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VENTILATION MODIFICATION IN A PARKING STRUCTURE

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ABSTRACT

The operation of very tall multi-use facilities present challenges to both the designer and engineer. An investigation was conducted to determine the indoor air quality in a very tall building as it related to the operation of an internal parking garage.

The original design for the garage called for continuous ventilation at the rate of 1 cfm/ft^2. Based on the degree-days in the Chicago area, the costs for operating the garage ventilation amounted to more than $290,000 per year. In an effort to reduce the operating costs, the ventilation system was operated manually as needed rather than be allowed to operate continuously. This resulted in the buildup of automobile emissions under certain conditions. Additionally, efforts to reduce natural infiltration of outside air into the garage during cold weather was complicated by the stack effect of the building and the need for regularly opening the garage doors.

A sophisticated system was designed for solving this problem. The solution consisted of four interrelated components including perimeter enclosure, continuous carbon monoxide sensors, computerized fan operation, and a garage door airlock. The perimeter enclosure sealed one contributing opening to the stack effect problem by eliminating the leak along the skin of the building. The computer received the CO information and would automatically start exhaust fans at a concentration of 35 ppm. Enough exhaust fans are started to prevent the CO concentration from reaching 50 ppm. Supply fans would ultimately be started, as would be the heat, to assure the effective operation of the exhaust fans and prevent the freezing of the garage sprinkler system. The airlock limits the surge of incoming air to thus control heat loss and infiltration.

The system has been fully functional for more than one year. The results have proven that indoor air problems can be solved with a cost savings.

INTRODUCTION

Chicago is home to a variety of fine architecture. It is also home to several of the world's tallest buildings. Tall buildings are challenging from a design standpoint and their operation requires logistical control. Most tall buildings are affected by the phenomenon of stack effect during the winter. Stack effect not only creates challenges for building operation but is a source of energy loss. This particular paper involves a building with more than 100 stories.

The subject building is a trussed-tube design consisting of a steel frame and an aluminum curtain wall. Designed and constructed during the 1960s, the building uses electricity as its primary energy source.

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The building is multi-use, consisting of 2.9 million square feet dedicated to: commercial, garage, residential, broadcast, mechanical and restaurants. The 33 million cubic foot building is serviced by some 50 supply and 50 exhaust fans. These fans move more than 1.3 million cfm of air.

The subject ventilation study focused on the seven floor garage located in the lower part of the building. The garage, which occupies floors six through twelve, is a potential source of indoor pollutants. The garage occupies 40,000 square feet per floor and was designed with a ventilation system to meet city code of 1 cfm per square foot. The 14 3-hp exhaust fans handle 20,000 cfm each. The 14 15-hp supply fans also handle 20,000 cfm each. When all the fans are operating, 280,000 cfm pass through the garage.

The garage was designed with a wet sprinkler system which is maintained at a minimum of 40 degrees to prevent freezing. The supply fans are equipped with three stages of electric resistance heaters for the required air tempering.

Electricity expenses to operate the ventilation system as designed for the garage were approximately $290,000 per year. The electrical costs for heating the air at maximum capacity are about $345 per hour assuming 6 cents per kilowatt.

Stack effect for the building finds its primary air source in the garage. Approximately 1000 cars use the garage daily. There are two garage doors of about 90 square feet each. At 2000 openings and closings per day, a ready source for air infiltration is available. It is calculated that infiltration due to the stack effect is about 130,000 cfm and the contribution from wind impingement adds another 45,000 cfm. When the garage doors are open, the air infiltration into the garage is thus about 175,000 cfm.

For the 127 heating days during 1984 and the 11 hours which the garage doors are open every day, about 15 billion cubic feet of air entered through the garage, was heated, and escaped by exfiltration. The heating costs for this air required 1.4 million kilowatt hours of electricity; an additional operating cost of $85,000.
One alternative to this air handling and heating dilemma was to simply turn off the garage ventilation systems. However, this would only be partially effective due to the need for temperature maintenance and the continued infiltration through the garage doors. Complicating the alternative of simply turning off the fans are the 1,000 cars per day utilizing the parking structure. Emissions could create unacceptable air quality due to the reduced ventilation. City code for carbon monoxide in the parking garage is 100 parts per million.
The chosen solution involved a four component design consisting of: garage entrance and elevator vestibule, perimeter seal, carbon monoxide sensors and automatic fan cycling.

