

MOISTURE, BUILDING ENCLOSURES, and Mold

How water gets into a structure, why it doesn't leave, and how these architectural flaws become HVAC headaches

Buildings leak. Conditioned air escapes, and outside air is sucked in. The relatively easy science of keeping unwanted water out of a structure is nearly a lost art. And many of the modern materials we use to build actually hinder the drying process once water enters. A typical new building has dozens of holes in the shell that don't show up in the blueprints because they were never intended. You may say to yourself, none of these problems technically fall within the purview of the mechanical engineer, and you're right. But keep two points in mind: Many of these problems translate into indoor-air quality (IAQ) complaints, which are your problem; and everyone involved in construction needs to develop a whole-building philosophy in order to improve how we build.

If such lofty goals don't appeal to you, think of your career. I speak from experience when I say that when you are called on the (wet) carpet for a water problem, it helps to be able to show that the problem was from poor architectural design, materials, or installation, rather than an HVAC "condensation" problem.

Learning to spot where breaches commonly occur in buildings is essential for mechanical engineers. With this knowledge, you may be able to prevent a catastrophe during the plan review. With this knowledge, you can ask to see the necessary architectural detail for determining if a water problem might exist while still early in a project—especially if you are representing the building owner. Simply tell the architect you need to see how much dehu-

midification you'll need for that unplanned natatorium they'll be building in the basement.

In this two-part series, I'll first discuss why these are pervasive problems in the construction industry and how they are inherited by HVAC technicians and engineers once the structure is occupied. I'll also discuss why keeping ground and rain water out of a building should be easy, but isn't, and what to do once water gets in. In the January issue of

HPAC Engineering, part 2 of this series will review air control and pressurization, ventilation, and humidity control and will include some resources to help expand your knowledge of design and construction errors that lead to HVAC headaches.

THE DYSFUNCTIONAL CONSTRUCTION FAMILY

Controlling water problems in buildings should be easy. Keep the rain and ground water out. Design and construct the building enclosure to be able to dry when it gets wet—and make no mistake about it, it will get wet. Control the airflow across the building enclosure because air carries water, so build the building enclosure without holes—at least without big ones. Remember that as part of this air-control system, you have to control the air pressure across the building enclosure. Should buildings be pressurized or depressurized, or should you attempt the impossible to maintain a neutral pressure? I think you should pressurize building enclosures everywhere, but we'll get into that later. Lastly, ventilate and condition the building enclosure in a controlled manner to control humidity.

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All easy stuff, right? Unfortunately, it's not. Out of necessity, we divide up the responsibility of doing all of this among various professionals and tradesmen. The people involved don't speak the same language, or just don't speak at all. They don't know the same things, and too often, no one seems to know the entire picture. It's like working on a puzzle without having a picture on the box to go by, so you don't know until the end of a very inefficient process that some pieces are missing, while others don't belong at all. In other words, the construction team is a big dysfunctional family.

Often, those making the financial decisions know even less. They let salesmen talk them into the next great thing: "Sure this works, we have 5,000 systems in Lower Elbonia." Finally, we "value engineer" the project—a term that to me can be best defined as: "A process by which someone who has no clue about sound construction takes out the stuff we really need to make things work."

KEEP THE RAIN AND GROUND WATER OUT

Controlling rain and ground water are the most important factors in the design and construction of durable buildings and for the control of mold. Let me make something painfully clear: Air-conditioning and dehumidification systems cannot be used to control rain- and ground-water problems. It is not the job of the HVAC engineer to design rain- and ground-water-control strategies. There are no guidelines available to size systems to handle rain and ground water—except to make these systems really big, which is a bad use of energy and poor engineering. Don't even try it. Fix the rain problem and fix the ground-water problem with drainage. There are situations where installing a dehumidifier in a basement works well, but that is not what I define as a ground-water problem. You don't install a dehumidifier when there is running water or standing water in a basement.

The fundamental principle of rain- and ground-water control is to shed water by layering materials in such a way that water is directed downward and out of the building or away from the building.

