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Can Ventilation Control Secondhand Smoke in the Hospitality Industry?

An Analysis of the Document "Proceedings of the Workshop on Ventilation Engineering Controls for Environmental Tobacco Smoke in the Hospitality Industry", sponsored by the Federal Occupational Safety and Health Administration and the American Conference of Governmental Industrial Hygienists.

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Abstract

A panel of ventilation experts assembled by OSHA and ACGIH concluded that dilution ventilation, used in virtually all mechanically ventilated buildings, will not control secondhand smoke in the hospitality industry. The panelists asserted that a new and unproved technology, displacement ventilation, offered the *potential* for up to 90% reductions in ETS levels relative to dilution technology. Air cleaning was judged to be somewhere in between, depending on the level of maintenance. However, they were unable to quantify the ETS exposure or risk for workers or patrons from any of these technologies, either before or after the imposition of the new technology. The panelists noted that some current building codes do not require that buildings be ventilated, and those that require ventilation do not enforce it. They also noted the lack of recognized standards for acceptable ETS exposure as well as the lack of information on typical exposure levels. However, indoor air quality standards for ETS have been proposed in the scientific literature, and reliable mathematical models exist for predicting pollutant concentrations from indoor smoking. These standards and models permit application of an indoor air quality procedure for determining ventilation rates as proposed in ASHRAE Standard 62. Using this procedure, it is clear that dilution ventilation, air cleaning, or displacement ventilation technology even under moderate smoking conditions cannot control ETS risk to *de minimis* levels for workers or patrons in hospitality venues (restaurants, bars, casinos, etc.) without massively impractical increases in ventilation. Although there is a scientific consensus that ETS is a known cause of cancers, cardiovascular diseases, and respiratory diseases, although ETS contains 5 regulated hazardous air pollutants, 47 hazardous wastes, and more than 100 chemical poisons, the tobacco industry continues to arrogantly deny the risks of exposure, to oppose smoking bans, to promote ventilation as a panacea for ETS control, and to work for a

return to *laissez-faire* concerning smoking in the hospitality industry. Smoking bans remain the only control measure to ensure that workers and patrons of the hospitality industry are protected from exposure to the toxic wastes from tobacco combustion.

Consultant Agreement No. 952-A-6330-C3778 with the Public Health Institute on behalf of the California Cancer Registry, Tobacco Control Section.

Contract Specifications

James Repace, MSc., Consulting Physicist, shall provide the Department of Health Service, Tobacco Control Section (DHS/TCS) with the following services:

1. A summary of issues raised in the 176 page document "Proceedings of the Workshop on Ventilation Engineering Controls for Environmental Tobacco Smoke in the Hospitality Industry", which was sponsored by the Federal Occupational Safety and Health Administration and the American Conference of Governmental Industrial Hygienists. This includes the available (dilution ventilation and air cleaning) and proposed (displacement ventilation) technology, and the contrasting views of ventilation engineers present at the workshop.
2. Perform an analysis of expected levels of environmental tobacco smoke (ETS) in restaurants, bars, and casinos with current (and proposed – to the extent this can be done) ventilation technology, using models to estimate levels and associated risks of ETS-related diseases.
3. Using results of item #2, critique the assertions that ventilation technology can be used to control ETS. Briefly discuss the chemical nature of ETS, the diseases it causes, and how the federal government controls ETS-like chemicals under the Clean Air Act.
4. Discuss the difference between RACT (Reasonably Achievable Control Technology, i.e. ventilation) and BACT (Best Available Control Technology, i.e. smoking bans) in controlling "ordinary" and toxic or carcinogenic air pollution.
5. Discuss various existing and proposed air quality standards for ETS and the ability of ventilation to achieve it. Discuss what is an "acceptable" level of ETS and what it would take to reach it using ventilation or air cleaning technology. The document suggests that "ACGIH or 'others' set a standard of acceptable exposure." Discuss what is an adequate marker for ETS.
6. Using industry documents, discuss the tobacco industry's goal to achieve ventilation standards for ETS rather than bans on smoking, and its past, present, and possible future efforts to effect the ASHRAE Standard 62 (Ventilation for Acceptable Indoor Air Quality) process on ETS; i.e., what they have done in the past, and what the industry appears to be doing about it presently.

7. Discuss the level of enforcement of existing ventilation standards.
8. Discuss the effects of adopting a ventilation standard, i.e. what enforcement bureaucracy would be required, and what kinds of a State indoor air quality standards for ETS would be required to protect against each of the diseases of passive smoking as identified by the California EPA.
9. Research and draft the report
10. Revise the report after peer-review.
11. Submit final report.

Invoice to: Dr. William Wright

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I. A summary of issues raised in the 176 page document "Proceedings of the Workshop on Ventilation Engineering Controls for Environmental Tobacco Smoke in the Hospitality Industry", sponsored by the U.S. Dept. of Labor, Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH). This includes the available (dilution ventilation and air cleaning) and proposed (displacement ventilation) technology, and the contrasting views of ventilation engineers present at the workshop.

SUMMARY OF PROCEEDINGS OF THE WORKSHOP ON VENTILATION ENGINEERING CONTROLS FOR ENVIRONMENTAL TOBACCO SMOKE IN THE HOSPITALITY INDUSTRY, JUNE 7-9, 1998, FT. MITCHELL, KY

CO-SPONSORED BY THE

U.S. DEPT. OF LABOR, OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION (OSHA) AND THE AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH)

Summary: In June 1998, OSHA sponsored a Technical Workshop on Ventilation Engineering Controls for Environmental Tobacco Smoke Exposure in the Hospitality Industry. The 3-day workshop, held in Ft. Mitchell, Kentucky, was coordinated by ACGIH. A panel of 14 experts was assembled to provide more information on ETS exposures and to discuss ventilation engineering controls for reducing exposures in restaurants, bars, and casinos. The panelists were either experienced ventilation engineers or facility managers from the hospitality industry.

The workshop was an outgrowth of OSHA's Notice of Proposed Rulemaking on Indoor Air Quality (59 FR 15968) required control of point sources of pollutants, and specified conditions under which smoking could be allowed in the workplace. Employers were required to establish designated smoking areas, permit smoking only in such areas, and ensure that those areas were enclosed and exhausted directly outdoors, and maintained under negative pressure sufficient to contain tobacco smoke. Employees could not be required to enter the designated smoking areas as part of their normal work. However, while the ETS provisions were feasible for many employers, "it became apparent to OSHA that in businesses where there is substantial contact between customers who smoke and workers (e.g. food, beverage and gaming industries, collectively known as the 'hospitality industry') this provision was not easily applied as written. During the public hearing on OSHA's proposed standard on indoor air quality, representatives of the hospitality industry supplied very little information on engineering and administrative controls that could be used to protect workers.

The purpose of the 1998 Workshop was "to obtain much needed information on feasible engineering and work practice controls for the hospitality industry (i.e., bars, restaurants and gambling facilities) that could potentially reduce ETS exposure, from the point of view of ventilation engineers and facility management personnel. A Mission Statement was delivered to the panelists by Dr. Steven Guffey, Workshop Chair, and ACGIH Industrial Ventilation Committee Member, University of Washington. Dr. Guffey stated that "the workshop mission was to come up with feasible controls for environmental tobacco smoke (ETS), particularly in the hospitality and restaurant business." He asserted that the workshop's primary aim was to achieve reductions in ETS levels. Dr. Guffey stated that the workshop focus included, but was not limited to, "the unique occupational exposures in the hospitality sector due to the interface between workers and smoking customers. ETS is a contaminant in bars, restaurants and gambling facilities. We will consider engineering controls, such as local source capture ventilation, that control the contaminant at its point of generation; controls that are technically and economically feasible. We can also consider other ventilation engineering controls employed in general industry, such as makeup air islands, and displacement ventilation."

Ventilation was defined (R. Hughes Presentation) as *an application of controlled airflow for the purpose of providing comfort and to provide for contaminant control*. The two basic types of ventilation are local exhaust ventilation and dilution or general ventilation. Local exhaust captures the contaminant right at the source. Local exhaust ventilation can be significant in reducing worker exposure, because the contaminant is captured at or near the source and is prevented from reaching the worker. Local exhaust is primarily for point source contamination. It is very effective for high contaminant levels, and requires low airflow. Dilution ventilation dilutes the contaminant by mixing the large quantities of air with it to lower the concentration level. It does not prevent worker exposure because the contaminant stays in the area. It is usually better for diffuse sources of contamination. Its application is better with low levels of contaminant or low toxicity contaminants. A disadvantage (in addition to the poor exposure control) is that it can require extremely large amounts of airflow.

The major source of information for ventilation design in the commercial or indoor environment is the ASHRAE Handbook of Fundamentals. Information in the ASHRAE Fundamentals focuses primarily on comfort although they do have information on industrial ventilation. ASHRAE does provide some of the theoretical aspects of ventilation. Industrial ventilation does have applicability for the control of the commercial environment, and while most of the past efforts have been directed to the industrial environment these ventilation techniques are readily adaptable. ACGIH's *Industrial Ventilation* focuses primarily on the industrial environment. It discusses in great detail local and general ventilation, providing information on system components, discussing the construction of exhaust hoods, fans, and duct design.

During the workshop, each panelist presented for 15 minutes on topics including local source capture vs. general dilution ventilation, supply air islands, ventilation performance monitoring, displacement ventilation systems, particulate and gas phase air cleaners, and current practice for designing heating, ventilating, and air conditioning (HVAC) systems. The panel then explored the technological and economic feasibility of applying current prudent practice for application of HVAC controls to the hospitality sector. Finally, the panel made recommendations of the most promising options.

The Executive Summary of the Workshop Proceedings, authored by Dr. Guffey, synopsized the issues involved in "engineering solutions to ETS exposures." Panelists discussed several possible engineering solutions for a variety of ETS exposure conditions in restaurants, bars, and the gaming industry. Displacement ventilation was deemed to have the greatest chance of producing substantial reductions, and could be less costly over time than the dilution methods now in common use. However, a major problem is that displacement ventilation is unfamiliar to most heating, ventilating, and air conditioning (HVAC) engineers, and presents challenges in duct placement, especially in retrofitting existing facilities. Another problem is that displacement ventilation is relatively new and practical applications too recent and sparse to state with confidence that it would apply to larger casinos or cases where turbulent mixing is not well-controlled. Likewise it may be difficult to use ventilated ashtrays on gaming tables because they would obscure some hand movements, a security issue in casinos. In general, ventilated ashtrays were thought to have less potential to achieve dramatic reductions in exposures, but would reduce the quantity of ETS released into occupied spaces, while using low levels of exhaust air. A drawback is that they would require cooperation of smokers and occupy counter or table space. A combination of displacement ventilation and ventilated ashtrays might be used together, in restaurants and bars.

Although the mission of the group was to develop engineering solutions to ETS exposures, it was recognized that a major complication was **"the lack of a recognized standard for acceptable exposure levels, and the lack of important**

information on typical levels of exposure." It was not clear to Panelists what the typical levels of exposures to workers in restaurants, bars, and gaming establishments would be if current ventilation strategies were well executed. Furthermore, for most ventilation interventions, it was difficult to predict the reduction in exposures that would result because in part efficacy depends on many factors beyond the control of the designer. Factors cited included sources of exposure, mechanisms of exposure, constraints imposed by material handling (e.g., serving of food or drinks or dealing cards), work practices such as standing within arm's reach and avoiding a hurried or unfriendly appearance), competing air motions (e.g. jets from diffusers, convection) and source strength, location, and mobility. Despite these unknowns, the panel believed it could propose measures which "will substantially reduce ETS emissions, and thus exposure to workers." The actual magnitude of reductions would have to be experimentally determined. The sufficiency of the reductions would have to be ascertained when ACGIH or others set a standard of acceptable exposure.

The panel considered such factors as identification of major issues, vital information that is missing or incomplete, smoking locations, sources of smoke, smoker behaviors important to source control, ETS monitoring, important constraints on solutions, general categories of possible solutions, and finally, a proposed general control measures for bars, restaurants, and casinos: dilution ventilation, displacement ventilation, and ventilated ashtrays. Estimated percent reductions were made, apparently based on professional judgment rather than data or models. Total elimination of ETS was not an option.

Panel discussion of major issues:

1. *Vital information missing or incomplete*: missing information on upward velocity of cigarette and cigar smoke (pipes apparently not considered) at different heights above the source, crucial for downdraft control. Panel concluded velocities too great for downdraft to work. Will increasing airflow increase burn rate, discouraging smokers from cooperation in holding cigarettes under small hoods between puffs? Uncertainty about buildup of tars on ducts. Effective filters may require excessive pressures, and may be poorly maintained. Optimal filters and placement -- in the hood or near the fan? Can filtered exhaust air be recirculated or must it be exhausted outdoors? Smokeless ashtray filters are poor on removal efficiency. Restaurant industry panelists complained of the difficulty of adequate maintainance and detrimental effects of increased fan pressures on equipment if filters added to existing systems. Panelists unaware of published data on the above, but could be obtained by future research.

2. *Smoking locations*: Engineering controls need to be discussed in terms of location of activity rather than type of establishment, e.g., tables and booths, bars, gaming tables, slots, and video games, designated smoking lounges where customers are served, stationary workers in service areas, change booths, or cashiers.

3. *Smoking sources*: Exhaled mainstream smoke diffused over large area, unless smoker directs it into a receptacle; smokers in motion are a diffuse source of both mainstream and sidestream smoke. Point source control strategies may not work. It is doubtful that if smokers blow smoke at workers any kind of ventilation can control it. Velocity and direction is important. Designing systems for mobile source control very difficult. How long does smoker hold cigarette, and how long is it down? Differences between cigars and cigarettes?

Pipe smoking rare, dismissed as source. ETS generation rate?

4. *Reduction in ETS that must be obtained*: No guidance provided.

5. *Necessary smoker behavior for solution success*: Smoking behaviors differ in restaurants, bars, and casinos. Restaurant smoking leisurely, casino smoking intense.

6. *Assumptions about smoker behavior, and likelihood of adoption of requested behavior necessary for substantial reduction*:: Smoking in designated areas, leaving cigarettes in ashtrays as much as possible, blowing smoke toward ventilated points? In panelists experience, compliance with posted rules is high for locations, directional exhaling possible, especially vertically. Leaving cigarettes in ashtrays unknown, but compliance judged likely.

7. *Monitoring of ETS*: Best indicators thought to be personal monitoring of airborne nicotine and UV or fluorescent particulate; literature suggests that respirable suspended particles poorly correlated to more specific measures. Body fluid or hair cotinine possible but affected by individual variability. Stationary monitors may be better than personal monitors for short periods due to individual variability.

8. *Important constraints on solutions*: Acceptable solutions should require minimal effort by smokers and should not make them feel conspicuous or punished. Acceptable solutions <u>must</u> stay within airflow capacity of current equipment except perhaps for large casinos.

9. *Likely attainable ETS reduction for each method*: Varies among methods. Discussed below.

10. Cost factors and limitations: Cost of additional exhaust ventilation was $1-$2 per year per cubic foot per minute per year ($1-$2/cfm-y).

General Categories of Proposed Solutions

- Smoking bans
- Limited smoking periods
- Smoking lounges, including self-serve dining areas where employees do not go
- Well-mixed dilution ventilation
- Displacement ventilation
- Local source capture and control using hoods

Since the mission of the workshop was to explore solutions that would allow smoking while substantially reducing exposure to employees, bans, limitations and non-service smoking lounge options were dismissed. Panelists concluded, furthermore, that while well-mixed dilution ventilation is currently widely used, it appears that it is not a satisfactorily efficient or effective method of controlling ETS exposures to workers in restaurants, bars, and gaming establishments. Especially given the absence of a prescribed quantitative level of acceptable control and measured data demonstrating that control. Thus the workshop focused on the remaining alternatives: displacement ventilation and local exhaust ventilation of ETS sources.

