Indoor Air Quality Commissioning of a New Office Building

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Synopsis

This paper presents a case study in the application of an indoor air quality (IAQ) commissioning program. In order to identify and understand the issues involved in implementing such a program, an IAQ commissioning program was developed and applied to a new office building in Rockville Maryland. This commissioning program is not presented as a candidate for a standardized protocol for IAQ commissioning. Instead, it is intended to provide experience and insight that will assist in the development of future IAQ commissioning protocols.

About the Authors

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Introduction

Building commissioning generally refers to the process of verifying that building mechanical systems are operating as designed. However, commissioning does not always include the verification of an "acceptable" indoor environment for the building occupants, including factors related to indoor air quality. In light of growing concern about indoor air quality, IAQ commissioning could become an important part of building commissioning programs. A well-defined and properly-implemented IAQ commissioning program could help provide a healthy and comfortable environment for the building occupants and help to reduce other problems related to building operation. However, there are currently no standard IAQ commissioning protocols.

The program described in this paper consisted of three tasks:

- Task 1 - Evaluate the mechanical ventilation system design from an IAQ perspective.
- Task 2 - Develop a set of environmental performance parameters and associated reference values that will be used to evaluate IAQ in the building.
- Task 3 - Measure the environmental parameters in the building and compare them with the reference values developed in Task 2.

This paper presents a brief overview of the project. A complete and fully-referenced description of the project is given by (Dols et al. 1995).

Task 1: Design Evaluation

The purpose of Task 1 was to compare those features of the building design pertaining to IAQ to relevant building codes and IAQ guidelines. These comparisons were made for outdoor air intake rates and pressure relationships between building zones. For this purpose, the building was subdivided into eleven zones: floors 2 through 10, the daycare center, and the auditorium. The first floor was not included in this commissioning program, because its design was not completed until this project was nearly finished.

The design outdoor air intake rates of the mechanical ventilation system were compared to both the BOCA Mechanical Code, upon which the ventilation system design was based, and ASHRAE Standard 62-1989. The design outdoor airflow rates conform with the BOCA Code and in some cases exceed the BOCA requirements. The design outdoor air intake rates are slightly below the ASHRAE recommendations in several zones and well above ASHRAE recommendations in other zones. However, the system is capable of providing outdoor airflow rates that would comply with ASHRAE Standard 62-1989 to all zones of the building.

Task 3: Indoor Environmental Monitoring

During Task 3, IAQ and ventilation measurements were performed in three phases of building construction:

- Phase 1 - Interior build-out complete
- Phase 2 - System furniture installed
- Phase 3 - Approximately one month after occupancy

The results of the indoor environmental measurements are summarized here.

Outdoor Airflow Rate

During occupancy (Phase 3), the outdoor air intake rate per person delivered to each of the eleven zones was at or above ASHRAE 62-1989 recommendations with the exception of the sixth floor and the auditorium. The outdoor airflow rate to the sixth floor was low because an outdoor air intake damper serving this floor was broken during Phase 3. An outdoor air damper serving one of the fifth floor mechanical rooms was also broken, causing outdoor air intake rates to the fifth floor to be below design levels, but still above the ASHRAE guideline of 10 L/s (20 cfm) per person for offices.

Pressure Relationships between Zones

All eleven zones were positively pressurized relative to the stair and elevator shafts. Therefore, a pollutant source in one zone would have minimal (if any) impact on other zones. It appeared that the garage exhaust fans were drawing air from the zones through the stair and elevator shafts. The restrooms were all negatively pressurized relative to the occupied space.

Carbon Dioxide

During Phase 3 (after building occupancy), all of the measured carbon dioxide levels were below the project reference value of 1000 parts per million (ppm). The only exception was on the sixth floor in the area served by an air handler with a broken outdoor air intake damper. The maximum carbon dioxide concentration measured in this zone was slightly greater than 1000 ppm.

Carbon Monoxide

All interior concentrations were below 2 ppm, which is well below the project reference value of 10 ppm. Based on the concerns of building management, an automated carbon monoxide monitoring system was used to monitor the possible transport of carbon monoxide from the parking garage into the daycare center that is located adjacent to the parking garage. Data was collected continuously for approximately two weeks, and there appeared to be no effect of elevated carbon monoxide levels in the garage on the levels of carbon monoxide in the daycare center.

