EFFECT OF BUILDING AIRFLOW ON REENTRY AND IAQ

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ABSTRACT

Obtaining clean outdoor air for ventilation and "free-cooling" in economizer air-handling systems is at best difficult and sometimes nearly impossible. This is especially true in ground floor offices or commercial space nestled among multistory buildings. Knowledge of the effect of airflow over buildings on pressure gradients and air movement around buildings is essential for engineers and architects seeking to avoid or minimize reentry of contaminated air into occupied building spaces and related indoor air quality (IAQ) problems.

Remodeling of the ground floor of an eight-story building across the alley from a single-story office element attached to a ten-story tower led to significant economic loss when reentry was not considered. A mushroom-type exhaust fan installed in the exterior wall of the remodeled space to serve a steak and hamburger grill exhausted grease fumes, smoke and odors into the alley at the ceiling of the first floor that were taken in by the outside air intake of the ground floor office. Although limited "whiffs" of cooking steak may whet one's appetite, continuous exposure to heavy hydrocarbon fumes and odors has a negative impact upon productivity and appeared to have a significant impact upon absenteeism and lost time.

Comparison of lost time for the first eight months of the year during the year before and the year after installation of the grill exhaust showed lost time of 543 manhours before and 1271 manhours after, respectively. Value of the lost time was estimated to be approximately $32,000. Losses of productivity among those who remained on the job could not be measured but lost time was evident.

This paper traces the activity that lead to revisions to the offending system that eliminated the problem.

INTRODUCTION

Finding acceptable air for office ventilation can be a very difficult task in center city, USA or elsewhere. It is especially difficult when an office is located on or near the ground floor of a multistory building. Contaminants such as "rubber" dust, carbon monoxide, carbon dioxide, NOx and hydrocarbons from auto traffic, blowing particulate, potential biological materials from open food waste and exhaust from various processes may be present in various concentrations. Air movement through downtown areas is also very complex and predictable only if one can afford the luxury of a wind tunnel test. General wind flow is disturbed by buildings and wind direction at street level may be directly opposite to that above due to flow down and around buildings. The general arrangement of the city block in which the office and grill are located is shown in Figure 1.

All of this became apparent when a new hamburger restaurant placed a grill exhaust system into operation in a downtown ground floor location. Grease fumes were discharged horizontally into a secondary street (alley) and entered an outside air intake in an office across the street. The downtown environment and the problem was further complicated by the involvement

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of two businesses, two building managements, and two legal firms -- one representing the restaurant and the other representing the building that housed the office with the IAQ problem.

CHRONOLOGY OF EVENTS

A chronology of events related to resolving the IAQ problem is attached as Table 1. The problem began in January 1986, and was not yet fully resolved until May 2, 1987. Each day brought a promise of final resolution. Each succeeding day brought the need for reminders that the project was not complete.

Complaints by office occupants began shortly after the restaurant opened. They were not voiced daily nor did the odor persist for long periods of time. As the weather became warmer, the air-handling system economy cycle began to modulate to its wide open position. As it did so, odors persisted much longer and complaints increased. This should have been anticipated when using an economy air cycle but was not.

The office is cooled by three DX air conditioning systems. Two of three take their outdoor air through the same louver on the secondary street. Both of them delivered the grease fumes into the office. The intake for the third unit was at the opposite side of the building. Odors were observed in the area served by the third unit but they were very light and it was believed that the odors were from convective transfer or diffusion from the other areas.

ABSENTEEISM

The manhours lost each month for reasons of illness during 1985, 1986 and to date in 1987 are plotted in Figure 2. Annual trends are similar for the three years with the exception of the spring and early summer of 1986. During this time, the wall-mounted mushroom fan discharged grill exhaust into the secondary street. Lost time during the period between installation of the mushroom fan and its replacement with a centrifugal blower and vertical discharge duct was about 730 hours with a market value of about $32,000.

