B; Walter, G. "Neurological investigations into 23 cases of pyrethroid intoxication reported to the German Federal Health Office." Neurotoxicology, 17(3-4): 645-51 (Fall-Winter 1996).
\textsuperscript{22} He, F; Wang, S; Liu, L; et al. "Clinical manifestations and diagnosis of acute pyrethroid poisoning." Arch Toxicol, 63(1):54-58 (1989).
\textsuperscript{23} Go, V; Garey, J; Wolff, MS; Pogo, BG. "Estrogenic potential of certain pyrethroid compounds in the MCF-7 human breast carcinoma cell line." Environ Health Perspect, 107(3):173-177 (March 1999).
\textsuperscript{25} Altenkirch, H; Hopmann, D; Brockmeier, B; Walter, G. "Neurological investigations into 23 cases of pyrethroid intoxication reported to the German Federal Health Office." Neurotoxicology, 17(3-4): 645-51 (Fall-Winter 1996).
Our major concern (aside from whether the spraying is justified) is that there are no regulations to ensure that pesticide and solvent exposures are kept to a minimum. Since the AFA began collecting detailed reports in July 2000, our members have documented conditions in which the walls, bunk beds, and seats are still wet with the spray when the flight attendants board, and in some cases, the food preparation surfaces in the galley are sticky with the spray. These reports indicate the opportunity for dermal absorption and ingestion, in addition to the reports of inhalation after opening a cupboard door or spending time in the bunk area, for example.

- **Contaminated air supply systems**

In apparent contradiction with our concern that there is no minimum ventilation standard is our concern over the fact that the air supply itself can be contaminated. The two major sources of supply air to the cabin are the aircraft engine compressors and the Auxiliary Power Unit (APU). The selection of the source (aircraft engines or APU) will largely depend on the phase of flight and the aircraft type. (As an aside, two less prominent air supply sources include the ground power supply and the air intake scoops. On most aircraft types, the scoops are located in the center of the tail of the aircraft. If an aircraft is deiced, the ram air that enters the air scoops can get contaminated with deicing fluid.)

The aircraft engine compressors are the primary source of air to the cabin. Most of the air compressed in the aircraft engines is used for engine thrust, but a portion of that compressed air is "bled off". The APU is the auxiliary source of power and air. It too is essentially an engine, but it is independent of the aircraft engines, and it sits, in most cases, in the tail of the aircraft. The APU is often used for air supply on the ground, and on many aircraft types, it supplies the cabin with air during takeoff and ascent when the aircraft engines need all of their compressed air for engine thrust. The supply air, whether from the aircraft engines or the APU, is then cooled, conditioned, mixed with about 50% recirculated air, and supplied to the cabin. What follows is a discussion of some of the contaminants that can enter both sources of supply air and the means by which they can do so during the various phases of flight.
In the APU, the moving parts are lubricated with oils that can be heated to high temperatures during operation. Usually these hot oils are kept separate from the compressor, but sometimes (whether it is because of a leaky seal, a cracked joint, or overfilling by maintenance workers), the heated oils (or the gases that are generated) can leak into the air supply. The APU can also ingest any fluids that leak or spill into the belly of the aircraft and make their way to the aircraft tail (where the APU is typically located) according to the line of flight. This includes hydraulic fluids, deicing fluid, and fuel. Lavatory fluids can also leak into the belly of the aircraft and enter the APU; for example, heavy lavatory use can cause the lavatory tank to overflow such that the blue fluid and sewage leak into the aircraft belly. Also, if the lavatory pipes are not drained before an aircraft is scheduled to sit overnight in cold weather, the lavatory fluids can freeze overnight, causing the pipes to crack and the fluids to spray into the belly when the system thaws.

Like the APU, the engines – whether mounted on the wing or the tail – are full of moving parts that are lubricated with oils, and those hot oils, like in the APU, can leak into the compressors and enter the air supply. In addition, wing-mounted engines can ingest deicing fluids and hydraulic fluids that leaked from local hydraulic systems in the event of a line break, for example. Tail-mounted engines may ingest hydraulic fluids that leaked from hydraulic systems throughout the aircraft, for example, those used to control the wing flaps, the landing gear, and the flight controls. Like the rear-mounted APUs, tail-mounted engines may also ingest any other fluids that accumulate in the belly of the aircraft.