Displacement Ventilation

Displacement ventilation is a dilution design strategy that eschews the turbulence mixing necessary to traditional "well-mixed" designs. Displacement ventilation requires that air released in a room is 5 to 10 degrees cooler than the air already in the room. Released at the floor level, it will travel horizontally across open spaces. Since people, mechanical and electrical devices are generally much warmer than this supply air, the convection currents from them carry warm contaminated air to the ceiling area where it can be removed by return air grilles. The rising plume of ETS being warm is helpful, and both sidestream and exhaled mainstream should rise. If the ceiling exceeds 8 feet, then the contaminants near the ceiling should be well above the breathing zone. This strategy contrasts with well mixed dilution ventilation, which attempts to mix floor and ceiling air using jets from the ceiling diffusers to provide the necessary kinetic energy. To be successful, displacement ventilation requires that there be relatively little disturbance to the air by moving objects (e.g., Casablanca fans), jets of air, etc. (in other words, it is a low-flow technique). It works best when the supply air can be delivered very close to the floor, requiring ducts and supply air grilles be installed at or near the floor. If tobacco smoke is exhaled downward, this runs counter to this strategy. Also, restaurant panelists objected to the constraints on layout and esthetics imposed by locating large diffusers near the floor. Experimental verification of efficacy is lacking if diffusers are located in the ceiling near walls and directed downward. The panelists concluded that if conditions are suitable, displacement ventilation has the potential to remove both sidestream and mainstream smoke, and may be used in conjunction with ventilated ashtrays, ventilated booths, and other local exhaust strategies.

Panelists estimated that total ETS reductions were likely to be around 90% or more for good conditions. However, they noted that poor conditions, especially those due to the introduction of turbulence and large eddies, could sharply lower the reductions.

The panelists observed the following concerns:

- Displacement technology is unfamiliar to many HVAC engineers
- Supply air diffusers take up significant wall space
- Ducting of air to floor level can be difficult, especially in existing facilities
- Technology is sensitive to errors in supply air temperature, affecting thermal comfort of patrons
- Low ceilings can lead to stratified temperatures (warm heads, cold feet)
- Concentrations of ETS at ceiling height are dense; workers at elevated stations (as in casinos) could experience increased exposures unless additional measures are taken

Ventilated Ashtrays

Ventilated ashtrays (“smokeless” ashtrays), according to the panelists, in principle could be highly effective in reducing sidestream smoke, but commercial models tested were largely ineffective, although an experimental ones have worked much better. In addition, for any ductless unit to remain effective, filters have to extremely well maintained. Panelists felt maintainance would likely be a continuing problem for the hospitality industry. Operational problems relating to scarcity of space on bar tops and tables and potential problems with cleaning the units and the surfaces they obstruct may limit their usefulness. Panelists had reservations about whether enclosed ventilated ashtrays would be accepted by restaurants and patrons. Panelists assumed that 50% to 70% of ETS came from sidestream smoke, and assumed that properly maintained devices could collect 95% of the effluent while the cigarette was resident, which they assumed would be

80% of the time, yielding **a net estimated collection efficiency of 38% to 53% of ETS.**

Advantages:

- High potential effectiveness
- Reduces total room ETS burden including room surfaces
- Low airflow requirements
- Low noise
- Convenient and easily cleaned

Disadvantages:

- Must be ducted to outside unless self-contained filter and fan
- Frequent cleaning of hoods and ducts if not filtered at hood
- Internal hood filters must be frequently cleaned
- For units without internal filters, duct plugging may occur

Canopy Hoods For Tables

Panelists stated reductions in ETS would depend on airflow levels, but did not estimated likely reductions because minimum airflows were impracticably high >300 cfm/hood.

Contrasting views of workshop participants (highlights)

1. ETS in Microenvironments
DEBRA JANES
OSHA

Ms. Janes was the OSHA project officer for the Indoor Air Rule. She expressed OSHA's view that that exposures in hospitality sectors can be four to six times those in office environments.

2. BRIEF OVERVIEW OF VENTILATION
ROBERT HUGHES, M.S.M.E., P.E.
Chair of ACGIH Industrial Ventilation Committee
NIOSH

ASHRAE is the authority for the commercial environment. There has been a perceived lack of need for ventilation for the commercial environment.

3. Local Source Capture & Dilution Ventilation
JEFF BURTON

IVE, Inc.

We typically go towards dilution if we have fairly low toxicity types of contaminants, and I don't know where cigarette smoke is considered here, I'm not a toxicologist. We lean toward local source capture if we have higher toxicity. In dilution, you'll always have some exposure. What you're doing is diluting the air down to some acceptable concentration, but that means people are going to be exposed. And so the final resulting concentration has to be non-irritating and non-odorous. With cigarette smoke, you would try to lean toward local source capture if in fact the final dilution values are going to still be a problem. If you're going to go dilution and you're going to use an engineering approach, and use some numbers, then dilution ventilation has to be based on the amount of emission of whatever contaminant you're concerned about controlling and the acceptable concentration.

Panelist: With dilution ventilation, would you have a big problem with tar deposits?

Even with dilution you still have the problem of tar depositing on things, and it's an extremely difficult problem. With local source capture, most of the tar, except for that which gets away under fugitive emissions, is retained in the system itself and it's not then plated out on the wall on all of your sink material and so forth. That's one of the biggest problems I think we have to deal with, in regards to smoking, is the residual tars.

Displacement Ventilation Systems
WILLIAM TURNER
Turner Group

Turner observes that conventional (mixing) dilution ventilation is "limited" in its ability to control ETS. He favors displacement ventilation that offers "promising approaches" to controlling any contaminant generated inside a building.

Panelist: You have an example where you have tested the classroom application, but you don't have classroom children that smoke. In a bar you do have people smoking, so what type of ventilation rate or exhaust ventilation rate would you project or do you have any experience projecting exhaust ventilation rates using this concept?

Turner: I don't know what the ventilation rate needs are. ... We'll look at the F.A.C.T. system that R. J. Reynolds created blowing it through carpet. See Appendix page 136.

Panelist: Putting ventilation supply air through a carpet frankly sounds disgusting to me. ... carpet is just unhygienic. Carpet gets a lot of stuff in it.

Turner: I believe you could apply displacement ventilation in the hospitality industry reduce ETS exposure where smoking is occurring and save a ton of fanned horsepower.

Particulate & Gas Phase Filtration
BUD OFFERMAN
Indoor Environmental Engineering

"ASHRAE Standard 62 prescribes ventilation rates and other stratification controlling contaminants. ASHRAE is very active right now in the revision of the Standard. Currently the Standard says that the rates accommodate a moderate amount of smoking. This is a mistake at which we are correcting. We didn't know back in '89 before EPA came out that tobacco smoke was a Class A carcinogen. The ASHRAE rates are largely comfort based, but the definition that we hold ourselves to is for health and comfort. We do not really know of any way to guarantee health with ventilation. We've pretty much ... don't believe there is any amount of ventilation to get down to the zero exposure levels of where we're really comfortable that it's healthy. I think there is an important role for air cleaning in the hospitality industry and others. Today I think the big things that I would point to are mechanical filtration, electrostatic filtration for controlling the particles, tobacco smoke. I'm not aware of any surveillance systems on the performance of electrostatics ...of course the plates get dirty, and then the particles start going through. And for the gas phase filtration, I think we're pretty much looking at absorption systems, activated charcoal, chemisorption, potassium permanganate, alumina as being our principal control techniques."

"For an engineer to purchase, or to put an air cleaner in a hospitality suite, you want to know a few things. You want to know, how efficient is it? How well does it remove the contaminant? How much can it hold before I've got to buy a new one? And then of course, what's its pressure drop or how many horsepower do I need to do to push it through that stuff? Those are the three things we'd really like to know. With the gas phase air cleaner, there isn't any real standard. Panel filters, that you have on your furnace at home, ... don't work at all. And of course the negative ion generators don't do well on tobacco smoke. And a fan just blowing air around doesn't do very good. Electrostatic precipitators are the only ones that can be made 100 percent efficient. [However] the *effective* cleaning rate is the efficiency times the air flow rate. That's the air cleaning power. People can tolerate [air flow] up to 700 feet per minute for eight hours, but anything more than that becomes too uncomfortable. I think coupling the air cleaning with like technology such as displacement ventilation and such as space pressure controls can afford some real improvements in control of ETS in the hospitality industry."

Panelist 1: In the hospitality industry where you have a restaurant with 40 tables in there, would it require having an individual unit at each table or a series of tables?

Panelist 2: Actually this would have probably only worked at a place, a station, like to protect somebody at one of the gaming tables who is stationary the whole time. I mean, this is practically the only application it could be used in. I don't think it would work out where the customers are, because you still have to dilute the area, to take care of all the contaminants that are still in the space.

Ventilation Performance Monitoring
GERHARD KNUTSON
ACGIH Industrial Ventilation Committee Member

Most HVAC systems get put in and you determine whether they work or not by the number of complaints that you get. I think you have to look at the air handlers. Fans are probably the most infamous problems that there are. More things can go wrong with a fan. Filters are used exclusively for particulate removal. There are some obvious problems associated with materials that have liquid. Liquid droplet [i.e., ETS] is still considered a particulate, and as that adheres to the filter you can get some evaporation. So, capturing it once may not always solve the problem. With activated carbon, what you've adsorbed can get back into the air stream and so one needs to be very careful about the problems of desorption. You also worry about the capacity of the carbon, how much material can be stored on there. Often with activated carbon you will have a very low capacity. The other problem that exists is the carbon is dusty and it sloughs dust. So you need particle filtration, then activated carbon, ... then a filter after that to collect the dust from the activated carbon. With potassium permanganate ... it doesn't react adequately with all materials. So, you may not be able to pull out all of the things out that you want. When the potassium permanganate reacts, it gets a dusty crust on it, and that dust can generate a fair amount of material.

Particulate filtration or filters of any nature do not remove gases. Particle size and dust loading can be quite important in the way that the filters work. For furnace filters to try to pull out environmental tobacco smoke is a joke. Mr. Offerman that said you can get 100 percent on electrostatic precipitation, I've never seen an electrostatic precipitator that can do that, and I doubt if I will live long enough to be able to. The other thing that happens is that you've got an electric discharge, a corona discharge. When you have corona discharge you always make ozone. If you make enough ozone, you've eliminated your environmental tobacco smoke problems because ozone is much worse than the environmental tobacco smoke.

OSHA has always had problems with recirculation —they don't particularly like it. There are some good reasons for that. When you do put in a recirculation system, I think you've got to put in something that you're able to monitor; it's very difficult to ensure that the air cleaning devices are working adequately. Some of the existing OSHA standards require routine monitoring where you would go back and verify —when you're using a ventilation system for the purpose of trying to control contaminant —prove that in fact that ventilation system is working adequately. So, the precedent has already been set. One must think seriously about what you are going to do to verify that the system works.

Hospitality industry presentations

Restaurant Ventilation Design
RICK McCAFFREY
Brinker International

Brinker International owns nine different restaurant concepts that are currently expanding. The information presented is typical of Brinker restaurants. It doesn't have anything to do with other casual dining restaurants. The restaurant concept discussed would be between 5500 to 7500 square feet. Restaurant operating hours are 10:00 a.m. to 2:00 a.m. 360 hours a month. Some cities require totally exhausted smoking sections and some cities don't require anything. In California, Brinker has mainly non-smoking restaurants because that is the standard. There are some areas of the nation where the smoking sections have gotten so small that certain restaurants have made the decision to go non-smoking, which is what Brinker prefers.

Brinker has tried numerous methods for controlling smoke. One solution provides four air changes per hour by the use of two exhaust fans with a return air in the middle to a separate HVAC unit added strictly for the additional exhausted air. This costs more than $20,000. A glass wall also had to be installed between the bar area and the dining area. This is not the best way to do designs in restaurants because you don't want the patrons put on display, or treated differently. The smoker doesn't want to be seated or viewed as different. So, to take them and put them into a glass room separating them from other patrons doesn't work very well. It is also the reason some of the solutions presented earlier are not feasible.

We have also done smoke evacuation using a slot diffuser along the bar and dumping air straight down, then exhausting it to a return air close by, but the volumes get so high that it causes wind draft. Brinker has investigated several methods of ventilation including air displacement. Using air displacement makes sense because of the air movement. The problem becomes the supply air grille sizes. They become way too large. A typical restaurant has windows all the way around three sides of the dining area, with the kitchen at the rear. They are typically a theme restaurant, in which we are trying to set a feel. When a huge perforated grill is put on the wall, it's really hard to make that fit the theme of the restaurant. Brinker has also tried smoke eaters. The problem is making sure that they're working, and that filters are clean. Maintenance with restaurant managers can be a challenge.

Brinker tries to do areas of smoking in the restaurants that have smoking patrons, but this all varies according to different areas & regions in the country. To design a permanent space that people are going to go sit in and hope that this will take care of smoking demands is not feasible. Smoking area requirements fluctuate back and forth. In the last five or six years as awareness of secondhand smoke has heightened, area requirements for smoking have continually dropped. The percentages of required smoking tables have almost been cut in half.

Panelist: In your experience, that four air changes per hour rule, is it effective for the control of smoke in a bar or restaurant?

I think when the unit is dedicated for that area and you have an exhaust so you're totally exhausting that air four times in an hour, it works. In fact, they've done huge smoke tests, and Arlington is probably one of the more stringent areas. They won't allow any bleed over of smoke into the other areas, This system does contain it within that area. This is not designed for taking it away from the people in that, but it does contain it within that area.

Panelist: Typically, just to expand a little bit on that, four air changes per hour, how many people would you anticipate would be smoking within that space as the *four air changes per hour?* A. Probably 40. *Panelist: Forty smokers at any one time?* A. Actually of actual smokers there would probably be half of that at the max, 20, in that range. I would imagine it would probably be less.

Dr. Guffey: One other thing I think I know personally is that the fact that someone is seating at the smoking section doesn't mean that they're a smoker. I mean, not only are there family members and friends who are accommodating the smokers, but also people who don't want to wait on a non-smoking table and who don't mind the smoke.

Use of Exhaust in Family Restaurant Ventilation Systems
GREG WEAVER
Bob Evans Restaurants

I represent the no bar, no alcohol segment of the industry. Therefore, we have a lot less smoke, so we have that going for us. We have 409 stores, anywhere from one to 20 years old. We have zoned rooftop air conditioning systems We have a central unit, a zoned unit on the left side of the restaurant, a zoned unit on the right side, and the kitchen has a separate zoned unit. We bring in approximately 70 percent makeup air to make up for all the exhaust. Our store sizes range from 3600 square feet to 7000 square feet. We are exhausting approximately 7860 cubic feet on a smaller store, to 10,270 cubic feet of air out of the stores, so we're bringing on an adjusted factor, five to seven air exchanges per hour in our stores. The non-smoking side of the store, has an exhaust fan in that area. Our biggest challenge that we have with smoke in our stores is one of turbulence, and that's caused by the air coming out of the diffusers, and the ceiling fans that are predominant in all areas of our store. Those two factors cause the turbulence. That may cause us to get some leakover out of the various areas. So that could become a problem but you usually have to have a lot of smokers for that to become a problem. As was noted earlier, we're seeing a lot less smokers in our store. The non-smoking side of the store is almost always full, the smoking side is has relatively few people in it,

Ventilation Design
RON CARLISLE
Carlson Restaurants Worldwide

We basically design the way Brinker International does, as was discussed by Rick McCaffrey. We have a couple of variations on restaurant size, from about 4600 square feet, to approximately 6800 square feet; we run four to six rooftop units for those restaurants. Inside the restaurant we have a bar. We operate from eleven o'clock in the morning to two o'clock in the morning in most cases.

Ventilation System Design and Consulting for the Restaurant Industry
PERRY ENGLAND
Melink Corporation

There are a lot of things that interplay with one another between the kitchen system and the dining room system. So, if the two don't work together and they're not orchestrated, then you're going to have a bad building, which are all associated with an improperly operated and maintained facility. Our primary business is test and balance services. Food service industry over the years has been notorious as far as practicing good and diligent maintenance. In casual dining, you have stores that range from 5000 square foot to as high as 10,000, but typically around 5000 to 6000 or 8000 square feet —total square footage in your space —including the kitchen. This comes down to about 2500 to 6000 square feet in your dining area, with about 2500 to 3500 square feet in your kitchen area. This is the typical size we're accustomed to seeing. When you get into a non-smoking versus smoking area, again, just like in industrial ventilation, you want to move the air from the clean side to the dirty side —clean being a non-smoking area, and dirty being a smoking area. So, that's why you see those non-smoking areas being positive pressure with respect to the smoking areas.

We see dilution ventilation and general exhaust in some areas as a couple of the methods used in the casual dining industry for controlling environmental tobacco smoke. Typically there are three to five package units on a typical casual dining restaurant ranging from 10 to 15 tons per unit. Max those things out to 30 percent outdoor air, which right now is a limitation of most packaged equipment. We do see electrostatic precipitators. When you go with an electrostatic precipitator, not only do you have the electrostatic precipitators, you also usually have activated carbon to remove the odors, and you also have pleated filtration to remove the particulate on top of the electrostatic precipitators to increase the efficiency of the overall unit. We're doing work with some of our customers in looking at closer control relief from smoke in the smoking areas and pretty much looking at taking out electrostatic precipitators, which are notorious for maintenance, and putting in just the traditional inline exhaust fan to suck out that contaminant and bring in additional makeup air to dilute that contaminant. You're seeing more and more of that.

