MARY'S STORY

A Lab Design Gone Wrong

"Mary" is a person who suffered terrible health problems, most likely stemming from the design conditions in a lab in which she worked. Designers everywhere can learn from her experience.

By JERRY KOENIGSBERG

I first became aware of Mary (not her real name) and her plight about a year ago, when she contacted me, asking for help. She was looking for someone who might be able to visit her laboratory and figure out why she and her coworkers were getting sick. What intrigued me about her story was that even though her laboratory was relatively new, quite small, and housed people working on repetitive analytical operations (unlike those performed in a research center), the staff was experiencing significant and diverse health problems. This was occurring at a time when we have more laws, codes, regulations, and standards than ever before. So what went wrong?

Anyone involved in the design of laboratory facilities is keenly aware of the myriad diverse issues that must be addressed during the design process. However, rarely are we exposed to the ramifications of these life-and-death decisions because few members of the design team get to visit the completed project. Laboratory design is an art form, not a textbook exercise that merely strives to meet all current codes, standards, and regulations. If that were the case, this disaster never would have happened. Mary's story gives us a unique opportunity to put ourselves in both her and the design team's shoes to gain insight into the potential impact that design decisions may have on the heath and safety of a building's occupants.

IN MARY'S WORDS

My story is one that never should have happened. It is the tale of good intentions gone wrong, of denial, of people's lives changed forever ... a story of frustration, wasted money, intimidation, threats, and silence, with a conclusion that has yet to be written. It is a story that is hard to tell, one that, as I look over the reports, memos, and personal accounts of the last five years, seems like a bad dream. Why did all this happen in the first place?

I have a comprehensive analytical background. I graduated with a bachelor's degree in chemistry in 1963 and have worked as a cancer-research scientist and a residue analytical chemist. For the last 15 years, I have worked in the field of environmental chemistry and in May 1999, I received a bachelor's degree in environmental health and safety.

In the late 1980s, I took a Civil Service test for the position of senior laboratory technician, environmental chemistry, and passed. In 1990, my town made plans to establish a permanent household-hazardous-waste drop-off site at the local waste-water-treatment plant. Because I had a great deal of knowledge in that field, I was hired.

The laboratory I began working in was the second one built at the plant, which opened in the early 1970s. In the '80s, prior to my arrival, the laboratory was moved from the main administration building to another structure situated at a remote location. I was told that the primary reason for relocating

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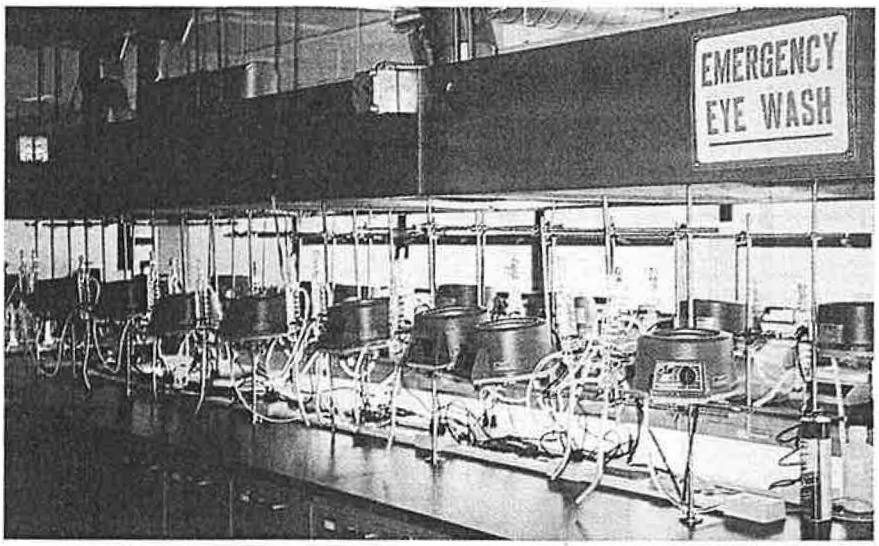
the laboratory at that time was that administration people routinely complained about the foul odors that emanated from the lab and spread throughout the building.

The building selected to house the second-generation lab was originally designed and operated as a production and storage facility for sodium hypochlorite, a chemical used to chlorinate the plant effluent going to the receiving stream. The building became available when plant management opted to purchase sodium hypochlorite from outside vendors and store it in tanks located in one of the building's back rooms.



