Energy and Buildings, 20 (1993) 143–150

Tobacco smoking policy and indoor air quality: a case study

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(Received June 25, 1993; accepted July 13, 1993)

Abstract

Policy on environmental tobacco smoke and its effect on indoor air quality are discussed in this paper. Passive (secondhand) smoke is examined in aspects ranging from health effects to laws surrounding smoking within public buildings in the United States. Engineering and administrative solutions to these indoor air quality problems are considered. A case study of a smoking area within an institutional building is presented and potential improvements and administrative actions are discussed. The results of this study should be helpful to those faced with or anticipating technical and legal indoor air quality problems and policy decisions.

Key words: Indoor air quality; Tobacco smoke; Ventilation

Introduction

Recent concerns in the United States (US) about radon and asbestos have increased awareness of the quality of the indoor environment. According to the US Environmental Protection Agency (EPA), people spend approximately 90% of their time indoors. The EPA and its Science Advisory Board have ranked indoor air pollution as one of the top five environmental risks to public health [1]. Because many pollutants exist at higher levels indoors than outdoors, some indoor air may be unhealthy [2].

The desire to promote and maintain good health has prompted interest in the removal of pollutants from the indoor environment in which people live and work. Due to a recent US governmental agency ruling, one indoor pollutant source, environmental tobacco smoke (ETS), is attracting the attention of building owners, operators, and users. These individuals face the challenge of balancing the need for a healthy, productive indoor environment versus the rights and desires of smokers and nonsmokers. Policymakers face the difficult tasks of creating and maintaining this balance which should be created through careful evaluation of health, technical, social, and business issues. This paper presents some of these issues and addresses them in a case study of a smoking area in an institutional building.

ETS as a pollutant source

The smoke produced from burning tobacco can be divided into two parts, *mainstream* smoke and *sidestream* smoke. Mainstream smoke is produced while a smoker is inhaling, and sidestream smoke is produced when the tobacco product is burning, but is unused. Mainstream smoke is produced at an average higher temperature than sidestream smoke and is filtered by the smokers' lungs before being exhaled into the environment. Sidestream smoke is emitted directly into the surrounding air. Over 2000 chemical compounds, including 40 known carcinogens, are released in sidestream smoke [3]. Tobacco smoke contains substances such as carbon monoxide, nicotine, acrolein, and acetaldehyde. Some of these substances are known or suspected to cause adverse short- and long-term health effects.

Direct exposure to tobacco smoke by the user of a tobacco product is called *firsthand* (or active) exposure. For people who breathe the sidestream and exhaled mainstream smoke, but are not direct users of the tobacco product in question, their exposure is called *secondhand* (or passive). In buildings where smoking is allowed and which have air distribution systems that allow tobacco smoke to mix in the air, the firsthand use of tobacco can create many secondhand exposures. In 1993, the EPA concluded the following about exposure to secondhand smoke [2]:

0378-7788/93/$6.00

in adults

- ETS is responsible for approximately three thousand deaths each year in the US.

in children

- ETS increases the risk of lower respiratory tract infections such as bronchitis and pneumonia.
- ETS increases the prevalence of fluid in the middle ear, a sign of chronic ear disease.
- ETS exposure irritates the upper respiratory tract.
- ETS exposure increases the frequency and severity of asthmatic episodes.
- ETS is a risk factor for new cases of asthma in children who do not display symptoms.

The EPA also classified ETS as a "Group A" carcinogen under their previously developed identification guidelines. Group A carcinogens include a small, potent group of known human carcinogens such as arsenic, benzene, and asbestos. The effects of exposure to these and other carcinogens may appear long after exposure to the substances. The EPA decided that there is significant known human data to conclude that ETS is responsible for approximately three thousand deaths each year in the US among nonsmoking adults [2]. These data were gathered during a study that began in 1988, and in July 1992, the EPA's Science Advisory Board endorsed the major conclusions of the report. A unanimous endorsement was given to the classification of ETS as a Group A carcinogen. The public announcement of this EPA ruling has increased concerns about the air quality in buildings where smoking is allowed.