How Mold Eats Walls

Leaky windows were not always such a big deal. More than a hundred years ago, exterior walls had hollow cores, or were made of solid masonry or lumber. If they got wet from a window leak, they could dry. Many were built with heavy timber framing with plank wall, or even balloon-frame wall with true two-by-fours sheathed with 1-by-6 in. diagonal boards that were sheathed on the interior with plaster on metal or wood lath. Whether these walls are uninsulated or insulated, they are very mold-resistant because both the materials and constructions can dry.

The composite materials that are used today have adhesives that can be digested by fungi we call molds. Mold will also digest sugars and starches in wood fiber, if the cell walls have been crushed or broken. Solid lumber has intact cell walls that cannot be penetrated by molds. Molds will grow on the surface, but the wood will retain its structural strength. Particle board, oriented-strand board (OSB a.k.a. waferboard), and medium-density fiberboard, as well as paper-covered gypsum board, are full of adhesives, which make them good "mold chow." Adhesives are used throughout these materials to give them form and to hold together the crushed, pulverized, or torn wood fragments or particles that make up the board. Mold digests the adhesives, and mold hyphae penetrate the resulting cracks and holes between

wood particles. Structural integrity is eaten away, and so is the wall. Paper-covered gypsum board also has the adhesives and cellulose that offer food to molds at the expense of the wall.



Mycelium of a wood-rotting fungus growing under the siding of a house. The mycelium is essentially the digestive organ of the fungus, secreting enzymes designed to digest the substrate (such as a cellulose-based building material) so that the dissolved nutrients can be absorbed.



Mold growth behind vinyl wall covering.



Mold growth on vinyl wall covering.

DRAIN EVERYTHING

Gravity is the driving force behind water management and drainage. The “down” direction harnesses the force of gravity, and the “out” direction gets the water away from the building-enclosure assemblies, openings, components, and materials. In general, the sooner water is directed out, the better.

The most elegant expression of this concept is a flashing. Flashings are the most underrated building-enclosure component and arguably the most important.

Drainage also applies to materials. Water that is absorbed in a material cannot be drained away. We paint and stain wood siding so that water is not absorbed by it and can be drained from the siding surfaces. We damp-proof concrete foundations for the same reason.

Drainage applies to assemblies such as walls, roofs, and foundations, as well as to the components that can be found in walls, roofs, and foundations, such as windows, doors, and skylights. It also applies to the openings for the windows, doors, and skylights and to the assemblies that connect to walls, roofs, and foundations, such as balconies, decks, railings, and dormers. Finally, it also applies to the building as a whole. Overhangs can be used to drain water away from walls. Canopies can be used to drain water away from windows, and site grading can be used to drain water away from foundation perimeters.

Drainage is the key to rain- and ground- water control:

- Drain the site.
- Drain the building.
- Drain the assembly.
- Drain the opening.
- Drain the component.
- Drain the material.

In other words, drain everything.

WINDOWS

My advice to engineers is to thoroughly review architectural drawings, particularly the window-opening details and flashings. These openings cry for “pan flashings.” Windows leak. I’m tempted to say always, but it’s sufficient to say that windows leak frequently enough that you need to treat them as if they are going to leak. An under-window “gutter” (or “pan flashing”) is essential to

redirect this leaking water to the exterior.

WALLS

Review wall assemblies to make sure they have drainage planes: a membrane covering the wall behind the exterior cladding. This is real important when we



Photo A. Typical mold “pink spot” created when organism releases digestive enzymes that react with plasticizers in the wall.

get to brick veneers and stucco—especially synthetic stucco. Remember that there are only two kinds of stucco: stucco that has cracked and stucco that will crack. There are now some magnificent synthetic stucco systems available: “Drainable EIFS” (external insulation and finish systems). These work because they drain. Watch out for the non-drainable systems especially when they are used with windows. Mold heaven is when you combine a non-drainable stucco with a leaking window.

It’s not uncommon to find wall sandwiches made from OSB or paper-covered gypsum, steel studs, cellulose or fiberglass in the cavity (to keep water from drain-

ing away), paper-covered gypsum, and vinyl-covered wall paper to keep the wall structure from drying. Does vinyl repel mold? Not at all. As shown in “How Mold Eats Walls,” mold will digest vinyl paper adhesive and grow into the paper as well.

