MOISTURE CONTROL AND INSULATION SYSTEMS IN BUILDINGS, CHILLED WATER PIPES AND UNDERGROUND PIPES

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A Guide for Architects, Engineers, Contractors, Facility Managers, Construction Professionals and Homeowners

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A MANUAL ABOUT INSULATION/VAPOR BARRIER SYSTEMS

This manual is about moisture control and insulation systems.

This manual is based on the direct, forthright experience of the author, engineer, designer, contractor and project manager: Mr. William Allen Lotz, P.E.

This manual about moisture control and insulation systems arises from an authority who has examined at least two thousand buildings, facilities and plants over sixty years.

And I know that some the readers are surprised: "Moisture control *and* insulation systems?" they ask.

Yes, moisture control is *directly* related to insulation.

Actually, it was insulation that thankfully drew the attention of many American engineers such as L.V. Teesdale (1937) and H.W. Woolley (1940) as early as the 1930s to the dark side of insulating homes, pipes, ducts, plumbing systems, etc.[1,2]

Yes, insulation has a dark side. This dark side is called condensation.

Let me explain: Simply put, the air—any air—always contains a certain degree of water vapor (or humidity). Houses "house" water vapor originating from breathing, cooking, heating, plants, wet basements, rain, etc. Nature also produces water vapor from rain, evaporation from open water sources, groundwater, etc.

However, air cannot hold an indefinite amount of water vapor. Air can only hold water vapor up to the point of saturation. Once the air is saturated, the water vapor will seek new places where there is less water vapor.

How much water vapor air can hold depends on the temperature in which the water vapor exists. The higher the temperature, the more water vapor the air can hold. However, this process, again, doesn't go on indefinitely. At a certain point, and despite the increase in temperature, the air will be saturated, and the water vapor will move from places of high concentration to places of low concentration.

This very movement is what creates problems in buildings (structures, roofs, floors, foundations, pipes, ducts, etc.) because, with movement, the water vapor in the air *can* encounter cold surfaces. And as anyone knows, when water vapor encounters a cold surface, water vapor condenses.

This is something as old as the hills. It happens every time you pull your cold beer out of the fridge. Have you ever observed the water droplets on the outside of your beer a couple of seconds after it's taken from the freezer? What happened? The water vapor in the air has "hit" a colder surface and condensed.

Have you wondered why the windshield gets laden with dew overnight? It's due to the cold temperature of your windshield. The water vapor finds a nice cool spot, loses energy and condenses.

Real-life Examples

Imagine you are a content dweller of New York City during the wintertime. You happily take a shower for half an hour each day, live with your wife and three daughters who cook pasta and also have long showers of their own. If you are this happy dweller and your house lacks a kitchen range hood and/or bathroom exhaust fans, then you are in trouble! Why? Because you and your family are producing too much water vapor (despite the heating system in your dwelling). The air inside your house houses too much water vapor. This water vapor wants to find its way out.

So, what happens? The water vapor will go everywhere where there is less concentration of water vapor; mostly through the walls. Yuck! It's

[1] Teesdale, L. V. (1937). *Condensation in Walls and Attics*. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.
[2] Woolley, H. W. (1940). *Moisture Condensation in Building Walls*. US Department of Commerce, National Bureau of Standards.

winter, the weather outside is cold, and it's freezing. What will the water vapor do, then, when it meets the cold wall surfaces? It will condense. It will turn into water inside the walls of your house, and the nasty ensues—mold, rot, mildew, wood termites, etc.

Now let's imagine another scenario: You are a happy dweller of Houston, Texas. But this time you are working in a metal building. It's June. It's hot as hell outside with an average of 86 °F. The air conditioning is running at full throttle all day long. It's so humid outside that the outside atmospheric air is saturated with water vapor, and this water vapor wants (and must go) somewhere. Where will this water vapor go? You got it. I hear you saying: "It will move into the building, where there is less water vapor."

Oops! It's cold inside this metal building as the air conditioning has been running non-stop. Given the cold inside weather, the water vapor will have nothing to do but condense on the roof, purlins, walls, beams and all the metal building's components. Fast forward two or three years in this condition, and the metal building is rusty, raining inside and unfit for service.

What happened? The water vapor condensed and caused rust wherever it settled in this relatively new metal building.

Let me give a third example to water vapor movement to drive my point home: You are the manager of a brick building natatorium in Des Moines, Iowa. The indoor pool has a very high humidity level. The weather outside is hot and humid during the summer. Where do you think the water vapor will move?

As always, the water vapor will move from areas of high concentration to areas of low concentration. And in this case, though it is hot and humid outside, the air inside the natatorium has a higher content of water vapor than the outside air. Thus, the water vapor will find any way to move outside of this brick-layered building. However, what happens if this brick building lacks the right insulation system between the extremely humid environment inside the natatorium and the relatively high humid weather outside the natatorium?

Good, you knew it: The water will condense in the brick walls of the building, despite the presence of fiberglass batts insulation. In no time, the once beautiful, expensive and classic building will turn into a mishmash of red "stuff."

So, what I'm getting at is the following: When water vapor moves from areas of high concentration to areas of low concentration and encounters a colder surface, the water vapor will condense and turn into water.

This, my dear reader, is the simple basis of moisture control—and all mechanical engineering indeed, the cornerstone of which is the psychometric chart!

Enough examples and explanations. Let's move a step forward to the essence of this book.

Simple, Effective Solutions

What can we do to stop water vapor from condensing in our buildings, roofs, pipes, foundations, etc.? We can do one of two things: A) tear down any structure where water vapor can condense; or B) (surprise of surprises) install a barrier that will regulate the rate of escape of vapor through the confines of any structure.

Of course, no sane person in their right mind would tear down the walls of their house. Rather, they would opt for the barrier option. In other ways, any sane person would choose to place a water vapor barrier (or vapor barrier, in short) between the areas of high concentration of water vapor and those areas of lower concentration.

A vapor barrier, in contrast to the popular belief, is not something that obstructs water vapor one hundred percent. Rather, it is a regulator that allows a constant rate of water vapor through the wall. A vapor barrier, when installed continuously on top of the insulation, will not only regulate the passage of the water vapor through the walls, but it will also allow a house's insulation to stay dry—and dryness, my dear reader, is the absolute condition for any insulation to prevent heat loss.

But why install insulation along with a vapor barrier? Simply because insulation not only minimizes heat loss but also prevents the outside walls of a building (the outside walls of a foundation, the outside walls of a pipe, etc.) from cooling. And, if you remember, water vapor "revels" in finding cold surfaces and condenses when it touches cold surfaces.

The combination of the vapor barrier and insulation is what our profound author calls, and rightly so, an "insulation system." Any insulation system is formed of two things: A vapor barrier and insulation, or what will be dubbed an "insulation/vapor barrier system" throughout this book.

I won't talk lengthily here about insulation, for insulation is widely understood. What is misunderstood, notwithstanding that it is common sense, is the condensation of water vapor. Hence why I took some liberty in describing the process and gave some examples.

The Scientific Basis of the Manual

What is the basis behind such a huge claim regarding the insulation/vapor barrier system as the foremost factor in moisture control?