While the US EPA has published this major assessment on the respiratory health risks of secondhand smoke, the EPA does not have any regulatory authority for controlling ETS in the workplace. This lack of authority is due to an exemption in the Toxic Substances Control Act which forbids the EPA from issuing any regulations involving tobacco [4]. Standards for regulation of the US workplace, including smoking regulations, are prepared by the Occupational Safety and Health Administration (OSHA). The EPA and OSHA have separate definitions of carcinogens. A carcinogen is defined by OSHA in the Hazard Communication Standard as a substance that is listed as a carcinogen in one of the following publications [5]:

– OSHA CFR 1910 Subpart Z;

– NTP Annual Report on Carcinogens, latest edition;

– IARC Monographs, latest edition (only groups I and II).

Examples of carcinogens defined by OSHA include: asbestos, benzene, cotton dust, and formaldehyde. The EPA's list of carcinogens is not used by OSHA. As a result, while the EPA has classified ETS as a carcinogen, it is not automatically regulated by OSHA. As of the writing of this paper, ETS has not yet been classified as a carcinogen by OSHA. The EPA's ruling does not affect private residences, but instead is for public buildings where people must congregate for work or pleasure. Various federal, state, and local laws and other regulations exist or are proposed that regulate smoking in public buildings.

Sample state and federal laws

Many laws, both statutory and common, must be considered when discussing smoking in public places. These laws vary significantly from location to location. In the State of Kansas, a *public place* is defined by the Kansas Statutes Annotated [6] as an enclosed indoor area open to the public or used by the public. Public places include, but are not limited to, educational facilities, libraries, restrooms, state, county or municipal buildings. By state law, smoking is currently permitted only in designated smoking areas of public buildings. Separate ventilation systems for smoking areas are not required, so the existing law does not address secondhand exposure. This state law is currently under review, and a total ban on indoor smoking in state-owned buildings is being suggested by some lawmakers.

The Title II Technical Assistance Manual of the Americans with Disabilities Act (ADA) of 1990 [7] gives public entities the authority to prohibit or impose restrictions on smoking in its facilities. The ADA provides protection from discrimination in services, programs, and activities for qualified individuals with disabilities. The ADA gives authority to employers to restrict smoking to protect individuals with disabilities like emphysema and other respiratory disorders. However, use of this authority should not be done unilaterally in a union environment. Public buildings are the "workplace" for employees who are represented by unions and collective bargaining agreements. In past court cases, such as *Burell School District vs. Burell Educational Association*, smoking policy was found to be a term or condition of employment [8]. Any change to working conditions must be negotiated with the union. Failure to do so can result in costly litigation and stalled contract negotiations. However, employers still have legal obligations under OSHA regulations to provide a safe and healthy work environment.

Nonsmokers rights

In the past, the legal relationships between smokers and nonsmokers in public buildings have been poorly defined. Recently, legal rulings in the US have increasingly supported the right of individuals to a healthy work environment. In this era of health consciousness, nonsmokers who are unwillingly subject to sidestream or exhaled smoke may have legal grounds for battery against smokers. The law recognizes that a person who intentionally causes harmful or offensive contact with another is liable for battery [9]. US tort action requires that to prove battery, *intent, contact, and harm or offense* must be shown. Intent must be proven, and tobacco users who know that their smoke will reach others may demonstrate the required intent [9]. The smoke reaching the lungs makes physical contact. Harm or offence, but not necessarily both, must also be proven. Harm can be demonstrated in simple forms such as diagnosed eye irritation or sore throats. Samples of actions that are offensive enough to justify a recovery for battery are listed in the Second Restatement of Torts [9]. As of 1990, there have been no cases brought to trial for smoker battery. While smoking laws and liabilities are in such state of change, the building designers, owners, and operators should take reasonable action now to ensure a healthy environment for the building occupants.

Controlling indoor pollution levels

The concentration of pollutants within an indoor space can generally be reduced by source removal, dilution with air, or by filtration. To understand the methods of improving indoor air quality, it is beneficial to understand how concentrations can be affected within the space.

