The Epidemiology of Indoor Air Problems

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All these buildings have something in common besides being in Seattle. They're all s.o.b.'s. Sick office buildings. In each case occupants felt that the building was causing their health problems. In some of these we could easily figure out what was going on. In others it's still a mystery. This one was just put up. I don't think it's even fully occupied yet, and already they're having problems. Whereas much of the focus of this conference has been on homes, I intend to talk more about offices and other public places. Some of the exposures are similar between the two, some are different. I think we can learn from our experiences in offices about homes and vice versa.

As an industrial hygienist I frequently get called to check out the air. "Help, our building is poisoning us." We are currently experiencing an epidemic of indoor air disease, also known as tight building sickness. We have these problems in Seattle. We have them in Spokane, in the Midwest, in the Northeast, in Japan and Scandinavia. It's not a unique problem here. Some of the things I'd like to discuss during this talk are things I've learned as a result of responding to these kinds of complaints. What I don't go out to do and what I'm often expected to do is go out and sample the air. Instead I follow a protocol which consists of a site evaluation, an interview with the affected personnel, and frequently a thorough walk through of the ventilation system.

Let's consider the experience of NIOSH, the National Institute of Occupational Safety and Health, with indoor air complaints. Before 1979 there were very few investigations, and in the period since 1979 they've increased dramatically. The figures for 1982 and 1983 which show a decrease are probably not realistic in that they've stopped taking and following through on these complaints. They simply don't respond to every request for assistance. I work in the Department of Environmental Health at the University of Washington and our experience has been very similar. Some of these problems are truly frightening in their implications, for the individuals involved and their health, for the building owners and managers. Just to give you one quick example: At a federal office building in a southwestern city the problem was so serious that they decided to rip out the entire ventilation system. They thought that the problem was due to biological contamination. So they ripped out the entire ventilation system, and every ceiling tile, every carpet, every furnishing that they could find in the building. They stripped it down to bare walls at a cost of about 10 or 12 million dollars. And at the end of that process, after people re-occupied the building, it became clear that the problems hadn't gone away. And in fact, some of the ventilation systems that were installed didn't have proper access for preventive maintenance. I've seen situations here in the Seattle metropolitan area where the entire workforce was sent home because they were all sick from new carpeting which was installed. And even in some of the less dramatic cases the problems can continue for long periods of, at times, months or even years without resolution. In one case in Spokane, I spoke with a woman whose physician had prescribed artificial tears because her eyes had stopped tearing due to the constant irritation.

So what's causing the problem? Wouldn't we all love to know. For the investigations completed by NIOSH, the perceived cause of the problem, in 98 of 203 cases, is listed as inadequate ventilation. That is, they believe about half of these problems were due to poor ventilation. And in actuality they never really measured the ventilation in many of these cases. They simply went in and they weren't able to find the specific agent that was responsible and the symptoms were non-specific, so they reached this conclusion. If you look at this 50% and the other 10% where no cause could be identified, we're talking about 60% of these cases where we really haven't identified a specific cause. Not a single, specific agent that we can say is responsible for these problems. So I would say in total we've met with very limited success in dealing with this indoor air problem.