Canopy hood with laboratory equipment below. The intended purpose of locating a large canopy hood over this laboratory bench was to exhaust fumes generated from distillation apparatus involved in ammonia and phenol analysis and for color development of cyanide tests using pyridine. Note the striped ribbon attached to the hood hanging straight down, indicating a lack of air movement.

When I arrived to begin work, I was shocked. In my 15 years of environmental-lab experience, I had only once been in a more poorly designed lab facility. It was obvious that very little thought went into its planning and execution. Rather, it appeared to have been thrown together just to get it out of the administration building as quickly as possible with minimal cost.

Many of the original auxiliary-air fume hoods were relocated to the new facility. Unfortunately, no one thought about tempering the makeup-air component when they re-installed the hoods. There were times during the winter when the incoming air was so cold that sample preparation procedures involving acid digestion did not work properly, resulting in serious operational problems. Additionally, since the laboratory's space pressurization was so negative, we were routinely aware of chlorine odors that were being sucked in from the sodium-hypochlorite storage facility. Also, it was obvious that we were experiencing re-entrainment of lab exhaust through the fume hoods' makeup-air system—we could smell it.

Six of us worked in this facility under these conditions. Anyone who visited us could see that we desperately needed a new facility. The hoods were corroded, with small pieces of rusted metal routinely falling into the samples. Also, acidic condensation from inside the hoods and ductwork was dripping down.

In light of the deplorable conditions, management requested that we write a justification report for a new facility. Based on our efforts, funding for a new lab was approved. They decided the new lab would be located at the site of the original administration building, which was going to be remodeled as part of the project. Given the size of the proposed laboratory, management decided to house it in a new wing.

The administration building was a small, one-story facility located across the driveway from the dewatering building, a four-story structure in which water was removed from sewage sludge (once dewatered, the sludge was loaded into large boxes and hauled offsite). The building also housed machinery that turned digested sludge into fertilizer pellets. There were several emission stacks on the roof, with a scrubber system in place to support these functions. As it turned out, these factors would seriously impact the new facility's performance.

Management solicited comments from lab personnel about items such as hoods, sinks, bench tops, and instrument location. They also sought advice from the director of workplace health and safety programs, school of industrial and labor relations, at a major university. This person was uniquely qualified to discuss the facility's needs because she was both a certified industrial hygienist and a licensed waste-water-treatment-plant operator. It was later said that her initial report including recommendations for the ventilation system (as applicable to a wastewater-treatment laboratory) was "unfortunately lost." We learned this several months after we made numerous complaints about the new lab.

We thought we were going to be involved throughout the entire design process. Unfortunately, that didn't happen. As the move-in date approached, we began to visit the new facility. We were both surprised and disappointed that many of our requests had been ignored. For example, changes in the room sizes, which resulted in crowded work conditions and difficulty servicing some of the instruments, were made without our knowledge.

The lab design consisted of a large, general room with five smaller rooms located at opposite ends. The smaller rooms were designated for the more specific waste-water tests. The facility had two offices, a sample receiving area, and a chemical-storage room.

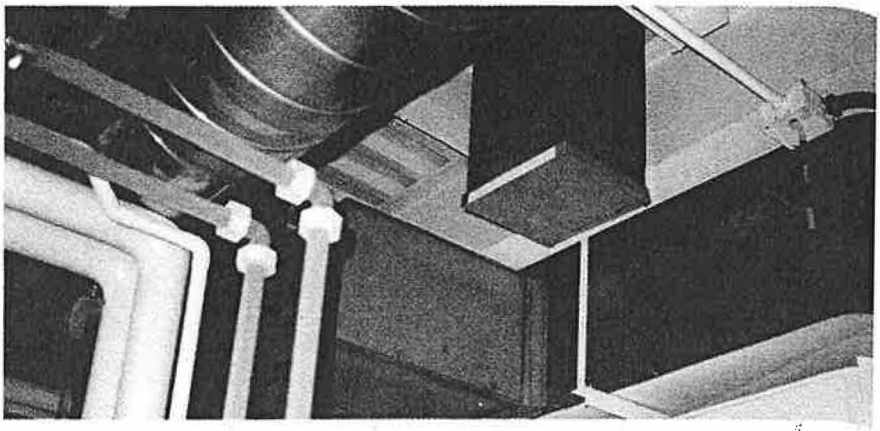
Because the designer opted to eliminate the suspended ceiling, we had a clear view of the ductwork, along with its joints, twists, and bends. The exhaust system looked like a rat's maze, with four to five bends in some places

as it headed for the main manifold exhaust duct. The ductwork material appeared to be galvanized steel. It wasn't epoxy-lined, nor was it made of stainless steel. I don't know who made this decision because we had recommended stainless steel.