The concentration level of a pollutant is determined by its *rate of emission into* and its *rate of removal out of* a space. There are two ways to increase the concentration of a pollutant in a room. One method is to increase the emission of the pollutant such as what occurs when tobacco is burned. The second method is to allow contaminated air to flow into the space from a region of higher concentration. In cases where smoking is prohibited indoors, secondhand smoke may still reach the occupants if smoking occurs near an outside air intake.

Reduction of the concentration of a contaminant within a space can generally be accomplished by two methods. One method is to remove the pollutants from the air by chemical or physical means such as filtration. The other commonly used method is to dilute the pollutant by using less contaminated air from outside. There are several means by which ventilation airflow in buildings is supplied or removed. These methods are shown in Fig. 1 and are defined as follows:

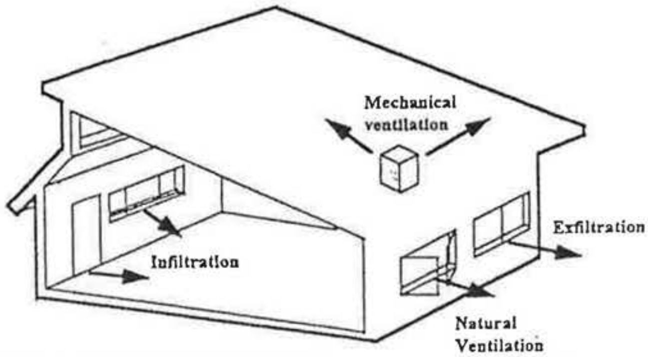

Fig. 1. Building ventilation and exhaust air paths [10].

- *infiltration* – the unintentional or uncontrolled flow of outdoor air into a building;
- *exfiltration* – the unintentional or uncontrolled flow of indoor air out of a building;
- *natural ventilation* – the intentional airflow through open windows and doors;
- *mechanical ventilation* – the intentional airflow created by an air distribution system.

Using any of these means, the concentration level of a pollutant will be reduced in a building with a higher ventilation rate as compared to a lower rate if the outdoor air is of a lower pollutant concentration [3]. Private residences in the US typically rely on infiltration and natural ventilation to provide ventilation air, but commercial and industrial applications typically control ventilation airflow with the use of mechanical ventilation.

Effects on buildings

Due to the rising cost of energy in the early 1970s, building operators were forced to conserve energy. Air leakage around windows and doors was reduced, mechanical ventilation airflow rates were reduced, and even some air intakes were sealed over to reduce heating and cooling costs. In 1973, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), to help conserve energy, lowered its standard for ventilation in offices from 7.5 litres per second (lps) (15 cubic feet per minute (cfm)) to 2.5 lps (5 cfm) per person [11]. Improved construction techniques and materials reduced infiltration as well. The result was a large reduction in the rate of outside air entering buildings from both mechanical ventilation and infiltration [12]. With reduced outside air, pollutants generated within a building tend to reach a higher concentration than would have occurred before the 1970s' energy crisis. Other conditions, such as mold and bacteria growth, the accumulation of carbon dioxide, and poor thermal control have led to complaints from building occupants about the quality of the indoor environment. These phenomena and the resulting dissatisfaction of occupants have been called the *sick-building syndrome*.

In 1981, due to rising concern about poor indoor air quality, ASHRAE published a revision of its ventilation standard. The revised standard required different ventilation rates for smoking and nonsmoking areas. Ventilation in nonsmoking offices was set to 2.5 lps (5 cfm) per person and 12.5 lps (25 cfm) per person for offices with smoking. These new standards led some organizations to segregate or totally ban smoking in their buildings to avoid having an increased energy cost for the proposed ventilation system [12]. Problems also occurred when smoking was eventually allowed in buildings designed with the nonsmoking ventilation rate. In 1989, another version of ASHRAE Standard 62 was published that addressed these problems. This new standard eliminated the distinction between smoking and nonsmoking areas and increased the ventilation rate in offices to a singular value of 10 lps (20 cfm) per person [11]. Use of this new standard may reduce the instances of the sick-building syndrome in new and updated buildings, but other factors such as pollutant reduction and source removal still need to be addressed.