LET IT DRY

In 25 years of being in the construction industry, I’ve concluded that we approach things backward. We focus entirely on preventing things from getting wet, which is a good idea, but we also need to provide a contingency plan by engineering the structure to let things dry after they get wet. The problem is that many techniques that prevent wetting also prevent drying. Vapor barriers are a prime example of this foolish thinking. Yes, vapor barriers stop vapor flow. But what if there is vapor in the assembly already? And remember that there are two sides to a wall: the outside and the inside. Walls can get wet from both the inside and the outside. Walls also can dry to both the inside and the outside. We seem to think that walls only get wet from the inside and that they can only dry to the outside—what I call “cold-climate chauvinism.” We do the calculations for the winter, but the walls rot in the summer.

I love code recommendations. One of my favorites directs engineers to “put a vapor barrier on the warm side.” Warm side when? In January or in July? We may need vapor barriers in Canada, but we don’t need them in the Lower 48. In Canada, there are only two seasons: this winter and last winter. In the rest of the world, especially the air-conditioned world, moisture flow is from the outside in. This means that a vapor barrier installed on the interior of a wall assembly is on the wrong side.

If you don’t believe me, open up a wall in Cincinnati in July and look on the cavity side of that polyethylene vapor barrier. What do you see and smell? Droplets of water and a bad odor. One sure way to make it worse is to install vinyl wall coverings on the inside of a wall. Notice all the pink spots—that’s literally mold vomit. Mold exudes digestive enzymes that react with the plasticizer, giving you the color as seen in Photo A. Pull back the vinyl and you have black mold and mushy drywall (see “How Mold Eats

Walls”).

The hotel construction industry has refined these flawed design concepts into a recipe for mold and odor. You start with a steel-stud wall. Put a non-drainable synthetic stucco on the outside, fill it with fiberglass insulation, and install a plastic condom on the inside. Then fill the building with cold air in July when the outside is hot and humid. Did I mention the leaking windows?

And then we blame the HVAC engineer for the mold in the walls and for the mold smell in the hotel or in the school or in the office.

Is there any way to make this worse? Of course. Use paper-faced gypsum sheathing on the outside of the steel studs and glue the foam to it. We’re building paper buildings that get wet and can’t dry. Even the dumbest of the three little pigs didn’t build a paper building.

IS YOUR VAPOR BARRIER SMARTER THAN YOU?

So what to do? Don’t use vinyl wall coverings. Don’t use paper-faced gypsum. What about vapor barriers? Doesn’t code demand these? Code says install something that has a perm rating of one perm or less. The kraft facing on a fiberglass batt meets this requirement, but only when the RH the kraft facing sees is low—25 to 30 percent. What is interesting is that this kraft facing becomes vapor permeable as the RH it is exposed to goes

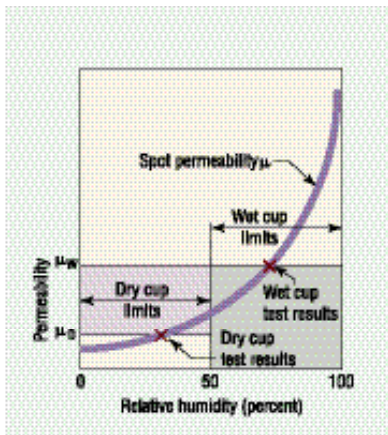


FIGURE1. A “smart” vapor barrier retards moisture in the winter and lets the wall “breathe” in the summer. In contrast to a simple plastic vapor barrier that has a perm rating of 0.1 perms year round.

up. In air-conditioned buildings, when the humidity is 50 percent—not atypical—the kraft facing is 10 to 20 perms. It’s a “smart” vapor barrier. It retards moisture in the winter and lets the wall “breathe” in the summer. That dumb plastic vapor barrier has a perm rating of 0.1 perms—all of the time (Figure 1). We’re talking two orders of

magnitude in difference. Stay away from plastic-film vapor barriers, foil-faced fibrous cavity insulation, and especially foil-backed gypsum sheathing on the interior.