Actually, the basis of Mr. William Lotz, P.E. claims is purely scientific—besides being, of course, highly pragmatic.

Mr. William Lotz, P.E. started his moisture control and insulation/vapor barrier system assignment while in college. He set out to examine a nasty problem in an orchid warehouse in Florida while he was a senior student.

Let's delve together into his scientific papers published by the American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Journal.

In 1962, Mr. William Allen Lotz, P.E., published his first paper on insulation/vapor barrier systems describing an experiment that lasted five years—yes, five years.[3] What was this experiment? It was about a chilled vessel of –100 °F that was wrapped in two layers of insulation with the vapor barrier on the warm side (i.e. on top of the insulation that covered the chilled vessel). The vapor barrier was sealed tight. And to add rigor to the experiment, there were six protrusions through this chilled vessel. All these protrusions were covered in insulation with the vapor barrier again placed on the warm side. Of course, the vapor barrier on the chilled vessel, as well on the protrusion, was continuous and sealed.

What happened following these five years? The insulation didn't condense water, and remained intact performing its function!

But one scientific paper is not enough. So, the young Lotz (a P.E. by that time) decided to conduct another experiment in 1964.[4] This experiment was the culmination of nine years of testing air and heat transfer in refrigerating warehouses in Tennessee and Louisiana. Simply put, the thermal sensors (also known as thermocouples) installed in the walls of these refrigerating warehouses showed that if there is a continuous vapor barrier, the walls of these refrigerating warehouses would lose neither their cold temperature nor have air currents taking their coolness away! (N.B. For those scientific paranoids who love Ph.D. mathematics, read the scientific paper titled "Heat and Air Transfer in Cold Storage Insulation" (1964) included in this book!)

Where was this 1964 article published? In the American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Journal.

In another scientific paper in 1964, published (yawn!) in the American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Journal, Mr. Lotz, P.E. speaks about vapor barrier specifications, vapor barrier correct placing, vapor barrier continuity and a "**blower-door test**" to tackle non-sealed vapor barriers.[5]

Fast forward to 1969, Bill Lotz, P.E. writes an article (also in ASHRAE Journal) titled "Facts About Thermal Insulation."[6] In this scientific article, he advises on the continuity and the sealability of vapor barriers as an absolute to protect the insulation. This vapor barrier must have at least a 0.1 perm rating (perm is the measure of the permeability of the vapor barrier—more about this in the book). In this article, he also refers to how a properly sealed vapor barrier will prevent the corrosion of pipes and the potential loss of hundreds of millions of dollars!

If you notice, my dear reader, all the articles mentioned above were published by the American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)—the leading world authority in its field. In a peer-reviewed journal like that of the American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), only the best of the best are allowed to publish.

[3] Lotz, William A., (1962). Five Year Test Study of Fibrous Glass Cushion Over Vapor Barrier on –100 °F Insulated Vessel. *ASHRAE Journal*, pages 76–78.

[4] Lotz, William A., (1964). Heat and Air Transfer in Cold Storage Insulation. *ASHRAE Journal, issue* (70), pages 181–187.

[5] Lotz, William A., (1964). Vapor Barrier Design for Cold Storage Applications. *ASHRAE Journal*, pages 46–48.

[6] Lotz, William A., (1969). Facts About Thermal Insulation. *ASHRAE Journal*, 11(6), 83–84.

What You'll Get Out of This Book?

Now my dear reader, let me tell you briefly what this book will show you:

The first chapter is a moisture control primer. It gives real-life examples that our author, Mr. William Allen Lotz, P.E., has examined over the course of 60 years. You will learn about the various causes of moisture and the solutions—real-life solutions—that have worked over and over again.

In chapter two, you will gain unique and profound knowledge regarding the insulation/vapor barrier system—a topic that I challenge you to find with as much detail and pertinence in any other source as it is depicted in this book. As I stated previously, it is true that some American engineers referred to the use of vapor barriers next to insulation as early as the 1930s, but Mr. Lotz, P.E., was the only one to point to the scope, applications and technicalities of the vapor/barrier system.

Chapter three gets more specific about moisture control and insulation/vapor barrier systems in cold Northern climates, as well as in hot, humid Southern climates—and those climates in-between. This chapter stands heads and shoulders above when it narrates the experiences of our formidable author, Mr. William Lotz, P.E., with timber framing. Look out for those articles.

The fourth chapter describes an area that most designers (architects and engineers included) fail to understand. This elusive subject is the design area associated with buildings that have very high humid contents. These areas include indoor swimming pools, hospitals, ice rinks, granite chopping plants, etc. Any area where water is used copiously or where high humidity is deliberately maintained, special attention to the design and the insulation/vapor barrier system is in due order. If you don't believe me, then I urge you to read about the fiasco of the elegant masonry hospital in Iowa that had to be rebuilt from the outside-in due to a faulty design. This rebuilding of a hospital (which has to maintain its function during construction) cost tens of millions of dollars!

Chapter five discusses roofs and their problems. Mr. William Lotz, P.E., examines the diagnosis and prescriptions for ice dams—an extremely common problem in any Northern climate. In one of his "blasphemies," Mr. Lotz, P.E. notes that attic ventilation creates more problems than it solves. Attic ventilation, the favorite baby of most architects, allows cold air currents to sneak stealthily into the roof. Thus, a roof missing the proper insulation/vapor barrier system will suffer from these cold air currents. These cold currents prolong the freeze/thaw cycles of the snow on top of the roof. These freeze/thaw cycles can cause permanent damage to roofs. Be sure to check this chapter out as many good surprises await you!

Chapter six will be of special interest to building professionals, facility managers and owners interested in metal buildings. This category of people will come to understand why everything in the building may be built as designed, and yet the building still rains inside! There is an interesting "duel" that has taken place many years ago between the director of research and engineering at the Metal Building Manufacturers' Association and Mr. William Lotz, P.E. If you would like to know what transpired out of this highly ethical "duel," read chapter six!

Chapter seven tells about pipe insulation in buildings and processing plants. This chapter, along with chapters eight and nine, is la crème de la crème of Mr. Lotz's endeavors. Not only does Mr. Lotz detail the moisture problems (like rust, insulation failure, blockage, etc.) pertaining to pipes, but he also offers innovative answers to the chronic problems surrounding pipes. Personally, I'd urge every person holding this book to read the article titled "Don't Create Piping Problems—Choose Correct Insulation."

Chapter eight continues the story of pipe insulation, specifically on chilled pipes. Filled with case studies, this chapter shows every person interested in pipe insulation how to design, commission, specify and install pipes properly.

In chapter nine, Mr. William Lotz reaches the climax and discusses underground water pipe insulation installation. You will laugh out loud at how ignoring a simple geology report led to the loss of tens of millions of dollars. You will learn how Mr. Lotz pinpoints the failures and summarizes the alternatives that should have been executed to prevent such a huge loss of money, time, effort and reputation. There are few who had ever written about underground insulated piping problems in this much depth!

Chapter ten deals with external cladding and painting problems. In a series of important articles, Mr. William Lotz provides solutions for rotting or cracking clapboards, wind-driven rainwater, choosing the right sheathing, recurrent paint peeling problems, failing flashing, etc.! I underscore again that chapter ten is one of solutions. Read it carefully!