Why have we met with such limited success? What are some of the obstacles and problems to fully understanding this problem? Epidemiological methods can help us link exposures and diseases. Sometimes that linkage is not very clear. What you would like to see is one exposure and one disease. Asbestos is a good example of this because one of the diseases it causes is mesothelioma, a very, very rare and specific tumor. When you see a mesothelioma you look for asbestos exposure, even if you have to dig twenty years back. In indoor air complaints this isn't the case. You will see a tremendous variety of complaints that people have, from mucous membrane irritation, dry skin, dry scratchy throats, to fatigue, back pain, headache, colds and other respiratory symptoms. These are called non-specific symptoms because so many different diseases can result in these kinds of complaints. This is the first reason that attempts to better understand the problem have been unsuccessful. No single disease or symptoms result. The second is that along with many different simultaneous diseases, we have many simultaneous exposures. If you sample the air in these cases, you find that there are maybe hundreds of substances present. I think one of the earlier speakers showed a peak from a gas chromatograph. Frequently more than one hundred chemical substances can be identified in an office air analysis. It would probably take you two or three days to pick out all the different substances that are in there. All are present in extremely low concentrations, sometimes three or four orders of magnitude below the permissible exposure limits. With this many substances present, which single substance or combination of substances is responsible for the complaints? Where are these things coming from? Well, we've talked about some of the sources in the home. In the office there are some similar sources: rugs, also many materials such as room dividers contain treated fabrics which will offgas. Copy machines with solvent based wet chemistry systems contribute solvents to the air. What's causing the problem? One, two, or three of these? Maybe an interaction of all of them? This is a difficult dilemma. Consider the building as a closed system. I won't go into great detail on this, but if you've got a situation where the sources are small, and you've got a lot of removal through ventilation, then you don't usually have much of a problem. You reach a steady state. Visualize a bathtub with the drain open most of the way (representing the ventilation removal) and the water running in at a trickle (the sources). The concentration in the air is low, or the level in the bathtub is low. In the last five to ten years though we've increased the magnitude of the sources, and we've reduced the ventilation. Suddenly we're starting to see a problem. Now imagine the drain partially plugged with the water running in the bathtub at full speed. The water level rises. Unplug the drain, increase the removal rate, and the level decreases. We don't understand why people should be reacting to these low levels, nevertheless the complaints are frequent. Why, in industrial work places where you see levels 100 times greater of chemical substances, do you not see health symptoms? Which leads to the third reason why these investigations are difficult. There are other factors in an office environment which can influence the development of disease. From what we understand of the disease process, it's not usually one factor which causes a disease, but many factors which contribute. Genetic susceptibility, diets, stress, ability of a family or other persons to provide support. We group a lot of these under the heading of job stress. Decision-making latitude, job control, relationship with supervisors, under- or over-utilization of skills. All these factors likely interact. To really understand the problem one needs to have a systems type of approach.

I'd like to go over a protocol which I use for indoor air investigations. First, don't start out by sampling. I'm an industrial hygienist and it's difficult to say that since sampling is an important part of our work. I start by looking for patterns of time, place, and person. What are patterns of person? Who's affected, do they have certain characteristics in common; are they all smokers or perhaps are they all non-smokers? You can get lots of clues by talking with people, interviewing them. Second, is it the entire building or perhaps just one floor that has a unique ventilation system to it? And then time. Is it worse on Monday mornings; is it worse in the afternoons? Perhaps it's worse in the heating season or the cooling season. A lot of these clues can provide valuable information in evaluating ventilation systems. Please keep these three factors in mind.

Make a site visit. I think this is pretty common and it is pretty obvious why you would want to do that. Talk not only to building owners, supervisors and managers, but also to the people who are complaining. See if you can define a symptom or set of symptoms. In some cases they might fit a pattern that's consistent with a particular kind of a problem. For example, a biological problem, hypersensitivity, pneumonitis, would be consistent with complaints of chest tightness. Or perhaps they might be problems relating to carbon monoxide where affected persons are nauseous and are having headaches. Sometimes you can rule out some possibilities. And then start looking at the ventilation system. I think this is the real key. While you're not sure at this stage, and perhaps never will be, that this is the problem; if the problem can be improved or if it will go away as a result of improving the ventilation, then the intervention has been a success. First determine the type of office ventilation system. Look at the blueprints. Even if you don't know how to read blueprints, look at them because they could be very useful. Look for the fans. Look into the the mechanical room. Find the intakes. Perhaps there's a truck parking nearby that's idling and giving off carbon monoxide.