THE REWARDS OF POOR DESIGN DONE WELL

I’ve tried to show how many of the decisions made without the input of a mechanical engineer during the design and construction phase lead to disaster. Here’s an example of how a series of bad decisions led directly to uncomfortable occupants. Let’s look at a rain-wetted brick veneer in July on the southwest side of a building on a sunny day at around 2 p.m. The outside temperature is 80 F at 75-percent RH. A psychrometric chart reveals that the outside vapor pressure is 2.29 kPa. Inside, the conditions are 75 F at 60-percent RH. Look at the psych chart again: The inside vapor pressure is 1.82 kPa. The difference between the inside and outside is not really such a big deal. But now look at the brick. It’s sitting at 120 F, and it is saturated, so it’s at 100-percent RH. At this point, the psych chart doesn’t apply because we’re literally off the chart. You have to turn to the steam tables at this temperature. The vapor pressure in the brick is 11.74 kPa. This is a serious vapor-pressure gradient. Behind

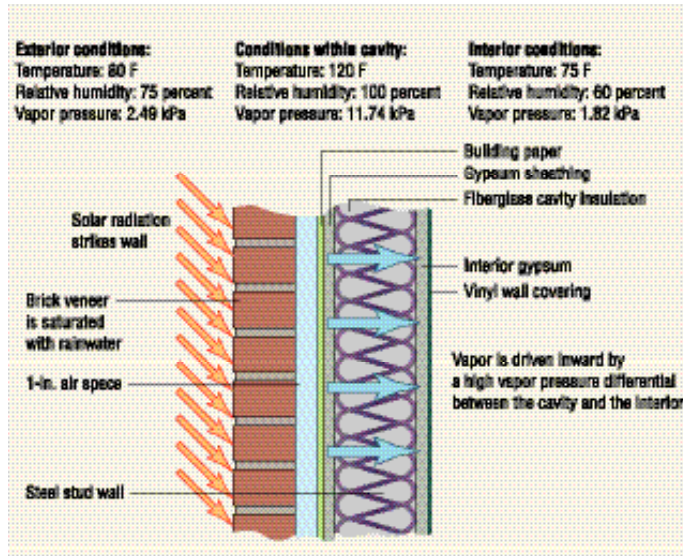


FIGURE2. In this design, the brick exterior can reach 120 F when exposed to the summer sun in many areas of the U.S. After a rain storm, the brick can become completely saturated and reach 100 percent RH. The vapor pressure in the brick is 11.74 kPa, a significant vapor pressure gradient with little chance of moisture removal.

the brick is an air space and it’s not likely to be a clear and well-ventilated air space. In this real-world situation, the amount of moisture being removed is zero (Figure 2).

What’s next in line of the incoming steam? Probably felt building paper. It is permeable—after all, a building has to breathe. Unfortunately, it breathes both ways. So inward the moisture vapor flows. Next is the exterior gypsum, which is permeable, followed by the fiber-glass cavity insulation. No problem, the vapor flows right on through. What’s next? Well, sometimes you get the polyethylene vapor barrier, which condenses the vapor and the condensate runs down the wall and rots, rusts, and corrodes the bottom plate. Other times, you get more gypsum board covered with impermeable vinyl wall covering—followed by the pink spots, the mold, and the mushy drywall. So what does this tell us? You need a vapor barrier on the outside with a brick veneer, not on the inside. This absolutely contradicts typical practice and building codes. And, of course, it’s all the HVAC engineers fault because the HVAC engineer didn’t design the right humidity-control system—and we all know that mold comes from high humidity. Humidity, mold, and HVAC engineers—inseparable.

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In the first half of this series, which appeared in the December 2001 issue, I discussed many of the pervasive problems in the construction industry and how they directly lead to indoor-air-quality (IAQ) problems. While many of these design flaws—poor drainage, leaky envelopes, and construction materials that fail to shed water—are not the typical design concerns of an HVAC engineer, the IAQ problems that result will be squarely placed at the HVAC engineer's feet. Therefore, mechanical engineers need to understand the roots of these problems in order to defend their work if IAQ becomes a problem once the building is occupied, and the architect and contractors are gone.