In summary, air supplied by the aircraft engine compressors, the APU, and the air scoops can be contaminated. Also, some of these contaminants can accumulate on the lining of the air supply ducts, and the ducts are rarely cleaned, providing an ever-present potential source of contaminants independent of ingestion into the engine compressors or APU. Finally, engine exhaust can be drawn into the air supply systems on the ground, and ozone can be drawn into the air supply at altitude.
In short, the now-Director of the Aerospace Medical Association stated as long ago as 1983 that the design of the air intake system means that

"...the release of fumes or mists from hydraulic fluids and gasoline is always a potential danger."

Incomplete combustion of these oils, fluids, and other organics is one potential source of carbon monoxide (CO). Tricresylphosphate (TCP), an anti-wear agent found in popular commercial engine oils, is another potential airborne contaminant. TCP is gaseous when heated and solid at room temperature. One question that has been asked, is it physically possible for these contaminants to be present if the air supply is contaminated with oil, for example? In the lab, researchers have measured airborne concentrations of both TCP and CO when they heated two engine oils to typical engine operating temperatures.

The other evidence of a problem with contamination of the air supply is the pattern and persistence of the reports provided by flight attendants. In the example referenced earlier at "Airline B", the company logged 760 incidents that involved either a smoke, mist, or odor in the cabin, or reported symptoms over a nine year period. The rate of reported incidents was about 7.6 per 10,000 flights or almost 7 incidents per month. Certain mechanical problems (identified after the fact) could often be associated with the phase of the flight and certain symptoms or a certain odor. An in-depth analysis of these reports at Airline B is provided in Appendix B.

In addition to the flight attendants at Airline B and others, the Civil Aviation Section of the International Transport Workers' Federation that represents aviation workers worldwide has been informed of "smoke in the cabin" incidents by flight attendants' safety representatives based on reports.

in the US, Canada, Australia, Sweden, Denmark, and the United Kingdom. The reported symptoms are sometimes consistent with exposure to carbon monoxide and neurotoxic agents.

In terms of international recognition, the Senate Rural and Regional Affairs and Transport Legislation Committee recently conducted an inquiry into cabin air quality in the BAe146 aircraft. They recommended that, where necessary, the Australian Civil Aviation Safety Administration introduce regulations to address the problem of a contaminated air supply, specifying specific maintenance procedures, collecting incident reports, and establishing a national standard for checking and monitoring the engine seals and air quality in all passenger commercial jet aircraft (Ibid., Executive Summary, Section 1(b)).

The Committee concluded that

"Exposure of air crew and, potentially, passengers to cabin air which may be…even minutely affected, by fumes originating in an aircraft's engines raises the potential of occupational illness and, for certain individuals, an incapacity to continue work."

(Ibid., Section 6.22)

Although the Committee had been charged with investigating complaints on the BAe146, they also identified similar problems on other aircraft, including the A320 and MD90 (Ibid., Section 6.2).

More recently, there has actually been some regulatory action in the US. For example, in response to

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"...reports of smoke and odor in the passenger cabin and cockpit due to hydraulic fluid leaking into the auxiliary power unit inlet, and subsequently, into the air conditioning system" (65 FR 48368, August 8, 2000),

the FAA published an Airworthiness Directive that requires certain maintenance procedures on specific hydraulic fluid lines in the APU of certain aircraft types. This will address a very small piece of the problem.

In conclusion, we know that these oils, hydraulic fluids, lavatory water, and deicing fluid can leak into the air supply systems; we know that certain contaminants can be generated under the conditions on commercial aircraft; and we know that flight attendants and passengers in a number of different countries have reported symptoms that consistent with exposure to some of these contaminants, and may have complained of nasty odors, mists, and fumes. We also know that in some cases, regulators and governments have acknowledged the problem. But somehow, the problem still has not been properly addressed.