I'm going to talk about some of these ventilation systems and how you can identify, classify and evaluate them. I've been emphasizing that a first response should not be to sample the air; but one exception to that would be to do a carbon dioxide measurement using Draeger tubes, which are portable detector tubes and a hand powered pump. They're not the most accurate sampling method but you can get a general idea of what's going on if you measure the level outside, then measure the level inside. Outdoors CO_2 is typically around 300 parts per million. Indoors you might find levels as high as 600, 800, 1000 parts per million. In some cases I've measured 2000 parts per million. This gives you a very quick indication of whether or not you're getting much fresh air coming in. A high level of CO_2 usually indicates a high degree of air recirculation. Sometimes a malfunctioning ventilation system is actually a ventilation system that's using more money than is necessary. So you can kill two birds with one stone so to speak, and not only improve the air quality, but save the building money in the process. When I do indoor air systems investigations sometimes I use a checklist or a form to help me go through the process. We have developed such a form at the University of Washington, and it is available upon request.

There are two basic types of ventilation systems: passive systems and active systems. Basically passive systems don't use a fan or other air handling equipment to move the air. An example of a passive system would be a home heating system using hot water; it doesn't actively bring air into the system. Passive systems basically depend on infiltration or the opening of doors and windows for fresh air to come in. Clearly this is the main problem. Depending upon how leaky the building is and how close the people complaining might be to these leaks, they may or may not get any fresh air. One example of a passive system might involve electrical resistance heating under the windows, with no forced motion of air. The convection currents distribute the heat. The only way that outside air can come in is to open the windows. With these passive systems in the summer, if the windows are open, the infiltration of outside air is high. But in the winter, with the windows tightly shut, there's really no source of fresh air. I measured 2000 parts per million of CO_2 in this building, because the people sat around working with the windows closed throughout the morning, they exhaled CO_2 and there was no ventilation system to remove it. So the CO_2 level will build up. You'd be surprised at the number of commercial systems that are like this, that don't have any active air introduction.

Active systems can be differentiated on whether or not they provide outside air. Ones that do provide outside air I divide into local and central systems. A local system is a smaller system or a unitized system in a larger building. A central system is more like what you would see in a downtown office building. As compared to passive systems, active systems should provide a lot better temperature control and facilitate the introduction of fresh air. They could also include cooling as well as heating. But they're not going to provide better indoor air quality if they don't have provisions for the introduction of fresh air.

Take, for example, a system that was installed in a print shop. They had a problem with all the solvents that they use, plate wash and that sort of thing. The system was just a fan pulling air through a filter, a mechanical filter that removes particles from the air. It's not going to remove vapors that are dissolved in the air. So what they really needed was a ventilation system to remove the vapors at their source, a local ventilation system, or at least a ventilation system that's going to circulate air and bring in some outside air to dilute the contaminated air. With the system they had all they were doing was circulating the contaminated air. Another example is an active system that's currently being installed in one of the buildings I mentioned earlier. It has ductwork and an air delivery system. At the very end there is an air handling unit. However, there's still no provision for outside air on this system. It simply takes the air from the room and it either heats it or cools it. There are two black hoses going in, which go to a central building system that provides cooled refrigerant and an electrical cable which leads to an electrical resistance heater. Again, there's a particulate filter here, but no provision for outside air intake. So the air supply simply gets blown around. Well, clearly it's a lot cheaper to run refrigerant lines to the room than to run ductwork and blow air through it and move all that air which takes a lot of work and energy. And it's a lot cheaper to keep conditioning the already heated or cooled air when it's the correct temperature rather than heating or cooling the outside air. This building already has indoor air problems. There are waffle irons that produce all kinds of combustion products as the shortening and the waffles burn. I went in there to take pictures and said I was interested in taking pictures of the ventilation systems since it was exposed. The first thing they did was start complaining. "The air is really awful and it always smells like burnt waffles! It hurts your eyes!"