The trends show in the casual dining industry that smoking levels are decreasing, not increasing, in the casual dining area. We need to separate smoking areas from the non-smoking areas so we're not putting the smokers on display, but making them feel part of the overall environment. We use things such as elevated dining areas, low-wall partitions, things that are creative and architecturally pleasing to the overall comfort environment yet provide a level of separation between smoking and non-smoking, isolating that contaminant so you can better control it. There's an open dining experience where there's no walls separating the smoking from the non-smoking areas, but yet when the smoke is present around the bar or in a smoking area it triggers increased ventilation, which keeps that additional barrier between the smoking and non-smoking areas.

When you start talking about ventilation, you start talking about owning costs, which are very critical to the highly-competitive casual dining industry. You start looking at ways to optimize profitability as an operator. What drives decisions in the casual dining industry, which I think is pretty typical of any industry, is first cost. Makeup air costs an owner $2 a cfm as a rule of thumb. For every cfm of makeup air you're bringing that building, it's going to cost you on a national average about $2 to treat that air.
Dr. Guffey: That's just treatment costs, that doesn't include capitalization?

That's just treatment costs.

Panelist: Has anyone that you know of ever looked at the cost reductions, for example, in California when they no longer allow smoking in a restaurant, to find out if they have less cleaning costs or any other cost savings?

A. In regard to restaurant owners, what we see is definitely an improvement. You no longer have that tar stain and the residual components of cigarette smoke when you go to a smokefree environment.

Panelist: That's moving heating and cooling air? Yes, owner costs, cooling cost and heating costs. Panelist: Per cfm annual, nine to five. *Panelist: We did something for the EPA a while ago on the soiling factor. It's pretty linear with concentration of ETS. So, if you can cut your ETS concentration down in half, then your soiling or repainting correlates. Dr. Guffey: The question is, how attractive is that?* Economically? *Dr. Guffey: Yes.* I think it's pretty significant.

On capital costs, it costs about $100,000, almost exactly, for a 6000 square foot restaurant, and that's for hood package, the HVAC and the equipment, the labor and equipment costs. Thirty-five thousand for the hood package, $24,000 for labor, and $40,000 equipment, and that's pretty close. That's a total, not just make-up. It's about 5000 cfm.

Panelist: We have about 4300 cfm make-up for a 6800 square foot restaurant, at about $75,000 for the package.

Panelist: If I was going to go out in the industry today and buy a 100-percent packaged makeup air unit that will handle 100-percent outdoor air, I'd be doubling my cost of equipment. That unit would cost me about $800 to $1000 a ton versus an off-the-shelf packaged unit which would be about $450 or $500 a ton.

In the casual dining industry we can't get out of the boundaries of dealing with packaged rooftop units because our first costs jump considerably. Whereas, casino owners and people like that in your larger hospitality industry are dealing primarily with chilled water systems which are very much more flexible in their application. Packaged units are going to handle 30 percent maximum for raw outdoor air, unless you go through some kind of energy recovery units which precondition that outdoor air.

Ventilation Systems in Las Vegas Casinos
DON KOCH
JBA Engineers

I'm a consulting engineer. My company's market is primarily in Las Vegas, Nevada. JBA has done quite a bit of work in the hotel casino business. We've done about half the hotel casinos in the Las Vegas and Southern Nevada area. Some of our past projects include the Rio, the Stardust, Caesars Palace Station High Rise, Treasure Island, Mirage, New York, New York and Sahara. That's about $4 billion worth of construction. Our current projects include Paris, Mandalay Bay, Bellagio and Aladdin. That's about $3 billion worth of construction. The codes and standards in effect in Las Vegas are the 1997 Uniform Building Code, Section 12.02.1. ASHRAE Standard 62-1989 is an accepted standard, but it's not mandated by law. The main driver of ventilation in Las Vegas is the perception and politics of it. Nowadays more and more people are demanding that the air in the casinos be much cleaner, whereas in the past casinos were expected to be smoke-filled rooms.

We look at smoking as being a diffuse source of pollution because you cannot control the actions of your customers. If you have smoking at a slot machine, at a gaming table or in a restaurant, you simply cannot protect people who are serving that customer from the cigarette smoke, no matter what. Now, what we can do is provide a lot of dilution ventilation, and that's what's being done in Las Vegas. First I want to talk about the three different types of practices used to achieve ventilation in Las Vegas, and then it's probably true elsewhere.

First of all, the Uniform Building Code, Section 12.02 reads: "All enclosed portions of Groups A, B, E, F, H, I, M and S occupancies customarily occupied by human beings shall be provided with natural ventilation by means of openable exterior openings with an area not less of 1/20th the total floor area or shall be provided with a mechanically operated ventilation system."

The thing that's interesting about this part of the code, which is the law of the land locally enforced, is that it permits natural ventilation systems in bars, restaurants, casinos. That is, if you have that kind of natural opening. So, what is a natural opening? That's a door to the outside. So, what you find is that many of the mom-and-pop-type bars that are down on the corner, are storefront buildings and buildings that are built out of wood. If you go up on the roof of these places, they have no ventilation whatsoever, and the reason is that the code allows them to say that if you open the doors they can get ventilation that way. So what happens is the ventilation system is no different than the ventilation system in your home. The air is recirculated through filters that don't work, and the smoke is recirculated and the tar builds up on everything and it's a horrible experience. If I had the authority to do something about the situation, that's where I would focus because that's where the worst environment is. You can do all you want about trying to mandate cleaner environments in areas that are already a lot cleaner than that. The thing you really need to do is go after those areas which are the worst.

The second type of facility is the type that has air-cooled package rooftop heating and cooling and ventilative equipment like what you've heard discussed for the chain restaurants here. Now, in those environments, again, smoking has to be contained to smoking areas because you can only bring in a fixed percent of outdoor air unless you use the Trane equipment that was discussed earlier. We do have some experience with run-around wheels. It was actually one that Simco Company did over at Binon's Horseshoe. They did have some problems with it, but it can work. That was with a chilled and hot water heating system. I have no personal experience, however, with this particular Trane equipment. And even with that, it appears that it's only about 50 percent outside air.

Current standard in Las Vegas in our big hotels and casinos is we use heating, hot water and chilled water which are generated at a central plant. One example of this is at Mandalay Bay. The advantage to using hot and chilled water is that you can bring in as much outdoor air as you want. Many of the facilities have an air change rate of about two-and-three-quarters to three cfm of square foot of total air, and right now we're looking about 50 percent of it as being outdoor air. Now, we've taken that particular design approach at the New York, New York and at The Rio, and both of those places have 34 foot ceilings. The combination of that amount of ventilation plus the high ceilings has produced a relatively satisfactory ventilation rate, and the client seems to be very satisfied with that approach.

The Rio has a two-story mezzanine that you walk across from the parking garage. As you stand on the mezzanine you can look across the casino floor, it's about 150 to 200 feet. There's not an apparent haze, or there's very little haze which is apparent to you. So, with the reduced amount of smoking and that ventilation rate, we found that there are very few complaints that are generated because of smoking. Again, that will not protect a non-smoker who happens to be sitting next to a smoker at the slot machine, but if that's the case, then the person will just go down to the next slot machine and try that one. So, that doesn't seem to be a big concern.

We found that in Las Vegas, we cannot limit smoking by our customers. Dean Rasmussen from Mirage Resorts is going to address that a little bit later. We have a very large clientele from Asian countries where smoking is very common, who spend a lot of money in these businesses.

We have had a problem with smoking lounges, and no matter what we do, we can't seem to find something that is totally satisfactory because smoking is so intense in those areas. What we do in these spaces, in the cigar lounges and poker rooms and the employee lounges, is we try to serve that area with 100 percent outdoor air at the ASHRAE Standard of 70 cfm per person. But the argument you can get into with people is how many people are really supposed to be in there and how many of them are smoking? So, we try to err on the conservative side in those areas. What we've found is that it doesn't make it perfect but that makes it better, and that usually there are so many people smoking in there that people come to accept that anyway.

Panelist: You started citing the UBC.

Uniform Building Code, Section 12.02.1 of the Uniform Building Code.

Panelist: The code doesn't really require you to operate the system.

Right. It's a building code, not an operational code. And that's one of the problems that we see in small restaurants and in bars that are not operated under chains where they have control over that in the type of training. We've seen local bars that have equipment similar to what a TGI Friday's or a Macaroni Grill has, but what they do is leave the ventilation system cycling, so then the air gets a lot raunchier in those places or it's a lot smokier in those places because the air is not allowed to circulate and you're not actually bringing in that extra outdoor air.

Panelist: I was getting more at the point that you mentioned that the attorneys said, "Well, ASHRAE's not a law so we do the UBC." But there's nothing in the UBC that says you have to operate your ventilation system, but you're operating them because you know that's a good thing to do.

All we can do as engineers, is design the systems. If a maintenance person or if the building operator decides not to operate them properly, then we don't have control over that. We can do the design and tell the contractor to provide the operations and maintenance instructions in accordance with the manufacturer's recommendations. So, we'd like to have more control over that but we really don't, and that's because of how the business is split up.

HVAC Approaches in Las Vegas Casinos
DEAN RASMUSSEN
Mirage Resorts

We are a reactive industry. I've been in the industry, as I said for about, 30 years and I've yet to have anybody call me up and say "It's comfortable in here."

We have both a foreign and a domestic customer base, and this customer base has a wide difference of opinion about smoking. Asian people feel different about it than Europeans, and Europeans feel different about it than Americans.

The number of people in the casino that smoke varies dramatically. It would be nice to just give it a certain amount of area, but on certain holidays in other parts of the world when people travel from that area, our smoking population can triple on any given weekend just due to the people that are in the casino and where they're from. So, we have to adapt.

Condensed Summary:

A panel of 14 experts on ventilation engineering and ventilation practices in the hospitality industry was charged with determining technically and economically feasible engineering controls for ETS in restaurants, bars, and casinos, assuming that total elimination of ETS was not an option. The panel recognized that there was a lack of information on typical ETS exposure levels in such venues, as well as a lack of recognized standards for acceptable exposure.

Panelists concluded that well-mixed dilution ventilation, the overwhelming majority of current installations, was unsatisfactory for controlling worker exposure to ETS in hospitality venues. Local area exhaust ventilation, smokeless ashtrays, air cleaning, and displacement ventilation were identified as potentially more effective. Of these, displacement ventilation was viewed as the most promising, with estimated 90% reductions under the most favorable conditions. Concerns about this technology included lack of familiarity by many ventilation engineers, difficulty with retrofitting existing installations, and potential aesthetic problems.

Ventilated ashtrays as currently available did not appear to be effective, although panelists felt the technology could be made 40% to 50% efficient, provided smokers could be persuaded to use them, a significant potential problem in areas where foreign tourists are frequent customers. Although air filters are capable of high capture efficiencies, they also require high airflow to be effective, and needed regular effective maintainance to remain effective. Costs are a major consideration in the restaurant industry, which limits the implementation of high technology solutions such as 100% outside air 1-pass systems. Costs are not a limiting factor in the casino industry for the large casinos, although they are for the small ones. Large fluctuations (e.g., factors of 3) in the smoking population of these venues may occur. A further significant problem is that some building codes do not require that the ventilation system actually be operated, especially in the small non-chain establishments.

Environmental tobacco smoke

Hazard Assessment. Environmental tobacco smoke (ETS) is the smoke emitted into the air from the burning end of a cigarette, pipe or cigar, as well as exhaled smoke from the smoker. The breathing of ETS is known as involuntary smoking or passive smoking. A body of evidence on the health risks of ETS has accumulated during the past two decades, connecting exposure to ETS to premature death. The most recent report on ETS from the United Kingdom, the SCOTH Report (1998), concluded that passive smoking is a cause of lung cancer and ischaemic heart disease. The SCOTH report concludes that restrictions on smoking in public places and work places are necessary to protect non smokers (SCOTH, 1998). The U.S. National Toxicology Program recently voted to include ETS on its list of carcinogens (NTP, 1998), and the Finnish Parliament also voted to list tobacco smoke on the national list of carcinogenic substances (CanFin, 1999).

In the USA, in 1997, the Environmental Protection Agency of the State of California (CalEPA, 1997), in a scientific report which considered public comments from individuals from federal, state, and local government agencies, universities, and various research organizations, as well as from the tobacco industry, concluded that in adult nonsmokers, ETS exposure causes lung cancer and nasal sinus cancer, heart disease mortality, acute and chronic coronary heart disease morbidity, and impairs fetal growth in pregnant women as well as inflicting acute eye and nasal irritation. The California EPA(1997) estimated that U.S. ETS exposure caused 3000 lung cancer deaths (LCDs) annually, from 35,000 to 62,000 heart disease deaths (HDDs) from ischemic heart disease per year, and caused an indeterminate number of cases of retardation of fetal growth.

In 1994, The U.S. Occupational Safety and Health Administration (OSHA, 1994), asserted that "employees working in indoor environments face a significant risk of material impairment of their health due to poor indoor air quality." In support of that determination, OSHA cited the risk of heart and lung fatality to nonsmoking U.S. workers from passive smoking, estimated to range as high as 722 annual cases of fatal lung cancer, and 13,000 deaths from heart disease per year, and that these deaths would be avoided by elimination of nonsmokers' exposure to ETS in the workplace. OSHA(1994) proposed a rule to eliminate nonsmokers' ETS exposures in the workplace. In 1992, the U.S. Environmental Protection Agency (EPA, 1992) declared ETS to be a "known human lung carcinogen," causing conservatively 3000 LCDs annually.

In 1992, the American Heart Association (AHA, 1992) declared ETS to be a "major preventable cause of cardiovascular disease and death," and estimated ETS-related mortality, from heart disease and cancer combined, to approach 50,000 annually, placing passive smoking as the third leading preventable cause of death, after active smoking and alcohol. In 1991, the U.S. National Institute for Occupational Safety and Health (NIOSH, 1991) declared environmental tobacco smoke (ETS) to be a "potential occupational carcinogen," legal terminology for a substance capable of causing human cancer or reducing its latency period. Based upon biological plausibility and epidemiological studies, a number of risk assessments have estimated the lung cancer mortality caused by passive smoking among U.S. nonsmokers to be of the order of 5000 deaths per year (Repace & Lowrey, 1985; 1990). Wigle et al. (1987) estimated that 330 Canadians die of lung cancer from passive smoking annually.

In 1986 The U.S. Surgeon General concluded that "involuntary smoking is a cause of disease, including lung cancer, in healthy nonsmokers." Also in 1986, The National Research Council (NRC, 1986) of the U.S. National Academy of

Sciences, a congressionally chartered private body established to further scientific knowledge and to advise the federal government on scientific issues, stated that "Considering the evidence as a whole, exposure to ETS increases the incidence of lung cancer in nonsmokers."

The body of evidence from spousal smoking studies suggests that the average excess risk of lung cancer from passive smoking is 24% (95% CI: 13% to 36%) [Hackshaw et al., 1997]. However, for nonsmokers exposed to the smoke of a pack of cigarettes per day or more, the risk increase can be considerably greater; the EPA summarized 12 studies that assessed the increase at these higher levels of smoking. For 9 studies in 5 countries, the risk in this category ranged from 57% to 220%; 3 other studies in 2 countries reported risks in the 10% to 20% range (U.S. EPA, 1992, Table 5-11). In the U.S. in 1980, the average smoker smoked 32 cigarettes per day (Repace and Lowrey, 1980). Law et al. (1997) reviewed the evidence from 19 published studies of passive smoking and heart disease; they reported that the average excess risk of ischemic heart disease from passive smoking epidemiological studies is 23% (95% CI:14% to 33%), and concluded that platelet aggregation provides a plausible explanation for the mechanism and magnitude of the effect. Kawachi, et al. (1997) studied coronary heart disease (CHD) in 32,000 female U.S. nurses aged 31 to 61 yr., for nonsmoking women exposed only at work, observed a dose-response for passive smoking and CHD. Adjusted relative risks of CHD were 1.00 [for no exposure], 1.58 *(95% CI, 0.93-2.68)* [occasional exposure], and 1.91 *(95% CI, 1.11-3.28)* [regular exposure]. In this study, regular exposure to SHS at work caused a 91% increase in CHD.