Indoor smoking

Environmental tobacco smoke is commonly perceived as the cause of health ailments because smoke is one of the few indoor pollutants that occupants can see or smell. ETS is blamed for sore throats, burning eyes, coughing, headaches, and a variety of related respiratory ailments. Yet, in studies done by the US National Institute for Occupational Health and Safety (NIOSH), only 2% of the environmental complaints were ultimately attributed to ETS [12]. An argument can be made that ETS is not a cause of sick buildings, but its accumulation in a building is a symptom of a poor ventilation system. If smoke can build up within a room, other contaminants such as carbon monoxide and formaldehyde can as well [12]. When examining the health problems and complaints of building occupants, both ventilation and pollutant generation should be examined.

Other factors

Poor ventilation and air distribution may lead to some indoor air quality problems. These problems can arise from reduced ventilation airflow rates, or from improper maintenance or building operation. Many other factors must be considered when trying to resolve indoor air quality problems.

Clean and appropriate filters installed in HVAC systems can remove larger particulate contaminants from the air stream before they enter the supply air. Filters that are incorrectly fitted or loose pose a threat to the quality of the indoor environment. Loose filters allow dirt and contaminated particles to enter the system. Yet, even if the filters are well fitted, they may still jeopardize the indoor air quality. Fibrous mat filters that are less than 15% effective at stopping respiratory dusts are frequently installed [12]. Higher efficiency filters are available, but may require increased fan power due to a higher pressure drop across the filter. All filters require periodic inspection and cleaning or replacement. Dirty filters will restrict the flow through an air distribution system.

The design of many air-conditioning systems does not provide for easy access or cleaning. The combination of a low airflow rate and high humidity can make the air ducts a possible breeding ground for bacteria, mold, and fungi, some of which are unhealthy. Inspection access, cleaning, and regulation of moisture in the air-side of an air distribution system are needed to reduce the possibility of contamination of the air supply.

Designing ventilation and filtration

The reduction of contaminant levels can be accomplished by use of properly designed ventilation systems. Following the fresh air ventilation standards set by ASHRAE [11], designing proper air distribution systems can help establish a quality indoor environment. Some likely considerations are:

— Use of *localized exhaust* when the exact location of the pollutant source within a space is known;

— Use *mechanical ventilation* to control the build-up of contaminants through dilution, without relying on unpredictable infiltration and natural ventilation;

— Follow guidelines for the recommended number of *air exchanges per hour* for ventilation air in general building spaces;

— Use *heat recovery systems* to help reduce the cost of heating or cooling the outside air used for ventilation;

— Use of *high quality filters* and proper fan sizing will be helpful in systems where particulates are a concern.

The ability of a filter to trap a particle depends upon the size of the particles. The smaller the particle to be trapped, the smaller the spaces between the fibers must be. To catch smaller particles, more fan power will likely be needed to push air through the filter [3].

There are alternative methods of catching the smaller particles that can pass through a filter. Electrostatic precipitation is a method where dirt and dust particles received a positive charge before they pass through a pair of metal plates. The dirt particles are attracted to and then captured on a negatively charged plate. With proper maintenance, these systems are effective in removing smoke particles, dust and some allergens from the building. However, even with extensive engineering of the ventilation system, building owners and operators will still need to develop an indoor smoking policy.

Common courtesy

One option proposed for the control of tobacco smoke is the use of common courtesy [13]. A suggestion by tobacco users is that nonsmokers should tell tobacco users if they are annoyed by the smoke. They propose that if asked pleasantly, smokers will not use their tobacco indoors. Survey data taken between 1974 and 1987 reveal that this approach is used approximately 5% of the time. The data show that most nonsmokers feel uncomfortable asking a person not to smoke and that 40–50% of the people are much more likely to move away from the smoking area. This method, however, does not adequately address the issue of secondhand smoke and its liabilities. Building occupants who do not complain or move away would still be exposed to airborne combustion products.

Segregation

Separating nonsmokers from smokers has been a popular method in US restaurants for fulfilling the desires of their customers. Segregation of workers often is not practical due to the need for interaction and efficient use of business resources. When segregation does occur, such as in restaurants, typically some or all of the air from both spaces recirculates through a common air distribution system. In this situation, the secondhand smoke issue has not been addressed. Without complete isolation, other occupants of an otherwise segregated environment will be exposed to pollutants created by tobacco smoking.

