ENVIROMETRICS INC.
4803 Fremont Avenue North Seattle, Washington 98103-6527
(206) 633-4456 FAX (206) 633-4835

LOCATING AIR INTAKES AND EXHAUSTS

Summary
New ASHRAE standards require an investigation of local ambient air quality and documentation of design assumptions and calculations on measures taken to control the quality of the air supply. They also provide guidance on the minimum separation distances between air intakes and sources of air contaminants. The standard references AIHA and NFPA standards that apply specifically to laboratory hood exhausts. This report suggests the minimum distances provided may not always tbe adequate and gives minimum dilutions of exhaust sources that will provide adequate protection of the air supply for several frequently encountered sources.

ASHRAE, NFPA and AIHA Standards
The new amendments to ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality*, require an investigation of the local air quality at a building site, both by reviewing the compliance of the region with federal air quality standards and by observation of any potential local sources of air contaminants (Section 4, as amended May 27, 2003) . The local sources to be observed include odors, apparent nearby sources of air contaminants and nearby traffic. The direction of the prevailing wind is also to be noted. This investigation is to be documented and reviewed with the building owner. If it is necessary to take corrective action, the design assumptions and calculations on measures taken to control the quality of the supply air are to be documented (Section 6.1.1, as amended May 27, 2003).

Other amendments (to Section 5, numbering not yet assigned, as amended August 5, 2004) provide a new method of classifying exhaust air:

Class 1: Air with no to low contamination and no significant odors.
Class 2: Air with moderate contamination, mild sensory irritation and mildly offensive odors.
Class 3: Air with significant contamination and sensory irritation and offensive odor.
Class 4: Air with highly objectionable or potentially dangerous contamination.

The standard provides example classification of the air exhausting from various spaces. Some of the examples are provided on the next page, along with our comments. The primary purpose of the classification is to determine which exhaust air can be directly circulated to another space (generally from a lower class to a higher is allowed). However it is also useful in determining the potential level of concern for air exhaust cross-over to an air intake.

Table I. Classification of air from a variety of sources

Space Type	Classification	Comments
Gambling casino	1	Without significant air cleaning, environmental tobacco smoke often makes casino exhaust air a 3.
Hospital patient rooms	1	Hospital patients are generally non-infectious by air pathway.
Office space	1	
Theater auditorium	1	
Auto repair facilities	2	Most auto repair facilities will duct the fumes from operating engines outside. This exhaust would be a 4.
Locker rooms	2	Some locker room exhaust air is clearly a 3
Parking garages	2	
Printing rooms	2	Some printing room exhaust will be a 3.
Retail stores, sales floors	2	
Toilets/public restrooms	2	
University laboratories	2	The exhaust from fume hoods is separate. See below.
Chemical/biological labs	3	
Day care sick rooms	3	This is a 3 while hospital patient rooms are a 1 because the air might be recirculated to intake air for other young children, who would be more susceptible than adults.
Kitchen vent hoods	3 & 4	Grease will increase the rating to 4.
Lab hoods	4	

An additional amendment (Section 5.4, as amended August 5, 2004) provides specific minimum distances between certain exhausts and air intakes, or operable windows and doors when they are a part of a natural ventilation system. The table below lists several of the recommendations.

Table II. Minimum Separation Distance

Source	Minimum Distance (ft)
Truck loading, dock	25
Busy thoroughfare	25
Dumpster	15
Garage entry, drive-in queue	15
Significantly contaminated exhaust	15
Dangerous or noxious exhaust	30

This amendment is careful to point out that these minimum distance recommendations do not apply to laboratory fume hoods or to industrial exhausts. It requires laboratory fume hoods to meet the requirements of NFPA 45 (2004), *Standard on Fire Protecton for Laboratories Using Chemicals* and ANSI/AIHA Z9.5-2003, *Laboratory Ventilation*. These two standards provide details on siting laboratory fume hood exhaust stacks. For industrial exhausts, the ASHRAE standard refers to the ASHRAE Applications Handbook.

The NFPA standard states (Sections 8.3 and 8.4) that laboratory ventilation stacks are to be designed so no chemicals will be recirculated back into the lab and laboratory air intakes are to be located so no fumes from its own building exhaust or from exhausts on other structures will be drawn into the supply air. They are to be discharged "above the roof". A further explanation of these sections states that "special studies such as air-dispersion modeling may be necessary to determine the location of air intakes for laboratories . . ." It also recommends that the exhaust stack exit be at least 10 feet above the highest point on the roof, but continues "studies might be necessary to determine adequate design."

The ANSI/AIHA standard refers questions of design (Section 5.3.5) to Chapter 43 of the 1999 ASHRAE *HVAC Applications* handbook (which is now Chapter 44 of the 2003 edition). It also requires a 10 foot minimum height above the roof line, discharge in a vertical up direction and a 3000 ft/min minimum discharge velocity. In comments on these requirements the standard suggests that for complex structures a detailed evaluation should be undertaken. This would include "physical modeling (wind tunnel, mockup or water fluid) or numerical modeling using appropriate methods (Computational Fluid Dynamics or other advanced numerical methods)".