Johnson and Repace (in press) observed that the epidemiological studies of passive smoking and disease are flawed where other exposure is common (e.g., in childhood, in social situations, or in the workplace). In such cases lung cancer and other disease risks may be seriously underestimated. Spouses of non-smokers exposed in other circumstances will be misclassified as nonexposed, contaminating the referent group, and attenuating the risk estimate. For example, Hackshaw et al.[2] estimate that the odds ratio for lung cancer and passive smoking would have been 1.42 (1.21- 1.66) if those with spousal exposure alone were compared with those who were truly unexposed. By comparison, in a recent meta-analysis of risk associated with workplace exposure, Wells [4] found an estimated relative risk of 1.39 (95% confidence interval 1.15-1.68) for the five studies meeting basic study quality standards. Repace and Lowrey found that when both workplace exposure and an unexposed referent group were taken into account in the American Cancer Society study of passive smoking and lung cancer, a population relative risk of 1.2 increased to 1.7.[5]

In fact, Repace and Lowrey modeled the risk of workplace exposure, estimating the average relative risk at 2.0 for U.S. office workers in the 1980's.[5] This result is consistent with a value reported by Reynolds et al.[5] for women with 30 or more years of workplace exposure, i.e. at ages at which lung cancer mortality begins to become significant. Moreover, all of these analyses focus on average risk. Repace et al. estimated that individuals at the 95th percentile (e.g., those experiencing high smoker density and low air exchange) have exposure -- and risk -- as much as four times as high as those at the median. This result is commensurate with observations of dose and risk (Johnson and Repace, in press). In general, the degree of ETS disease risk depends critically upon the average ratio of the smoker density to the air exchange rate in the exposure venues a person frequents during life; e.g., workplace smoker densities are often far higher than in homes, while air exchange rates may be comparable (Repace and Lowrey, 1985; 1993; Repace et al., 1998).

Hazardous Chemicals in ETS

What chemicals in ETS are responsible for these diseases? ETS is a complex mixture of 5000 chemicals (NRC, 1986), many of which remain to be characterized. Listed in the appendix are 103 chemicals in tobacco smoke which can reasonably be identified as hazardous. Although TLVs exist for many of these chemicals, the effects of exposure to all of them simultaneously, with the multiple possibility of additivity, synergism or antagonism of effect, is not known. There are 60 known or suspected carcinogens in ETS (Repace and Lowrey, 1985).

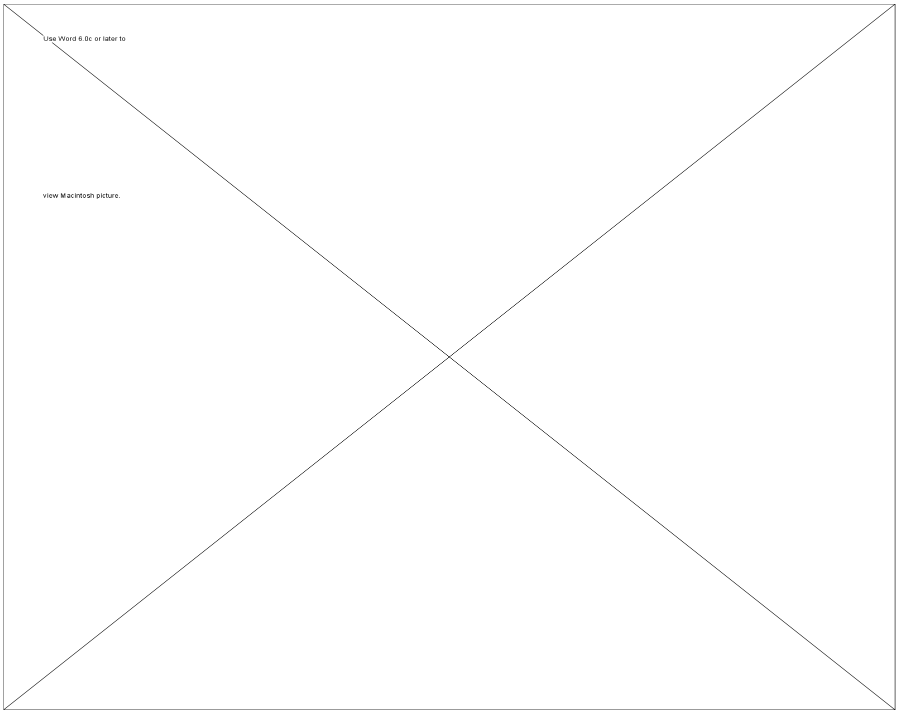
Markers for ETS: Nicotine and its primary metabolite cotinine are the best indicators of ETS exposure and dose in nonsmokers. Airborne nicotine has been found to be highly correlated to the number of cigarettes smoked in the presence of nonsmokers and to urinary cotinine in those nonsmokers. During passive smoking, nonsmokers inhale nicotine proportionally to the product of concentration, exposure duration, and respiration rate. Inhaled nicotine is absorbed into the bloodstream through the lung, and is rapidly and extensively metabolized with a half-life of the order of 2 hrs by the liver into cotinine and nicotine N-oxide. The intake of nicotine reflects exposure to other constituents of ETS. In nonsmokers, cotinine has a half-life in plasma on the order of 17 hrs and thus is an indicator of the integrated exposure to ETS over the previous 1 to 2 days. Cotinine in body fluids provides a valid quantitative measure of recent integrated ETS nicotine exposure (Samet, et al., 1999). Cotinine appears in all body fluids and on average is excreted in fixed relationships from plasma (i.e., serum) into saliva and urine. Although nicotine is present in trace amounts in certain vegetables, dietary sources are negligible compared to passive smoking as a contribution to body fluid cotinine. Air nicotine can be used to predict ETS-RSP (Leaderer and Hammond, 1991; Repace and Lowrey, 1993; Daisey, 1999). ETS is the major source of exposure of the population to indoor fine particles (Repace and Lowrey, 1980; Wallace, 1996).

The following set of equations permit calculation of one ETS marker from another (Repace & Lowrey, 1993; Repace et al., 1998):

For example: the estimated daily average population average ETS-RSP exposure during the mid 1980's (U.S. smoking prevalence about 33%) according to Repace and Lowrey (1985) was Q = 1.43 milligrams of ETS-RSP, and at a respiration rate of 24 m^3 per day, corresponds to a daily average ETS-RSP concentration of R_{ave} = 60 $\mu g/m^3$. The equations in Table 1 below permit the corresponding mean nicotine and cotinine levels to be calculated: $N_{ave} = R/10 = 6$ $\mu g/m^3$. [Daisey (1999) has re-affirmed that nicotine can be used to estimate RSP exposures in indoor environments where smoking regularly occurs]. The corresponding estimated daily average population salivary cotinine level is then $S_{ave} = (0.0071)(24)(6) = 1$ ng/ml. The estimated daily average population serum cotinine level is then P_{ave} = (1 ng/ml/ 1.16) = 0.88 ng/ml, and the estimated daily average population urinary cotinine level is given by U_{ave} = (6.5)(0.88 ng/ml) ≈ 6 ng/ml. Repace and Lowrey (1980, 1985) estimated that most-exposed nonsmokers had exposures ten times average, yielding maximum exposed individuals with the following: R_{mx} = 600 $\mu g/m^3$; N_{ave} = 60 $\mu g/m^3$; S_{mx} = 10 ng/ml; P_{mx} ≈ 9 ng/ml, and U_{mx} ≈ 60 ng/ml.

The only national probability sample of any ETS marker is that of serum cotinine, performed in the NHANES III study, with data taken between 1988 and 1991 (U.S. smoking prevalence about 29%). NHANES III reported that adults $\geq$ 17 years who reported work exposure only > 3 hr/day had geometric mean cotinine levels of 0.6 ng/ml, home exposure only was 0.7 ng/ml, both home and work exposure, 0.9 ng/ml. A bimodal distribution was observed, with a

Table 1:



separation between 10 to 15 ng/ml, the region between heavy passive smoking and light active smoking. Despite the uncertainty introduced by comparing geometric means to arithmetic means and the 12% lower smoking prevalence (CalEPA, 1997, fig. 2.6), the model estimates are close to observations. In general, the model predictions can be compared to data reported in the literature, with general agreement as shown in Table 2 below.

Table 2. Comparison of model with reported measurements of ETS markers

Marker	**Modeled Range**	**Observed Range**	**Reference**
	(ave. to peak) Repace et al. model	Various measurements	CalEPA (1997):
ETS-RSP	60 - 600 μg/m^3	5 - 500 μg/m^3	Section 2.3.3
Nicotine	6 - 60 μg/m^3	0.3 - 65 μg/m^3	Section 2.3.3; Hammond (1999)
Saliva Cotinine	1 - 10 ng/ml	5.6 - 14.2 ng/ml*	Section 2.4.2 table 2.4 and table 2.5
Serum Cotinine	0.9 - 9 ng/ml	2.0 - 13.7 ng/ml*	
Urine Cotinine	6 - 60 ng/ml	7.7 - 49.7 ng/ml*	

*****(ave. to peak);

Analysis:

General dilution ventilation, which I will characterize as "reasonably achievable control technology," or RACT, was judged to be inadequate by the panelists for ETS control. RACT, as applied to pollution sources in outdoor air pollution control, is the lowest limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility (EPA, 1983). Displacement ventilation possibly coupled with ventilated ashtrays in some installations (but impractical for all), which I will describe as "best available control technology," or BACT, was judged to be the best potential control measure by the panelists. BACT, again as applied to pollution sources in outdoor air pollution control, refers to the maximum degree of air pollution reduction attainable by a source considering energy, environmental and economic impacts, through the application of available systems, methods and techniques (EPA, 1983). In outdoor air pollution control, BACT does not permit the source to pollute in excess of any requirements imposed by Section 112 of the Clean Air Act.

The panelists' conclusions on ETS controls were reached on the basis of professional judgment, which they identified as being hindered by two major problems. The first problem identified by the panelists was the lack of information on existing exposure levels, and the second one was the lack of recognized standards of acceptable ETS exposure, so that even if displacement technology were to be universally adopted in the hospitality industry, and 90% exposure reductions could be routinely achieved in practice, there is no guarantee that the residual exposure would yield an acceptable risk for hospitality workers. A further problem which emerged in the discussion is that since some building codes do not require operation of the HVAC systems, they would have to be changed. Also, some establishments may have only natural ventilation. Finally, even assuming that recognized standards limiting ETS exposure are adopted an enforcement apparatus would be required to ensure that the standards are being met.

Outdoor air pollution regulation and control has long been guided by atmospheric models for plume dispersion (Turner, 1970). However, it has not generally been recognized that indoor air pollution, particularly from ETS, can be modeled with far greater accuracy than stationary source outdoor air pollution (Wadden and Scheff, 1983; NRC, 1986; Repace, 1987; Ott, 1999). ETS concentrations predicted by models agree well with measured values in real settings, both on a minute-by-minute basis and for longer time averages, and the models are especially useful for determining the ventilation required to meet suggested indoor air quality standards (e.g., the National Ambient Air Quality Standard for fine particles (currently $PM_{2.5}$) for given smoking activity levels (Ott, 1999). In particular, the panelists did not apply existing models to estimate current exposure. Further, the U.S. Environmental Protection Agency has declared ETS to be a human carcinogen, a conclusion endorsed by the National Cancer Institute (NCI, 1993). Panelists also did not consider whether the residual exposure of workers to ETS after application of BACT would yield an acceptable risk.

I will now employ published models of ETS exposure and risk to the hospitality workplace to evaluate the current situation for workers and patrons with dilution ventilation, and estimate the efficacy of a putative 90% reduction in exposure using displacement ventilation, a reduction estimate for which there is no supporting data.

Modeled Exposure and Risk for ETS in Restaurants

Introduction

Repace et al.(1998), Repace and Lowrey (1993), Repace (1987), Repace and Lowrey (1985), and Repace (1984) developed models for ETS exposure, dose, and risk which agree well with observations. It is important to note that these ETS models have gained widespread acceptance in the scientific community:

The National Research Council (1986) observed that the most extensive use of the mass-balance equation for assessing ETS in occupied spaces was by Repace and Lowrey (1980), and observed that the model "predicted ETS-Respirable suspended particle (RSP) levels reasonably well over a wide range of values of input parameters." The model was also favorably reviewed in the 1986 Surgeon General's Report on Involuntary Smoking. Ott et al. (1992) derived and validated a general equation for the mean concentration of ETS in an indoor space and concluded that it was structurally equivalent to the model of Repace (1987). The Monte Carlo model of Repace et al. (1998) for predicting ETS exposures was favorably reviewed by Spengler (1999).

Weiss (1986) commented "on the association between passive smoking and lung cancer and the biological and mathematical assumptions underlying Repace and Lowrey's (1985) assessment of risk." Weiss concluded, in part: "Despite the simplifying assumptions of the risk estimates and the flaws in the epidemiologic data from which they are derived, Repace and Lowrey's figures remain the best current estimates of lung cancer deaths from passive smoking." Kawachi et al. (1989) estimated the "relative risk for lung cancer death from exposure to passive smoking in the workplace ... via an exposure response relationship derived by

Repace and Lowrey [1985; 1987]." Wigle et al. (1987) used the methods of Repace & Lowrey (1985) to assess lung cancer risk in Canadians. Nagda et al. (1989) assessed the lung cancer risks of passive smoking for flight attendants and passengers on U.S. carriers in part using the risk assessment model of Repace and Lowrey (1985). The U.S. EPA (NCI, 1993) described the risk assessment approach of Repace and Lowrey (1985) for lung cancer as "a novel approach that contributes to the variety of evidence for evaluation [of lung cancer risk] and provides a new perspective on the topic." Tancrede et al. (1987) used the risk assessment model of Repace (1984) to estimate a mean lifetime risk for lung cancer for U.S. nonsmokers from passive smoking of about 5 per thousand, with a 98th percentile of 3.8%. Finally, Samet and Wang (2000) have observed that the calculations made possible by the exposure, dose, and risk models of Repace et al. (1998) for estimating worker risk of lung cancer illustrate that passive smoking must be considered as an important cause of lung cancer death from a public health perspective, since exposure is involuntary and not subject to control.

Modeling Exposure and Risk in Restaurants, Bars, and Casinos

Exposure Modeling

Ott (1999) in the OSHA-sponsored Workshop on Environmental Tobacco Smoke Exposure Assessment, observed that much progress has been made over four decades in developing, testing, and evaluating the performance of mathematical models for predicting pollutant concentrations from smoking in indoor settings. Ott (1999) further commented that although largely overlooked by the regulatory community, these models provide regulators and risk assessors with practical tools for the quantitative estimation of ETS exposures. In the same workshop, Spengler (1999) observed that generally the highest ETS exposures are occurring in bars, restaurants, and nightclubs, and using the techniques developed by Repace et al. (1998) reasonable estimates may be made of ETS exposures in offices, restaurants and bars. Repace et al. (1998) have shown that ETS exposure is directly proportional to the smoker density D_{hs}, (in units of habitual smokers per 100 m^3), and inversely proportional to the air exchange rate ϕ_v (in units of air changes per hour: h^{-1}), where a habitual smoker is assumed to smoke at the national average rate of 2 cigarettes per hour, where the smoker density = 100 n_{hs}/V, and where n_{hs} is the number of habitual smokers and V is the volume of the space in cubic meters. ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality (now supplanted by ASHRAE Standard 62-1999) specifies design ventilation rates based on design occupancy, i.e., 10 L/s per design occupant, and so many occupants per 100 m^2 (100 m^2 is ~1000 ft^2) this becomes a volumetric measure when a ceiling height is assumed. Therefore, for a given smoking prevalence, the design occupancy determines both the smoker density and the air exchange rate.

Repace(1987) derived an equation for the calculation of ETS-RSP levels in units of micrograms per cubic meter ($\mu g/m^3$) for a workplace as a function of the habitual smoker density D_{hs} (units $HS/100m^3$) in the building and the building's air exchange rate ϕ_v (units hr^{-1}):

$$RSP_{ETS} = 220\frac{D_{hs}}{\phi_v} \qquad \textbf{(Eq. 1)},$$

where ϕ_v (phi-vee) is the air exchange rate due to dilution ventilation. The equation incorporates a 20% removal rate for ETS-RSP deposition on surfaces, and assumes an emission rate of 14 mg of ETS-RSP per cigarette and a smoking rate of 2 cigarettes per smoker per hour. If there is additional air cleaning, ϕ_v would be increased by the air exchange rate due to the air cleaning. ETS nicotine levels may be estimated by dividing Equation 1 by ten.