Chapter eleven will—I promise you—be one of the most irritating chapters to all folks dealing with energy efficiency. If you have been following me through this introduction, you will know by now that any insulation is only as good as its vapor barrier. Try as you please to insulate a building with ten-inch insulation per wall. This insulation is almost useless without the right, continuous and sealed vapor barrier. In one of his landmark presentations, Mr. William Lotz tackles the reason behind the failure of many "green" LEED (leadership in energy and environmental design) buildings.

Chapter twelve details the simple, most effective methods to protect your foundation and basement from moisture problems. At the center of this chapter is two solutions: A) Insulate your footing and foundation from day one to prevent moisture problems down the road; B) Choose the correct place in a lot to build your building.

Chapter thirteen will surprise many people, as this chapter outlines important basics regarding moisture control. This chapter busts the idea that moisture control is the consequence of natural water (i.e. rain, groundwater, water ponding, etc.) per se. Rather, Mr. Lotz, P.E. draws our attention to the fact that a faulty design for a heating and cooling system contributes to moisture problems. It also draws attention to the relationship between the number of people in any given house and the moisture content in this house. The chapter is full of forensic moisture problem case studies. Some of these problems were solved with the installation of something as simple as a bathroom exhaust fan. Read this chapter and be ready for a couple of good laughs!

Chapter fourteen deals with the right business practices. And yes, this chapter pertains directly to the core of this book—moisture problems and insulation systems. For without good business practices between all the professionals in the building industry, lawsuits will keep mushrooming.

Chapter fifteen terminates this book with the history of the Lotz family in the insulation industry. It gives you a tour-de-force on the amazing accomplishments of the Lotz family in the business and engineering. Not only was the Lotz family one of the pioneers of installing insulation as early as the 1920s in New England, but they also proved to be a profound contributor to the development of flame-resistant insulation and all service pipe insulation. The "dominance" of the Lotz family from New England down to Florida merits a whole, albeit smaller, chapter.

In more precise words, by the time you have gone through the first couple of chapters, you will be able to peek into a building and pose the precise questions that will lead you to the right answers pertaining to the moisture status of this building. By a single peek, you will start at the soil of a building, the foundation, the exterior cladding, walls, ceilings, finishes, windows, doors, paint, kitchen condition, bathroom condition, roofs, attics and the activity of the human inhabitants in this given building. You will look at all that and be able to pinpoint what the heck is going on with this building (or any components of a given building or facility).

Said differently, this book provides a unified theory for not only identifying the source of moisture but also for providing simple, practical solutions.

Stepping on Toes

Now, let me step on some of the toes by declaring something you might think heresy: This manual, my dear reader, will teach you energy efficiency like no other book. Most schools of energy efficiency think only of mitigating the "sinful" human act of living on earth and utilizing its resources. This kind of energy efficiency thinking results, more often than not, in simplistic answers (e.g. no need for any jogs in a building or sloped roofs or drop basements out of any residential building, etc.). These simplistic answers prove to be very, very expensive, and downright prohibitive with ugly, unindividualized architecture.

I won't mention the names of these "schools." Suffice to say that many of their passive claims originate in Germany—as well as in Canada. Yes, I've come across Canadian pioneers who think that energy efficiency is one-size-fits-all thinking. Fortunately for people, like myself, who believe in the diversity of solutions to our most entrenched problems, this manual teaches us that energy efficiency follows suit a well-designed, well vapor-barrierized, well-insulated building. The tightly sealed, continuous insulation system in any building (or facility or plant) will by itself take care of the energy efficiency.

Equally, I know that this book will step on and irritate the (proclaimed) experts of moisture control in the states of Massachusetts, New York and Illinois—all of them in the United States of America. None of these self-proclaimed experts is a registered professional engineer—unlike Mr. William Allen Lotz, P.E. They can say whatever they want to say. What they say is theory, and not a fact of someone who has been there, done that!

Long, Live the Doers!

Mr. William A. Lotz, P.E., has examined over two thousand buildings and facilities. Moreover, Mr. Lotz has worked with the foremost American pioneers in insulation development, where he supervised the production and execution of hundreds of projects. However, the most important aspect that makes the work of Mr. Lotz dearest to me is his hands-on experience installing insulation as a contractor from a family steeped in the insulation business.

I, myself, am a carpenter/builder, besides being engineering student. I still find it incredibly satisfying to build something out of nothing. A well-designed and well-executed project can challenge you mentally as it does physically like nothing else in life. Anyone can get a university degree, but there are few of those who can get a degree and are able to artfully execute the theory a university degree imparts!

My dear reader, I'll stop here.

Feel free to reach me at moisturecontrolbook@gmail.com should you've any questions or praise or scorn.

I love listening to scorn as much as I do to praise!

Joseph M. Hough
Vancouver, British Columbia, Canada
moisturecontrolbook@gmail.com

CHAPTER ONE

THROUGH THE SPECTRUM OF MOISTURE CONTROL: *DISCOVER THE INSEPARABLE RELATION BETWEEN INSULATION, VAPOR BARRIERS AND MOISTURE CONTROL*

WET BUILDINGS: A MOISTURE PRIMER*

An investigation into the various causes of moisture problems in buildings.

This article will attempt to clarify the various issues that must be solved when investigating the cause of a building moisture problem. Several classic errors that have resulted in engineers and contractors defending themselves in lawsuits will be reviewed.

Moisture from internal and external sources is the most frequent cause of building problems and subsequent legal action. Many reported "roof leaks" are, in reality, condensation problems that have nothing to do with the roofing contractor. Indoor swimming pools, trash plants, ice rinks and humidified buildings—hospitals, printing plants, museums, etc.—can have severe condensation damage with rot, corrosion, peeling paint, water stains, and in some cases building structural failure. Mechanical design engineers need to work closely with the building owner, architect, and contractors to ensure a dry, durable building.

The first issue to examine is if the moisture is coming from the outside—i.e., rain and/or groundwater.

Rain Leaks

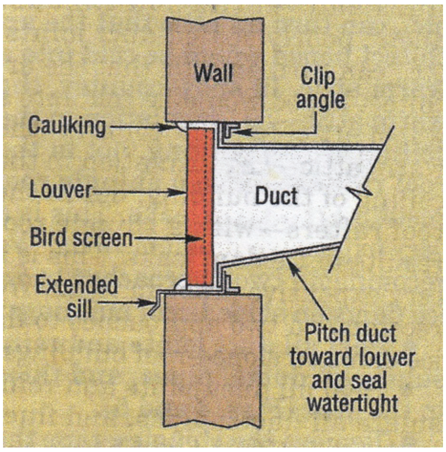
Rain leaks can be so severe that they add to the air conditioning latent load. We find this to be particularly true for hilltop and ocean-front buildings due to the driving effect of the wind in these locations. These exposed (to the wind) sites are more likely to have wind and rain leaks and added HVAC loads.