The locations of the exhaust fan discharge and the outside air intake are shown in Figure 3 and a photo of the fan is shown in Figure 4. Both are at the same elevation and the horizontal separation is approximately 45 feet. The hoped for dilution which is expected to occur between exhaust discharge and outdoor air intake did not occur. Designs based upon such assumptions frequently fail because the mixing and dilution do not occur.

In this particular case, airflow down the building housing the grill drove the fumes down into the secondary street under many wind conditions. The downflow was enhanced by the fire escape enclosure adjacent to and north along the west wall from the fan. Wind could not flow freely in either the northerly or southerly direction because of the obstruction shown in Figure 5. In either case, the exhaust would be contained in the flow cavity and tend to be driven down to the street. For those unfamiliar with how air flows over buildings, Chapter 14 of the ASHRAE Handbook -- 1985 Fundamentals, will provide many useful insights and understanding of this too often ignored source of building reentry and contamination problems.

AN EVOLUTIONARY SOLUTION

When action finally was taken in June 1986 to correct the exhaust discharge, a centrifugal fan and a short length of ductwork was installed. The fan and duct installation are shown in Figure 6. This first attempt to get the exhaust fumes up and away from street level was moderately successful. Note in Figure 2 that absenteeism dropped subsequently to "normal" levels. It was unclear, initially, whether the reduction occurred because less outdoor air was being taken into the office, because dilution was occurring before the fumes got down to street level, if indeed they did, or because absenteeism under any condition is lower during summer.

Subsequently, some reentry was experienced even though the duct discharge was vertical. It is of interest to note that on one day in which grease fumes were very heavy, the jet followed classical expansion theory and extended to the top of the building. A window on the top floor was open, however, and the jet turned and entered the building.

Because of concern for outdoor air intake volumes during economy cycle operation and the now and then entry of odors, the complete solution was requested. As noted in August 14, 1986 through February 26, 1987, this caused further action and solution discussions. The next step in the evolutionary solution was to extend the ductwork to the south side of the building with a discharge directing the exhaust plume to the southeast as shown in Figure 7. Horizontal discharge was accepted after the city officials expressed concern for reentry into the building in which the restaurant is located if the fumes were discharged vertically.

To date the installation is not complete, but it is expected that the final additions will solve the IAQ problem.

SUMMARY

Reentry of fumes from exhaust systems may be a significant source of indoor air quality problems and economic loss in office buildings in downtown locations. Careful attention must be given to how wind forces cause air to move over and around buildings and to use such movements to advantage in avoiding reentry and IAQ problems. In downtown locations, best results will be obtained if exhaust fumes are released at the highest point of the building in which the source is located. This is supported by the fact that three other restaurants in the same basic city block have grill exhausts that discharge at the roof of their building. All had been in place for several years prior to installation of the offending exhaust. Such exhaust systems should end with vertical discharge through drain type stack hoods. Outside air may be taken from various levels without IAQ problems developing, but good engineering practice must be followed to avoid bringing contaminated air into a building. An effort should be made to make engineers and code officials aware of the effect of airflow over buildings on reentry and energy conservation.