Learning to spot where breaches commonly occur in buildings is essential for mechanical engineers. With this knowledge, you may be able to prevent a catastrophe during the plan review. With this knowledge, you can ask to see the necessary architectural detail for determining if a water problem might exist while still early in the project. In this article, I will review air control and pressurization, ventilation, and humidity control and provide some resources to help expand your knowledge of design and construction errors that lead to HVAC headaches.

CONTROL THE AIR—NO BIG HOLES

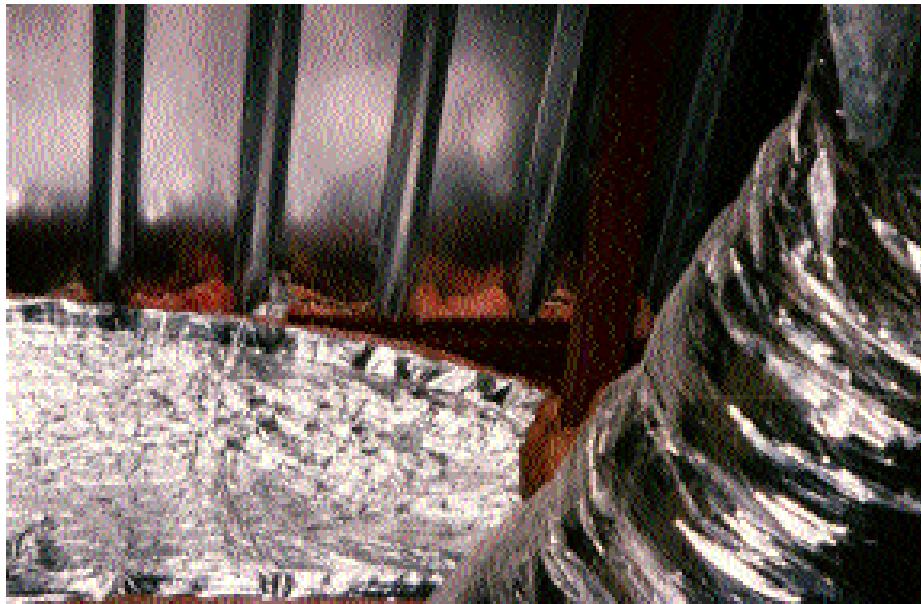
The purpose of a building enclosure is to contain conditioned air and keep outside air from entering. It shouldn't have to be said, but the following concept is one that escapes many in the construction industry: You cannot enclose air with a sieve. Nor can you condition a sieve.

Unfortunately, this is what HVAC engineers are asked to do all of the time. Proof of this may be just above your desk at work. Poke your head above the

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Continued on page 80

An example of the lack of air control at a fluted roof where roof or floor meets the exterior wall. Mineral wool within flutes does not stop air.



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Sample construction details to keep water out

The Massachusetts Board of Building Regulations and Standards (BBRS), with the financial support of the State's gas and electric utilities, commissioned the Boston Society of Architects to develop a series of sample construction details in support of the new Massachusetts energy code for commercial, institutional, and high-rise (more than four stories) residential structures, including hotels and motels of any height—in other words, all buildings other than low-rise residential. The key difference in all of them is the new requirement for designing an air barrier into the building envelope.

Certain assumptions were made about design conditions and other elements that could make the samples incorrect for some applications. Of course, the responsibility for a suitable and workable design remains with the professional designer of record.

Each sample set contains a narrative description of its assumptions, a discussion of advantages and disadvantages, and alternative materials that might be used. All materials discussed are generic, and no preference of one product over another is implied.