Smoking bans

One method to avoid the problems of secondhand smoke is the adoption of a policy that completely bans smoking indoors. The removal of an indoor air pollutant, such as ETS, at its source is a good method for control, but may not be the optimal solution. This method might not involve any operational or maintenance costs and is becoming popular in the US. However, smoking bans may have drawbacks. A ban only removes the specific source in question and does not address the accumulation of other toxic substances in the indoor environment. If tobacco smoke can accumulate in a building due to a poor ventilation system, so can other substances. Also, the productivity of smokers may be reduced because of increased work breaks. Smoking areas with urns must be established outside, preferably covered and away from entrances and circulation paths of other workers. Smoking, and other sources of pollutants, must not be allowed near outdoor air intakes of buildings.

The smoking lounge

Another approach suggested by the tobacco industry and others to control tobacco smoke is the development of dedicated smoking lounges [14]. This method of ETS control would typically include a general smoking ban in a building, but indoor smoking lounges with separate ventilation systems are provided to accommodate tobacco users. Use of this approach may maintain productivity and eliminate undesired exposure to secondhand smoke. Before designing a smoking room, it is suggested the following questions be asked [14]:

- How many smokers will use the area?
- When will the lounge be used?
- Where is the best location for the lounge? A location with an exterior wall makes installation of exhaust fans easier.
- What attributes will help make the area productive? Telephones and tables allow employees to continue to work while in the area.

The ASHRAE Standard 62–1989 requirement for ventilation air in smoking lounges is 30 lps (60 cfm) per person [11]. However, this ventilation air does not have to be 100% outside air [14]. All or part may be supplied by transfer air. ASHRAE defines transfer air as "the movement of indoor air from one space to another" [11]. This implies that it is permissible to use air from another space in the building to fulfill all or part of the smoking lounges' ventilation air requirement. The smoking lounge must be at a lower air pressure than adjacent nonsmoking areas so that air does not migrate from the lounge into other occupied spaces. None of the lounges' return air should be recirculated, but should instead be exhausted so that it does not readily reenter the building. The pressure balance and venting of a smoking lounge should be designed with care, much as is done with chemical fume hoods and laboratories.

Case study

In this research project, an existing smoking area was sought to examine ETS. A small snack bar with a smoking area that is within an institutional building was selected. The snack bar area is as shown in the floor plan of Fig. 2. The designated smoking area is bordered on three sides by other interior rooms of the buildings. There is one exterior wall to the smoking area. A highly used hallway passes through the smoking area. Movable benches and ashtrays are located around the perimeter of the space. Frequently, long lines of customers form while waiting to purchase items at the snack bar. Doors are located between an adjoining art gallery and the smoking area, but these doors are generally left open. Magnetically operated fire doors in the hallway are usually open and are occasionally obstructed by ashtrays or benches.

Observation of this smoking area was done in time slots and days chosen at random. Temperature and occupancy data were recorded at fifteen minute intervals during the observations. A summary of the reduced data collected is shown in Table 1. A 95% confidence interval, as used by the EPA [1], was used to estimate the number of smokers in the area at various times. To determine the mean number of smokers, the equation used is:

$$\bar{X}-t_{(n-1,\,\alpha/2)}\frac{\sigma}{n^{1/2}}<\mu<\bar{X}+t_{(n-1,\,\alpha/2)}\frac{\sigma}{n^{1/2}} \quad (1)$$

where $\bar{X}$ is the sample mean, and σ is the sample standard deviation based on n observations. Using the recorded data yields the equation:

$$3.58-2.060\times\frac{2.71}{26^{1/2}}<\mu<3.58+2.060\times\frac{2.71}{26^{1/2}} \quad (2)$$

