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CASE STUDY

*[In each issue **IAQU** presents a case study on an investigation of indoor air quality in a particular building. The editorial staff relies on information provided by the environmental consultants involved in the investigation. **IAQU** presents a variety of approaches to investigation and mitigation implemented by consultants with a broad range of experience, philosophies, and expertise. Inclusion of a particular case study in the newsletter does not imply **IAQU**'s endorsement of the investigative procedures, analysis, or mitigation techniques employed in the case. **IAQU** invites readers to submit comments, suggestions, and questions concerning any case. At the discretion of the editors, correspondence may be presented in a future issue. This particular case involves a pro-active evaluation of the building in questions, and is not related to building problems of complaints. Information was excerpted from public reports filed by the researchers.]*

Diagnostics Evaluate Building Design Before and During Occupancy

When designing buildings for acceptable IAQ, the goals are usually to find cost-effective ways to improve the indoor environment and reuse occupant productivity. However, to evaluate whether these goals have been achieved, investigators need to both establish and measure building parameters.

One such approach has been taken by the US government in constructing advanced technology office buildings. To achieve this, the General Services Administration (GSA) contracted with the Building and Fire Research Laboratory at the National Institute of Stan-dards and Technology (NIST), which developed specifications for thermal and environmental performance of new office buildings.

These specifications include measurement techniques for determining how well the building meets performance objectives. One building to which these techniques are being applied is the Federal Records Center (FRC) in Overland, Missouri. This case is taken from a report — by Andrew Persily, W. Stuart Dols, and Steven J. Nabinger — detailing the results of the building evaluation from initial occupancy until after full occupancy.

Building Description

The FRC is a government facility consisting of two buildings, an older structure built in 1956, and the newer one, which is the subject of this study. Construction of the new facility began in 1988 and occupancy began in 1990.

The building contains seven floors, five above grade designated Levels 1-5, and two below, designated B1 and B2. With a total floor area of 378,000 square feet (ft^2), the building has a total volume of about 4,570,000 cubic feet. The new structure connects to the old through doorways on the first, third, and basement levels.

Most of the building contains open office space with partitions for individual workspaces. However, it includes some private offices, conference rooms, and classrooms. These all feature floor-to-ceiling walls.

In addition, Level 1 contains a two-story-high meeting hall and Level B2 contains a large computer facility. The building is square with a skylit atrium extending from Level 1 through the roof. Mechanical rooms are located on the east and west corners of each floor. See Figure 1 for a typical floor plan.

HVAC Description

The FRC ventilation system consists of 30 supply fans with a total capacity of 440,000 cubic feet per minute (cfm), corresponding to about 5.8 air changes per hour (ach). However, the fans are controlled never to exceed 60% of their rated capacity, making the actual capacity 264,000 cfm or 3.5 ach. Design value for minimum outdoor air (O/A) is 58,700 cfm or 0.77 ach. The authors note that, assuming an occupancy rate of one person for each 143 ft^2, the air change rate would be well above the ASHRAE recommendation in Standard 62-1989.

The ventilation system is zoned horizontally. Each of the two mechanical rooms on each floor contains two air handlers connected to a common supply duct that serves one side of the building.

Each fan serving Levels 1 through 5 has a design airflow capacity of 16,000 cfm, giving a total supply capacity of 64,000 cfm on each floor. The basement fans are rated at 12,000 cfm each.

Minimum O/A intake for each system is 6,400 cfm on each side for Levels 1 through 5, 3,200 cfm on each side for Level B2, and 4,800 for Level B1. The supply airflow capacity for the atrium air handlers is 24,000 cfm, and the minimum O/A intake is 4,800 cfm.

Return air flows directly into the mechanical room, where it is mixed with the O/A. This makes the mechanical room part of the return air system. See Figure 2 for the layout of a typical mechanical room.

Diagnostic Center

An important facet of this study was the establishment of a diagnostic center that the researchers used to monitor the building's environmental performance.