Still another example of a local active system might be air conditioners mounted in the window. This is the same building where I measured 2000 parts per million of CO_2 in one of the office suites where the tenants had not put an air conditioner in the window. Air conditioners are a good example of a local system and they can and do bring in outside air. Usually they only work in a cooling mode. A roof mounted unit for one of the buildings mentioned earlier is another example of a local active system. All these systems are really very simple and they follow this general schematic. You've got a supply fan which draws air from the outside, usually through dampers. Before the supply fan, the air will pass through filters, and then a heating coil or a cooling coil. One of the two would be energized depending upon the time of the year. And then the air is delivered to the occupied space by ductwork. But you can't just blow outside air into a building because otherwise it would be pressurized too much. To keep the balance, an identical volume of indoor air must be exhausted, hopefully not too close to where the intake is for the supply fan, although you do see that. And there's a shunt between the two systems so that a majority of the air can be recirculated. Usually all these different connections have dampers on them so that the amount of recirculated air can be adjusted. The reason that any air at all is recirculated is that it does save money and energy so that you don't have to use 100% fresh air and constantly, for example in the winter, be heating it. You can use some recirculated air and some outside air and mix them. There's nothing inherently wrong with these systems if they're designed correctly and functioning correctly, if they're bringing in sufficient fresh air as well as being properly maintained.

Let's look at that same rooftop system more closely. On one side it has an air conditioner condenser which blows out hot air. The heat is being removed from the space. On the other side there's a cable leading into the duct. An electrical resistance heater is located there to warm the air if necessary. And then there is the outdoor air intake. In this case it is a fairly small outdoor air intake. This one had a little adjustment on it so that you can adjust the amount of air that was coming through. But when I got up on the roof and checked it out, when it said closed, the thing was really open. When it said open, it was really closed. These kinds of problems are pretty obvious. You can just stick your finger in and feel where the damper is. But no matter how open this damper might have been it wasn't going to let a lot of air into the system just because of its small size. Probably the amount of air that was coming into the building via the fresh air intake was about what was going out through the toilet exhaust, which wasn't a whole lot of air. With this system you couldn't adjust it to bring in a significant amount of fresh air. In many of these systems, you're always stuck with the small amount of fresh air. But in a lot of the fancier systems you can actually draw in 100% fresh air during certain parts of the day. For example, in the morning if it's 60 degrees outside and you want to deliver cool air to offices in the middle of a downtown office building, you can use 100% fresh air. It's actually cheaper. That's called an economizer cycle. With that type of system you have the option of increasing the outside air coming in, perhaps during a period of remodeling or after new carpet has been installed. The first thing to do when investigating indoor air problems is to walk through the ventilation system looking for some of these obvious problems. I heard one story about a building that during the Mt. St. Helens eruption, they had covered over the air intake with plastic so that they wouldn't draw in any ash, and after the problems of indoor air continued for about a year or so, somebody got up on the roof and looked at the air intake and found that it was covered with plastic.

Don't be intimidated by looking at blueprints. Reviewing blueprints is a good start in checking out any ventilation system. It may look like a total mess, but it really isn't that difficult. In the building with the roof mounted air handling unit already described, there are four systems each containing an HVAC unit on the roof. Each of three systems feeds the space occupied by a single tenant. The tenant has exclusive control of that ventilation system. One system feeds two tenants, one of which employs smokers, the other employs avid non-smokers. Of course, since air is recirculated within the ventilation system, it is being circulated from the smoking office into the non-smoking office. It didn't take a whole lot to figure out what the problem was; you almost didn't have to go into their offices. All you had to do was go to the main renting office and look at the plans and see what the problem was going to be. One ventilation system serving two tenants, the ductwork recirculating most of the air. In examining blueprints you quickly learn the shorthand for flexible duct, for the diffuser and the riser, which is the part that will go out to the roof and have the air drawn in. They're really not that complicated.