ASHRAE Standard 62-1989 specifies the following occupancies, in persons per 100 m^2 of floor area (Table 3) for the given hospitality venues: If a smoking prevalence of 25% is assumed, then the number of expected smokers and the smoker density (in units of habitual smokers per 100 m^3) may be estimated, assuming a 4 meter ceiling height multiplied by the unit space area for the number of occupants. The product of smoking prevalence and occupancy (number of persons per 100 m^2) yields the estimated number of smokers. The corresponding air exchange rate for pollutant removal, in units of air changes per hour (ACH) may be calculated, as follows.

Table 3. Smoker density and Air Exchange Rate (dilution ventilation) at full occupancy for various hospitality venues for a ceiling height of 4 m under ASHRAE Standard 62-1999 per 100 m^2 of floor area, and a smoking prevalence of 25%. (US smoking prevalence in 1993 = 24%.)

Hospitality Venue	Design Occupancy, Persons per $100m^2$	Design Ventilation Rate (Lps/occ)	ϕ_v, air changes/hr	n_{hs}, # of habitual smokers (HS) per 100 m^2	D_{hs}, habitual smoker density, HS per 100 m^3
Smoking Lounge	70	30	19	70	17.5
Bar, Cocktail Lounge	100	15	13.5	25	6.25

Dining Room	70	10	6.3	18	4.5
Gambling Casino	120	15	16.2	30	7.5
Bowling Alley	70	13	8	18	4.5

The air exchange rate ACH = (Occupancy, Persons)(Vent Rate Lps/P)(1 m^3/1000L)(3600 s/hr) / (space volume, m^3). For example, for a Dining Room, an occupancy Occ = 70 persons per 100 m^2 of floor area, or per 400 m^3 of space volume, assuming a 4 m ceiling. For a smoking prevalence of 25%, the number of habitual smokers n_{hs} = (0.25)(70) = 18, the habitual smoker density D_{hs} = (.25)(70)/(400) = 4.5 smokers per 100 m^3. The air exchange rate is ϕ_v = (70 occ x 10 Lps/occ x 1 m^3/1000 L)(3600 s/h) / (400 m^3) = 6.25 h^{-1}. [It should be pointed out that there is no enforcement of operational ventilation rates, providing an economic incentive for building owners to supply less.]

Table 4. Estimated RSP and Nicotine Concentrations Based on Equations 1 & 2

Hospitality Venue	D_{hs}, habitual smoker density, HS per 100 m^3	ϕ_v, air changes/hr (design, not enforced)	Estimated RSP level ($\mu g/m^3$)	Estimated Nicotine level ($\mu g/m^3$)	Comment
Smoking Lounge	17.5	19	203	20	Levels will triple if all smoke at once
Bar, Cocktail Lounge	6.25	13.5	102	10	More intensive smoking likely
Dining Room	4.5	6.3	157	16	
Gambling Casino	7.5	16.2	102	10	More intensive smoking likely
Bowling Alley	4.5	8	124	12	

The estimated RSP and nicotine concentrations, estimated in Table 4 for the RACT case of dilution ventilation are liberal in that they assume full occupancy, but are likely to be conservative in other respects: (a) since nonsmokers are known to avoid smoky restaurants and bars (Biener et al., 1999), the number of smokers will likely be greater than their prevalence in the population; (b) the air exchange rates are likely to be less than design because to provide design rates of ventilation costs money, and there is no enforcement of operational rates; (c) in bars, nightclubs, and casinos, smoking is likely to be more intensive than the national average of 2 cigarettes per hour (chain smokers smoke up to 6 cigarettes per hour); (d) cigars make more pollution than cigarettes -- the above table is estimated for cigarettes only; (e) if smokers are restricted to designated areas, hospitality workers will work in environments where almost everyone is a smoker, increasing the number of smokers by as much as a factor of 4. For restaurants, cutting back on ventilation might mean air exchange rates closer to 1 air change per hour rather than 6. Nevertheless, the above levels can be compared with the range of observations reported by EPA (1992): for restaurants average RSP values (ch. 3, fig. 3-8) ranged from 40 to 1000 $\mu g/m^3$, and nicotine in restaurants (not necessarily in the same ones) from 6 to 18 $\mu g/m^3$, consistent with the predictions in Table 4, and the caveats in this paragraph.

The ETS-nicotine (N) levels may be estimated from the RSP levels (R) (Repace and Lowrey, 1993; Daisey, 1999) by the ratio N = R/10. In table 4, the estimated nicotine levels range from 10 to 20 $\mu g/m^3$. The only data that I am familiar with that has expressed nicotine concentration in pubs as a function of smoker density (the active smoker density D_{as} is the average number of burning cigarettes per hundred cubic meters ($D_{as} = 1/3\ D_{hs}$) was measured in Canada in 1995. Figure 1 below shows measured levels in ten Vancouver British Columbia (BC) restaurants and pubs with smoking and nonsmoking sections in 1995 (Lockhart, 1995). The smoking prevalence in BC is 23% (Gallup, 1996). It is seen that nicotine levels ranged as high as 40 $\mu g/m^3$ in the smoking sections and as high as 30 $\mu g/m^3$ in the nonsmoking sections, and that the differences between the smoking and nonsmoking sections were slight, due to "well-mixed" dilution ventilation. This corresponds to estimated RSP levels above background of 300 to 400 $\mu g/m^3$, comparable to the levels measured by Repace and Lowrey (1980). Both the measured nicotine and estimated RSP levels are consistent with the EPA summary discussed above. Ott has given a nomograph to evaluate ETS-RSP levels which is useful for field surveys where the active smoking count, or number of burning cigarettes averaged over the sampling time, is known. Ott(1999) has shown that the mass-balance model accurately predicts the time-averaged ETS concentration in field surveys of smoking whenever the ratio of the difference in the concentration at the beginning and end of the sampling period to the product of the air exhange rate and sampling time is small compared to the ETS concentration. For a discussion of the equivalency of the Repace (1987) and the Ott (1999) mass-balance models, see Appendix B. These models apply to well-mixed dilution ventilation.

Although panelists were sanguine about the prospects of displacement ventilation, I have noted that there is little data to support its efficacy. Its usual application is a one-pass system with 100% outside air introduced into a designated nonsmoking section, with positive air flow directed through an open passageway into a negatively-pressurized smoking section. I will describe my personal experience with a show-case displacement ventilation installation in a TGIF restaurant in Mesa, Arizona, while on a consultation for the Mesa City Council in September 1999. We entered the nonsmoking section of the facility in mid-afternoon. I could not smell any smoke. However, after about 15 minutes, eye and throat irritation set in. Upon entering the smoking section, on the opposite side of the front door, the air quality in the smoking area was terrible, although only a few smokers were observed. While displacement ventilation may reduce exposures in the nonsmoking section, it may increase exposures for workers in the smoking section. Since the smoking and nonsmoking areas were equal in volume, the smoke was now contained in a smaller space. Further, as one panelist observed, displacement is a low-flow technology, whereas dilution air is involves much larger airflow. Further, during busy periods, with waiters traversing between sections, the uniform flow of air required to minimize backflow of smoke into the nonsmoking area would likely be disrupted, permitting greater amounts of smoke to diffuse. Also, displacement works preferentially on large molecules, while smaller ones easily diffuse.

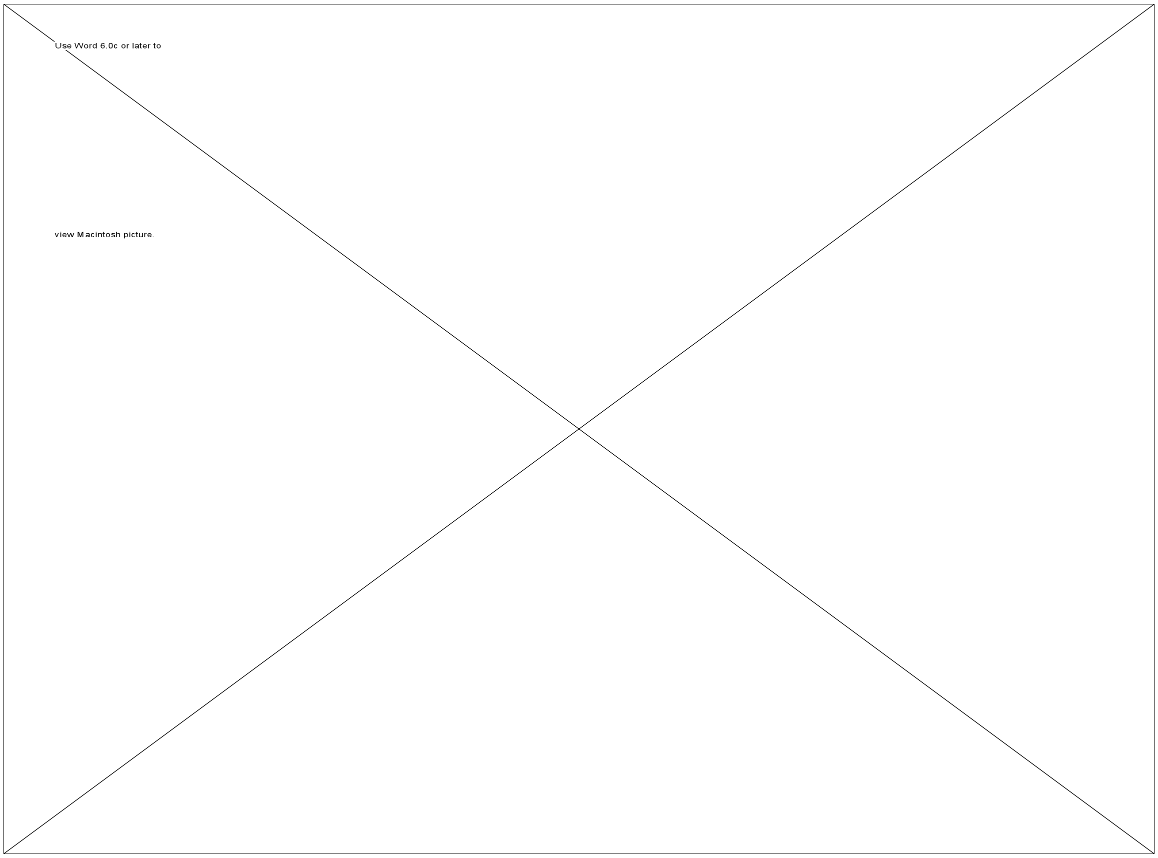


Figure 1. Nicotine levels measured in 10 Vancouver, British Columbia Pubs for the Heart and Stroke Foundation of BC and Yukon (Lockhart, 1995). The active smoker density D_s (the average instantaneous density of burning cigarettes) is 1/3 of the habitual smoker density D_{hs} of the habitual smoker model of Repace (1987).

Presumably, these restaurants and pubs should have been ventilated according to ASHRAE Standard 62-1989, which specifies 15 Lps per occupant for pubs and 10 Lps per occupant for restaurant dining rooms. As shown above, this corresponds to design air exchange rates of the order of 15 hr^{-1}, and should have resulted in nicotine concentrations of the order of 10 $\mu g/m^3$ (an active smoker density of 2 burning cigarettes per 100 m^3 corresponds to a habitual smoker density of 6 habitual smokers per 100 m^3). That levels as much as 2 to 4 times higher were observed suggests that either the actual ventilation rates were one half to one quarter of the level mandated by the ASHRAE Standard, or that the smoking rates were 2 to 4 times higher than expected, or some combination of lower ventilation rates and higher smoking rates. In either case, this suggests that the estimates in Table 4 are conservative. Figure 1 shows the importance of always measuring the smoker density whenever ETS concentrations are measured, so that the results can be generalized and interpreted.

Regulatory Risk Levels

Involuntarily imposed worker risks from ETS can be compared to societal standards for permissible human exposures to environmental carcinogens such as industrial chemical emissions and radionuclides in air and water, and carcinogenic molds and pesticide residues in food. Several U.S. federal regulatory agencies promulgate regulations and standards to protect the public from exposure to environmental carcinogens. It is of interest to inquire as to what levels of population cancer risk typically trigger regulation, what levels are beneath regulatory concern, and how consistently are they applied among various federal agencies. Travis et al.(1990) reviewed the use of cancer risk estimates in prevailing U.S. federal standards and in withdrawn regulatory initiatives, to determine the relationship between risk level and regulatory action in 132 U.S. federal regulatory decisions of record concerning lifetime risk of mortality.

Travis et al. describe two technical risk assessment terms: *de manifestis* risk and *de minimis* risk. A *de manifestis* risk is literally "a risk of obvious or evident concern," and has its roots in the legal definition of an "obvious risk", i.e., one recognized instantly by a person of ordinary intelligence. *De manifestis* risks are those that are so high that U.S. federal regulatory agencies almost always acted to reduce them, and *de minimis* risks are so low that agencies almost never acted to reduce them. For various reasons, risks falling in between these extremes were regulated in some cases but not in others; however, **residual risks after control are generally *de minimis***. Travis et al. found when the population at risk was large, as with ETS, *de manifestis* risk corresponded to a lifetime risk of mortality of 3×10^{-4}, and *de minimis* risk was 1×10^{-6}. The U.S. Occupational Safety and Health Administration has defined a working lifetime (45 yr.) risk level of 1 death per 1000 workers at risk as corresponding to a “significant risk of material impairment of health” (U.S. DOL, 1994).

Risk Modeling, Dilution Ventilation (RACT)

ETS risks are estimated based on the ETS-RSP levels from Table 4, using the exposure-response models of Repace and Lowrey (1985b), Repace and Lowrey (1993) and Repace et al. (1998). Under these models, a time-weighted 8-hr average exposure for 260 days/yr over a 40 year working lifetime to an ETS-RSP level of 75 $\mu g/m^3$ corresponds to a working lifetime risk of 1 per 1000 for lung cancer mortality, and 1 per 100 for heart disease mortality. These exposure and risk assessment models may be used to assess the fatal lung cancer and heart disease risk to hospitality workers from ETS exposure at work. This modeling is summarized in Table 4 for five hospitality venues.

Under dilution ventilation and occupancy as specified by ASHRAE Standard 62-1999, and with a typical U.S. average smoking prevalence, the combined estimated lung cancer and heart disease mortality risks to hospitality workers range from 15 to 30 per 1000, exceeding all applicable environmental and occupational regulatory levels. A risk of 20 per 1000 is twenty thousand times the *de minimis* risk level. The risks calculated in Table 4 are likely to be underestimated relative to real-world situations, because of two factors: first,

Table 5. Estimated ETS-RSP concentration and associated[c] lung cancer, heart disease and combined risk for hospitality industry workers using dilution ventilation, assuming a smoking prevalence of 25%, (approx. the U.S. average), and compliance with the ASHRAE Standard 62 1999.

Smoking Area	**Estimated ETS-RSP, μg/m³**		**Est. Excess Lung Cancer Mortality per 1000 workers**	**Est. Excess Heart Disease Mortality per 1000 workers**	**Est. Total Excess Mortality per 1000 workers**
Smoking Lounge[†]	203		2.4	24	26
Bar, Cocktail Lounge	102		1.4	14	15
Dining Room	157		2.0	20	22
Gambling Casino	102		1.4	14	15
Bowling Alley	124		1.7	17	18
Risk Level	LCD[a]	HDD[b]			
de minimis risk	.075	.0075	0.001	0.001	0.001
de manifestis risk	22.5	2.3	0.3	0.3	0.3
OSHA Significant risk	75	7.5	1	1	1

†: assumes workers serve in lounge; a: lung cancer death; b: heart disease death
. c: assumes worker exposure for 8 hours per day, 260 days/yr; 40 yr Working Lifetime.

since there is no enforcement of operational ventilation rates, and since it costs money to treat outdoor air which is cold or hot and humid, operational rates will be less than design -- it is a simple matter of turning a dial to close down outside air dampers. Second, smoky restaurants, bars, and casinos are likely to have far less nonsmokers and far more smokers than national prevalence figures suggest, because nonsmokers are known to avoid such establishments (Biener et al., 1999); in fact during 1995, based on data provided by Biener et al., the number of Massachusetts nonsmokers who said they avoided smoky restaurants and bars was 80,000 more the total number of Massachusetts smokers.

Based on Table 5, assuming regular patrons have an exposure duration of about 10% of the workers, or 4 hrs per week, the combined lung cancer and heart disease mortality risks to the patrons also exceeds all environmental and occupational regulatory levels.

