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Environmental Air Control Incorporated, (EACI) is a recognized industry leader in air purification techniques. In collaboration with affiliated firms, EACI provides a full range of services, from testing for air quality and certification through the manufacturing and servicing of filtration systems and facilities, designed to accomodate specialized indoor air purification requirements.

ENV Services, Inc. an affiliate, specializes in the evaluation and analysis of airborne contamination within controlled environments. It serves manufacturers of micro-electronic components, private, public and military hospitals, U.S. Public Health Services facilities, medical schools, medical research institutions and pharmaceutical companies. ENV has been under contract to the National Institutes of Health for twelve years and more recently was awarded a contract with the Center for Disease Control.

Contrary to what many believe and some have said, there exists today the technology to develop light-weight, high-performance, economical filter systems that effectively remove gases and particles from the air, including Environmental Tobacco Smoke (ETS). That technology is known as the High Efficiency

Particulate Air (HEPA) filter. A HEPA filter may be generally defined as any extended surface, dry-type filter having a minimum particle capture efficiency of 99.97% for particles as small as 0.3 micron in diameter. A HEPA not only captures ETS, it also captures particles such as bacteria, attached viruses, household dust, animal dander, attached Radon daughters, mold spores and plant pollens.

Currently, the problem of air quality in airliner cabins appears to be focused solely on eliminating ETS as a means of protecting the health and comfort of non-smoking passengers and crew. If, in fact, the health of the travelling public is the issue, eliminating smoking as a solution essentially ignores those hazards posed to any individual in a closed environment by other proven hazardous airborne contaminants in the form of volatile organic compounds and certain microorganisms. While ETS is a visible, odiferous substance, its impact on the health of individuals is scientifically debatable.

Eliminating ETS does not achieve the desired objective, as many airborne pollutants still remain that inhibit the health and comfort of exposed individuals. Today's technology,(the latest state of the art) can render airliner air quality concerns moot by removing <u>all</u> airborne pollutants to a desired level of acceptability.

In the event that controlled scientific measurement of ETS and microbial concentrations on airliners indicate a real need exists for mitigation, or if mitigation measures are desired only to improve air quality, there are three independant,

recognized methods available. They are: 1) Ventilation (intake of "fresh" air and exhaust of "contaminated" air), 2) Source Control (reduction, isolation, or removal of contaminant sources), and 3) Filtration (removal of the contaminants from the inside, recirculated air).

Ventilation entails the intake and exhaust of two necessarily equal volumes of air. The source of intake on contemporary airliners is bleed air from the compression stage of the main engines. This source is used to provide the push needed to overcome the resistance of the exhaust valves used to control and maintain cabin pressure while in flight. This intake air is temperature conditioned and, in some aircraft, mixed with recirculation air prior to its introduction into the cabin.

Two characteristics of this intake air are particularly significant with regard to the cabin environment. First, it contains very little moisture. At cabin comfort temperatures this low moisture content equates to a low relative humidity. In addition to a certain amount of dry air discomfort, the low relative humidity can increase the viability of viruses and decrease that of bacteria. It can also accentuate both the odor and irritation perceived from ETS.

Secondly, the ozone content of the intake air is the major contributor to cabin air concentrations of the toxic gas. In the absence of any treatment mechanism, the cabin ozone concentrations will correlate closely with the outside atmospheric concentrations.

The exhaust aspect of ventilation is important in that it carries with it, or removes, contaminants at a rate equal to the rate at which they are being generated in or introduced into (intake air) the cabin, under steady state conditions. Exhaust air volume (which equals intake air volume) will, therefore, have a profound affect upon cabin air contaminant concentrations. If the exhaust air volume is reduced by 50%, the concentration must double, or increase by 100%, to balance the generation/intake vs removal equation. Conversely, doubling the exhaust would halve the concentration.

Increased ventilation would be an effective method of mitigating elevated airborne contaminant concentrations in airliner cabins. However, the cost of ventilation, in excess of the capability already in place on airliners, would be prohibitive. The cost of ventilation on an airplane can be 22-37 times the cost of the same amount of ventilation in a commercial or residential building.

Source control in the mitigation of airborne contaminant concentrations is by far the most effective method. If a source of a contaminant is eliminated or reduced, the portion of the concentration contributed by that source will likewise be eliminated or reduced. The airline industry currently employs a form of source control by isolating smokers in one portion of the cabin and by prohibiting pipe and cigar smoking.

Theoretically, source control is an ideal mitigation method, but practically, it is difficult to employ. A ban on smoking on airliners, theoretically, would eliminate ETS and all chance

of fires resulting from smoking. In reality, this may not be the result because of the possible increase in number and severity of smoking related fires, the added enforcement burden placed on flight attendants, social implications, etc...Smoking is not the primary source of some contaminants and is not a source at all of many other contaminants which may pose greater health risks. An absolute source control of ETS, a ban on smoking, will not achieve the implied resultant health and safety risk. A smoking ban may only divert deserved attention from other contaminants.

Mitigation of excessive airborne contaminant concentrations in airline cabins by filtration is the third alternative. The Report of the National Academy of Sciences, entitled "The Airliner Cabin Environment, Air Quality and Safety" states:

"The Committee also recommends that maximal airflow (ventilation) be used with full passenger complements to decrease the potential for microbial exposure and that recirculated air be filtered (to remove particles larger than 2-3 micro meters) to reduce microbial aerosol concentrations."

This recongition of filtration for control of microbial aerosol concentrations is laudable but falls short of addressing the full potential of filtration as a mitigation mechanism.