The HVAC system incorporated a heat-recovery wheel to save energy. The system design required all laboratory exhaust (room and hood) to pass through this air-handling heat wheel to pre-treat the ambient supply air. We later learned that the heat-wheel technology selected by the designer allowed up to .04 percent, or 400 ppm, of contaminants to be returned to the supply-air system. This unit was housed on the roof and had a 3-ft-high vertical exhaust stack. The air intake for the makeup air was located at the end of a heat-exchange unit. The intake faced east, directly across from the dewatering building and the box-removal area.

In September 1994, our move-in day arrived. Our 6800-sq-ft lab looked like a showplace, as it could have been featured on the cover of a lab-design manual. Excessive noise in the laboratory space was our first complaint. We were told that additional adjustments and balancing would be made shortly to bring down the dB level. Within days, the contractor attempted to adjust and balance the ventilation system, but had little success. Although it was still quite noisy, it was tolerable.

There were other indicators of design flaws—things that had nothing to do with the ventilation system. For example, one of the sinks had an electric-eye control for the water. With the faucet located directly over the divider in the double sink, water splashed everywhere when the faucet was turned on. Additionally, many of the faucets on other sinks were installed backward. It was a real hassle to get them changed, as the manufacturer's representatives told us that lab faucets are supposed to turn in the opposite direction of those at home. It took months to get this resolved. I recall that our own plumbing department finally finished the conversions. It was interesting that more than half the faucets were installed correctly, but that problem was never addressed. Is it any wonder that as more and more problems arose, we became more concerned? If some of the basics were so wrong, what about the major items?



Black and yellow streamers were placed in different areas of the lab and indicated an uneven air flow. Also various duct work for exhaust and air intake vents are visible.

Several months later, we discovered odors emanating from the large acid-neutralization sump located in the lab. Apparently, the contractor had used ordinary rocks instead of marble chips. For nearly six months, the effluent had not been treated as planned.

Complaints of poor air quality continued to surface. Streamers that were hung from various vent sites revealed an uneven air flow. The lab director was on the phone every day with the town engineers and the HVAC contractor with odor and noise complaints. Something was being checked or adjusted nearly every week, yet the problems continued.

On October 1, 1994, our lab director implemented a system for employees to report problems. The reports included complaints such as health problems, noise, odors, uneven heating and cooling, and ventilation warning lights and alarms going off.

In early February 1995, due to continued complaints by our lab director, the consultants performed smoke-bomb tests in the lab hoods. One of the side rooms in the lab was the inorganic prep room, which was used for the digestion of waste-water samples for total phosphorous/total Kjedahl nitrogen (TP/TKN) and metals. The TP/TKN procedure called for digesting the samples at a temperature of up to 680 F with a sulfuric-acid/mercuric-oxide mixture. The other hood in the room housed the metals-digestion operation, which used concentrated nitric, sulfuric, and hydrochloric acids. This room was a real source of odors and irritation to some personnel. The hoods didn't appear to trap the fumes from the processes.

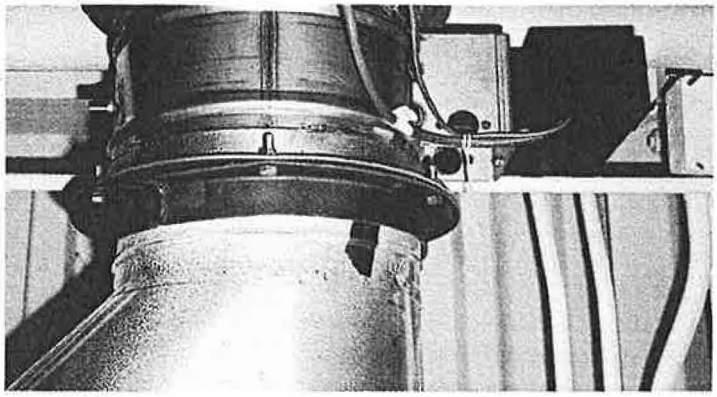
On the day the smoke-bomb testing took place, I went outside intending to observe the smoke coming out of the exhaust. There was none. When I went back into the lab, it was filled with smoke. The smoke had come out of the top of the hoods instead of exhausting out. This was only five months after the lab opened—five months during which we were exposed to various unknown fumes and gases.