Such increases in RSP levels would also be expected to result in the denial of access to the workplace and public places of accommodation for both workers and patrons who are asthmatics or who suffer from other cardio-respiratory diseases. Dockery and Pope (1994) found that total daily mortality associated with particulate air pollution shows an approximately 1% increase per 10 $\mu g/m^3$ daily increase in particulate matter below 10 microns in aerodynamic diameter (PM_{10}). They also found that particulate air pollution is even more strongly associated with cardiovascular mortality, with a dose-response showing a 1.4% increase per 10 $\mu g/m^3$ increase in PM_{10}. The U.S. National Ambient Air Quality Standard (NAAQS) for $PM_{2.5}$ protects against health effects such as premature death, increased hospital admissions and emergency room visits (primarily the elderly and individuals with cardiopulmonary disease); increased respiratory symptoms and disease (children and individuals with cardiopulmonary disease such as asthma); decreased lung function (particularly in children and individuals with asthma); and against alterations in lung tissue and structure and in respiratory tract defense mechanisms. The level of 15 $\mu g/m^3$ of the annual standard is an annual average which defines clean air. The supplemental 24-hr standard of 65 $\mu g/m^3$, is intended to prevent short-term peaks from impacting public health (Fed. Reg., 1997).

In fact, Eisner et al.(1998) studied the association between ETS exposure and respiratory symptoms in a cohort of 53 bartenders before and after California's prohibition on smoking in all bars and taverns in 1998. 74% of the bartenders initially reported respiratory symptoms; of those symptomatic at baseline, 59% no longer had symptoms at follow-up. 77% initially reported sensory irritation symptoms; at follow-up, 78% of these had symptom resolution. After ETS exposure completely ceased, objective measures of pulmonary function showed a marked 5% to 7% improvement after only one month of smoke-free air. Eisner et al. (1998) concluded that establishment of smoke-free bars and taverns was associated with improvement of respiratory health.

As discussed above, Spengler (1999) has observed that ETS exposures in restaurants can be modeled using the techniques of Repace et al. (1998). Samet and Wang (2000) have observed that the risk models of Repace et al. (1998) are useful for estimating worker risk. Figure 2 combines these models to estimate ETS risk as a function of ventilation rate in a restaurant at a smoking prevalence of 29%, equivalent to 2 smokers per 1000 ft^2 or per ~100 m^2 of floor area. It is seen that for RACT, or ordinary dilution ventilation to reduce the ETS risk to restaurant workers to *de minimis* levels would require ventilation rates in excess of 100,000 Lps/occ, levels which are impractical by more than 4 orders of magnitude (10,000-fold). At a smoking prevalence of 25%, as used above, ETS risks are reduced only slightly compared to the risks shown in Fig. 2. If one assumes that BACT, or displacement ventilation, can reduce ETS risks to 1/10, equivalent to a ten-fold increase in ventilation efficiency, the risks still remain unacceptable by three orders of magnitude (1,000-fold). This is discussed in further detail below.

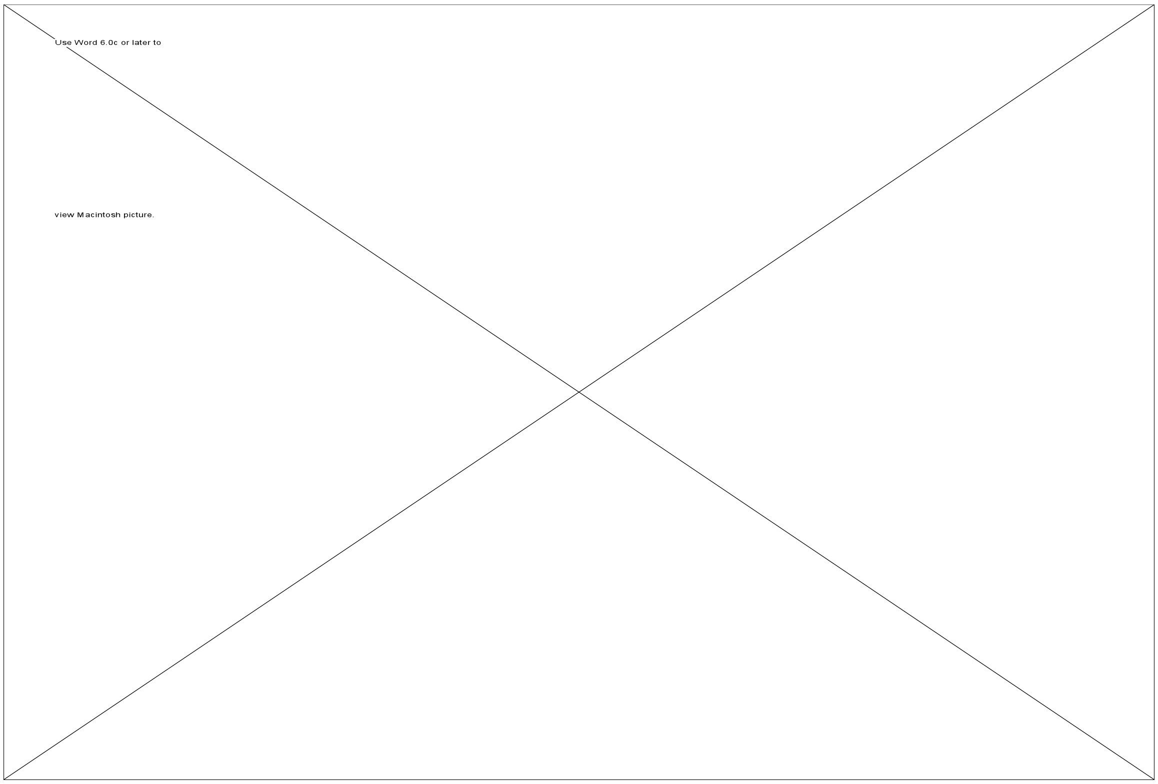


Figure 2. Estimated excess risks of lung cancer and heart disease for hospitality workers for a smoking prevalence of 29%, a restaurant occupancy of 70 persons per 100 m^2, as a function of ventilation rate supplied per occupant. The ASHRAE Standard recommendation of 10 Lps/occ (20 cfm/occ) is shown (Risks are estimated based on the models of Repace and Lowrey, 1985; 1993; Repace et al., 1998). Risks to workers in bars and casinos would likely be greater, due to higher actual smoker prevalence and closer proximity of bartenders and casino dealers to smoking.

Siegel(1993), in a review of the literature, found that restaurant waitresses had a 50% to 100% higher risk of lung cancer compared to the general population. EPA(1992, p. 187) estimated that the annual risk of lung cancer for U.S. nonsmoking women from the general population from all causes was 15 per 100,000, corresponding to a 70 year lifetime risk of 10 per 1000, with 1/3 of that risk from passive smoking, for an estimated lifetime risk from passive smoking at about 3 per 1000 above a non-ETS background of 7 per 1000. By comparison, the estimated excess risk for lung cancer for restaurant workers in Figure 2 from passive smoking in a restaurant workplace in compliance with the ASHRAE Standard is about 3 per 1000, which when added to the general population background, would constitute a 100% increase. Thus, the estimated lung cancer risk from Figure 2 is in good agreement with the results of EPA and Siegel.

Risk Modeling, Displacement Ventilation (BACT)

As discussed above, the OSHA Ventilation Workshop Panelists concluded that displacement ventilation had the potential to achieve 90% reductions in ETS concentrations, although no data on real hospitality facilities taken for real workers was presented to support this contention. Nevertheless, for the purposes of this analysis, I will presume that this can be accomplished, and that the technology will work as designed and be properly maintained over a working lifetime. Using dilution ventilation, the hospitality venues of Table 4 using perfectly designed and properly operated HVAC systems would have total working lifetime risks for workers of from 15 to 30 per 1000. I will assume that 90% reductions on this ideal level (and not the realistic levels shown in Figure 1) can be achieved using displacement technology or BACT. This would yield estimated combined lifetime risks for workers of from 1.5 to 3 per 1000, which still exceed all environmental and occupational regulatory levels. A risk of 2 per 1000 is two thousand times the *de minimis* risk level. There is a third concept in outdoor air pollution control known as LAER, or lowest achievable emissions reductions (USEPA, 1983). This is the most stringent level of reduction which is contained by any source or category of sources. BACT clearly will not achieve LAER. This level of reduction, however, is easily achieved by smoking bans such as in the State of California. Smoking bans reduce the risk from ETS exposure to zero.

Airborne carcinogens, are not regulated using RACT or BACT. They fall under Section 112 of the Clean Air Act, which governs hazardous air pollutants, i.e., pollutants which “may reasonably be anticipated to result in an increase in mortality or an increase in serious irreversible, or incapacitating irreversible, illness” (CAA, 1977). Hazardous air pollutants are regulated under a National Emission Standard for Hazardous Air Pollutants, or NESHAPS. NESHAPS are regulated after a risk assessment. Dose-response relationships are estimated for NESHAPS pollutants, and severe emissions limitations are imposed on sources emitting them. The emissions limitations are typically designed to reduce the aggregate or population risk to *de minimis* levels. This is accomplished by estimating dose-response relationships, estimating population exposure, and requiring reduction of the source emissions to limit the downwind concentration to *de minimis* risk levels. This means less than 1 estimated death per lifetime for the population at risk, irrespective of the costs of containment, since Section 112 is exempt from economics tests.

Table 6 below shows the risks before control for various hazardous air pollutants regulated by the US EPA, compared with ETS. In the case of arsenic, the only copper smelter in the U.S. to emit arsenic (an impurity in the ore) closed down because it could not meet the NESHAPS requirement economically. Note that with the exception of asbestos, all the remaining NESHAPS pollutants are constituents of ETS (Repace and Lowrey, 1985; 1990). Risk assessments were performed for ETS by the U.S. EPA (1992), the CalEPA (1997), by Repace and Lowrey (1985), and by others (Repace and Lowrey, 1990). Unlike the other ETS risk assessments which have been performed, Repace and Lowrey (1985) derived a dose-response relationship. Clearly, based on the number of deaths, ETS falls in the category of a hazardous air pollutant. Note that NESHAPS requirements override both BACT and RACT. If regulated under a NESHAPS, ETS deaths would have to be less than 1 death per year, nationally. NESHAPS are also set such that risks to the most-exposed individual are controlled to acceptable levels. Note that unlike ETS, which is a best-estimate risk, the remaining pollutants are generally estimates at the 95% upper confidence interval of a maximum likelihood estimate.
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Table 6. Hazardous Outdoor Air Pollutants Regulated under the Clean Air Act compared to ETS, which is not federally regulated.

Hazardous Air Pollutant	**Estimated Annual Cancer Mortality**
Environmental Tobacco Smoke	5000
Vinyl Chloride*	<27
Airborne Radionuclides*	17
Outdoor Asbestos Emissions*	15
Coke Oven Emissions*	<15
Benzene*	<8
Arsenic*	<5

*Regulated under Section 112 of the Clean Air Act

ETS itself contains vinyl chloride, radionuclides (e.g. Po^{210}), coke-oven like chemicals (e.g. polycyclic aromatic hydrocarbons), benzene, and arsenic. Cigarettes have been manufactured with asbestos filters. In addition, another 47 chemicals in ETS can be classified as "hazardous waste" (Appendix C). Alone among well-known toxic and carcinogenic chemicals, ETS is not subject to a NESHAPS, TLV, or air quality standard. Although EPA classified ETS as a "known human carcinogen" in 1992, EPA has no authority to set indoor air quality standards, is explicitly forbidden by Congress from regulating indoor air quality, and EPA's ETS research program was abandoned in 1990. While OSHA proposed (1994) to regulate ETS in workplaces in, work on its proposed rule ceased in 1995.

In the absence of any official safe level for ETS, it is foolish to make -- or accept -- vague claims that ventilation can control ETS. The only prudent approach is a smoking ban. Smoking bans will achieve *de minimis* risk without any engineering controls.

Although smoking bans have been widely opposed by the hospitality industry, their opposition been founded in a misguided belief in business losses that have failed to materialize in any part of the U.S. Although many in the hospitality industry worry about loss of smoking customers, few seem to realize they have already lost a substantial amount of nonsmoking trade. It might be expected that since many nonsmokers avoid smoky places (Biener et al., 1999; Glantz, 1999), and since adult nonsmokers outnumber adult smokers by more than 3:1 nationally, that there would be no economic penalties. In fact, as Figure 3 shows, smoking bans have had no discernible economic impact in California.

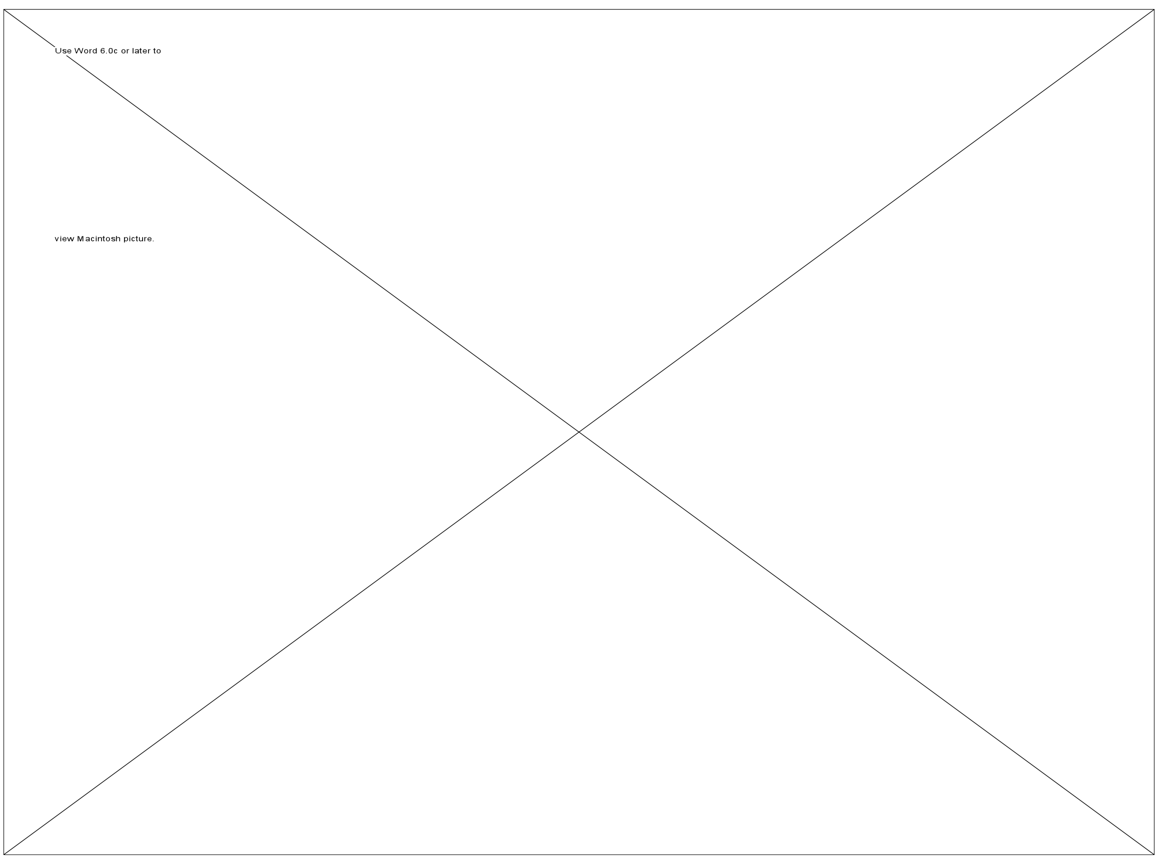


Figure 3. Data from California food and beverage industry tax receipts shows no economic impact from smoke-free restaurant or bar ordinances.

Conclusions on Risks for RACT and BACT:

The best that current dilution engineering technology (RACT) can provide is worker risks of the order of 20 thousand times the *de minimis* level. The best that future displacement engineering technology (BACT) can provide is worker risks of the order of 2 thousand times the *de minimis* level. Smoking bans (LAER) provide risks thousands of times lower (actually zero) at no discernible cost to the industry as a whole, while providing obvious significant public and worker health benefits.

The Tobacco Industry and Ventilation

Background. In 1973, ASHRAE Standard 62-73 Section 6.2, specified 30 cubic feet per minute per occupant (cfm/occ) (15 Lps/occ) to 50 cfm/occ of outdoor makeup ventilation air for bars and cocktail lounges and 10 to 20 cfm/occ for restaurant dining rooms. In 1981, ASHRAE Standard 62-1981, in order to save energy, specified different ventilation rates for smoking and nonsmoking in Section 6, Table 3: smoking restaurants 35 cfm/occ, nonsmoking 7 cfm/occ. Smoking bars and cocktail lounges, 50 cfm/occ, nonsmoking 10 cfm/occ. These rates were recommended by a committee of ventilation engineers from industry in a consensus process. It also added a new "indoor air quality procedure" which would bring contaminants to some specified acceptable levels (similar to the procedure I have employed above and embodied in Figure 2). [It further recommended that "best available control technology be employed for toxic indoor contaminants such as asbestos, radon, and formaldehyde, but stated that for other contaminants such as tobacco smoke, precise quantitative treatment can be difficult.]