We see many examples of caulk failure resulting in leaks, rot, corrosion and general building deterioration. Care must be taken in writing the caulk specifications. Then, the building owner needs to take responsibility for inspection and maintenance of the caulk. Caulk does not last forever. I frequently see caulk less than two years old in need of replacement or repair. In one South Carolina shopping center, the walls had inadequate caulking and flashing and this (along with no housewrap) resulted in severely rotted walls within 24 months of occupancy.

The HVAC specifications for louvers and exterior exhaust grilles should require caulk around each exterior mechanical penetration. The same is true for flashing around HVAC penetrations. We have seen several buildings where rain has leaked into the structure via the HVAC louvers. Fig. 1 shows a detail of a properly designed exterior wall louver installation. The engineer's efforts, however, were defeated by the contractor. The required caulking between the louver and the wall was not done. Also, the bottoms of the ducts where they terminated at the louvers were made horizontal rather than pitched down toward the louver for drainage (Fig. 2). As a result, water leaked into the building during most rainstorms through these exterior duct penetrations (Fig. 3).

Roof overhangs aid significantly on low-rise buildings in providing protection from rain leaks.

*Permission to publish this article was granted by Heating, Piping, Air Conditioning (HPAC) Engineering Magazine. The article first appeared in January 1998.

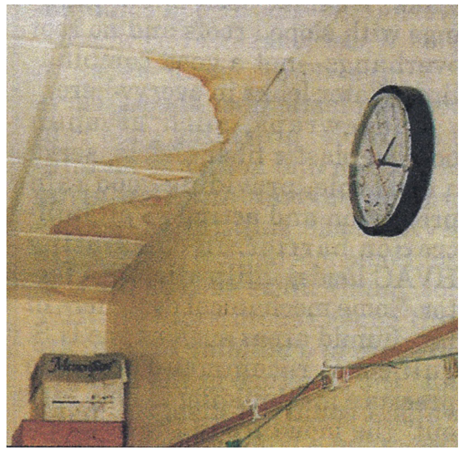


1. The engineer drew this good louver detail; the contractor ignored it and built the bottom of the duct flat. Caulk was "forgotten," and the ducts leaked during most rainstorms. Nothing was watertight.

2. The engineer designed the classroom outside air grilles as shown in Fig. 1. This photo shows the actual installation. The contractor claimed there was not enough room to slope the bottom of the duct. The ducts could have been offset, however; close to the wall or possibly installed at a slightly higher elevation.

We have seen a few buildings with sloped roofs and no roof overhangs—not a good combination! Water leaks in everywhere.

Housewraps such as spun bonded plastic fiber sheets serve a dual role by providing good rain protection and acting as an infiltration barrier. In calculating HVAC loads, infiltration is a factor. Some mechanical designers in hot, humid areas such as the U.S. Gulf Coast recommend positive pressure in a building to help "dry out" the moisture in the building's walls—I could not disagree more! Designing a building to blow conditioned (expensive) air out



3. Leaks stained the acoustical ceiling under most of the outside air ducts shown In Fig. 2.

through cracks in the walls results in cooling costs that are completely wasted. It's like designing an air-conditioned building with the doors and windows open. In my opinion, it is much more cost effective to install an air and vapor barrier on the exterior of the wall insulation (remember, hot and humid climate) to prevent the moist ambient air from entering the wall in the first place (pardon the sermon).

We see rain leaks at all types of doors and windows due to inadequate design and specifications. Windows are made to different code standards for wind and rain velocities. Architects need to require wind and rain tests that are suitable to the area and specific site.

Ice Dams

A source of ice dams and subsequent leaks in northern climates is HVAC equipment in supposedly "cold" attics. Usually, these attics are nearly room temperature in the dead of winter due to heat/air leaks in the HVAC equipment, ducts and pipes. Uninsulated flues and ventilation exhaust ducts, poorly sealed duct joints, etc., can turn an attic that the architect hoped would be cold into a warm attic. In snow country, the warm attic—i.e. insulation in the ceiling of the building, not in the roof rafters—with a shingle roof results in ice dam leaks. This is a very expensive problem to fix. We recommend two approaches to fix ice dams on sloped-roof buildings:

- Seal all duct joints and reinsulate all ducts, pipes and flues in the attic (Figs. 4 and 5).

- Remove the shingles, tape the roof sheathing joints airtight with a rubberized asphalt tape, insulate the entire roof with one-and-a-half to two-and-a-half inches thick isocyanurate foil-faced insulation board, cover the insulation with plywood and a good-quality membrane and reshingle.

Conventional eave and ridge vents in the attic are frequently inadequate to vent the HVAC equipment leaks. From my 40 years' experience as a moisture consultant, attic ventilation seldom solves anything and frequently results in reduced thermal effectiveness of the attic insulation, especially in northern climates.

4. Uninsulated bathroom exhaust ducts in a nursing home resulted in ice dams and leaks.

5. The duct joints were poorly sealed. and there were many gaps in the duct insulation. The attic was warm as a result, and ice dam leaks were everywhere.

Groundwater Leaks

Many of the reported roof leaks that I see are not really roof leaks but condensation that results from groundwater leaks into the basement of crawl-space. A simple test to determine if moisture on the concrete surface is leakage or condensation is to duct-tape a polyethylene sandwich bag to the floor. Within a few hours, you can check whether the moisture is on top of the polyethylene (condensation) or under the bag (leakage). This is a simple, inexpensive test that gives easy-to-understand results. It is also important to study the geotechnical engineer's report on the soil and water table in the area of the building.

Most crawl spaces are under multi-family housing or older light commercial buildings. A crawl space without a concrete slab covering the earth is a disaster waiting to happen. Recently, I consulted on an eight-year-old building where the owner discovered he had a moisture problem when a couch leg went through the ceramic tile floor. The building had a dirt floor crawl space and it took eight years for the plywood subfloor to rot to destruction. Dirt floors in crawl spaces are, in most climates, an almost infinite source of moisture into the structure. Polyethylene membrane on the floor helps cut down on the moisture, but the best solution is a three-to-four-inch concrete slab on top of the polyethylene membrane. I recommend a heavy-duty polyethylene membrane (cross-laminated, high-performance polyethylene membrane is best) under floor slabs. It is a very inexpensive assurance of a dry slab.

Concrete block foundations are more prone to leaking than poured concrete foundations. Concrete foundations withstand leaks quite well but may leak at joints and cracks. There are several excellent underground waterproofing systems on the market, such as rubberized asphalt sheets and bentonite clay panels. To repair existing leaking cracks in a concrete foundation, we generally recommend chipping out the cracks about one-inch wide and one to one-and-a-half inches deep and filling the crack with epoxy grout.

Roof Leaks

Roofs do leak. We have looked at countless leaking roofs in the past. Most HVAC engineers are not interested in the subject of chasing roof leaks, and we will therefore not discuss this subject further. (Please see the chapter titled "Roofs" for more detailed information.)

The second issue to examine is if the moisture is from internal sources. This must also include a discussion of vapor barriers and insulation systems.

Vapor Barriers

Most building codes require an Underwriters Laboratories (UL) fire-rated (flame spread under 25) vapor barrier wherever the vapor barrier is not covered and in contact with sheet rock or other non-combustible materials. I have opened up countless acoustical ceilings and looked up at combustible vapor barriers eight to twelve inches above the acoustical tile. This is a fire hazard and a code violation.