The diagnostic system draws air for sampling from 52 locations in the occupied space and another 40 from areas in the mechanical systems and the outdoors. Most locations are connected to the diagnostic center with 3/8-inch polyethylene tubing. However, one location on each floor is connected with copper tubing for sampling particulates and volatile organic compounds (VOC).

Mechanical system samples come from both the return air and supply air, while outdoor air samples come from about a foot outside the O/A intake grilles.

Sampling tubes run through junction boxes on each floor into a main junction box in the diagnostic center, where jumpers allow for a variety of sampling schemes. In the diagnostic center, 20 pumps draw air for tracer gas and pollutant monitoring.

Other sensors measure temperature, relative humidity, and outdoor wind speed and direction. The diagnostic center also monitors fan status.

An important element of the center is the tracer gas system that transports sulfur hexafluoride (SF_6) to 15 injection locations. The center also contains three microcomputer-based data acquisition and control systems.

Investigation

The researchers initially studied the building in early 1990, before occupancy and during early occupancy. They repeated the studies from late 1990 to 1991, during partial occupancy and after full occupancy.

Measurements included the thermal performance of the building envelope, radon, formaldehyde, CO, CO_2, and VOC.

Using infrared inspection with the building unoccupied but heated, the researchers found no major thermal defects in the building envelope, and only minor heat loss areas due to air leakage and thermal bridging.

A whole-building pressurization test determined the air-tightness of the building envelope. The test involved turning off all exhaust and relief fans and sealing them. Air was then brought into the building through the air handlers and could leave only through leaks in the envelope.

The researchers compared the results of the test with seven other new buildings studied. The

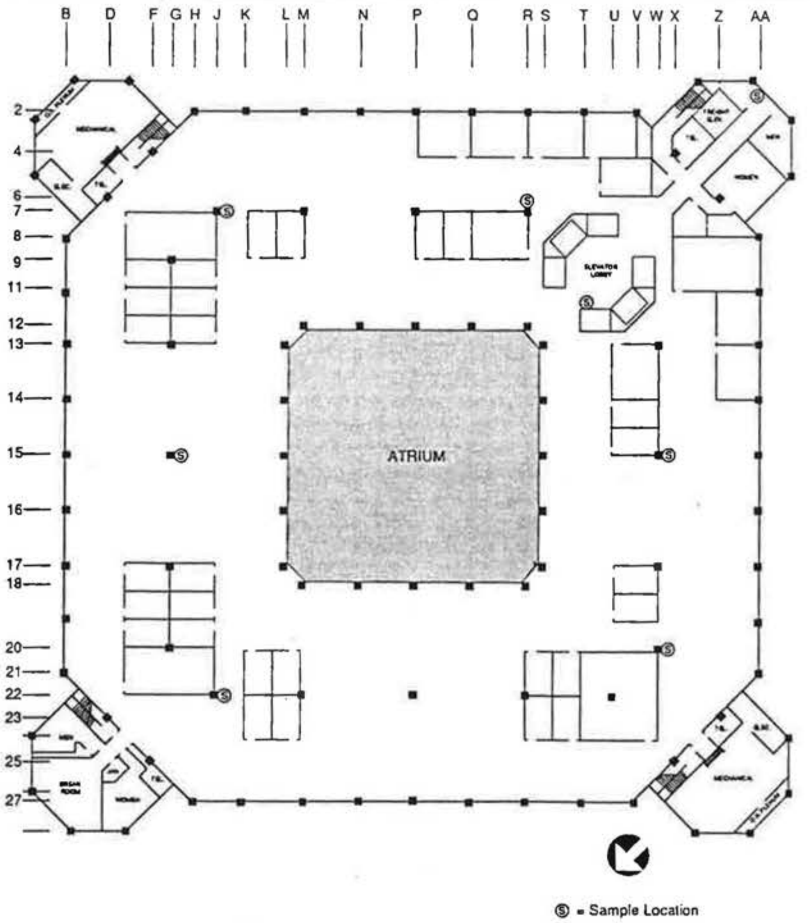

Figure 1 — Typical Floor Plan

FRC scored poorly, showing a leakage rate of 1.96 ach at 25 pascals, while the other buildings to which it was compared scored between 0.45 to 1.45 ach. After correcting for some inconsistencies, researchers calculated a rate of 1.55 ach for the FRC, still elevated in comparison to the other new buildings.