In an appendix the ANSI/AIHA standard summarizes three design methods discussed in the ASHRAE *HVAC Applications* handbook. The first relies on look-up tables which provide a generally conservative result. They are based on the Wilson static method, which has proved useful for calculations on simple buildings. The second provides an estimate of the amount of dilution required between the stack and a potential air intake. Based on two different methods of calculation the appendix calculates a necessary dilution of 5000:1 for a 1000 cfm exhaust stack or 2800:1 for the same stack. The difference between the two is two different criteria for the concentration of a contaminant at the air intake when a chemical is released in the laboratory hood.

For other than laboratory exhausts the new ASHRAE amendment, in an explanatory appendix, recommends a minimum dilution of 15 for a Class 3 exhaust and 50 for a Class 4 exhaust. It provides an additional calculation method for determining the minimum separation distance.

Dilution Recommendations for Lab Hoods

An alternative method of calculating the minimum separation distance uses the required dilution approach described in the ANSI/AIHA standard but bases the decision criteria on exposure standards developed by public agencies for the specific chemicals that are expected to be present in the lab hoods.

Essentially the calculation begins with the concentration in the stack and determines the amount of fresh air that must be mixed into the stack exhaust to reduce the concentration to the acceptable level defined by the standard. A stack with a concentration of 100 ppm diluted 10 times has a concentration of 10 ppm.

One obvious choice for a target standard would be the Permissible Exposure Limits (PEL) or Threshold Limit Values (TLV) for occupational exposures. Most of these assume an 8-hour exposure. Regulations by the occupational health agencies require employers to take action to reduce exposure when the concentrations reach one-half the established standard. This “action level” would then be the appropriate standard. (However it is important to remember that many of these were developed when there were few women in the workforce or from tests on military personnel and young men who were in top physical condition. They may not be particularly conservative.)

An alternative would be the air toxics guideline values developed by several agencies. These values are intended to provide a level of protection for the general public, which includes more sensitive individuals than the workforce and does not assume either medical monitoring or a legal responsibility for consequential health care as is present for an occupational exposure. A particularly comprehensive list has been adopted by the Washington Department of Ecology. These are called Acceptable Source Impact Levels (ASIL). Many of them were developed from the TLVs, so the main difference is in how they were adjusted to include public exposure. Part of the adjustment was to assume a 24-hour exposure. Therefore if ASILs are used for design calculations on an air intake where the expected exposure is less than 24-hours it would be appropriate to adjust the vaule up by that ratio (e.g., 24/8 for an 8-hour exposure). As a general rule many of the non-carcinogenic ASILS are about 150 times the action level for a given chemical.

The necessary level of dilution can be estimated from accident scenarios which might release greater than normal amounts of the chemicals into the lab hood exhaust. A spill into a lab hood of a volatile chemical would evaporate the chemical into the lab hood exhaust. If we assume the area of the spill covers the lab hood working surface, about 3 feet in diameter, and the lab hood is operating at 1000 cubic feet per minute (cfm), we can then compute the concentration in the exhaust from the evaporation rate of the chemical. This can be compared to the inhalation standard for the chemical to determine the amount of dilution that would be necessary to avoid adverse exposures among sensitive individuals relying on an air intake intercepted by the lab hood plume.

For some high hazard chemicals, such as benzene, carbon tetrachloride, chloroform, methyl isocyante and methylene chloride, the necessary level of dilution is so large that venting a spill through the fume hood would be the precisely wrong response. Some chemicals which could be vented through the fume hood, such as triethylamine, require a dilution of approximately 40,000 times to to meet the ASIL standard and avoid any adverse impact. Carcinogenic compounds particularly lead to high dilution requirements. More commonly used laboratory chemicals, such as nitric acid or hydrochloric acid, require a dilution of approximately 5,000 to 8,000 times.

Using the occupational exposure action levels would suggest a standard of about 50 dilutions to protect a worker.

Odors from such a spill are more easily avoided. The maximum dilutions required to minimize complaints from odors are only 4,000 for diethylamine (one of the most odorous of laboratory chemicals) and 1,000 for acetaldehyde, for example.

Another accident scenario that might occur in a fume hood would be a broken valve on a lab bottle of compressed gas. If we calculate the exhaust velocity and thus the exhaust volume through the broken valve, mix it into a 1000 cfm lab hood exhaust and compare the concentration to an adjusted industrial hygiene Immediately Dangerous to Life and Health (IDLH) concentration (adjusted down by a factor of 100 to account for sensitive individuals in the population) we find that a chlorine bottled gas accident would require more than 160,000 dilutions and an ammonia or sulfur dioxide bottled gas accident would require about 25,000 dilutions to avoid adverse impacts at a receiving air intake. Again, this appears to be an accident that generally cannot be mitigated by the relative placement of the lab hood exhaust and an air intake.

The calculated dilutions required for a variety of chemicals, based on achieving the ASIL concentration at the air intake, is provided in the table below. (Note that the dilutions required also depends on the evaporation rate so there is not a simple relation between the ASIL and the dilutionvalue listed.)