A double vestibule, one for entry and one for exit, was installed on the sixth floor which permitted the garage doors to open and close with minimum air infiltration. Several cars were allowed to be present in the vestibules simultaneously. The vestibules also served to isolate the passenger and freight elevators, a migration path for stack effect. The vestibules were serviced by an independent ventilation system.

Each floor of the garage was sealed at the perimeter. This seal consisted of additional insulation and integral drywall. This seal also improved the aesthetics at the perimeter.

Solid-state carbon monoxide diffusion sensors were selected for monitoring the air quality. Two sensors were located on the sixth floor and one sensor was located on each of floors 7 through 12. The sensor was located at the top of the exit ramp of each floor. The carbon monoxide sensors and temperature probes, for ensuring that the sprinkler system did not freeze, were interfaced with remote and central serving computer terminals. The 8 CO sensors and 28 temperature probes were among the 1000 total remote points monitored continuously by the central computer. The computer updates the 1000 monitoring points on a 22-second cycle time.

Fans are cycled automatically by the computer according to the following schedule:

1. If the carbon monoxide concentration is less than 35 parts per million and the temperature is above 40 degrees, no fans are operating.

2. When the carbon monoxide concentration reaches 35 parts per million, one exhaust fan starts.

3. If the concentration continues to rise towards 50, a second exhaust fan starts.

4. When 50 parts per million is reached, a supply fan is started.

5. If heat is required according to the temperature probe, the resistance heater starts.

As a complement to the automatic fan activity initiated by the carbon monoxide sensors, one exhaust and one supply fan operate on alternating floors during rush hours.

The costs associated with this project are summarized below. First, the annual costs for manually operating the system to maintain heat for sprinklers and an acceptable air quality from auto emissions was $290,000. Secondly, the costs to modify the system were as follows:

Air lock perimeter and vestibules	-	$150,000
Enclosure/sealing	-	150,000
CO sensor system	-	10,000
Computer point hook up -	-	2,000
TOTAL		$312,000

Finally, the 1985-86 operating costs for this revised system were $85,651.

CONCLUSIONS

Buildings designed during the period of low energy costs generally require some updating. These modifications have the potential to cause problems such as indoor pollution if not handled properly. Through a combined effort of contaminant control, and other efforts such as infiltration reduction, cost savings can be realized which will easily justify the expense.

Discussion

K. TRAMPOSEH, Center for Residential Health, Wayland, MA: How extensive was the CO contamination the residential floors above the parking section, and are other contaminants such as hydrocarbons, especially benzene, in these residential units?

BOELTER: Premodification sampling was conducted on the residential floors. It was determined that carbon monoxide, as well as other contaminant concentrations, was not significantly different from typical outdoor air concentrations.

TRAMPOSEH: Is there any long-term monitoring for CO and other pollutants in these units?

BOELTER: The decision to conduct long-term monitoring would be made by the residential owners. With the successful completion of the garage modification, to the best of our knowledge, the residential management has not determined the need to perform long-term monitoring.

H. LEVIN, Uiversity of California, Berkeley: How would the retrofit have differed if it had been exclusively for energy conservation?

BOELTER: There would probably not have been any differences except that temperature may have been selected exclusively for monitoring rather than the combination of both temperature and carbon monoxide.

LEVIN: What have you learned about sensor performance and calibration requirements?

BOELTER: Approximately 50% of the sensors require minor (±2%) adjustment during the monthly inspection. When these adjustments are made, sensor performance is reliable and consistent. There have not been any long-term problems with the performance of the integrated system.

C. LAWSON, Carl N. Lawson and Associates, New Port Richey, FL: What is the maintenance schedule and cost of sensors?

BOELTER: The manufacturers representative inspects the sensors on a quarterly basis. The building engineer inspects and calibrates the sensors on a monthly basis.

LAWSON: Are there any design parameters of locating CO_2 sensors?

BOELTER: The main traffic flow patterns were selected for placement of the sensors. Sensors are placed above these flow patterns to eliminate skewed readings from parked or idling automobiles.