An engineer in Florida recently told me he solves the condensation problem by pressurizing the building with the HVAC system and lets the cool, dry conditioned air blow out through the insulation in the walls to prevent condensation. This may prevent condensation in the wall but at a huge price to the owner in operating costs. When air moves through the insulation system, the air flow negates the *R*-value of the insulation.

Fifty years ago, condensation was not a major issue due to the use of minimal insulation and to buildings' tendencies to leak large quantities of air. In today's market, we cannot afford to go back to uninsulated buildings. I have seen many 12-inch thick insulated ceilings and 6-inch thick insulated walls that had effective *R*-values close to zero due to air flow. If air can flow through the insulation, so can moisture. Unless a *vapor* barrier is also an *air* barrier, it is not a vapor barrier at all.

The best overall wall insulation system, in my opinion, is a combination of foam insulation, glass fiber, and a good (UL rated as required), *sealed* vapor barrier.

Continuity

When thinking of continuity of insulation systems, think of a ship's hull—if there are holes, it will leak. Insulation system continuity is necessary to prevent condensation. By *system,* I mean the insulation, the vapor barrier (or retarder, if you prefer) and the adhesives, tapes, and fastening clips that hold everything in place. Continuity means the wall vapor barrier is sealed to the floor and also to the roof or ceiling vapor barrier. It means that if the insulation/vapor barrier system in penetrated by structural components, it must have special provisions with design details—not just a blanket statement that all insulation must be continuous. Continuity means that all electrical, plumbing, HVAC, sprinkler etc., penetrations of the insulation/vapor barrier system are sealed air and vapor tight.

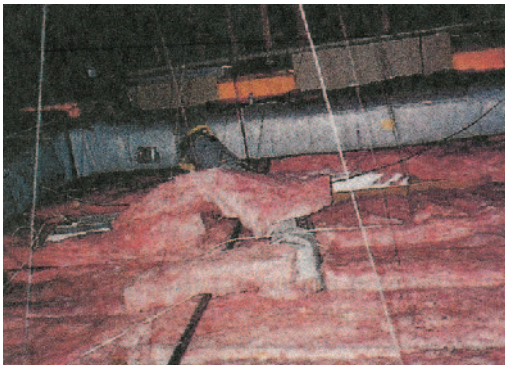
Common practice in insulating metal buildings is to squeeze down the four-inch insulation at purlins to three-eighths-of-an-inch thick or less and to fold and staple the vapor barrier facer. *This is not continuity!* Both of these practices result in condensation, dripping and corrosion. If the four-inch thick insulation is only three-eighths-of-an-inch thick at the purlins on 60-inch centers, you can count on condensation—even in non-humidified buildings in a cold climate (say, north of Kansas City and Washington, D.C.). When a contractor folds and staples a vapor barrier, it is not sealed and vapor (along with wasted energy) flows readily to the cold exterior wall. I have seen many metal buildings reduced to a rusty mess as result of these common practices.

Glass fiber is the ubiquitous insulation and an excellent, cost-effective product. It relies 100 percent on vapor barrier workmanship to prevent condensation in the insulation. Unless the vapor barrier joints are sealed with a suitable adhesive or tape, the vapor barrier is of little value. Have you ever tried to make a canoe out of a screen door? You get the same result—water where you don't want it. It is difficult to get continuity with the typical glass fiber residential-type batt insulation. In attics, I recommend a combination of batts and blown wool.

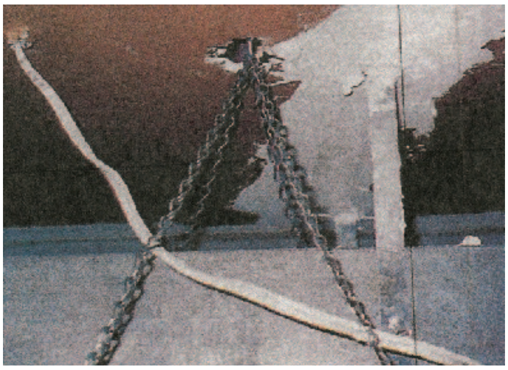
Figs. 6 through 9 show, in vivid detail, the serious damage that can occur when the insulation/vapor barrier system is either improperly designed or damaged during construction.

Humidification

Many humidified buildings function without problems but adding humidification to a building (in the



6. Attic in office building. Batts on acoustical ceiling resulted in almost zero *R*-value due to air flow through the ceilings and batts.



7. Holes in sheet rock, vapor barrier and insulation for lighting fixture support resulted in heat loss, condensation and staining.

8. Unsealed polyethylene membrane vapor barrier resulted in major heat loss, condensation and stains. This also violates building codes as polyethylene membrane is not Underwriters Laboratories-rated Class A fire resistant.

previously defined cold climate) can cause major, costly problems. Condensation takes place when the humidified air comes in contact with a surface that is below the dew point temperature. The key to keeping the building dry (free of condensation) is to design a continuous insulation/vapor barrier system.

More often than not, the engineer designs the HVAC humidity control, and the architect designs the insulation/vapor barrier system. Neither talks to the other about the basis for their designs. Frequently, this approach doesn't work, and both the engineer and architect get sued by an angry owner when condensation is dripping on his desk.

9. Batts above acoustical ceiling. There is no continuity of insulation or vapor barrier, and the Kraft facer violates code for fire resistance.

Architects assume that the engineer has the humidity under control—at 40 percent relative humidity, 50 percent relative humidity, or even 60 percent relative humidity. Well, let's look at the points at a 70 °F room temperature: at 40 percent relative humidity, the dew point is 44 °F; at 50 percent relative humidity, the dew point is 51 °F; and at 60 percent relative humidity, the dew point is 56 °F. The situation is even worse for an indoor pool building where the typical design conditions are 82 °F and 55 percent relative humidity, which equals a dew point of 64 °F.

It is obvious that you don't have to be in Duluth to have wall or ceiling surfaces below the dew point and hence have condensation. As a consultant on moisture, insulation and HVAC issues, I tend to see only disasters. Addressing the moisture and insulation issues prior to construction saves spending money on lawyers' fees. When a moisture problem occurs in a new building, the owner wants it corrected immediately.

In quickly built buildings, the moisture from the curing of the concrete, etc., which can be substantial, is still drying out when the owner moves in. The owner wants a reasoned explanation of whether the problem is construction moisture or the beginning of a long-term condensation problem.

Chilled Water

Mechanical systems are sometimes the source of condensation problems; especially in hot, humid climates such as the South Carolina coast down to Florida and over to Houston. One of my first troubleshooting calls to diagnose a dripping chilled water system (in 1958) turned out be to a leaking valve. Most chilled water drips are not so easy to fix.

Well designed and properly installed foam insulation systems with vapor barrier integrity are a critical factor in preventing ceiling drips and stains from the cooling pipes above the ceiling. Foam insulations, such as cellular glass and some flexible elastomeric foams, are also good vapor barriers—as long as the seams are well sealed (please—not with common duct tape). Other foam insulations, such as urethanes, polystyrenes and isocyanurate, need a well-sealed vapor barrier. Closed cells do not necessarily mean a vapor barrier.