Recirculated air, from which filtration has removed a contaminant, is qualitatively equal to the same volume of additional ventilation. Since aircraft that are equiped with recirculation systems appear from the NAS report to have a

recirculation volume equal to their maximum ventilation volume, then, with proper filtration, these aircraft could effectively double the mitigation potential and halve the cabin contaminant concentrations. The NAS Committee recognized this principal with regard to ETS when it stated:

"Light-weight, high-performance, economical fliter systems that effectively remove gases and particles from ETS could eliminate many of the problems of and objections to onboard smoking. Such systems that are compatible with requirements for installation on airplanes have not yet been developed".

As stated previously technology does exist that can make such a system possible. More importantly, such a system could be effective in the removal of other hazardous contaminants.

Filtration can be divided into two functions; 1) vapor phase/gas filtration (absorption) and 2) particulate filtration. For vapor phase/gas adsorption, activated carbon (charcoal) is generally recognized for treatment of the widest spectrum of contaminants. Just one gram of activated carbon can have an adsorptive area about the size of half a football field. One pound of the material has about five million square feet of adsorptive area. According to the Student Manual, Testing of Class II Biological Safety Cabinets, prepared by the Harvard School of Public Health for the National Institutes of Health: "Important properties of activated carbon are: efficiency for trapping vapors of radioactive and carcinogenic materials, breakthrough capacity, ability to retain sorbed materials,....

and resistance to ignition."

Activated carbon alone is an effective mechanism for removal of most vapor phase/gas contaminants and can be applied in conjunction with other materials such as potasium permanganate for chemical adsorption of specific other contaminants for which carbon is not highly effective. Therefore, a technology exists which can not only remove the vapor phase/gas contaminants associated with ETS, but also those stemming from other sources.

The second function of filtration is the removal of particulate contaminants from recirculated air. For this application, technology is both available and time tested in the form of a High Efficiency Particulate Air (HEPA) filter, refered to earlier in this statement. HEPA filters are often refered to as "absolute filters". HEPA filter specifications are rigidly defined by the Institute of Environmental Sciences in its IES-RP-CC- 001-B3-T document; it is specified for government applications by the Military Specification, MIL-F-0051068E (EA); and its effectiveness must meet the criteria as set forth in the Federal Standard, Fed. Std. No. 209B. These rigorous standards separate the true HEPA filter from the oft advertised "HEPA 'type" filters.

The minimum efficiency of HEPA filter is 99.97% at a particle size of 0.3 micron. For particle sizes larger than, or smaller than, 0.3 micron, the capture efficencies are even greater. An additional feature of a HEPA filter is that its efficiency, at all particle sizes, increases with time of use.

HEPA is the only particulate filter used where large volumns of clean air are involved with the protection of human life. It is used in orthopedic operating rooms to deter bone infection, in hospital burn units, chemotheropy wards, preparation of intravenous add mixtures,pharmaceuticals production, and in biological safety cabinets used for cancer, DNA, and infectious disease research.

Perhaps the most publicized conditions resulting from the use of HEPA filtration exist in patient isolators. The "Boy in a Bubble" lived in air cleansed of infectious organisms by HEPA filtration and the technology was employed at the Manhatten Project. Paradoxically, even cleaner air is needed and provided by HEPA filtration for the production of microelectronic devices. Small geometry devices, with line widths of one micron or less, are produced in clean rooms supplied with air containing fewer than ten particles, .126 microns or larger, per cubic foot. This may be compared with average household concentrations of over three million particles per cubic foot. The HEPA filter technology is used today throughout the nuclear industry for containment of radioactive particles.

HEPA filter technology would meet the particle removal requirement of the NAS Committee's ETS mitigation system. That, in itself, would remove the major health risks associated with environmental tobacco smoke. One study conducted by C.R.E. Coggins, et al, Battelle, Geneva Research Center, reports: "Our conclusion is that most (pathological) changes produced

(in rats) can be attributed to exposure to the particulate phase of the (tobacco) smoke..."

HEPA filtration may not only be function effective in the mitigation of contaminant concentrations aboard airliners, but may also be cost effective. Hypothetically, if HEPA filtration is used in four recirculation zones of a widebody aircraft, at a two week (eight hours operation per day) replacement cost of about $500.00 per zone (total filter replacement cost of $2,000.00), it could provide clean recirculated air, mixed with ventilation air from only two operational air packs, equivilant to an average of 35 CFM per passenger (381 - full load on 747) at a total cost of about $7,837.00. Operation of all three air packs <u>without</u> filtration would cost about $11,675.00 for the same two week period and provide only 23 CFM per passenger. In this example, filtration could yield a net increase of 12 CFM per passenger, over a three pack operation, at a net savings of $3,800.00 per two week period (or about $100,000.00 per year per aircraft). This example is given to show the impact filtration can have on cabin air quality and its cost effectiveness. It should not be construed as advocating any reduction of ventilation air under full load conditions.

In summary, in the event that controlled measurement of ETS and microbial concentrations on aircraft indicate that a need exists to mitigate the condition, there are three mechanisms that may be considered; 1) ventilation, 2) source control, and 3) filtration. Cost and existing system limitations of

ventilation preclude use of ventilation for additional mitigation. Beyond the current reduction and isolation forms of source control, there is little more that can be reasonably achieved by the source control mitigation method. Filtration holds the greatest promise of improved airline cabin air quality. Filtration, specifically HEPA filtration in conjunction with adsorptive materials such as activated carbon, is both function effective and cost effective. Filtration is not contaminant specific in that it will act equally in the reduction of all contaminants from all sources. Finally, the technology exists which would permit installation of effective HEPA filtration mechanisms in aircraft. It need only be done.