A more complex system will add a couple of things like reheat boxes, as you would find in a larger building. Again you've got the supply fan drawing through two filters, heating coil, cooling coil, and being delivered to the rooms. In each room you've added these things called reheat boxes which have electrical resistance heating. The reason for reheat boxes is, if you've got a big building and one side faces east in the morning, that side might heat up quite a bit from the sun. And it might need cooling and on the other side of the building, the west side of the building, it might be rather cold. So you can blow cold air through the central ventilation system to cool the warmer areas, and then reheat the cooler air before it's blown into the areas that need warmer air.

We've talked about some different kinds of ventilation systems, starting with simpler systems such as some passive systems and progressing to active systems. We've talked about local systems and have begun to talk about central systems in describing the reheat boxes. Central systems come in two varieties. Constant volume and variable volume. Constant volume systems, which are the ones I've been discussing, deliver the same amount of air all the time and vary the temperature to suit the conditions. In addition to the problems that I've already mentioned with some of these systems, ducts can leak so that by the time the air reaches a room there may not be much of it. Filters become clogged, belts on fans start to slip, the quantity of air delivered to one room is a lot greater than that delivered to another room. The system needs to be rebalanced. Balancing means that you call in somebody who theoretically measures the amount of air coming out of all the vents and then starts putting restrictions or moves levers that control restrictions in the system to get the system to put the right amount of air in each room. Of course, the seasons change, the whole balance of the system changes, or the fan wears a little bit and the whole thing is off. Any ventilation, if it's not properly designed and maintained, will never work well. Maintenance is definitely critical and a lot of the moving parts in these systems can and do wear.

The other kind of system you see in central building is the variable volume system. This is the most complicated system I've talked about, and if you've followed me up until now, you'll follow me through this and perhaps you'll get an insight into the kinds of ventilation systems seen in buildings. Perhaps if your building is having problems, or another building, you'll recognize some of the problems. In a variable volume system the air remains at a constant temperature. The room thermostat decides how much air should be let in. In a cooling mode, for example, the air might be 58 degrees and only a little amount of air is allowed into the room. Then the room, if it's a conference room, might fill up with people, or it it's an office, the machines get turned on, the heat output in the room goes up, the thermostat signals for cooling and a damper in the ceiling will open up so that more cold air is delivered to bring the temperature down. The damper arrangement in each room is called a variable volume box and it's controlled by the thermostat. The quantity of air flowing through this ventilation system can vary depending on where the boxes are, at any given moment. If all the boxes want less air the fan has to be able to back off, as they say in the trade, in other words, deliver less air.

Let me describe a downtown Seattle office building as an example. It's a thirty-six story office building that has this kind of a system. It's got eight separate ventilation systems. Four of them serve the top eighteen floors, four the bottom. Each serves a quarter of building: southeast, northwest, that sort of thing. It's really not a very difficult system to understand. It's just like the ones I've described. Many of the problems with these systems are very obvious. Calling in an industrial hygienist to fix them is like calling an electrician for a blown fuse? For many of these systems just by walking through them you can identify some of the simpler problems.

Looking at the schematic layout of that system, you would see the fan arrangement on the top. You would see a concrete shaft that runs vertically throughout the entire building; one for the supply air and one for the return air. You would note the variable volume boxes on each floor. The fans are just like other fans. You've got a supply fan, a return fan, coils, filters, and damper arrangements to adjust the amount of air. If you look at the blueprints closely you'll see these crosshatched things that are actually filters. To the side of the filters are the cooling coils, with the supply fan on the bottom and the exhaust fan on the top. A little arrow shows you that it's blowing the air out. Basically it's pretty straight forward. When you walk into a fan room it will be even more obvious because you can see in greater detail the cooling coils and filters and that sort of thing. These are pretty big units. Maybe on the right there are filters that are filtering the air coming in, with the cooling coils on the left. Inside the big box with all the pipes are the fans. In the foreground there's a pump that pumps the refrigerant around. If you look at the blueprints, you'll see the same kind of arrangement. The compressor is just like on an auto air conditioner or a home air conditioner; inside the unit. It compresses the refrigerant and there's a unit on the roof, the condenser.