A lot of recent pipe insulation workmanship that I see leaves a lot to be desired, and it is frequently done by the plumber. Many of the old-time, experienced pipe insulators have died due to asbestos related illnesses. This makes it even more important for the engineer to write a good, clear, simple mechanical insulation specification.

If you want to keep up to date on mechanical insulation, call your local mechanical insulation contractor. From my experience, the insulation manufacturers seem to have few, if any, salesmen who call on engineers anymore.

Warehouses

Warehouses are normally "dry" occupancy—or so you would think—and hence have no condensation problems, right? Wrong. Common warehouse construction is either concrete block or metal, lightly insulated with a direct gas-fired heating system, and to make matters really wet, minimal ventilation. Direct-fired gas produces water vapor as a result of combustion of the hydrocarbon. The first winter finds the block walls saturated (no sign of a vapor barrier) or metal building rusting (no seal in the vapor barrier). The solutions include retrofitting with a viable insulation/vapor barrier system, an indirect-fired heating system, or a major outdoor air and exhaust system. All of these are costly. Direct-fired systems can provide very satisfactory heat as long as adequate ventilation is provided to handle the moisture.

Metal buildings are more sensitive to moisture problems. Wood and concrete buildings absorb great quantities of moisture before the condensation becomes apparent. With metal buildings, the dripping shows up immediately.

Trash Plants

Trash plants —i.e., trash-to-energy facilities— have a huge storage room filled with wet trash and garbage. These rooms are generally unheated, even in cold climates, and are either uninsulated or lightly insulated. They are also very humid and rusty. Ventilation is controlled to prevent odors, and often the ventilation air is used as combustion air in the trash-burning chambers. Relative humidities of 80 or 90 percent and above is not uncommon. Corrosion damage is swift and severe. Fig. 10 is an example of serious, repetitive corrosion found in a trash-to-energy plant.

Cheap solutions are not viable for this type of severe condensation environment. Our solutions have included glass fiber reinforced plastic (FRP) panels, stainless-steel fasteners and factory-made isocyanurate panel systems.

10. Severe purlin corrosion in this trash-to-energy plant resulted from constant condensation. Owner paid to sandblast and repaint almost yearly to no avail.

Indoor Pools

Indoor pools are a reliable source of condensation headaches[1] (Figs 11 through 13). Outdoor air, as a means of humidity control, does not provide year-round acceptable results. There will be days in

[1] Superscript numerals indicate references listed at the end of the article.

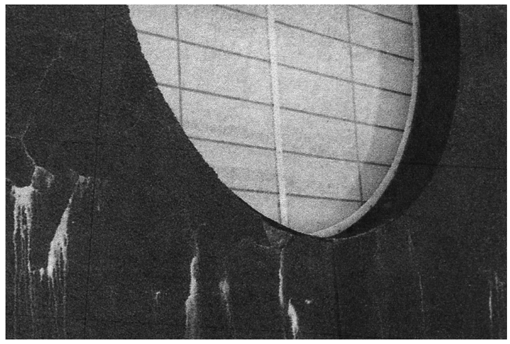
11. Asbestos aircell insulation. If you encounter it, call the abatement contractor immediately.

12. Typical lack of detail above acoustical ceiling resulted in costly damage. There should have been both insulation/vapor barrier in the roof flutes.

13. Damage to building exterior due to interior details shown in Fig 11. The masonry deteriorated, and the steel rusted.

August when the outdoor air is warmer and more humid than the indoor pool environment you are attempting to control. There will also be days in January when bringing in outdoor air can create a cloud inside the building. I recently consulted on the design of an indoor pool in south Louisiana where the indoor and outdoor conditions were about the same. In northern climates, moisture problems in pools seem to be rather common, unfortunately.

Air-to-air heat exchangers provide better (than just ventilation) relative humidity control along with energy conservation, but still there will be summer days when the relative humidity goes very high (70 to 90 percent). Many of my indoor pool HVAC designs utilize dehumidifying heat pumps,



14. Severe wall damage and stucco failure as a result of no wall vapor barrier before the inside surface of the extruded polystyrene insulation.

which provide year-round humidity control with the waste heat reused to heat the pool water.

Dehumidifying heat pumps are an example of sophisticated equipment that must be properly sized and installed and must be regularly serviced. We have seen malfunctioning dehumidifying heat pumps installed in small towns where none of the local HVAC contractors had any idea of how to service this type of equipment. With minimal training, the small-town contractor can learn to keep these systems controlling indoor pool relative humidity 365 days a year. Few other types of indoor pool humidity control systems operate day in and day out at the design conditions of 50 percent relative humidity of ±5 percent.

Hot, Humid Climates

One of the many states in which I maintain a professional engineer license is Florida. Florida *really* experiences moisture problems. The building vapor barrier in hot, humid climates (previously defined) must be on the exterior side of the insulation—just the opposite of cold-climate buildings. The use of building vapor barriers in this climate is just starting to evolve. Unfortunately, the residents of this geographic area have put up with condensation, mold and mildew for years as being "part of the territory." It doesn't have to be that way.

The solutions are simple—a reasonable degree of vapor resistance on the exterior of the building and an air conditioning system designed to control humidity. I consulted on one central Florida nursing home that had the cheapest wall-mounted air conditioner, much mold, and 86 percent relative humidity. There was mold on beds and lamp shades. Significant dehumidification equipment was quickly retrofitted, and the problem was solved.

Conclusion

There are probably a few humidification equipment salespeople who think I am against humidifying buildings—this is not so. What I recommend is that any building that is humidified have a carefully designed and installed insulation system. If a humidified building does not have a better-than-average insulation system, there will be condensation problems.[2]

Humidity is needed in hospitals and in countless process applications. In any humidified building, the HVAC engineer must work with the architect (or whoever else is involved in the design) to assure the adequacy of the structure's insulation system. In one museum (humidified), the owner insisted on a building designed to be free of condensation problems. There were several large duct chases adjacent to outside walls—with no wall insulation or vapor barrier. It was a costly error for the architect.

Moisture problems are the most frequent problems in buildings. In this article, I have attempted to give the engineer and contractor some tips on how to avoid moisture-related lawsuits.

References

1. Lotz, W., "Indoor Pool Design: Avoid the Potential for Disaster," *Heating, Piping, Air Conditioning Magazine*, November 1995.
2. Lotz, W., "Humidify Without Moisture Problems," *Heating, Piping, Air Conditioning Magazine*, September 1989.

CONDENSATION IN BUILDINGS—CAUSES AND SOLUTIONS*

When we "tighten up" old buildings as a part of an energy retrofit, moisture problems become accentuated. Buildings that previously used huge quantities of energy are now energy efficient, wet and rotting.

Moisture in a building is a result of people breathing, bathing, humidifiers, indoor plants, washing clothes and dishes; construction water in plaster, paint, wood and concrete; pools, rain leaks, wet basements and crawl spaces and bare ground in basements (old houses) or crawl spaces. These are primarily problems in cold climates—approximately 4,000-degree days or more.