Researchers also used tracer gas techniques to measure air infiltration, the amount of outside air that enters the building uncontrolled through the building envelope. Initial results indicated an infiltration rate of 0.2 ach, but the investigators acknowledged that these were preliminary results and needed to be updated once the measurement system was fine-tuned.

First IAQ Assessment

To measure radon concentration in the building, researchers deployed about 30 charcoal canisters in various locations, covering all seven floors. These canisters have a lower level of detection of 0.3 picoCuries per liter (pCi/l). Despite the fact that radon enters a building through the soil, the researchers explained that the gas can move to all floors through vertical shafts and chases. The highest levels of radon detected during the August 1990 sampling were in the basement level, and all registered between 1 and 2 pCi/l, below the US Environmental Protection Agency's action level of 4 pCi/l.

Subsequent radon tests in June 1991 and January 1992 showed considerably lower levels, leading the authors to speculate that either a higher air-change rate or lower entry rate had reduced radon levels.

Formaldehyde

Formaldehyde measurements took place over a six-day period in August 1990, using sodium bisulfite passive monitors, which have a minimum detection level of 0.01 parts per million (ppm) and a precision of 15%.

At the time of the measurements, the building was unoccupied, but the air handlers were operating during the daytime with no O/A intake. The handlers were off at night. Building furnishing had been installed from one to four months earlier.

The monitors sampled locations on all seven floors and showed results that ranged from 0.02 ppm to 0.07 ppm. The report notes that levels above 0.1 ppm are considered a cause for concern and levels below 0.05 are generally considered to be of no concern.