On the ninth day of February I became ill from the fumes in the lab. I was given oxygen and taken to the emergency room. Gradually, I began to react more often and with increasing symptoms while working in the lab. Numerous incident reports in February contained a litany of complaints that all pointed to ventilation problems.

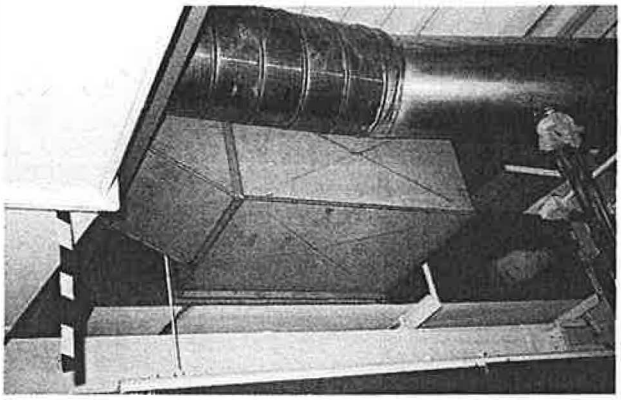
Around this time, I noticed a greenish, acidic liquid dripping from the duct outside the prep room. We later discovered it was the result of corrosion. After only five months of use, corrosion had eaten through the duct. Evidently, there was insufficient air flow through this part of the system and condensation of acid fumes from the process.

All concerned parties met to evaluate the heat-recovery unit. They discovered that the rubber seals on the unit were damaged—which possibly could have happened in transit to the site—so they were replaced.

In March 1995, representatives from all companies involved again were in the



Exhaust ducts located over the cyanide distillation hoods. Corrosion and separation of the ducts is visible. This picture was taken within one year of installation, June 1996.



Portion of the air intake (straight line ducts) and the exhaust system (round ducts). Note the streamer indicating a lack of directional air flow normally required to suppress contamination in the laboratory.

lab. They performed a test that "confirmed that the heat wheel or ventilation system was allowing re-circulation of contaminants into the air space." Discussions were held as a result of the testing and the evidence of corrosion in the ductwork. In a follow-up memo to the HVAC contractor, the heat wheel manufacturer strongly recommended that two or three of the hoods be put on separate coated or fiber-glass fans. The manufacturer also said it couldn't warrant the system against the effects of corrosion to fans, motors, bearings, etc., given the current system utilization. Our laboratory director couldn't believe it. The consultants knew what kind of testing we did at the lab before they designed the facility. The number of analyses we performed was very small compared to what contract laboratories typically performed.

The memo went on to say that having our testing done outside would give us flexibility and peace of mind. Why didn't they recommend this earlier? The decision was made to stop all testing that used acids. All plant and pre-treatment samples that involved a digestion step were sent to an outside contract laboratory. This was very expensive, as many of the tests we contracted out required rapid turnaround and were billed at a premium rate. This outside contracting of certain tests lasted for 11 months. We were told that it was taking that long to get the new ductwork fabricated and other modifications completed. It later was testified during a hearing that my employer allowed the consulting firm to take that much time because the consulting firm's insurance carrier wanted the firm to make substantial changes to the system.

The consulting firm decided to remove the heat wheel and replace it with a non-contact heat-exchange system. The firm said it did this so future claims would not be focused on that particular technology, which might drag my employer into litigation in the future. However, the heat wheel remained in place and was used for another year, during which time we continued outsourcing certain tests. The remedial act of separating venting of the inorganic prep hoods was completed at the end of 1996, when we began running all tests in-house again.

Complaints from lab personnel—not just about health-related issues, but problems relating to the mechanics of the ventilation system—continued. There were reports of the hood alarms going off for no apparent reason and at times when no one was in the lab. The main control alarm for the ventilation system was showing intermittent failure. On most mornings, it was obvious from the stale air and odors in the lab that there was a lack of fresh air and improper movement of air. Later, it was discovered that the system went into setback mode at night.