The tobacco industry's response to these new two-tiered rates, which imposed a penalty on smoking establishments, was to disrupt the committee's functioning using parliamentary maneuvers (Repace, 1987) and ultimately to threaten ASHRAE with litigation. The net result, incorporated into ASHRAE Standard 1989, was abolition of the differential rates for smoking and nonsmoking establishments. The new rates for restaurants were a blanket 20 cfm/occ independent of smoking status, and for bars, 30 cfm/occ. However, in a further capitulation to the tobacco industry, a footnote to the standard stated: "Table 2 prescribes rates of ... outdoor air required for acceptable indoor air quality. These values have been chosen to control CO_2 and other contaminants with an adequate margin of safety and to account for health variations among people, varied activity levels, and a moderate amount of smoking." In the foreword to the Standard, the following opaque disclaimer appeared: "... with respect to tobacco smoke and other contaminants, this standard does not, and cannot ensure the avoidance of all possible adverse health effects, but it reflects recognized consensus criteria and guidance."

The tobacco industry widely touted ASHRAE 62-1989 in support of its contention that tobacco smoke could be controlled by ventilation, and that smoking bans were not needed. Confidential tobacco industry documents from a Settlement Agreement Website observed that because ETS was perceived to be a health risk and annoyance, and smoking bans were proliferating. The ASHRAE Standard 62-1989 revision was identified as a major issue: "The proposed revised standard ... would preclude any building where ETS is present from being classified as having acceptable indoor air quality. For new buildings designed to adhere to this standard the result could be the same de facto prohibition of smoking contemplated by the OSHA [Indoor Air Quality] proposal." The strategy document's listed Goal: "Perpetuate the substance of Standard 62-1989, which provides for smoking, as the accepted standard and amend the terms of the revision to accommodate smoking." Litigation options were among the actions considered to further this goal. The hospitality industry was singled out as a major target for "accommodation," with hotels, restaurants, pubs and taverns specifically mentioned. [pmdocs.com, Worldwide Strategy and Plan, pp 2-4, Bates # 2060577486, -87, -88; -502, -522], .

However, despite numerous attempts at amending the standard and several appeals to both ASHRAE and ANSI, the industry failed. After a decade, a new version of the standard was issued which reflected the general medical/scientific consensus on ETS: ASHRAE Standard 62-1999 contained an addendum 62e, which repealed the statement that the ventilation rates in Table 2 accommodate a moderate amount of smoking. The Foreword to Standard 62-1999 noted: "Since the last publication of this standard in 1989, numerous cognizant authorities have determined that environmental tobacco smoke is harmful to human health. [A list of authorities was given, including the US EPA, WHO, AMA, ALA, NIOSH, NAS, OSHA, and the Surgeon General.] This addendum does not prohibit smoking or any other activity in buildings, but rather removes the statement that the recommended ventilation rates are intended to accommodate a moderate amount of smoking." The indoor air quality procedure continued to be listed as an alternative performance method to the Ventilation rates prescribed in Table 2.

Current Tobacco Industry Statements on ETS, Ventilation, and the Hospitality Industry

The major tobacco companies, Philip Morris (PM), RJ Reynolds (RJR), and British American Tobacco (BAT) [BAT's U.S. subsidiary is Brown & Williamson] maintain corporate websites {PhilipMorris.com; RJReynolds.com; BAT.com} which discuss *inter alia*, ETS health and ventilation issues, and the hospitality industry.

Philip Morris, the largest U.S. tobacco company maintains the most extensive ETS information (see website headings titled: *Secondhand Smoke; Options Program; Accommodation; Ventilation*: PM states that while it recognizes that ETS can be annoying to nonsmokers, there are options to "minimize" ETS, and a "sizable segment of the population continues to support 'accommodation' of smoking. PM has an "Accommodation Program" which targets business owners in the hospitality industry by offering access to information on the latest ventilation technology. Ventilation, says PM, plays an important role in accommodation. PM asserts that "owners of restaurants, bars, casinos and other hospitality venues should be permitted to choose what kind of smoking polices to adopt for their establishments. "Designated areas, separate rooms, smoking lounges, and sometimes, no separation at all, are ways that business owners choose to accommodate the 'preferences' of nonsmokers and smokers," says PM. PM cites the Courtesy of Choice program sponsored by the International Hotel and Restaurant Association. The program is supported by local hospitality associations, Philip Morris International, and other tobacco sponsors in some 47 countries and is available in almost 8000 individual hospitality outlets." PM acknowledges that "many scientists and regulators have concluded that ETS poses a health risk to nonsmokers, but that "we do not agree with many of their conclusions." Philip Morris states that "So long as unwanted exposure is minimized, ... concerns regarding ETS can be addressed without banning smoking."

RJ Reynolds states on its website under "*Secondhand Smoke*," that although "many people find secondhand smoke annoying, and that some ... believe it presents a risk to their health ... There are many ways to allow smokers and nonsmokers to 'peacefully coexist' in public places without resorting to smoking bans: Common courtesy ... -- coupled with adequate ventilation and filtration, and designated smoking areas ... ." RJR also "does not believe that the scientific evidence concerning secondhand smoke establishes it as a risk factor for lung cancer, heart disease, or any other disease in adult nonsmokers." "... business owners know best how to satisfy their customers, and they should be allowed to decide whether they want to allow, restrict or ban smoking in their establishments."

BAT also recognizes {website headings *Environmental tobacco smoke; ETS -- accommodating both smokers and non-smokers*] that ETS "is a significant annoyance" and that "there have been claims that ETS is a cause of disease ... " however ... we do not believe that exposure to ETS is a risk factor for chronic disease in adults." "We support sensible accommodation of ... smokers and nonsmokers ... through good ventilation." "We also support the Courtesy of Choice campaign run by the International Hotel and Restaurant Association. It aims to help the hospitality industry to accommodate all its customers in restaurants, convention centres, cafes, bars, clubs and hotels, and involves technical analysis of ventilation and owners allocating flexible smoking and non-smoking areas." "... we do not believe that public smoking bans are needed to protect nonsmokers from diseases linked with smoking."

Summary: Thus, the big three tobacco companies state that they all believe that ETS is just an annoyance -- not a serious health threat, despite all those authoritative government reports to the contrary -- and that ventilation which minimizes smoke is the cure, not smoking bans, especially in the hospitality industry. In other words, the tobacco industry is saying that the hospitality industry should make the final decision on ETS controls: using RACT, BACT, or doing nothing. No mention is made of enforcement, or of acceptable levels of exposure or risk.

Discussion: Mainstream medical and scientific opinion has reached a consensus that passive smoking causes lung cancer and heart disease, as well as many other serious health effects. In addition, it is a major annoyance due to eye, nose, and throat irritation. Although every major medical and scientific group in the U.S. is in unanimous agreement, the tobacco industry has refused to accept this consensus, and have seriously obstructed federal, state, and local attempts to regulate ETS via smoking bans. Smoking bans lead to reductions in smoking due to lost opportunity, causing losses in profit for the cigarette companies, as well as diminishing the acceptability of smoking in general. The tobacco industry's opposition is clearly self-serving and lacks any scientific credibility; however, because of their great economic and political power to obstruct change, they have the ability to promote options which leave buildings contaminated with ETS.

The industry has promoted "accommodation" of smokers, particularly in the hospitality industry. Accommodation involves using ventilation as a control measure, which leaves workers and nonsmoking patrons exposed to ETS. This promotion of ventilation as a "solution" to passive smoking has several flaws. Ventilation is not tied to risk. Instead, the industry confines itself to stating that "exposures are low," citing the Oak Ridge Study (Jenkins and Counts, 1999), which the tobacco industry funded under contract (Glantz et al., 1996)) as evidence, although this study was not representative (Hammond, 1999), and asks us to accept on faith that the risks will be trivial or non-existent, and promotes ventilation to provide comfort for building occupants exposed to ETS. However, as Spengler (1999) has observed, the goal of ASHRAE Standard 62 -- providing air of quality that satisfies 80% of occupants cannot be met at the current specifications of the standard.

Indoor air quality standards for ETS have been proposed by Repace and Lowrey (1985b) based on ETS-RSP and Repace and Lowrey (1993) for nicotine and plasma and urinary cotinine, and extended to saliva cotinine by Repace et al. (1998). These standards are premised on an exposure-response relationship with the numerator based on lung cancer rate differences between two California cohorts of lifelong nonsmokers-- one presumed to be unexposed to ETS (California Seventh Day Adventists) and the exposed to ETS (Non-SDAs from the general California population). The denominator of the exposure-response relationship was based on assessing the average population exposure to ETS-RSP. Later, ETS-RSP was translated into airborne nicotine and body fluid cotinine using the equations in Table 1. Estimates of average population exposure to ETS-RSP were validated by predicting serum cotinine levels in good agreement with a national probability sample measured in NHANES III. These atmospheric and body fluid cotinine measures were traced back to the primary determinants of ETS exposure: smoker density and air exchange rate. The air exchange rates were those based on ASHRAE Standard 62 (Repace et al., 1998). And the risk model was extended to heart disease mortality (Repace et al., 1998). As Figure 2 shows, contrary to the tobacco industry's vague claims about the efficacy of ventilation, risks cannot be controlled to an acceptable level of risk for workers or regular restaurant patrons using even the best possible displacement ventilation technology.

Even if a way could be found by some as-yet undiscovered ventilation or air cleaning technology to reduce ETS exposures by 4 orders of magnitude, a regulatory bureaucracy would be required to issue permits for the new technology, which would have to be retrofitted into all existing establishments, and designed into all new establishments. Then an enforcement squad would have to be assembled, trained, and fielded to handle complaints. Measuring either ETS concentrations or ventilation rates is difficult, time-consuming, and expensive. Although ETS-RSP can be measured in real-time, RSP is non-specific for ETS. While ETS nicotine is specific, it cannot be measured in real-time. Ventilation rates also cannot be measured in real-time. Since most ventilation engineers are familiar only with dilution technology, they would have to be trained to install the new technology, and building inspectors would have to be retrained to approve those plans. Because there are tens of thousands of establishments in a State the size of California, this would rapidly become an enforcement nightmare. However, smoking bans will achieve zero risk, and currently appear to be easily enforceable. Further, ETS tars contaminate building surfaces

A final problem concerns new and emerging ETS risks which have not been quantified and for which no dose-response relationships exist. Other studies have linked ETS to mortality from SIDS, and nasal sinus cancer, and possibly cervical cancer and respiratory disease (CalEPA, 1997). New studies have linked ETS to breast cancer, and stroke. The risk of breast cancer appears to be highly non-linear, as shown in Figure 4, suggesting that developing an ETS-IAQ standard for breast cancer would be problematic. Another largely unrecognized issue is that ETS particles are re-emitted again from room surfaces where they have been deposited, indicating that room surfaces act as secondary sources of ETS particles (Johannson et al. (1993). Gases are also likely to be absorbed on and re-emitted from surfaces. This means that buildings where smoking is permitted become highly contaminated toxic waste dumps, massive surfaces sources of PAHs and other carcinogenic and toxic substances to which nonsmokers can be exposed even when there is no smoking taking place. To appreciate the magnitude of the problem, consider a restaurant with an occupancy of 70 persons per 1000 ft^2, with a smoker prevalence of 29%, for an area smoker occupancy of 2 smokers per 1000 ft^2. Each smoker smokes 2 cigarettes per hour. Assuming smoking occurs in the restaurant for 8 hours daily, and that each cigarette liberates 14 mg of tar, 20% of which deposits on room surfaces. Thus (2.8 mg/cigarette) (2 smokers)(2 cigarettes/smoker-hour)(8 hours/day)(300 days/year) = 27 grams per year of toxic substance deposited on room surfaces -- including the HVAC system -- per 1000 ft^2 of floor area.

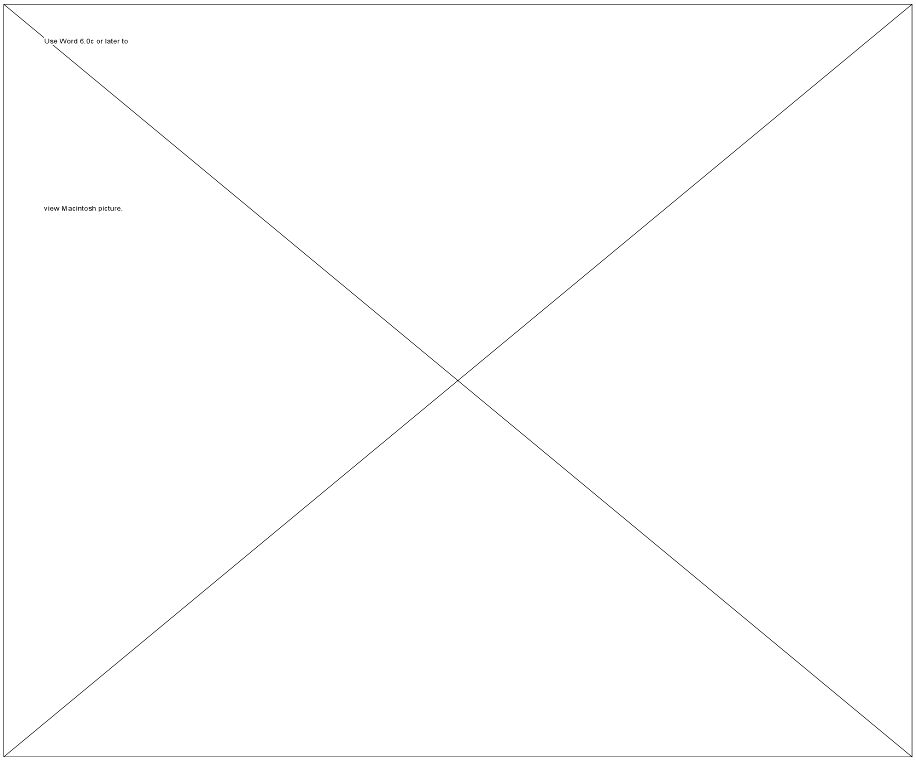
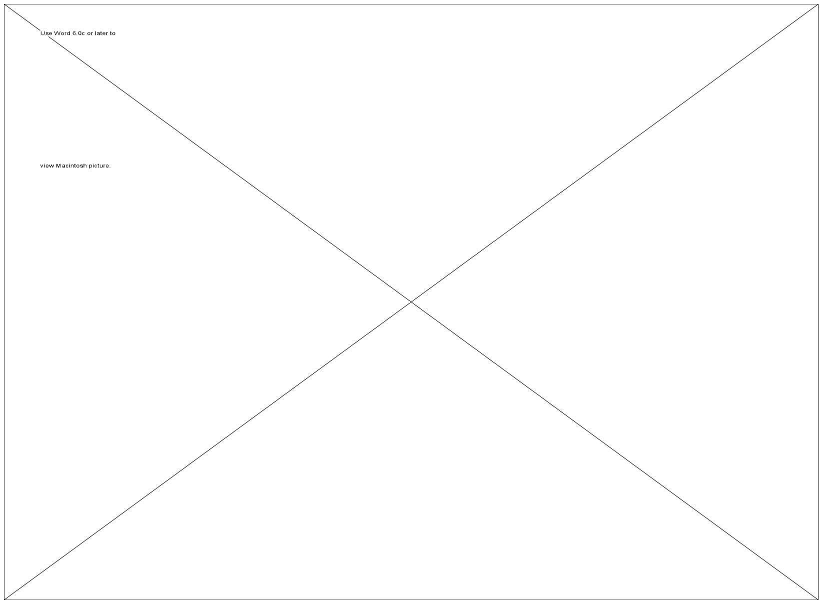


Figure 4. Active and passive smoking and breast cancer in pre-and post-menopausal women [KD Johnson, et al., Health Canada, Cancer Causes and Control, 2000].

Table 7 shows some of these risks (except stroke) as estimated by Wells. Standards would have to be developed for all of them, plus stroke.