To access the sample construction details, visit www.state.ma.us/bbrs/sample_details.htm

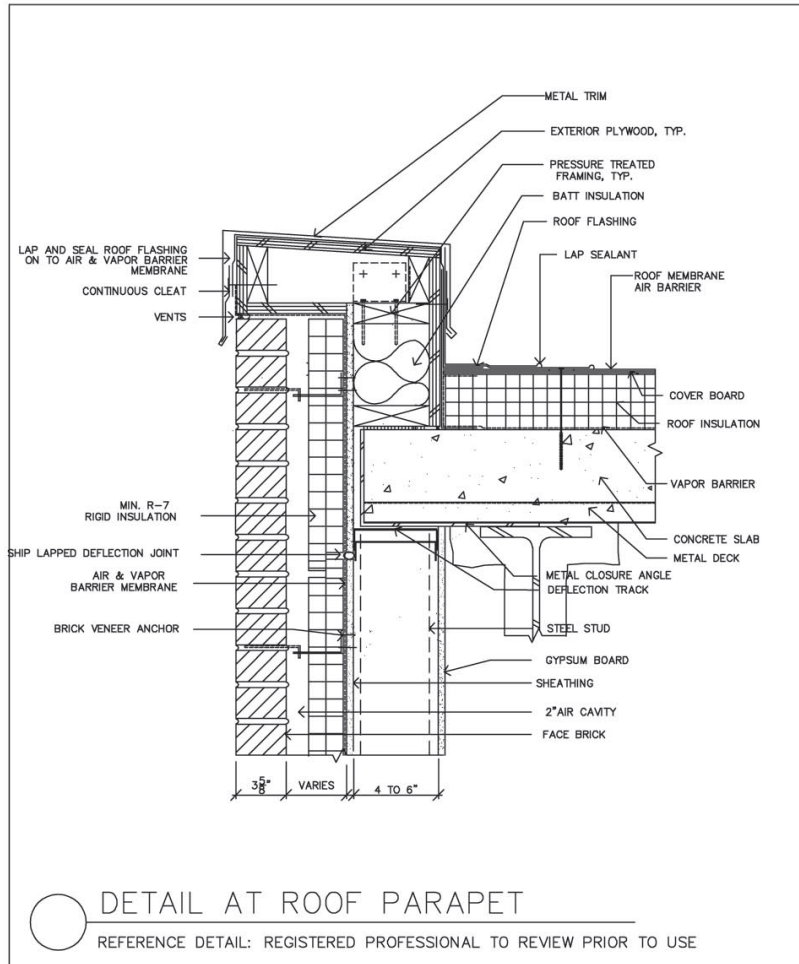
This figure shows detailing for a steel stud wall with brick veneer insulated with rigid foam sheathing. The foam sheathing is installed on a membrane that acts as a drainage barrier, air barrier, and vapor barrier. Notice that the parapet-wall detailing does not allow warm air from inside the building to enter the parapet wall cavity and that the drain plane extends to the cap of the parapet wall. A metal coping with drip edges is flashed to the roofing and extends down below the top of the brick veneer.

This wall is resistant to rainwater intrusion and condensation problems.

This drawing is part of "Brick Veneer Design -A," available at the BBRS Web site, which also includes details for the roof edge, parapet, foundation, and the window head, jamb, and sill. This particular design is the work of Wagdy Anis, AIA, of Sheply

Bulfinch Richardson and Abbott; Mark Kalin, FAIA, FCSI, of Kalin Associates Inc.; Jeff Wade AIA, CSI, of Building Envelope Technologies Inc.; and Steven Rigione of HKT Architects Inc. Continuity of the air barrier from the

building foundation to the roof is the main focus in this sample design plan. The design is based on a maximum of 35-percent interior relative humidity during the winter and normal exterior conditions in Massachusetts.



DETAIL AT ROOF PARAPET
REFERENCE DETAIL: REGISTERED PROFESSIONAL TO REVIEW PRIOR TO USE

DETAIL	TITLE: PARAPET: BRICK VENEER DESIGN A	SKETCH NUMBER
ENERGY CODE: CONCEPTUAL DETAILS FOR EDUCATIONAL PURPOSES ONLY	Date: 10/10/2001 Scale: 1-1/2"=1'-0" Drawn: ---	SK-A2 3 OF 11

Continued from page 77

ceiling tile into a dropped ceiling and look toward the outside wall. Does the gypsum board run up to the underside of the next floor? Is the joint at the underside of the floor sealed? Probably not. Typically, someone shoves some mineral wool into the flutes, and they're gone.