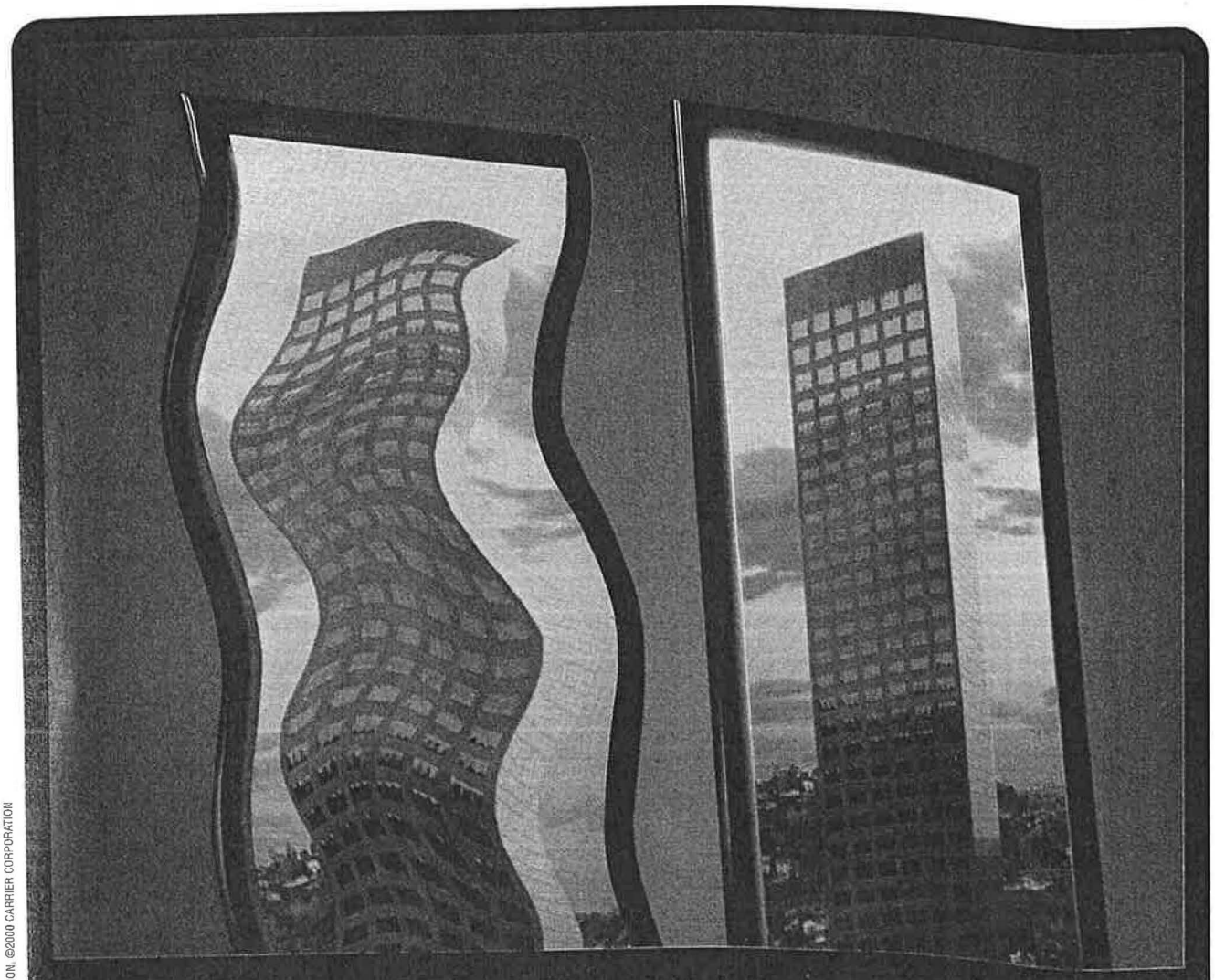
In April 1995, my employer brought in an air-testing firm, which decided to again replace the heat-wheel technology. However, it wanted answers with respect to any contaminants that might be present before any modifications were made. My employer told the company what to test for.