Conclusions

1. The "Proceedings of the Workshop on Ventilation Engineering Controls for Environmental Tobacco Smoke in the Hospitality Industry", sponsored by OSHA and the ACGIH concluded that the presently available ventilation technology (well-mixed dilution ventilation) was unsatisfactory for controlling worker exposure to ETS. Air cleaning was similarly viewed as problematic. Of proposed technology, displacement ventilation was viewed as having the potential for 90% reductions in ETS levels, although the lack of performance data, the lack of familiarity of most ventilation engineers with the technology, and the difficulty in retrofitting existing installations poses major problems. Panelists viewed the lack of enforcement of ventilation rates by local building codes and the use of natural ventilation as further problems. Smoking seems to be declining among restaurant patrons.

2. ETS RSP and air nicotine levels were modeled for restaurants, bars, smoking lounges, bowling alleys and casinos to estimate hospitality workers' exposure to ETS. Both of these have been used as tracers for ETS. Air nicotine and body fluid cotinine are specific tracers for ETS. Using U.S. average smoking prevalence, ASHRAE Standard 62-1999 default occupancy levels, and recommended makeup air supply rates as ideals, shows for this ideal dilution ventilation, estimated ETS RSP levels will be between 100 and 200 $\mu g/m^3$, and air nicotine levels of from 10 to 20 $\mu g/m^3$. These predicted levels appear to be significantly lower than most observations, suggesting lower ventilation rates or higher smoker densities than expected. This is not surprising since neither smoker density nor ventilation rates are regulated.

3. Assuming ideal dilution ventilation, i.e., reasonably achievable control technology (RACT) estimated ETS risk levels for lung cancer and heart disease combined ranged from 15 to 25 per 1000 workers, 15 to 25 times OSHA's significant risk level, and 15,000 to 25,000 times the *de minimis* or "acceptable risk" level for federally hazardous pollutants.
4. Assuming ideal displacement ventilation, i.e., best achievable control technology (BACT) estimated ETS risk levels for lung cancer and heart disease combined would be reduced 90%, ranging from 1.5 to 2.5 per 1000 workers, 1.5 to 2.5 times OSHA's significant risk level, and 1,500 to 2,500 times the *de minimis* or "acceptable risk" level for federally hazardous pollutants.
5. All cognizant health and scientific authorities in the U.S., including the US Environmental Protection Agency, the National Institute for Occupational Safety and Health, OSHA, the Surgeon General, the National Academy of Sciences, the National Cancer Institute, the National Toxicology Program and the American Medical Association have concluded that ETS exposure causes morbidity and mortality. The tobacco industry arrogantly rejects this consensus.
6. Under Section 112 of the federal Clean Air Act, pollutants may be designated as "hazardous air pollutants" (HAPS) if they can cause serious morbidity or mortality, as ETS does. These ETS-like chemicals are regulated by NESHAPS which are far more stringent than either RACT or BACT. RACT and BACT are designed to control ordinary non-hazardous air pollutants. NESHAPS regulate HAPS to levels of *de miminis* risk with an adequate margin of safety. ETS contains 5 HAPS pollutants, more than 100 poisonous chemicals, and 47 chemicals classified as hazardous waste under RCRA. Although ETS qualifies, it remains unregulated as a HAP, as a poison, or as hazardous waste.
7. There are currently no indoor air quality (IAQ) standards designed for ETS in use in the U.S. Proposed NESHAPS-style ETS IAQ standards are based on limiting ETS lung cancer and heart disease risk to *de minimis* levels. Application of these proposed standards to restaurants, bars, and casinos shows that tornado-like levels of ventilation would be required, 4 orders of magnitude (i.e. ten thousand fold) greater than possible by dilution ventilation, and 3 orders of magnitude (i.e., one thousand fold) greater than possible by displacement ventilation, with air cleaning intermediate.
8. Ventilation of buildings is a local government responsibility. Some building codes do not require that ventilation systems be operated after installation. Even under codes that require operation, ventilation standards are not enforced. Enforcement of ventilation standards, although desirable, would require establishment of new regulatory bureaucracies.

9. Enforcement of indoor air quality standards would also require additional new regulatory bureaucracy. Establishment of indoor air quality standards requires a high level of technical expertise, would be beyond the capacity of most local government, and would be a years-long process (not including the resultant litigation, based on federal experience. It is doubtful that most jurisdictions would be willing or able to pay for these new regulatory regimes. Even if all the regulatory hurdles involving the setting of IAQ standards for ETS could be surmounted for lung cancer and heart disease, setting standards to protect against risks of ETS-induced breast cancer, stroke, SIDS, nasal sinus cancer, respiratory diseases, etc. would remain.

10. The tobacco industry's open and stated goal, currently available on their websites, is to actively promote ventilation technology as a control measure for ETS, at the option of hospitality business owners. The tobacco industry has made the hospitality industry a special target for ventilation technology. None of the "big three" tobacco companies concedes that ETS poses health risks to nonsmokers, and all promote "accommodation," a vaguely-defined code-word for letting the marketplace decide how to control ETS.

11. It is clear that smoking bans, such as in effect in the State of California represent the most cost-effective, easiest-to-enforce, and lowest risk alternative to ETS control. They appear profitable for business, and are also the only control measure known which is capable of yielding *de miminis* risk.

Appendix A. **103 Poisonous Substances in Tobacco Smoke**

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This review is based upon the following definition:

poison. def.: a substance (as a drug) that in suitable quantities has properties harmful or fatal to an organism when it is brought into contact with or absorbed by the organism: a substance that through its chemical action usu. kills, injures or impairs an organism <strychnine, carbon monoxide, and other ~s>

Websters Third New International Dictionary, Unabridged. Merriam Webster, Springfield, MA, 1986.

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1. NIOSH Pocket Guide to Chemical Hazards, U.S. Dept. Health & Human Services, Centers for Disease Control & Prevention, June 1994.

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4. Reducing the Health Consequences of Smoking, 25 Years of Progress. A Report of the Surgeon General, 1989. USDHHS, Rockville, MD. 1989.

5. Smoking and Health, A Report of the Surgeon General, 1979. USDHEW, Washington, DC.

6. Wynder E & Hoffman D, Tobacco and Tobacco Smoke, Academic Press, New York, 1967.

N.B.: The following substances are listed as in tobacco smoke. Although few of them have been actually measured in secondhand smoke, all of them have been measured in mainstream and to a lesser extent, sidestream smoke. Secondhand smoke consists of fresh and aged exhaled mainstream and sidestream smoke, and mainstream smoke is formed in the same burning cone as sidestream. Generally, sidestream and secondhand smoke contain greater total quantities of given chemicals (e.g., more NO_2 and more NNK), and are more toxic than mainstream smoke, which is formed at a higher temperature, and is also filtered by the tobacco rod and the cigarette filter.

	Compound(s) Listed in Tables 5,6,7,8 or 9 in Ref. 4 or in Ref.5, Chapter 14.	**Poison (Y=yes) Superscripts refer to references sources above**
1.	1,1-Dimethylhydrazine†	**Y**[4]
2.	1-Methylindole	**Y**[5]
3.	2-Naphthylamine	**Y**[4]
4.	2-Nitropropane	**Y**[4]
5.	2-Toluidine	**Y**[4]
6.	3-Vinylpyridine	**Y**[4]
7.	4,4-dichlorostilbene	**Y**[5]
8.	4-(Methylnitrosamino)-1-(3-pyridil)-1-butanone (**NNK**)	**Y**[4]
9.	4-Aminobiphenyl	**Y**[4]
10.	5-Methylchrysene	**Y**[4]
11.	7H-Dibenzo(c,g)carbazole	**Y**[4]
12.	9-Methylcarbazole	**Y**[5]
13.	Acetaldehyde	**Y**[4]
14.	Acetone	**Y**[4]
15.	Acetonitrile	**Y**[1]
16.	Acrolein	**Y**[4]
17.	Acrylonitrile	**Y**[4]
18.	Alkylcatechols	**Y**[5]
19.	Ammonia	**Y**[1]
20.	Anabasine	**Y**[3]
21.	Aniline	**Y**[1]
22.	Anthracenes (5)	**Y**[2]
23.	Antimony	**Y**[2,5]
24.	Arsenic	**Y**[4]
25.	Benz(a)anthracene	**Y**[4]
26.	Benzene	**Y**[4]
27.	Benzo(a)pyrene	**Y**[4]
28.	Benzo(b)fluoranthene	**Y**[4]
29.	Benzo(j)fluoranthene	**Y**[4]
30.	Benzo(k)fluoranthene	**Y**[4]

31.	Benzofurans (4)	**Y**[2]
32.	Butadiene	**Y**[1]
33.	Butyrolactone	**Y**[6]
34.	Cadmium	**Y**[4]
35.	Carbon monoxide	**Y**[4]
36.	Carbonyl sulfide	**Y**[4]
37.	Catechol	**Y**[4]
38.	Chromium	**Y**[4]
39.	Chrysene	**Y**[4]
40.	Cresols (all 3 isomers)	**Y**[5]
41.	Crotonaldehyde	**Y**[4]
42.	DDD	**Y**[5,2]
43.	DDT	**Y**[5,2]
44.	Dibenz(a,h)acridine	**Y**[4]
45.	Dibenz(a,h)anthrancene	**Y**[4]
46.	Dibenz(a,j)acridine	**Y**[4]
47.	Dibenzo(a,i)pyrene	**Y**[4]
48.	Dibenzo(a,l)pyrene	**Y**[4]
49.	Dimethylamine	**Y**[2,6]
50.	Endosulfan	**Y**[5]
51.	Endrin	**Y**[5,2]
52.	Ethylcarbamate	**Y**[4]
53.	Fluoranthenes (5)	**Y**[2]
54.	Fluorenes (7)	**Y**[2]
55.	Formaldehyde	**Y**[1]
56.	Formic acid	**Y**[1]
57.	Furan	**Y**[2]
58.	Hydrazine	**Y**[4]
59.	Hydrogen cyanide	**Y**[4]
60.	Hydrogen sulfide	**Y**[1]
61.	Hydroquinone	**Y**[5,2]
62.	Indeno(1,2,3-c,d)pyrene	**Y**[4]
63.	Indole	**Y**[2]
64.	Isoprene	**Y**[2]
65.	Lead	**Y**[4]
66.	Lead 210	**Y**[5]
67.	Limonene	**Y**[2]
68.	Manganese	**Y**[5,2]
69.	Mercury	**Y**[5,2]
70.	Methanol	**Y**[1]
71.	Methyl formate	**Y**[1]

72.	Methylamine	**Y**[1]
73.	N'-Nitrosoanabasine	**Y**[4]
74.	N'-Nitrosonornicotine	**Y**[4]
75.	N-Nitrosodiethanolamine	**Y**[4]
76.	N-Nitrosodiethylamine	**Y**[4]
77.	N-Nitrosodimethylamine	**Y**[4]
78.	N-Nitrosoethylmethylamine	**Y**[4]
79.	N-Nitrosomorpholine†	**Y**[4]
80.	N-Nitrosopyrrolidine	**Y**[4]
81.	Naphthalene	**Y**[1]
82.	Nickel	**Y**[4]
83.	Nicotine	**Y**[4]
84.	Nitric oxide	**Y**[4]
85.	Nitrogen dioxide ($\mathbf{NO_2}$)	**Y**[4]
86.	NNN	**Y**[4]
87.	Nornicotine	**Y**[3]
88.	o-Toluidine	**Y**[4]
89.	Palmitic acid	**Y**[2]
90.	Parathion	**Y**[5]
91.	Phenol	**Y**[2]
92.	Phenols (volatile)	**Y**[4]
93.	Picolines (3)	**Y**[3]
94.	Polonium-210	**Y**[4]
95.	Propionic acid	**Y**[1]
96.	Pyrenes (6)	**Y**[2]
97.	Pyridine	**Y**[1]
98.	Quinolines (7)	**Y**[2]
99.	Styrene	**Y**[1]
100.	Toluene	**Y**[1]
101.	Toluidine(s)	**Y**[2]
102.	Urethane	**Y**[5,2]
103.	Vinyl chloride	**Y**[4]

Appendix B.

Equivalency of the Repace (1987) and Ott (1999) models of ETS-RSP

Note on the equivalence of the Repace (1987) (Eq. 1) and Ott(1999) models for ETS-RSP: Ott (1999) gives the following values: For a V = 500 m^3 bar with an effective air exchange rate $\phi_p = 6\ hr^{-1}$ (where $\phi_v = \phi_p/1.2 = 5\ hr^{-1}$), and an average smoking count $n_{ave} = 2$ cigarettes, the predicted ETS-RSP level is 57 $\mu g/m^3$. (The effective air exchange rate for particles was measured to be 1.2 times the air exchange rate due to ventilation alone). Ott's n_{ave} is the same as the number of active smokers n_{as} under the Repace model (Repace, 1987), where the number of habitual smokers $n_{hs} = 3\ n_{as}$ under the Repace model. Thus n_{hs} = (3 habitual smokers per burning cigarette)(2 burning cigarettes) = 6 habitual smokers, where an habitual smoker is assumed to smoke at a rate of 2 cigarettes per hour.
$D_{hs} = 100\ n_{hs}/V$ = {(100)(6 hs)} / {(500 m^3)} = 1.2 habitual smokers per hundred cubic meters (hs/hcm). Eq. 1 predicts: ETS-RSP = 220 D_{hs}/ϕ_v = (220)(1.2 hs/hcm) / (5 hr^{-1}) = 53 $\mu g/m^3$. The slight differences in predictions of the two models are probably due to round-off error. Thus the two models are equivalent. The particle size incorporated into both the Repace and Ott models is $PM_{3.5}$, which is essentially the same as $PM_{2.5}$ (Wallace, 1996). Thus, the Repace (1987) model is understood to be useful under the following conditions: it predicts the time-averaged ETS-RSP ($PM_{3.5}$) concentration assuming that the smokers in the space each smoke identical cigarettes of emissions 14 mg/cigarette at the identical rate of 2 cigarettes per smoker-hour. The model incorporates the ventilatory air exchange rate (essentially that specified by ASHRAE Standard 62), assuming that the effective air exchange rate for ETS particles is 20% higher. Both models are also useful in estimating air exchange rates if the other model parameters are given.

Appendix C

47 Chemicals in ETS are classified as "hazardous waste" under RCRA (Resource Conservation and Recovery Act)

RCRA Landfill Disposal Regulations from the Code of Federal Regulations (CFR 40: 268) on the disposal of Hazardous Wastes in Landfills.

I have identified 47 chemicals in cigarette smoke subject to restrictions by EPA on land disposal (i.e., being dumped in a landfill), as listed in 40 CFR. In Part 268, Land Disposal Restrictions (a) the hazardous wastes which are restricted from land disposal are identified and limited circumstances are defined which permit an otherwise prohibited waste to be disposed are given. In Subpart A of 40 CFR section 268.2 (b): "Hazardous constituent or constituents means those constituents listed in **Appendix VIII to part 261** of this chapter. Below in Table C-1 is a list of 32 carcinogens in cigarette smoke and also in Appendix VIII to part 261.

Table C-1. Chemical compounds identified in tobacco smoke for which there is "sufficient evidence" of carcinogenicity in humans or animals according to the International Agency for Research on Cancer (1986), and which appear in Appendix VIII, part 261.

acrylonitrile	**dibenzo(a,e)pyrene**	**vinyl chloride**
arsenic	**dibenzo(a,l)pyrene**	**1,1-dimethylhydrazine**
benz(a)anthracene	**dibenzo(a,h)pyrene**	**2-nitropropane**
benzene	**formaldehyde**	**2-napthylamine**
benzo(a)pyrene	**hydrazine**	**4-aminobiphenyl**
benzo(b)fluoranthene	**lead**	**7H-dibenzo(c,g)carbazole**
benzo(k)fluoranthene	**nickel**	
cadmium	**N-nitrosodiethanolamine**	
chromium VI	**N-nitrosodiethylamine**	
DDT	**N'-nitrosodimethylamine**	
dibenz(a,h)acridine	**N'nitrosonornicotine**	
dibenz(a,j)acridine	**N-nitrosopiperidine**	
dibenz(a,h)anthracene	***ortho*-toluidine**	

In addition, the following 15 compounds listed in Table C-2 are in cigarette smoke (1979 Surgeon General's Report, Ch. 14), and are **also** listed in Appendix VIII to part 261:

Table C-2.

acrolein
chrysene
cresol
cyanogen
DDD
endosulfan
endrin
hydrogen cyanide
maleic hydrazide
mercury
nicotine
parathion
phenol
pyridine
resorcinol

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Appendix D.

Documents on secondhand smoke, accomodation, ventilation, and smoking bans downloaded from tobacco industry websites.

1. Philip Morris <philipmorris.com>
2. British American Tobacco <bat.com>
3. RJ Reynolds <rjr.com>