TABLE 1

Chronology of an IAQ Problem/Solution

February 1980 - Ground floor office occupied. Outdoor air intake expanded.
February 1980 - December 1985 - Occasional entry of truck exhaust fumes. O.A. secured manually immediately (perhaps half a dozen excursions).
January 1986 - Restaurant opens - Mushroom exhaust fan installed near grade. Food odors noticed daily for extended periods. Complaints filed with owner and city building code officials. Code officials rule exhaust not a violation. Building housing office notes odors observed up to eighth floor.
February 5, 1986 - Proposed relocation of O.A. intake across roof of office. Building owner objects. Restaurant proposes cost sharing.
February 6, 1986 - Owners of offended business propose action with restaurant paying for modifications.
February 17, 1986 - Attorney for building management places restaurant on notice for need to take corrective action.
March 16, 1986 - Problem continues with odor intensity increasing with mild weather - economy cycle taking % percent outdoor air. Office owner proposes building management notify City Health Department and Air Pollution Agency of problem and points out reentry threat to rental and leases.
March 27, 1986 - Restaurant owner indicates a "shield" will be installed April 1 over fan to direct air upward for temporary relief. Exhaust stack will be run to roof in 60 to 90 days.
April 3, 1986 - No action yet. Building management announces intent to file suit against restaurant owner.
April 8, 1986 - Restaurant owner asks for plan of revised air intake. Request not granted. He indicates air intake is a code violation.
June 5, 1986 - No action yet on revision of exhaust.
June 10, 1986 - Judge agrees to hear dispute June 20. Restaurant owner files for permit to construct new exhaust duct. Judge gives attorney for restaurant 48 hours to move on permit.
June 18, 1986 - Attorney for restaurant indicates permit issued June 13. New fan and duct would be erected June 27. Duct to be extended to roof of building.
June 28, 1986 - New fan and duct installed. Duct extends vertically to a point about 30 feet above street. Vast improvement but odors still experienced.
August 14, 1986 - Letter to building management attorney notes corrective work incomplete and points out that outside air intake was reduced to code minimums during summer. More odors expected to be experienced when mild weather sets in.
September 16, 1986 - Restaurant management frequents office to question employees about odors, improvement, etc. Letter to attorney requests such visits (harassment) cease and notes that work is incomplete. Key employee loses week of work. Has pleurisy and bronchitis. Doctor suggests fume reentry may be contributing factor.
October 22, 1986 - Food odors again strong. Weather much milder and economy cycle working. Status queried.
November 10, 1986 - Restaurant owner asks for "relief" when it is learned that building wall will not support duct unless hangers fastened with through bolts. Suggested that duct be carried to roof on structure supporting fire escape. If city would not permit this, proposed extending duct to south side of building, then vertically about 10 feet.
December 6, 1986 - Office management requested to have representation at hearing on December 8.
December 9, 1986 - Meeting with restaurant owner's attorney to review duct modification reiterates move to south wall with vertical discharge at outlet.
January 29, 1987 - Reviewed three alternatives offered by restaurant owner.
a. Duct to roof on fire escape if permitted by city - preferred.
b. Activated carbon system - accepted with provision that maintenance be a part of the agreement. Suggested this would prove to be too expensive.
c. Extend duct to south side of building and provide 10-foot vertical extension.
February 13, 1987 - Reconfirmed acceptance of three alternatives but had learned that duct-to-roof and carbon adsorption alternatives had been abandoned.
February 16, 1987 - Building management reports total agreement reached. Duct will be extended to south side and 10-foot vertical extension will be added.
March 17, 1987 - Hearing planned, construction to follow.

March 21, 1987 - Duct extended to south side of building and terminated with elbow.
March 23, 1987 - City requires duct to discharge away from the building to avoid reentry. Agreed to have discharge directed to southeast.
April 16, 1987 - Contractor delivers 10-foot section with gooseneck. Building management informed that "gooseneck" will violate agreement. Furthermore, it would cause fumes to be blown toward ground.
April 20, 1987 - No action on installation.
May 2, 1987 - Final duct section put into place. "Gooseneck" remains but angle of discharge not 45 degrees down from horizontal rather than 90 degrees.