The testing was performed that same month. On the day the tests were performed, we conducted business as usual, running all the analytical procedures we normally ran each day. Employees reported headaches and skin and respiratory problems. Even the industrial hygienist reported that irritating odors were present throughout the lab.

The test results revealed levels well below the Permissible Exposure Limits set by the Occupational Safety and Health Administration (OSHA). The tests performed were for the acids we used, some heavy metals, and a few organics. (Later two other sources said that testing for ammonia compounds—especially sulfur compounds—should have been included because our lab analyzed waste-water-treatment plant samples. They also said that the testing firm should have measured for particulate matter. The firm admitted much later that, in hindsight, it should have used a portable gas chromatograph to measure for possible compounds created in the thermal destruction of the sludge cakes during the drying and volatilization process.)

When testing was completed, the firm recommended extending the exhaust stack located on the air-handling unit to get it further away from the unit's intake. Standing only 3-ft tall, it violated the municipality's own building code. It was raised to 12 ft a few months later.

The firm's second recommendation involved modifying the intake again to increase the separation distance between the exhaust and the intake. This was to be accomplished by installing a diverter to shield the air intake. Origi-



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nally, the installation was delayed because the consulting engineers had elected to replace the heat-changing component within the air-handling unit, which required a number of modifications. Somehow, the diverter installation never came about.

The testing firm also recommended additional balancing. (While experts recommend re-balancing whenever changes are made to a system, our system wasn't balanced very often—even though it was altered a great deal.) Furthermore, it found our noise level to be 64-68 dB. This was below the OSHA limit, but annoying to us nonetheless. Time moved on, yet the problems continued.

In March 1995 my health problems were diagnosed as work-related. I had been to several doctors, none of whom could explain what was happening to me, especially since the symptoms would only occur at work. I finally consulted Dr. L, a board-certified occupational medical doctor. He put together all the reports from doctors, read all the incident reports, reviewed all the procedures performed in the lab, studied the chemicals involved, and was able to relate my symptoms to a diagnoses of occupational disease. The diagnostic codes included toxic effects of unspecified gas/fumes, asthma, unspecified/allergic bronchitis, rhinitis, and airway irritation. Dr. L's office was quite a distance from my home; so I went to local doctors for treatment.

My health problems worsened. In April 1995, I was diagnosed with obstructive sleep apnea. With conventional treatment not successful, the doctor who diagnosed this recommended surgery to remove reactive tissue from my upper airways. He believed that the work exposure was causing the tissues to swell and that if they were removed, I would have an easier time breathing. It was also thought that with the surgery, I would be able to continue to work without any problems.

Dr. L wasn't keen on the idea of surgery, the reason for which I later became painfully aware. I underwent the surgery in June and returned to work about two weeks later. Within days, I was in terrible pain. The air in the lab irritated my airways more than ever.

Around the time of my return, the consulting firm was back in the lab for further observations. One of the project managers went up on the roof. He stated that he could smell the odor of the sludge cakes coming out of the lab exhaust. The wind direction was such that the exhaust was being pulled into the air intake. At this point, the exhaust stack had not been raised nor the air intake shielded. The exhaust stack was raised in August, but nothing changed for me.

I was in and out of work that summer. I saw Dr. L in September. He removed me from work, saying I was not to return until remedial actions were taken in the lab. I went on an unpaid

leave of absence. I received a letter from my department head in January 1996 stating that I was to return to work. I asked for clarification of what had been done to mitigate the ventilation problems. The only information I received was a letter stating that all the recommendations had been completed and the final balancing had recently taken place. Dr. L requested a letter stating exactly what had been done. He never received an answer. He sent another letter stating that he could not approve my return without this information. Again, he received no answer.

I then received a letter threatening me with the loss of my job unless I returned immediately. I asked for—and received—a letter from Dr. L stating that he would allow me to return on a trial basis, providing the heat wheel had been turned off. I was told that it was turned off in late February and that alternate means of supplementing the heat were being used. This supplemental heating involved the use of several ceramic space heaters. I returned to work on April 30, 1996.

The State Dept. of Health (DOH), Bureau of Occupational Health, inspected the lab during my leave of absence. The inspection was initiated by the DOH at the request of our union. The DOH's report to my employer said that in regard to accepted laboratory design principles, the heat-recovery wheel should not have been used within the laboratory ventilation system and that materials exhausted through the laboratory hood system should have been discharged of in a way that wouldn't contaminate the supply system. (At this time, some of the air was being recirculated. The heat wheel was still in use. It was shut down the following month.)