Just to remind you what we're talking about, let's go back to the basic system. One of the major problems with this kind of a system is as you back off on the supply fan because the boxes are calling for less air, the return fan has to back off too, so that the system is in balance. This doesn't always work so well. I'm going to talk about that a little more. In theory you've got these things tracking each other, but that doesn't always happen. Take the variable volume box that we saw before connected to a thermostat. In real life you can often see the thermostat hanging off it. When they finish the building, they'll mount that on the wall. Inside the ductwork leading up to it are the dampers. Again, the variable volume box delivers air out through the duct work to a diffuser. They call them an air terminal control unit. It's got some kind of a coil for heating, then it's got the dampers and it's got pneumatic controls which go to the thermostat.

As I mentioned, the return fan has to keep track with the supply fan. The supply fan is not blowing its full capacity all the time. In fact, most of the time it's blowing around 50 to 70 percent of capacity. We use a frequency distribution of the fan operating cycle to show the percentage of time that it's blowing a particular volume. In this case, it's not very frequently blowing less than 30% of its capacity. And it's also not very frequently blowing more than 70% of its capacity. Most of the time it's in the middle. If the system is working right, you've got the return fan tracking the supply fan. As the supply fan backs off the return fan backs off. The difference between the two is the amount of outside makeup air that's coming in. This doesn't always work well. One of the reasons it doesn't work so well is that architects frequently overdesign these systems. You never get sued for making a system bigger than it was designed for. If the supply fan backs off and the return fan doesn't, you're sucking more air out of the building than you're blowing in. So the building "goes negative". What that means is that in relationship to the outside world, the building is under negative pressure, so air will start infiltrating. It will carry dirt and dust through doors and windows and cracks. In one case I saw a building running negative that was adjacent to a warehouse where there were lots of forklift trucks. CO and diesel exhaust from the diesel powered forklifts was being drawn in. The whole system gets messed up when the building goes negative.

This building we've been discussing was never operated as a variable volume system because of these kinds of problems. Another area where we see a lot of problems is in the diffusers, the things that actually deliver the air into the room. If you look up above you, you can see that there are two kinds of diffusers in this room. There are the square ones which are blowing air out, and then there's that one right here which is drawing air in. You can tell which they are if you take a little piece of tissue paper and tape it up there. The air will get drawn one way or the other. There are circular diffusers, floor mounted diffusers, ceiling mounted diffusers. I've seen one unique system where they made little holes in the ceiling and tried to squeeze all the air out of the little holes. It's kind of like a pasta machine with air. As you can imagine, it takes a lot of energy to push the air through those little holes.

With any kind of system, what we're really interested in is air that reaches people. Even delivering the air that may contain a good quantity of fresh air isn't going to do any good unless you deliver it to people. In a heating mode a system which uses a floor mounted diffuser may have a stagnant area near the floor. In the summer that same system blowing cool air is going to have a stagnant zone in the opposite corner at the ceiling. They don't use floor mounted systems anymore; instead they use ceiling mounted ones. Building codes don't like you to punch holes in the floor to deliver air because of fire regulations and it's very expensive to build a false floor. So you see these dropped ceiling kinds of arrangements. With this sort of arrangement distribution is not always very good. In the cooling mode, the air basically spreads out on the top of the ceiling and then drops down. The temperature is relatively uniform throughout the entire vertical profile of the room. But with that same system in a heating mode, the hot air isn't going to drop down. The hot air is going to keep rising and it's going to stay on the ceiling. So you get a very, very strong difference in temperature between the bottom of the room and the top of the room. And, in fact, three quarters of the room is stagnant. On a lot of these systems, these diffusers have never been evaluated in terms of their ability to control for indoor air contaminants. At best what's been done is to see how they affect air temperature. And we assume this correlation between air and contaminants which may or may not be the case.