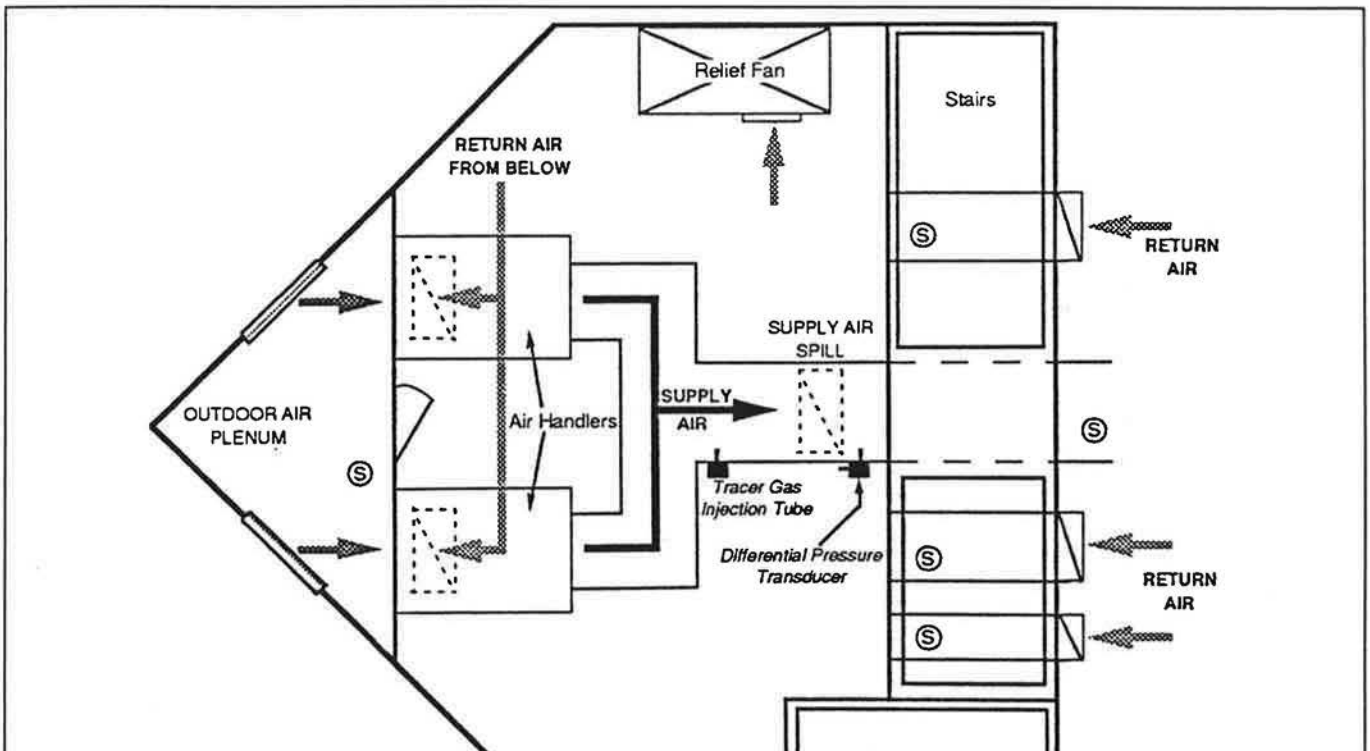

Figure 2 — Typical Mechanical Room

The authors also included in their report that the results, while falling within ASHRAE guidelines, should still be viewed with concern. On the other hand, concentrations measured in conference rooms, where the researchers had expected higher results because of the preponderance of pressed-wood furniture, were not significantly different from other areas of the building.

When the formaldehyde sampling was repeated in June 1991, all the concentrations, except one, were below 0.05 ppm. Researchers speculated that the lower levels came from the effects of running the building's ventilation system, the aging of the formaldehyde-producing furnishings, or a combination of the two.

Results from both the August 1990 and June 1991 formaldehyde sampling are shown in Table 2.

Carbon Dioxide

Because the major source of CO_2 in a building is the occupants, preoccupancy measurements — or measurements during partial occupancy — aren't enlightening.

Researchers began monitoring the CO_2 levels in November 1990. As expected, the CO_2 levels began to increase as the occupancy increased, and original readings of 400-500 ppm gradually increased to as much as 800 ppm. During this time, the ventilation system was operating with O/A intake.

The researchers noted some CO_2 spikes and, while some of them occurred late in the day, they occurred too late to be connected to motor vehicle exhaust during commuting hours. Records indicated that the spikes occurred coincidentally with wind directions from the north and northwest. Researchers were unable to determine the source of the elevated CO_2 levels.

CO_2 measurements during full occupancy showed values between 400 and 1,400 ppm. The higher readings occurred on days when the air handling units were not operating as specified. Researchers still detected spikes late in the day that correlated to wind direction.

Carbon Monoxide

With no known source of CO in the building, researchers weren't surprised to find relatively low concentrations that tracked the outdoor levels. These usually fell into the 0-2 ppm range, well below the National Ambient Air Quality Standards level of 9 ppm.

CO spikes in the outdoor air late in the day also coincided with winds coming from the north and northwest.

Volatile Organic Compounds

Researchers measured VOC using active sampling on a sorbent followed by gas chromatography/mass spectrometry. They carried out tests on two dates in June 1990 and July 1990, both times with the ventilation system operating with no O/A intake. During both tests investigators took one measurement from each level and one from outside.