Cantilevers present an even greater



Fiberglass insulation is a filter, not an air-barrier. Note the dark markings (filtered dust) in the material.

problem. Compounding the problem is that the HVAC engineer is trained to turn the dropped ceiling into a return-air plenum so that we can suck air out of the wall cavities through the flutes. But at least with the mineral wool in the flutes we clean the air as it whistles in—the big dust particles are captured.

Another problem is structural steel at a

45-degree angle, such as a sway brace. This usually means that there will be holes in the interior sheathing (usually gypsum board). Another common problem area is above the ceiling in the plenum, wherever there are pipes or wires penetrating an interior wall or the exterior wall sheathed on the interior with

gypsum board.

In these instances, air can and will flow through the wall penetrations. Additionally, although these holes could have been drilled with a bit slightly larger than the pipe or conduit, they are usually made with an 8-lb sledgehammer. These penetrations aren't often sealed, which is also likely a violation of fire codes. Fire-stopping materials are good sealants for these types of penetrations.

This leads me to another real annoyance: The attempt to stop airflow with fiberglass insulation. Fiberglass insulation does not stop

airflow. Fiberglass insulation is not an air barrier. To stop airflow, you need something rigid, such as gypsum board, concrete, sheet metal, or a membrane adhered to gypsum board.

HOLE HUNTING

Where are the big holes in buildings? You can find them all over. I particularly

like parapets and port corcheres. Cantilevers and dropped-ceiling assemblies are likely hole hideouts, as well. How about elevator penthouses and the elevator shaft? Of course, window-to-wall connections should be high on your list of suspects when hunting for holes. We have enough trouble keeping the rain out of these joints. Air leakage at window "seals" is legendary. Of course, the windows themselves don't leak air, but the connections between them and the rest of the wall do. Stuffing or "chinking" this gap with fiberglass once again is like trying to stop airflow with a filter.

Holes can almost always be found at awnings, facades, and covered walkways, where the framing system joins the wall. Air barriers for these constructions often are poorly constructed or forgotten altogether.

So what is the HVAC engineer supposed to do? I recommend that you specify an airtightness requirement for the building enclosure and that the design of the HVAC system be based on specified envelope-performance characteristics. This would require that the envelope be commissioned. In other words, actually require that the building not leak air. This would require coordination and cooperation with the architect and the contractor—I can dream can't I?

CONTROL THE AIR BY PRESSURIZING

Buildings should not be depressurized. They should be slightly pressurized to between 2 and 5 pascals (convert to inches of water: 1 in. of water is 250 pascals). This is true in most of the U.S., but not in Canada (and parts of the U.S. that might as well be Canada). A rule of thumb is that if your locale is over 8,000 degree days (base 65), you shouldn't be pressurizing your buildings. Exceptions to this rule of thumb include building spaces with unavoidable and large humidity sources within the structure, such as pools, and commercial kitchens.

In low-rise buildings, weather sometimes can override this low-pressure difference, but that's OK because this is a temporary situation. In high-rise buildings, pressurization is more complicated. In cold weather, everything below the neutral pressure plane will be running negative unless you have isolated the floors well and do not have vertical duct-

work that runs more than a few floors. The sidebar “Managing Pressure Differentials in High-Rise Buildings” provides more details and a good reference for accomplishing this.

MAKE IT TIGHT

Buildings should be pressurized with conditioned air that is brought into a building in a controlled manner in a known location. With this approach, you can actually filter air in a meaningful way. Most of us put filters in equipment to protect the equipment. If we pressurize buildings with filtered air, we actually are doing something good for the occupants, not just the equipment. Of course, in order to pressurize we actually need an enclosure, which brings me back to a recurring theme: You can't pressurize a leaky building unless you have really big fans and a fabulously wealthy client who can afford the operating expenses. With a tight enclosure, you don't need big fans. Do it right—make it tight.