One other area I haven't talked about is biological problems. Biological contamination of ventilation systems. Any leakage of water or any humidity in these ventilation systems greater than 70% is very risky in terms of mold growth. In some of these newer systems the inside is lined with insulation, fibrous glass insulation. Now you've got a perfect medium; you've got a substrate for all kinds of things to start growing inside there, if there's the introduction of water or if it's a humid system. Phil Morrey of National Institute of Occupational Safety and Health (NIOSH) has done quite a lot of investigative work in this area. In one of the buildings that he investigated, not only do you have bacteria and fungi, but we've got protozoans and nematodes. We've got all kinds of little animals. It's like a little ecosystem, like a little pond that you've got growing. This is inside the ventilation system. There was a slime covering all the insides. This happened because they had a system that used an open water humidification process in which the air passed through a space where they were blowing atomized water just out into the air and they would recirculate that water. Legionalla was mentioned earlier today. This was a problem where bacteria and molds were growing in the cooling system because the water was recirculated through the system, and these things started growing.

Biological contamination is addressed in the list of references that I have provided. It is from the ACGIH transactions, which I think is a very good compilation of twelve or fifteen different speakers. Finally, here are NIOSH's recommendations. First, no water spray for humidification. No cold mist vaporizers. They can result in similar kinds of problems. The correct way to humidify air is with a steam system. And, again, no recirculation. No humidity greater than 70%. But you do see these systems. I recently saw a system that had open water that was being used to filter the air and to slightly condition it. The space used to be a warehouse so that it wasn't much of a problem. But they moved people in, a lot of people, probably a couple hundred people and they never changed the ventilation system. The building should always be run positive. Just like with radon infiltrating from the ground, a negative building is a disaster waiting to happen. It will suck in anything around it; it will be drafty; it will cause lots of problems. The air intakes should not be located near a contaminant source. Maintenance is a critical issue. As these systems age they need constant and frequent maintenance. Sometimes the people who are maintaining them really don't understand the systems. I've seen situations where they've gone around to all the VAV boxes and changed the limiting adjustments, which have provisions so that you can't reduce the outside air beyond a certain amount. They've changed the limiting adjustments so that they could make it [the outside air] as little as possible.

I've discussed a number of ways in which ventilation systems fail. First, in not delivering the right quantity of air to the space, either because of problems in the central system or problems in the distribution within the room. Clearly, if the air is contaminated, the quality of air is poor due to biological and chemical contamination. A second problem is the timing of the system. Some of these systems don't operate 24 hours a day. In fact, most don't. Usually they'll turn on in the morning, turn off in the afternoon. If you have a swing shift, is the ventilation system running during that period? Is it running for the maintenance people? A lot of systems turn off Friday and don't turn on again until Monday morning. All during that time you've got sources in the building which are continuing to generate and that's what you'll be hit with when you walk into the building on Monday morning. A lot of these systems, in the cold weather, won't bring in outside air for the first two hours. They just recirculate the inside air and heat it up in cold weather. You've stored up two-and-a-half days worth of pollutants to subject people to when they come in Monday morning.

So who do you blame for these problems? Do you blame the designer of the system? Often the designer knows nothing about how the building is going to be used. They might not know when they put in supply ducts every sixteen feet that you're going to divide the room up with six foot floor dividers and prevent a reasonable circulation of air. Many of these systems are designed, and then the contractor installs them. The installed system may or may not bear any resemblance to the prints. Before occupancy they're never evaluated. The equipment manufacturers have been making less than ideal equipment for many of these systems, but I think that's improving. Probably the key is better communication between all people involved.

In this short time I've spoken about some of the problems seen in ventilation systems and some of the different designs which you might see. In the past there was lots of room for slush, but with all the tightening that's gone on in recent years, this isn't the case anymore. The protocol I follow is: site visit, interview, ventilation system evaluation.