Formaldehyde

Most concentrations were at or below the reference value of 0.05 ppm; outdoor levels were sometimes as high as 0.04 ppm. During Phase 1 all levels were at or below 0.05 ppm. During Phase 2, the daycare center, auditorium, second floor Library and Conference room exhibited slightly higher levels. During Phase 3, concentrations in the daycare center were at the reference value, and those in the third floor hearing room were approximately 0.10 ppm. While the reasons for these slightly elevated levels are not certain, both the hearing room and the daycare center contain a fairly high loading of pressed-wood products that could be a source of formaldehyde.

Respirable Particulates

The measured concentrations of particles with aerodynamic diameters of 10 micrometers (μm) or less (PM10) were below 50 $\mu g/m^3$ which is well below the project reference value of 150 $\mu g/m^3$. Elevated levels were recorded on the fourth floor during Phase 1 due to smoke generated by welding.

Radon

All measured concentrations of radon were approximately 1 picocurie per liter (pCi/L) or less, which is well below the reference value of 4 pCi/L. This includes concentrations measured in the lowest level of the parking garage.

Total Volatile Organic Compounds

The levels of total volatile organic compounds (TVOC) were well below the project reference value of 1000 $\mu g/m^3$. Only one measurement exceeded the reference value, and that corresponded to the episode of elevated particulate levels on the fourth floor when welding was taking place. During Phase 3, the TVOC levels were all below 300 $\mu g/m^3$. Analysis of the TVOC source strength indicated that the source strength decreased steadily after the base building was complete, even though the systems furniture was installed and the building was occupied. This is an indication that the major sources of VOCs were related to activities and building materials used during the interior build-out and not to the systems furniture or occupant-related activities.

Thermal Comfort

After the building was occupied, thermal comfort was evaluated during August and September by calculating the predicted percent dissatisfied (PPD) from the measured thermal comfort parameters. PPD is an indicator of the percentage of people that will be dissatisfied for a given set of thermal comfort conditions. Based on the assumptions of slightly active office workers wearing summer clothing, all eleven zones had PPD values that were less than the project criteria of 10%. This result indicates acceptable thermal comfort during the cooling season.

Discussion

In addition to providing IAQ performance data in a new office building, the implementation of this IAQ commissioning program revealed several issues that could be helpful in planning and carrying out future commissioning efforts. These issues are discussed in this section and can be categorized as follows: (1) Logistics and jurisdiction, (2) Impact of construction activities, and (3) Equipment and controls problems. The IAQ commissioning efforts in the NRC building also resulted in some unexpected benefits that are described in this section. Finally, based on the experiences in this building, several recommendations are proposed for future IAQ commissioning efforts.

Logistics and jurisdiction issues are related to the fact that the construction of a new building is a complex process involving many people, and that the responsibility for the building and its systems change hands during the construction process. Given the various groups involved in the design and construction of the building and administering the IAQ commissioning program, it is inevitable that some logistical and jurisdictional issues arise. These issues include access to the building by the IAQ commissioners, a lack of familiarity with the HVAC systems on the part of those operating the mechanical systems, responsibility for utility costs associated with system operation schedules required for commissioning, responsibility for repair of system defects, ability of the commissioning staff to obtain up-to-date system design information and information on the construction schedule, and notification of the IAQ commissioners of construction related to change orders.

In implementing the IAQ commissioning program in this building, several issues arose related to the *impact of construction activities*. The process of constructing a commercial building usually involves unanticipated changes and problems that result in unscheduled construction activities and the need to modify completed spaces. An IAQ test period was included in the construction schedule for each zone during which no construction activities were to take place. However, some last-minute construction occurred during these measurement periods. Several of these activities interfered with and delayed the IAQ testing. However, most of these delays occurred in the early phases of Task 3 and were not a factor once the building was ready for occupancy.

Equipment and controls problems with the HVAC system are not unexpected during the construction and early-occupancy phases of a building, and the identification of these problems is a major benefit of commissioning. However, these problems can interfere with IAQ commissioning.