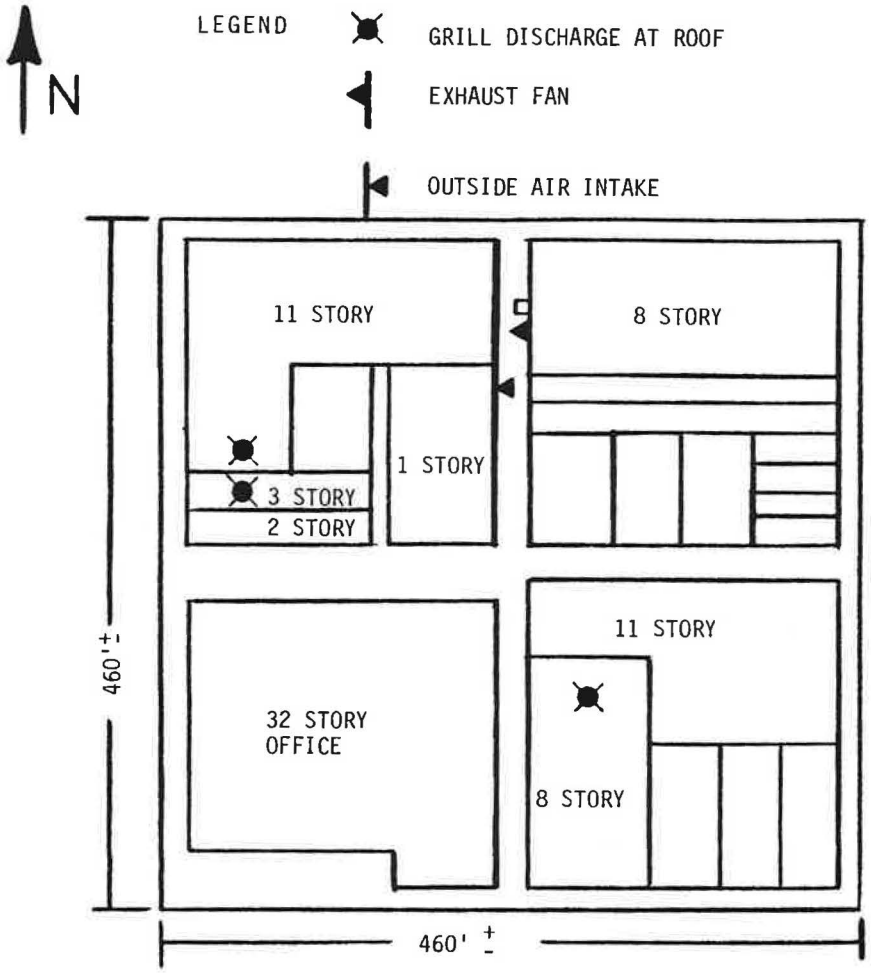

Figure 1. Building location and height in block in which restaurant and office are located