Table 2 — Formaldehyde Concentrations in the FRC (in ppm)

Sample Location	Level	Aug-90	Jun-91
Room 599 - Conference room	5	0.07	0.03
Room 599 - Conference room	5	0.07	0.02
Room 510 - Conference room	5	0.07	0.02
Column G15	5	0.07	0.02
Column R22	5	0.07	0.02
Room 499 - Conference Room	4	0.06	0.04
Room 499 - BLANK	4	0.01	
Room 410 - Conference Room	4	0.06	0.04
Column J22	4	0.06	0.04
Room 399	3	0.05	0.03
Room 310 - Conference Room	3	0.04	0.02
Room 310 - Conference Room	3	0.04	0.02
Column R22	3	0.07	0.03
Column G15	3	0.06	0.02
Room 210 - Conference Room	2	0.04	0.06
Room 210 - BLANK	2	0.01	
Column P22	2	0.03	0.04
Column G15	2	0.02	0.04
Meeting Hall B	1	0.04	0.03
Room 145 - Conference Room	1	0.03	0.03
Room 145 - Conference Room	1	0.03	0.03
Column P22	1	0.04	0.04
Column S17	B1	0.03	0.02
Column N14	B1	0.03	0.02
Column N14 - BLANK	B1	0.00	
Room 168	B1	0.03	0.02
Computer Room	B2	0.06	0.03
Column J22	B2	0.07	0.03
Hall by Column P7	B2	0.06	0.03

Source: Persily, Dols, and Nabinger

As a result of the tests, 95 VOC were identified, most of which have been recorded in other building studies. From the results of the June test, researchers calculated TVOC levels for the various floors, ranging from 520 micrograms per cubic meter (mg/m^3) on Level 2 to 5,020 μg/m^3 on Level B1. While no official guidelines for TVOC are in force, some researchers have suggested that levels should be below 1,000 g/m^3.

Of the most common VOC measured, researchers determined that 7 had a source outside the building, 18 were related to building materials, 30 came from activities — most likely construction — within the building, and the source of 3 was unknown.

In the July test, researchers recorded mixed results, finding generally higher VOC levels outdoors. This, they hypothesized, might have come from the placement of the sampling location, which in the second test was nearer the door and may have recorded some inside VOC.

Discussion

This fairly exhaustive diagnostic approach to a building in the early stages of its occupancy was not in response to a problem or anticipated problem. The value of such a study will be in providing much-needed data on how building parameters relate to occupants' perceptions of IAQ in the building. When building investigations take place as a result of problems or complaints, investigators often lack baseline data to which they can compare the findings of their investigation.

One important feature of the investigation is the creation of the diagnostic center and the multiple sampling locations that allowed researchers to continually monitor and analyze contaminants and IAQ within the occupied space.

For more information on the FRC investigation, contact Andrew Persily, NIST, Building Fire and Research Laboratory, Gaithersburg, MD 20899, USA; (301) 975-2000.

NEWS AND ANALYSIS

Helsinki Conference Attracts Worldwide Attendance, 690 Papers

Many of those attending Indoor Air '93 in Helsinki, Finland, in early July agreed that the conference demonstrated both a growing concern with IAQ and a maturing of the research approaches to indoor environmental problems.

More than 1,300 persons from a variety of disciplines and from six continents had access to 690 papers on subjects ranging from cleaning HVAC systems to the increasing threat from microbes. Concurrent sessions — as at many such conferences — meant that those attending had to choose among the various offerings, often a difficult choice.

While some people expressed disappointment that there was little information presented of a revolutionary nature, many IAQ veterans said they were encouraged by the increased interest and the direction that IAQ research is taking.

Conference organizers said they had received over 1,000 abstracts of papers offered for presentation and narrowed the list down to the 690 that were given, either in oral presentation or poster form.

For many attendees, the most productive sessions at the conference were the daily workshops, concurrent sessions each afternoon that focused on specific issues. These consisted of panels of experts and active audience participation, with all concerned trying to come to a consensus on current issues of discussion in the IAQ community.

Keynote Address

An appropriate tone for the conference was set by Dr. Jonathan Samet of the University of New Mexico, USA, who in his keynote speech addressed IAQ concerns from a public health perspective.

He observed that indoor pollution may be not only a common cause of frequently reported symptoms, but that a growing body of evidence indicates that IAQ problems may account for an increase of lung and other cancers.

He also addressed the thorny conceptual question of how to categorize or characterize "adverse health effects." This is a controversial area, at best, not only for IAQ research, but in other areas of health concern. At the core of the