Unfortunately, we tend to install devices such as rooftop exhaust fans for restrooms and mechanical and/or electrical rooms. These devices run all the time. Unfortunately, unit ventilators that supply air do not run all of the time. The result is a building that is depressurized. One solution is the installation of makeup air units installed with preconditioning so that the exhaust air is replaced. Unfortunately, these often get “value-engineered” out of the design by the client's representative, who argues that these units are too expensive. My only advice to mechanical engineers at this point is to dig in their heels and fight. Do you want to design a system that works or one that doesn't work? How would this approach fly in other industries? Does the automobile industry build models without brakes in order to save customers a pile of money?

VENTILATE AND CONTROL HUMIDITY

Some believe dilution is the solution to indoor pollution. In reality, dilution often is the cause of indoor pollution especially in southern states. The more dilution you have, the more outside moisture you bring in. Unless the air is dry, air conditioning will lower the temperature of a huge mass of inside materials below the outdoor-air dewpoint temperature.

Managing Pressure Differentials in High-Rise Buildings

For high rise buildings, you need to pressurize all floors when it is cold. Several steps are needed to accomplish this:

- Seal between floors.
- Seal the corridors so the elevator shafts are their own isolated zones.
- Seal fire-egress stair chases. These need to be sealed so you have two tall towers that serve isolated floors.
- Air-side mechanical equipment has to be distributed so each system serves only a few floors. By spreading the systems around, you can more easily deal with the stack effect by pressurizing each floor, thus segmenting the stack effect.

Reference: “Building Science for a Cold Climate,” by Neal Hutcheon and Gus Handegord, National Research Council, Canada, 1995.

Any air that infiltrates from outside, or which is not mechanically dehumidified, is wetting the materials. Condensation will appear on nonporous surfaces—this is obvious to behold. However, adsorption will occur on porous surfaces, which is less obvious but equally onerous. A can of cold beer pulled out of a refrigerator will sweat, but if you pull a 2-by-4 or a brick out of the fridge, it probably won't sweat; however, it will adsorb water.

You can only dilute with dry air, which means preconditioning. Also, you have to make sure that there are no places where air is being sucked in from the outside. I say separate the sensible control system from the ventilation and humidity-control system. In fact, I think an ideal system would include independent control of temperature, humidity, and ventilation. Depending on who you ask, I'm either thinking way ahead of everyone else or insane.

CONCLUSION

Controlling water problems in buildings should be easy, but we make it hard by convoluting the design and construction process and pointing fingers from start to finish. HVAC engineers often take the blame for “condensation problems,” which can be seen, smelled, and touched, even if the root causes of the problem are poor drainage, poor envelope design, and construction flaws. The goal of this two-part article was to provide HVAC engineers with knowledge to pressure owners, architects, and contractors to keep up their end of the construction process regarding moisture control.

The plan is simple, the materials available, and the results of proper practice immeasurable. To recap:

- Keep the rain and ground water out.
- Let it dry if it becomes wet.
- Make it tight—You cannot control air until you enclose air.
- Control the air by pressurizing (when it makes sense to do so).
- Ventilate, and control humidity.

The first three measures are primarily the responsibilities of the architect and contractor. The last two are the responsibilities of the HVAC engineer and contractor. Only if the first three steps are completed adequately can the second two steps be cost-effectively achievable. As mechanical engineers, your success is dependent on the work of others, so it's to your professional benefit to make sure steps 1-3 are done correctly.

FURTHER READING

HPAC Engineering has published many articles on moisture problems within structures and the litany of resultant problems. These include:

- August 2001, Lew Harriman and Terry M. Brennan, “Better Dehumidification for Commercial Buildings.”
- September, October, and November 2000, Donald P. Gatley, PE, “Dehumidification Enhancements for 100-Percent-Outside-Air AHUs,” Parts 1-3.
- June 1998, William G. Acker, “Water Vapor Migration and Condensation Control in Buildings.”
- July 1997 Burge, H. A., “The Fungi: How They Grow and Their Effects on Human Health.”