The DOH investigators also found that the exhaust discharge for the chemical-storage room was below and adjacent to the supply-air intake for the laboratory—another example of an exhaust discharge stack that was not in accordance with recognized design principles and applicable building codes.

My respiratory problems gradually worsened with my return to the lab. It seemed to take forever to do any modifications. We would open windows and doors to bring in fresh air to try to alleviate symptoms and used fans to circulate the air. Certain areas of the laboratory appeared to have dead pockets where the air quality was particularly poor. We knew that a balanced system is set with the windows and doors closed. Unfortunately, there were times we felt ill without the addition of this fresh air. The consulting firm granted permission for this "open" policy; however, it was rescinded in May 1996 under suspicious circumstances. We continued to use fans to circulate the air as needed. The lab director was constantly monitoring lab temperatures, observing quirks in the

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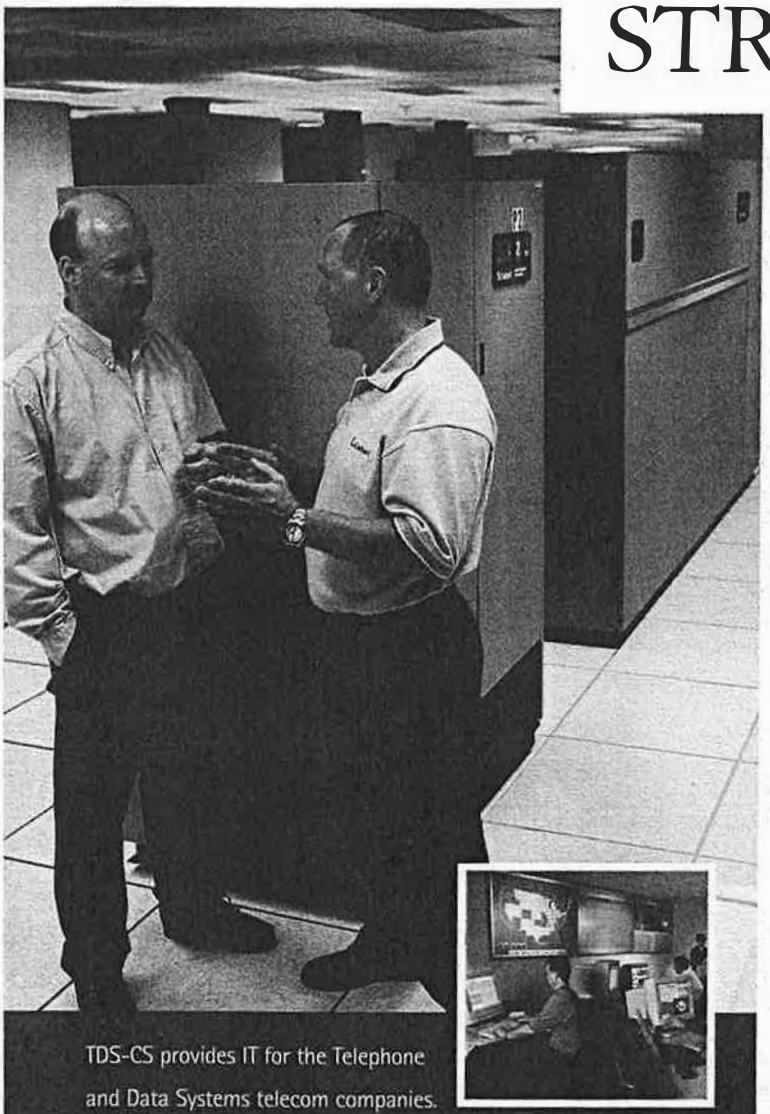

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ventilation system, and reviewing the constant flow of incident reports. At this point, the heat wheel had been off for months. Still the complaints—chlorine odors, diesel fumes, sludge odors, unknown odors, noises from the HVAC system, malfunctioning alarms, uneven heating and cooling—kept coming.

In response, the firm would adjust the belts on the system, change the filters, open a damper, close a damper, set the thermostat, change the thermostat. Still, the problems waxed and waned.