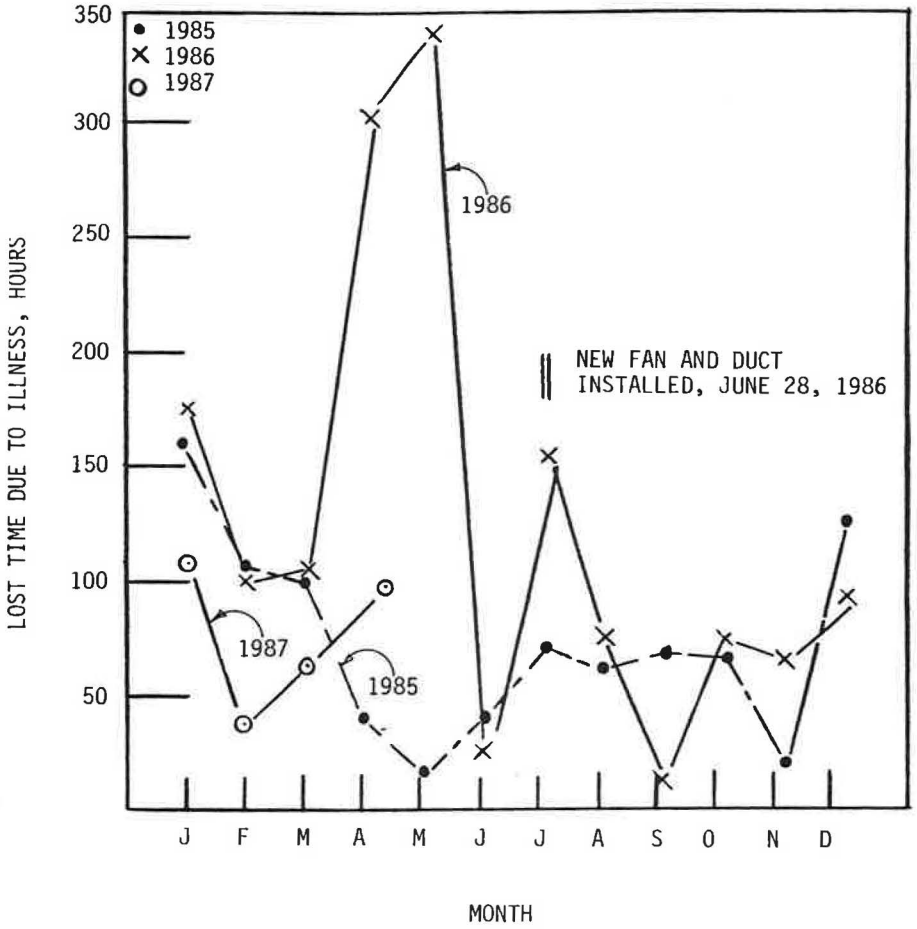

Figure 2. Sick time reported monthly 1985, 1986, and 1987 to date

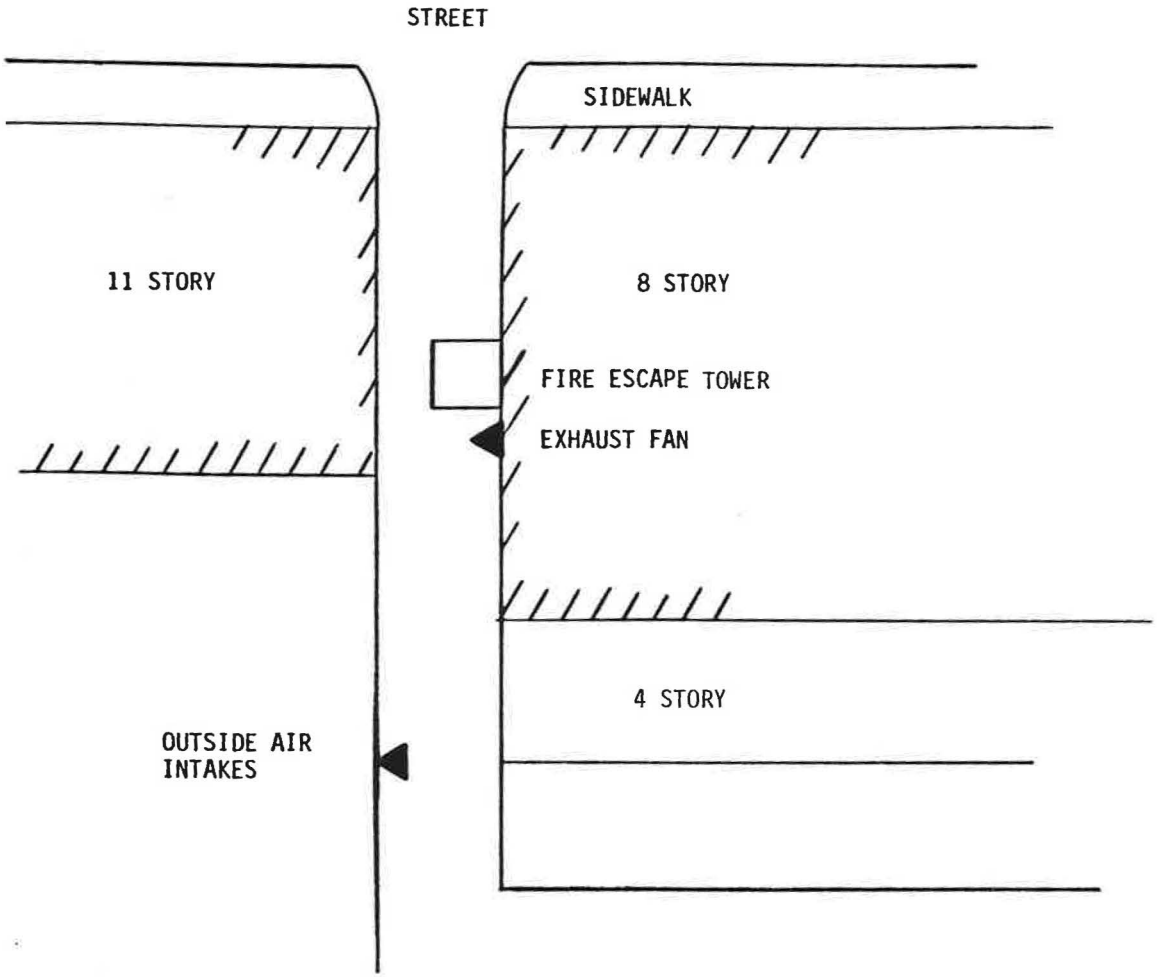

Figure 3. Part plan showing location of exhaust fan and outdoor air intake

Figure 4. Wall mounted mushroom fan exhausting short order restaurant frying grille