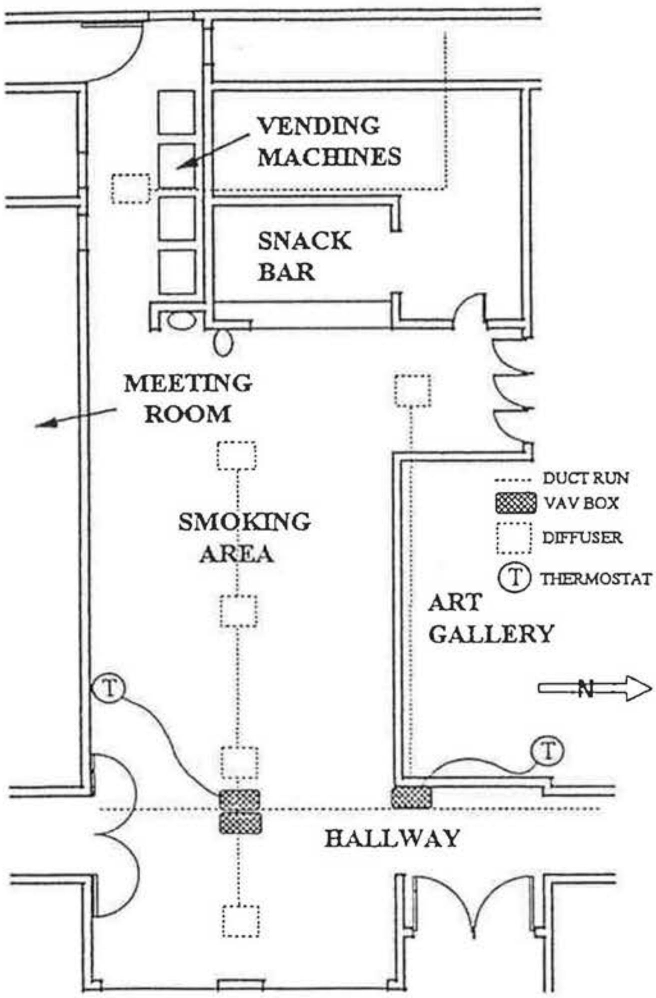

Fig. 2. Floor plan of the snack bar and smoking area.

TABLE 1. Case study: population data

Population data		$n=26$
People	Mean	19.85
	Std dev.	9.16
Smokers	Mean	3.58
	Std dev.	2.71
	C.I. 95%	2.49, 4.68
Employees	Mean	2.54
	Std dev.	1.58

The result of eqn. (2) is a 95% confidence that the average number of smokers in the space is between 2.49 and 4.86.

Observations

During this study, there were several interesting observations of nonsmoker behavior. Often, nonsmokers who entered the space after smokers had left moved the ashtrays several feet from where they had chosen to sit. This action reveals an often overlooked side-effect of tobacco smokers; cigarettes can continue to burn after the smoker has left. All of the smoke released from tobacco burning in this manner is sidestream smoke. Another observation of this space is that it serves as a passage way for wheelchair-bound people and that some employees use this area as their lunch room.

Discussions with the facilities operation staff revealed that this building has had many complaints about air-conditioning and ventilation. Construction documents for the ten-year-old mechanical systems were obtained for the snack bar area. Six supply air diffusers were specified to deliver a total of 725 lps (1450 cfm) into the area. These documents specified shut-down variable air volume (VAV) boxes, therefore no ventilation air is supplied when the thermal load is met. A thermostat which controls a 125 lps (250 cfm) VAV box is located in an adjacent room, and not the snack bar area. Additional supply air is shown to be delivered by a diffuser placed in an adjacent room with the intention of airflow through a doorless opening as shown in Fig. 3. As built, this opening was closed off by glass doors.

Many undocumented changes have been performed on the building through the years in attempts to improve the ventilation system. However, complaints about the air quality continue, and tobacco smoke visibly spreads throughout the building from the smoking area. Based on the frequent complaints, the observed failure of the ventilation system to clear the tobacco smoke, and the low supply air design values, this appears to be a "sick building".