The heat-recovery wheel was finally removed during the summer of 1996, about two years after the lab opened. Someone heard the workers who removed it say they could not believe it was less than two years old based on the corrosion inside.

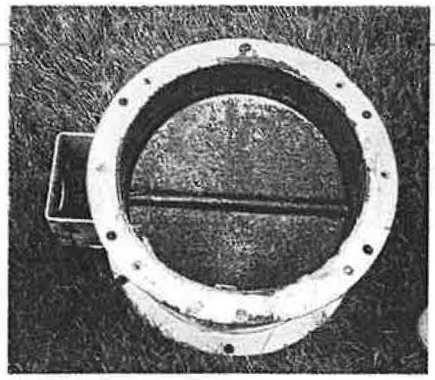
Around the same time, a non-contact heat-exchange unit was installed and became part of the existing air-handling unit. Meanwhile, employees continued to file incident reports, complaining of heavy, odorous air; lab temperatures in the high 70s and 80s; high humidity; respiratory and skin irritations; "backdraft" from the hoods; and intermittent chlorine and hydrogen-sulfide odors.

At one point, someone noticed that the unit was sucking air out of the lab, but not bringing fresh air in. They discovered that the air was being exhausted at a rate less than the 5300 cfm necessary for proper system operation. Then, one of the components shut down for no apparent reason.

There was another problem: The system was not properly cooling the facility and no one had the equipment manuals. This problem was finally solved. A third component to the unit necessary for its operation had never been turned on. Prior to this, we had been told the high temperatures in the lab were due to the high volume of air moving through, that the temperatures we were experiencing were the best we could expect. This is an example of the reasoning that perpetuated these problems.

The lab director continued to investigate in an attempt to create a safe, healthy workplace. In many instances, it was only because of her constant monitoring of HVAC-associated problems that any actions were taken. Coincidentally, her position was eliminated from the 1997 budget, which effectively ended our efforts to improve our working conditions.

The odors were irritating to me because of my sensitivities. I always had at least one air filter running on my desk. On some days, I had two. I experienced symptoms of reactive airway disease and was taking medication every day. I informed my supervisor of the problem and basically received the same response I received in the lab—silence. My office area also had heating and cooling problems. I would be very cold, while the office behind me would be extremely warm. The thermostat



Picture of a segment of an exhaust assembly removed from the canopy hood over the sink in the inorganic prep room after less than one year of service. This was from one of the hoods that went on separate exhaust due to corrosion in the duct system. A pH was done on the assembly and it registered as very acidic.

did nothing. We discovered that the supply-air diffuser was closed with an inoperable damper—hence, one of the reasons the air was so stale in there.

Eventually, I began to experience cardiac symptoms and more health-related problems. About five months passed and I knew I couldn't work there much longer. I finally admitted to myself that I was in a bad situation that wouldn't improve. It wasn't worth risking my health any longer. In June 1998, my employer offered an early-retirement incentive. In October, I retired.

After about three months of retirement, my cardiac symptoms all but disappeared. My sensitivities to environmental exposures have not gone away, nor is it likely they ever will. From what I hear, nothing has changed with the ventilation system, either in the lab or the building as a whole. Several months ago, I put my former employer in contact with an expert on ventilation. They talked, but, thus far, nothing has happened. I don't know if anything will.

I've been told that the air quality is bad throughout the building and correlates to the heat being turned on. The lab's problems have been numerous and varied. I don't know what the answers are, but I believe it all goes back to the original design. Others who have seen the lab and surrounding area have hinted at the same conclusion.

There is a sense of closure for me. On Jan. 3, 2000, at my workers' compensation hearing, my former employer's representative said they wanted to settle my case. They would state that I had a permanent partial disability resulting from occupational disease related to the workplace. It was a hard-fought battle; however, I had won.

Perhaps now they will take a closer look at the lab's problems and make it a safe and healthy workplace before they have more disabled employees. I sincerely hope that no one else will have to go through what I did.

AUTHOR'S POSTSCRIPT

I had been after Mary for over a year to let me tell her story so the laboratory-design community could learn from her experiences. Unfortunately, because she feared the effect on the outcome of her case, she was reluctant to come forward until her case was settled. With that out of the way, she worked feverishly to get her story out. For that, I believe we all owe her a debt of gratitude and best wishes. ■