- **Exposure limits**

It is fair to say that the air in the passenger cabin is different from most workplaces. Aside from the envelope and the air supply system, the change in pressure, and the fact that the cabin is pressurized to a maximum of 8,000 feet, the quality of the air must meet the needs of both the public and the workers, all occupants. It is our view that occupational exposure limits that are largely designed for industrial work sites are not suitable for commercial aircraft, whether passengers are on board or not. Few of the permissible exposure limits set by the US Occupational Safety and Health Administration (OSHA) have been updated since 1968 and there can be considerable variation between exposure limits such as the almost six-fold difference between the CO limits set by OSHA and the EPA and the 15-fold difference between the formaldehyde limits set by OSHA and Health Canada.
As an example of the problem of relying on occupational exposure limits, one research team collected air quality measurements in tandem with questionnaires that assessed flight attendants' symptoms and impressions of air quality\(^{30}\). The majority of the 185 flight attendants that participated classified the air quality as less than acceptable, but the study concluded that "overall air quality was good" because occupational exposure limits had apparently not been exceeded.

Another issue concerning exposure limits is that ground-based limits, particularly for asphyxiants, may need to be modified when applied to the flight environment. For example, a United States Air Force report on respiratory environmental thresholds and physiologic limitations indicates that "flying at 6,000 feet breathing 50 ppm carbon monoxide in air results in a physiologic equivalent altitude of about 12,000 feet\(^{31}\)."

Another consideration is that the relative toxicity of contaminants in an oxygen-deficient environment will depend (at least) on whether the body requires oxygen to metabolize the contaminant, and how the toxicity of the metabolite compares to that of the parent compound. These questions have not been addressed and need to be addressed when defining acceptable exposure limits at 8000 feet.

**RECOMMENDATIONS**

In closing, we submit the following recommendations:

- **Altitude limit**

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\(^{29}\) OSHA/FAA = 50 ppm, NIOSH = 35 ppm, ACGIH = 25 ppm, by Health Canada = 11 ppm, EPA = 9 ppm


\(^{31}\) United States Air Force MIL-E-87145 (USAF) "Appendix B. Respiratory Environmental Thresholds and Physiologic Limitations."
We recommend that the rationale for the existing cabin altitude design limit be reviewed, and that blood oxygen saturation measurements be collected from flight attendants and a representative sample of members of the public, at altitude, to determine an appropriate operating limit for cabin altitude.

• **Contaminants and ventilation**

We recommend requisite continuous monitoring for a handful of contaminants (at least carbon dioxide, carbon monoxide, and ozone) to better characterize representative contaminant levels during flight. For exposure limits, we recommend that only public health limits are considered, and that they be modified as necessary for exposure at altitude.

• **Aircraft disinsection**

We recommend that the countries test and implement alternative mechanical means (e.g., repellent-treated curtains, air blowers) to keep insects off aircraft. In the meantime, airlines must be required to ensure that, after residual application, the cabin interiors must be dry and odor free before flight attendants are expected to board. Also, we recommend that flight attendants must be notified of the possible health effects associated with exposure to these sprays and (as per the 1995 US Department of Transportation Notice of Proposed Rulemaking) that passengers must be informed of countries' disinsection requirements before they purchase their airline tickets.

• **Contaminated air supply systems**

We recommend a proactive inspection and maintenance program to reduce the likelihood of air supply system contamination, and to identify leaks and spills promptly if they occur. To meet this, we also recommend that the airlines be required to route aircraft such that ground time at maintenance bases is maximized. Also we recommend that funding be approved to investigate
alternative system designs and modifications to reduce the likelihood of contamination in the first place.

On behalf of the 50,000 flight attendants that the AFA represents, we thank the Committee for the chance to submit these comments.

APPENDICES

APPENDIX A.
Copies of three research papers that have been cited to apparently justify a proposal for a minimum ventilation rate of 5 CFM/p on aircraft.

APPENDIX B.