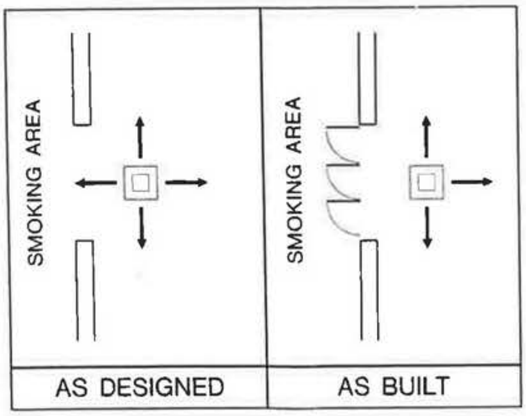

Fig. 3. Diffuser location with respect to door locations.

Alternatives

In this project, engineering and policy solutions were sought that could correct this indoor air quality problem. Pertinent ventilation rates from ASHRAE Standard 62–1989 were used in the analysis. Assuming the use of the entire snack bar area as a smoking lounge, the required ventilation air would be:

$$30\,\frac{1}{\text{s}\cdot\text{person}}\times 70\,\frac{\text{people}}{100\ \text{m}^2}\times 135\ \text{m}^2 = 2835\ \text{lps}$$

or (3)

$$60\,\frac{\text{cfm}}{\text{person}}\times 70\,\frac{\text{people}}{1000\ \text{ft}^2}\times 1450\ \text{ft}^2 = 6090\ \text{cfm}$$

Because the existing air-conditioning system within the building is unable to serve the space in a adequate manner, it cannot deliver the extra volume needed to comply with this standard. Instead, the creation of a separate smoking lounge was considered.

A smoking lounge

One solution to this indoor air quality problem is to construct a smoking lounge on the east-most (exterior) portion of the snack bar area as shown in Fig. 2. A glass curtain wall can be built to separate the smoking and nonsmoking sections. This wall will let natural light into the interior nonsmoking space and create a 16 m^2 (176 ft^2) smoking lounge between it and the exterior wall. Following the ASHRAE guideline of 70 people per 100 m^2 (1000 ft^2), this space can serve about 12 smokers. Statistical calculations based on a 95% confidence interval show that there are between 8 and 13 smokers using the existing space, so the proposed smoking lounge is appropriately sized.

The ventilation air requirements for this space would be provided from a combination of the existing air-conditioning system and transfer air from the nonsmoking section. Exhaust fans and ducts would be installed to remove air from the smoking lounge. The exhaust duct should be installed to above the roof line much as a vent for a fume hood. A negative pressure zone must be maintained in the smoking lounge by the exhaust fans. This negative pressure would allow transfer air to pass through grilles low in the glass wall and keep the smoke from passing out of the door into the adjoining nonsmoking area. The use of this transfer air system may also help improve the indoor air quality of the nonsmoking space by increasing its exhaust airflow rate.

The total ventilation requirement for the proposed smoking lounge is 370 lps (740 cfm). A separately operable terminal box with a single diffuser is currently installed in what would become the smoking lounge. This VAV box and diffuser are sized for up to 200 lps (400 cfm). Therefore, up to 170 lps (340 cfm) of transfer air are needed to meet the ventilation air requirement. All of the smoking lounge supply air would be exhausted outside in a way to produce a negative pressure relative to the surrounding spaces. For very precise but expensive control, pressure balancing valves such as available for fume hoods could be used. An occupancy sensor in the smoking lounge would allow for varying the ventilation airflow rate to help reduce energy consumption.

Conclusions

Because of the recent research declaring that environmental tobacco smoke (ETS) is a carcinogen, US federal agencies may be pressured to enact new regulations governing smoking in the workplace. Until then, building designers, owners, and occupants should take prudent engineering and policy measures to reduce exposure to ETS. Some of these measures include increased ventilation, air treatment, segregation, indoor smoking bans, and construction of smoking lounges. Failure to make reasonable efforts to control ETS and other indoor air pollutants may increase future liabilities of individuals and organizations involved with the built environment.

Acknowledgements

This research project was completed as part of course requirements for ARCE 681, Architectural Engineering Senior Studio II. The support of the Architectural Engineering Department is gratefully acknowledged. An earlier version of this paper by the first author was submitted to the 1993 ASHRAE Student Project Competition for judging.

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