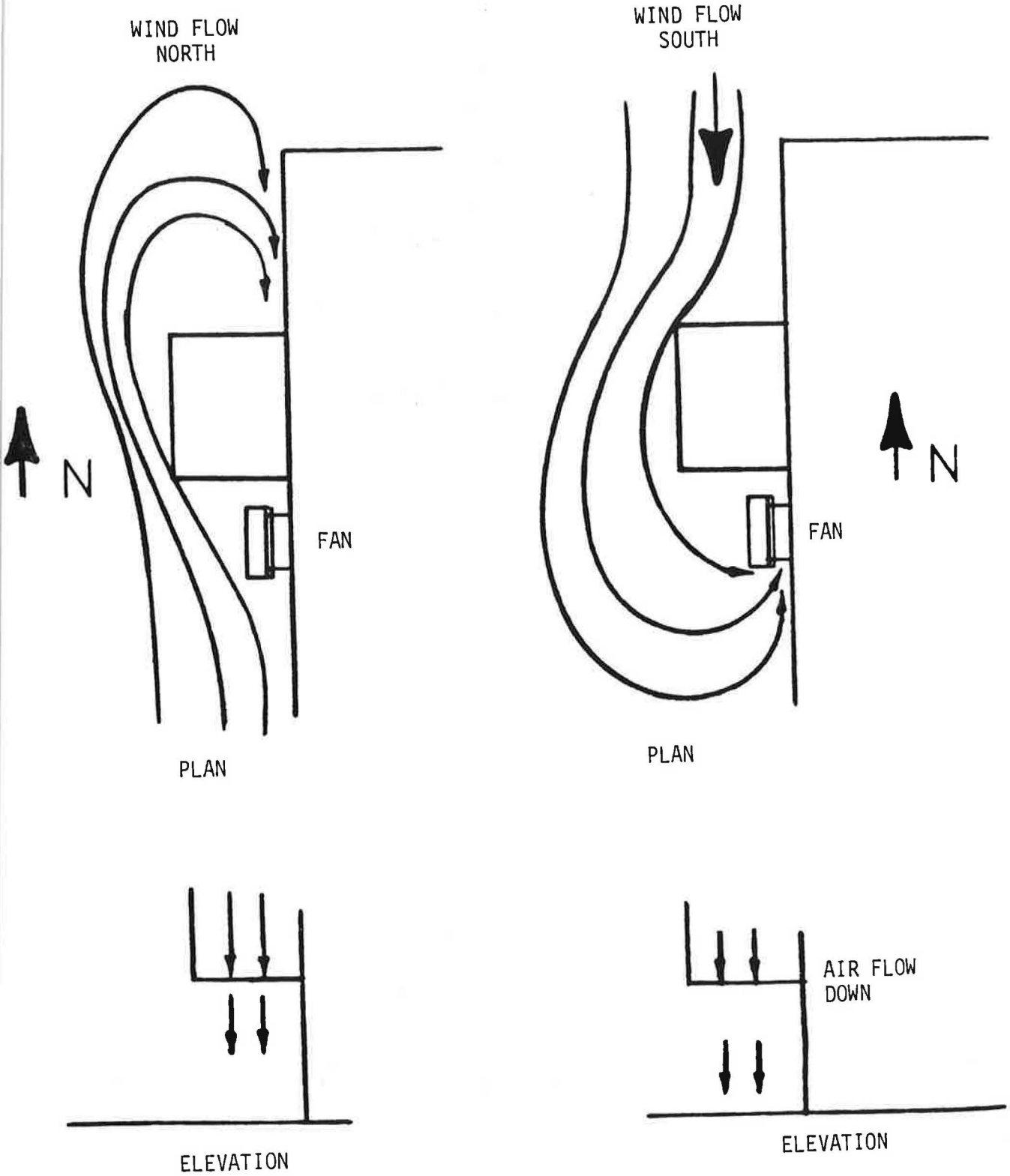

Figure 5. Effect of fire escape enclosure on wind flow and movement of exhaust fan discharge air

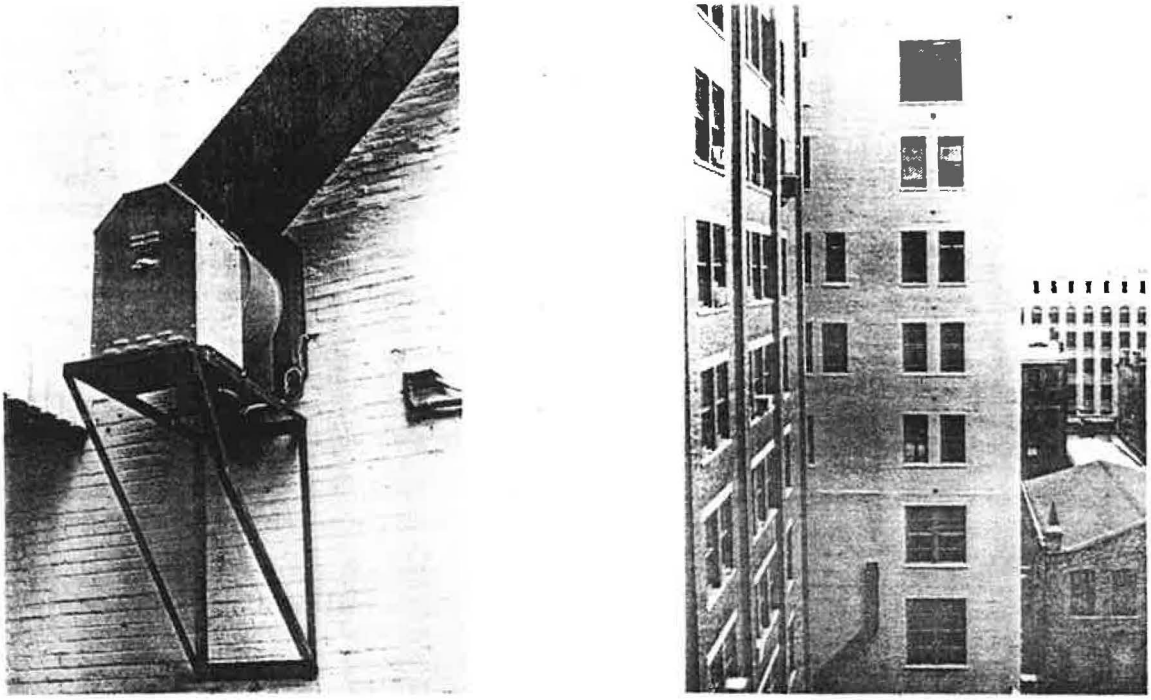

Figure 6. Centrifugal fan (left) and ductwork installed to minimize contamination of outdoor air intake