Table III. Dilutions Required by Example Chemicals

Chemical	ASIL (micrograms/m^3)	Adjusted ASIL dilutions needed	Odor threshold dilutions needed
Carbon Tetrachloride	0.067	1,370,000	6
Bromine	2.2	663,000	560
Benzene	0.12	271,000	
Nitric Acid	17	8,310	137
Hydrochloric Acid	7	4,840	74
Sulfuric Acid	3.3	1,710	24
Acetone	5900	111	35
Isopropyl Alcohol	3300	31	32

Dilution Recommendation for General Building Exhaust

The positions of the general building exhausts must be at a sufficient distance to avoid significant re-entrainment of the exhausted air into the main building intakes. This exhaust has no particular toxic qualities attributed to it, but it is desirable to prevent recycling of building air to avoid a buildup of carbon dioxide and internal odors. The criteria will depend on the amount of fresh air that is used both for the building being exhausted and the building with the air intake. A dilution of 10 to 20 times should be quite sufficient to avoid any significant problem with carbon dioxide buildup if both buildings are on 100% outside air or if the exhaust is being re-entrained to itself and it is on 100% outside air. If a building is on less than 100% outside air a dilution of 100 may be necessary. A dilution of about 25 may be sufficient to avoid any detection of "stale" odors for a building on 100% outside air. Again, a dilution of about 250 may be necessary for a building with a high recirculation fraction.

Dilution Recommendation for Odor Source Exhaust

Odor sources are classified by the number of dilutions necessary to make the odor not detectable by 50% of the population. This also means that 50% of the population can still detect the odor. It varies greatly from one odor to another, but in general at about 2 to 3 dilutions remaining before non-detection the odor can no longer be specifically described as to its source. Again, generalizing at about 5 to 7 dilutions remaining before non-detection, 50% of the population will no longer complain about the odor, unless it is recurring and persistent. Thus using the published detection threshold concentrations as the target will result in an odor that can be detected by half the population but not at a level that will generally lead them to complain.

Based on data collected from a variety of sources we estimate that the general odors listed in Table IV will reach their detection level at the dilutions shown.

Table IV. Dilutions Needed for Odorous Sources

Source	Dilutions needed from source to receptor
Asian restaurant kitchen stack (soy/garlic)	5,000 – 15,000
Garbage bin	10
Bathroom exhaust	25
Grass clippings/ lawnmower	100

Dilution Recommendation for Garage and Traffic Exhaust

Garage exhaust fans are commonly designed to begin operation and evacuation of an enclosed parking garage when carbon monoxide (CO) sensors exceed a preset level, such as 30 or 35 parts per million (ppm) of CO. However, typically in a below-ground garage there will be one or a few areas which are significantly higher in CO concentration than others, because of traffic patterns, locations that cause backups and consequent long idling periods, or poor ventilation, often from an inadequate supply of makeup air. As a result, when these areas trigger operation of the ventilation system, the remainder of the garage is still at a lower concentration. Thus it is reasonable to assume that the exhaust from such a garage will be less than the preset trigger level, say, 20 to 25 ppm.

CO is an air pollutant regulated by the Environmental Protection Agency. The National Ambient Air Quality Standard is 9.0 ppm for an eight-hour exposure or 35 ppm for a one-hour exposure. The standard is generally understood to be only marginally protective of the most vulnerable populations, such as pregnant women and persons with chronic obstructive pulmonary disease or emphysema, but with a reasonable margin of safety for the remainder of the population. Carbon monoxide requires exposure over a period of time for it to be absorbed into the blood and to have an adverse effect. The normal human body burden of CO is 0.5 ppm.

The background concentration of CO in urban air is variously measured between 2.5 and 5.0 ppm under all but adverse weather conditions. It only occasionally rises above 9.0 ppm at outdoor locations in the Seattle area and rarely for more than eight hours at a stretch. If the exhaust air from a parking garage is diluted 10 times from the level at the exhaust fan sensor, the air in the plume at the 10 dilution level would then range from just under 5 ppm to 7 ppm, still below the long-term exposure ambient standard. Based on this analysis, the recommended criteria for garage air exhaust at pedestrian locations is 10 dilutions.

Garage air that is being re-entrained into a garage makeup air intake should be more diluted. If it is no more dilute than 10 dilutions it will take much longer to reduce a high concentration in the garage. A level of at least 20 dilutions is recommended for a garage makeup air intake.

Traffic emissions are a health concern not due to just the levels of carbon monoxide, but also from hydrocarbons, and other pollutants that exist in the exhaust. Diesel exhaust contains additional toxic components and is also odorous. During busy peak hours under certain atmospheric conditions the exhaust may build to levels reaching the ambient air quality standards. Channelization, influenced by high-rise buildings in urban areas, may further increase this problem by discouraging dispersal. A dilution of at least 20 times is recommended between a street-side concentration and a building air intake. If diesel trucks are frequent users of the street, a dilution of 200 may be required. If a parking location where diesel trucks or buses idle or a stopping point where diesel trucks or buses start up and shift gears under load is nearby, it may be necessary to locate the fresh air intake at a place that provides a dilution of 1,000 or more.