Moisture can result in mold problems in warm climates, but for purposes of this discussion, we will only consider cold climates.

Moisture problems become more severe as the climate gets colder, but contractors and designers in colder geographic areas are more aware of moisture problems and hence more careful—usually. Moisture vapor in the air is no particular construction problem until it condenses into liquid or freezes into ice.

Condensation occurs when there is a cold surface inside a building that is below the dew point temperature of the air and the humidity is "high." In New England, 40 percent relative humidity could be considered "high" whereas in more temperate climates 60 percent would be high.

Basics

The purpose of a vapor retarder is to control water vapor travel within a building. Vapor condenses into water when it touches a surface that is cold. (Cold means a temperature that is below the dew point temperature of the air.) The two keys to preventing rot, mold and other severe results of condensation are to reduce the humidity level and to keep the vapor retarder warm.

The vapor retarder (usually four-or-six-mil polyethylene membrane with joints sealed with special tape or acoustical sealant) should cover all ceilings (or roof), walls and under the floor slab or crawl space. Use common sense and keep it simple in making the vapor retarder connections at the foundation and roof. Keep the vapor retarder as continuous as possible. Wood and sheetrock are not an adequate vapor retarder for the climate of New England. A good-quality, foil-Kraft laminate (depending upon foil thickness) can be a good vapor retarder. The foil on sheathing-type product is a good vapor retarder but remember it is critical to seal the joints! Also, foil is subject to corrosion from many sources including Portland cement products. Many foil facers have extremely thin foil and their value is questionable.

Reverse Flow

In some areas of a building, reverse vapor flow can occur. This can occur in a wall between an attached greenhouse and the main portion of the house or in a floor above a crawl space or damp basement or in a building that is air conditioned for six months of the year. There are several possible solutions. One solution is to use an insulation with vapor resistance such as foil faced foam board, extruded polystyrene or extruded polyethylene foam. Another solution is fiberglass with a double polyethylene membrane vapor retarder—one on each side. This should be done with care. A third approach, which is used in floors above crawl spaces, is unfaced fiberglass batts (no vapor retarder) with vapor porous non-woven air barrier material on the bottom of the floor joists to keep the batts from falling out.

Construction Water

Construction water can cause condensation problems before the building is lived in. Concrete can take two years to dry out, and wet or green lumber can be a source of moisture problems. In some cases, on the other hand, moisture is not a problem or does not become apparent as the construction materials absorb the water for years before rot is evident.

Vapor Retarders

At this point, let's define a vapor retarder for northern climates—climates of 4,000 or more-degree days. Northern climates require a 0.1 perm vapor retarder (a perm is equal to a grain of water per hour per square foot per inch of mercury vapor pressure differential—obviously). A grain of water equals one drop of water. Typical vapor pressure differentials run between 0.15 and 0.5.

*Published in the Massachusetts Builder Magazine in May/June 1989.

The Kraft vapor retarder on residential fiberglass batts is rated at approximately 1.0 perms and the foil faced vapor retarder is approximately 0.5 perms. Acceptable vapor retarders include four-mil-thick polyethylene membrane and any film or foil-Kraft where the foil is at least one-third-mil thick. Light weight roofing felt is not a vapor retarder. Some special paints applied in proper thickness are adequate vapor retarders. Some plywoods are an excellent vapor retarder. The joints must be sealed for an effective vapor retarder system, however.

There are "high-performance" cross laminated polyethylene vapor retarders made by a variety of firms that are far superior to "ordinary" polyethylene membrane in perm rating, toughness and durability.

Periodically, we hear rumors of polyethylene membrane degradation and failure. I have yet to find an actual case of polyethylene membrane failure in a building. Polyethylene membrane can be damaged by leaving it in the sunlight for many months. All materials can be degraded by improper use, but polyethylene membrane is our best available product for building vapor retarders. There are a variety of good foil laminate vapor retarders available on the market, but they are more expensive than polyethylene membrane and have more joints to seal.

Retrofit

A retrofit vapor retarder can be created by painting the sheetrock with two coats of vapor retarder paint. On my old Cape, I did it the hard way. I carefully removed selected clapboards and the sheathing under those clapboards. I then checked the stud spaces to make sure I had access to the entire wall. Next, I cut a four-mil polyethylene membrane film to fit each stud space with about a two-inch overlap on each stud. I stapled the polyethylene membrane onto the lath and either poked the vapor retarder into place or used duct tape to attach a rock to one end of the film and let gravity take the polyethylene membrane to the bottom of the stud space. This approach is not ideal; however, it is much cheaper and faster than gutting the interior of the building. I did this nine years ago and it is performing well.

Buried Vapor Retarder in The Wall

Where a high moisture level (relative humidity) is not anticipated, the vapor retarder can be buried inside the insulation. For example, in an R-30 wall, the vapor retarder could be placed one third of the *R*-value into the wall (from the warm side). This approach must be used with caution, but it provides a means of getting the vapor retarder away from possible damage by other trades.

Multiple Vapor Retarders

Frequently, we are asked about potential problems when there is more than one vapor retarder in a wall. First: put the most effective (lowest perm rate) vapor retarder on the warm side. Second: don't seal the joints of the colder-side vapor retarder. Some examples are:

- Polyethylene membrane on the warm side of the foil or Kraft fiberglass batt "vapor retarder"—no problem.
- Polyethylene membrane on the warm side of foil-faced sheathing—probably no problem as long as the polyethylene membrane is well sealed, and the sheathing joints are not sealed. This is a calculated risk depending upon how much *R*-value exists between the two vapor retarders. (See Buried Vapor Retarders above.)
- Foil-faced batts and foil faced sheathing on the cold side—this is potential disaster.

Basements and Crawl Spaces

On new construction, it is good practice to put heavy (eight-mil) polyethylene membrane under the floor slab. Crawl spaces should definitely have polyethylene membrane (preferably black) on the ground. A foundation wall vapor retarder of some good-quality waterproofing should be considered.

Insulating Walls of Existing Houses

People often ask me about the advisability of insulating the walls of an old house—but before I can answer the question, I have to ask several questions.

Is there a wet basement or crawl space? Are there effective bathroom exhaust fans as well as a kitchen outside exhaust fan—and are they used or for decoration? Is the clothes dryer vented outdoors? How many people live in the house and what is the size of the house? Are there unusual moisture sources (greenhouse, spa, pool, hot tub, etc.)?

Can the interior walls be painted with vapor-retarder paint? What are the sheathing and clapboards made of?

With reasonable answers to the above, I would recommend insulating the walls with fiberglass or rock-wool blowing wool.

Case Studies

The following case studies are "wet" buildings from Martha's Vineyard to Maine that we have investigated for clients.

SANFORD, MAINE

Residence built approximately 1965

There were six people in this three-bedroom home. On the exterior walls behind pictures, dressers and in closets, there was a black mold on the paint. The walls were constructed of cement block with a good foil vapor retarder next to the sheet rock. There was no ventilation in the bathroom or kitchen. The basement was dry. The problem was caused by very cold walls (no insulation) and a high moisture level resulting from six people in a small house with no ventilation. The solution was to install exterior bead-polystyrene board insulation on the walls with a stucco type finish and add ventilation fans to the kitchen and bathroom.