In addition to increasing the likelihood of providing an indoor environment in the NRC building that is acceptable in terms of occupant health and comfort, there were other benefits to this IAQ commissioning program. The process of conducting the tests revealed defects with the HVAC system that may not have been identified until later in the construction process or perhaps well into building occupancy. Another benefit of the IAQ commissioning was the ability to address specific issues of concern that arose during construction and early occupancy based on the building layout, specific pollutant sources, and occupant concerns. For example, occupant concerns were raised regarding the possibility of motor vehicle exhaust entering the daycare center from the adjacent parking garage. Even though this was not part of the original IAQ commissioning plan, an automated carbon monoxide monitoring system was installed to monitor carbon monoxide levels in the daycare center and garage.

Based on the results of the commissioning effort in the NRC building, several recommendations can be made for the planning and implementation of future IAQ commissioning programs. The first recommendation is to start planning the commissioning effort as early as possible, well before the design of the building. The need for an early commitment is true for all building commissioning, not just for indoor air quality commissioning. It is critical that the commitment to commission the building is made before the building is designed by defining the responsibilities of the various individuals and organizations involved in the process. By defining these responsibilities early, quick and effective methods of addressing any shortcomings encountered during the commissioning process can be implemented. ASHRAE Guideline 1 describes the steps in this process for commissioning HVAC systems.

The pre-design commissioning activities should include identifying the logistical needs of the IAQ commissioners in terms of building access, parking, telephones, and the storage of test equipment. The manner in which the ventilation system is to be operated at various stages of building construction and IAQ testing must also be identified, as well as those responsible for operating the ventilation system throughout the construction process. Particular attention must be given to these logistical details at times of transition, for example when the contractors responsible for the base-building construction complete their responsibilities and the next phase of construction begins.

Even though the building construction schedule inevitably changes, specific times should be included in the schedule for IAQ testing. These should be selected in consultation with those doing the IAQ testing to avoid times at which other activities in the building might interfere with the testing. The IAQ testing schedule also needs to be sufficiently flexible to deal with situations in which such confounding activities do occur or in which the ventilation system is not operating as desired. Flexibility of the commissioning program is also important in order to address IAQ concerns that arise during construction or early in building occupancy.

There are three additional considerations that merit discussion with reference to IAQ commissioning: environmental parameters for measurement, contaminant source characterization, and ventilation system operation. Specific guidance in these areas will ultimately be required when developing future IAQ commissioning programs, but the information needed to develop this guidance is not yet available. The environmental parameters that are measured in the program and the reference values to which they are compared are both critical in defining an IAQ commissioning program. The NRC program involved the measurement of several specific airborne contaminants and other environmental parameters, but these are by no means the only contaminants of concern. The concentrations of individual volatile organic compounds and bioaerosols are also important and could have been included in the program at significant additional cost. It is not yet clear which parameters are most appropriate for measurement in an IAQ commissioning effort, and, more importantly, what are the most appropriate target values for the measured parameters. The reference values used in the NRC program were based on the limited guidance that is currently available, but more well-founded contaminant concentration limits specific to the indoor environment are needed.

Another aspect of IAQ commissioning that was not addressed in this project is the characterization of the source strengths of the building materials and furnishings used in the building. In the NRC building, material and furnishing selection was already complete when this study was undertaken and did not involve the characterization of pollutant emissions from the office furnishings and other building materials. It is generally accepted that low emitting products should be used whenever possible, and that material selection should be based on careful and thorough consideration of the potential emissions from materials and furnishings. Ideally, this consideration would involve the characterization of emissions from the products prior to and as a basis for their selection (Levin 1987; Black et al. 1991). However, standard test methods do not exist for measuring the emissions from building materials.

Finally, the manner in which the ventilation system is operated during construction can play a role in minimizing the potential for IAQ problems. Assuming that sources will exist inside the building during construction, higher ventilation rates will lead to lower concentrations and less absorption onto interior surfaces. Various recommendations exist for ventilation system operation during construction and immediately following the completion of construction. These recommendations include implementing a building flush-out period, sealing off the ventilation system ductwork, installing a temporary exhaust system, and maintaining specific pressure relationships between particular building zones. The manner in which the ventilation system is to be operated, any temporary arrangements involving building operation and maintenance, as well as any other requirements must be described in detail in the commissioning program plan. However, additional research is needed to define the most appropriate ventilation strategies in more detail and to identify optimal approaches.

References

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