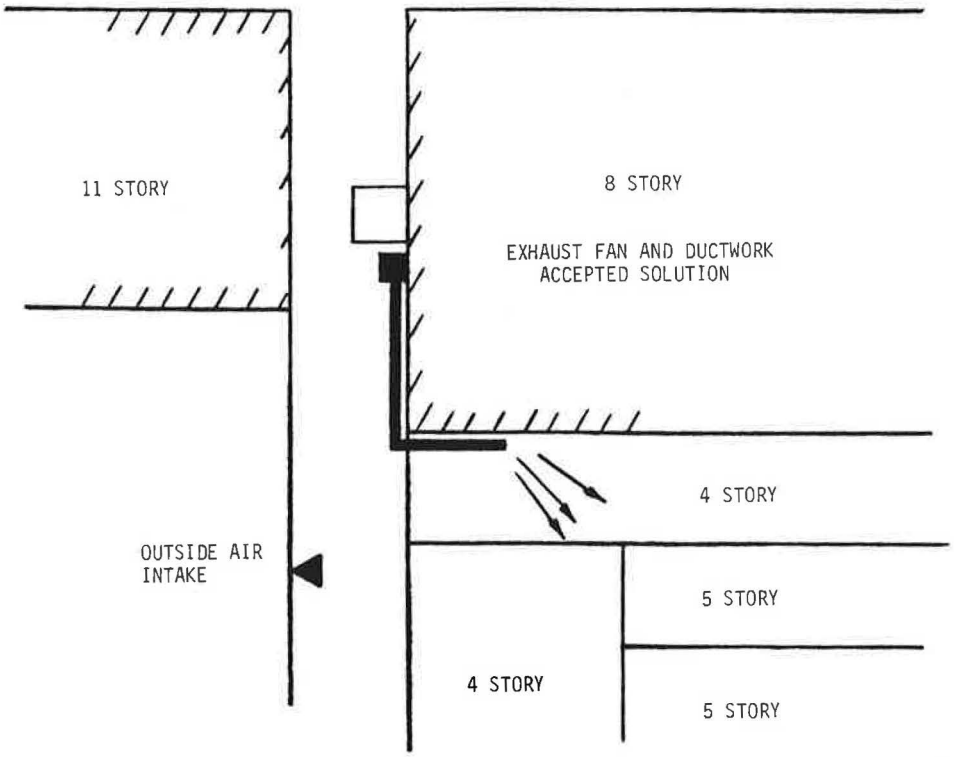

Figure 7. Part plan showing final duct arrangement for exhaust system

Discussion

H. LEVIN, University of California, Berkeley: To what extent do engineers utilize the available knowledge (ASHRAE Handbook) regarding airflow around buildings when designing new buildings and their HVAC systems?

BAHNFLETH: Use of available knowledge about airflow over buildings is not as widespread as one would like it to be. There are two reasons for this: (a) Engineers of the late sixties, when a substantial part of the present day data base was developed, ignored such details in design. (b) The new generation of engineers, responsible for much of the current design, are technically illiterate in this and many subtle areas of practical engineering design. They will learn with time, given bad experiences or interest in personal growth through continuing education.

LEVIN: Please comment on legal and regulatory issues in dealing with air contamination by adjacent buidlings.

BAHNFLETH: The body of law relating to cross contamination by adjacent buildings is very limited. The various actions listed in the chronology represent some of the first such actions. Air pollution control regulations address some of the questions relative to cross contamination, but usually are applied when a relatively high degree of toxicity is anticipated. IAQ problems, on the other hand, more often involve offensive rather than toxic materials.