CAPE NEDDICK, MAINE

Seasonal residence built approximately 1955

This home was built over a crawl space that seasonally was a small "swimming pool." The north wall was severely rotted including studs, sheathing and clapboards. The walls were insulated with Kraft faced mineral wool batts. The problem was caused by the wet crawl space. The solution was a sump pump, 8-mil polyethylene membrane film on the ground and ventilation of the crawl space during all but freezing weather.

NEWPORT, MAINE

Large luxury seasonal home built 1979

On the second floor there was a 15-foot square closet that was uninsulated and every time the sun shone on the roof in cold weather it "rained" in the closet. The architect had installed roof ventilators to "solve" the problem. When I saw the closet, there was a quarter-of-an-inch layer of frost all over the roof sheathing except for six inches around each of the ventilators. Further study showed that the house was built in a swamp and the crawl space had six inches of gravel, a polyethylene membrane vapor retarder and then six inches of sand. This was good design except the water table rose up above the polyethylene membrane and it now became a "swimming pool liner." There was no crawl space ventilation. The solution here was to get the vapor retarder above the water table or pour a concrete floor and to ventilate the crawl space. The floor above the crawl space had foil faced fiberglass batts which did little to retard vapor flow from the crawl space to the living area.

HUDSON, NEW HAMPSHIRE

Small residence built in the mid- 1960s

This was an all-electric house with ten people living in it. One wall of this two-story house was severely rotted, the plywood sheathing had delaminated, clapboards had fallen off and you had to hold on to the windows when you opened one or it would fall out. The house had a polyethylene membrane vapor retarder that the owner and his lawyer were convinced had caused the problem. They wanted to sue the corporation that recommended the vapor retarder. I was hired to help with the technical aspects of the suit. My investigation revealed that the builder had installed the polyethylene membrane vapor retarder on the first floor from the floor to the ceiling and went upstairs and did the same thing. Hence, there was a 10-inch space horizontally around the house with no vapor retarder. The two two-by-ten lumber in that space had turned to black mush. There were ten people in a 1,000-space foot house with three baths and no bath or kitchen ventilation. There was no furnace to use air for combustion. A fan in the hall ceiling connected to a humidistat and vented into the attic where the moist air hit the cold sheathing, condensed and ran down to the eave. Time had provided part of the solution—several of the children had grown up and moved off to their own homes. The remaining solution included bath and kitchen fans that vent outdoors. Unfortunately, by the time I was called in to consult, the house had been rebuilt with the same gap in the vapor retarder!

GREENFIELD, NEW HAMPSHIRE

Dormitory, two-story, built in 1972, brick construction

The plaster around the windows had severely deteriorated and condensation was evident in selected areas of the wall. The building was fairly dry with no significant humidity sources, so my first thought was to look for rain leaks. It was finally discovered that the insulation ended about eight inches from the window frame in the brick wall. It was also found that the architect extended the concrete floor slab to the exterior of the wall with no insulation. The net result was two cold areas—one around the windows and the other at the second-floor slab where sub dew point temperature existed. The solution was to encase the building walls and roof in four inches of polystyrene bead board with a stucco exterior finish and new roofing.

YORK, MAINE

Residence built in 1980

The owner became concerned when he found frost in the attic under the few two-by-eight lumber boards that were used as a walkway on top of the ceiling joists. The problem was caused by the lack of a vapor retarder in the ceiling. The solution was to install polyethylene membrane under the fiberglass batts.

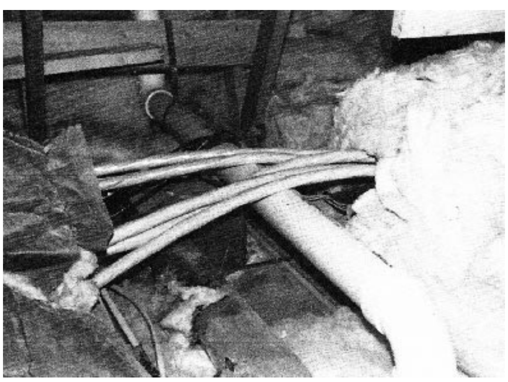


Photo A. Ceiling above bathroom (note exhaust fan). Ceiling was covered with black mold due to missing insulation and non-use of exhaust fan.

BERLIN, NEW HAMPSHIRE

Roller skating rink built in 1980

This is a metal building that was insulated with cellulose (sprayed) adhesive insulation. This product is made from ground up newspapers with a water-based adhesive and chemicals added for fire resistance. The product was sprayed on the metal building interior. There was no other finish on the walls or ceiling. The insulation had been applied twice and both times it fell to the floor in one by eight-foot pieces as soon as cold weather started. The pieces hit the floor with a "splash" as they were *quite* damp. The problem was a result of no vapor retarder. The moisture from the people roller skating easily penetrated the porous insulation and condensed on the cold steel. The insulation became a blotter, and eventually the wet weight exceeded the ability of the adhesive to hold the insulation to the ceiling. The solution was a totally different insulation system with a proper vapor retarder.

MARTHA'S VINEYARD DOME HOUSE—MASSACHUSETTS

This was a two-year-old kit-owner-built house that was in various stages of completion. The interior "finish" was clear polyethylene membrane film covering the pink fiberglass batts. The exterior consisted of seven-foot triangular plywood pieces and framing with asphalt shingles for weather protection. When the sun shone, there was a mist of condensation visible on the backside of the polyethylene membrane. The polyethylene membrane joints had not been sealed.

The housewife had a kettle going on the wood stove 24 hours per day, the clothes were dried indoors, there was no bathroom exhaust fan and the kitchen exhaust was seldom used.

The solution included venting the bathroom outdoors with an exhaust fan during showers, drying the clothes outdoors, cutting down on the use of the tea kettle on the woodstove, dry out the fiberglass and install a new polyethylene membrane vapor retarder with sealed joints.

LOG HOME—RURAL MAINE

There were three people living in a two-story new log home. The walls were solid wood. The cathedral ceiling was tongue-and-groove planks, two-inch foil faced urethane, air space, plywood and shingles. It was "raining" in the house almost year-round. The contractor did not install a separate vapor retarder and did not tape or seal the joints in the foil faced insulation. Moisture from showers and cooking (no exhaust fans in either the bathroom or kitchen) found its way through the joints of the insulation, condensed on the cold sheathing and dripped back into the house. The solution was to install exhaust fans and rework the roof insulation/vapor retarder system.

YORK BEACH, MAINE

This is a summer home. It is uninsulated. The cathedral ceiling had a tongue-and-groove planking with built-up roofing (shed-type roof) applied on the planking. The basement was half exposed ledge and half concrete. Some ground water entered the basement when it rained and during thaws. The owners had never used the home during winter previously. Last winter they left the electric heat on to keep the pipes from freezing (previous years, they had drained the pipes). In January, they returned to the house to find everything in sight stained, and what looked like rain coming from the ceiling. The electric heat had evaporated some of the basement water. The vapor condensed and froze on the ceiling at night and when the sun came out each morning, the frost melted, and it rained. It was a mess. The solution was to dry up the basement and install commercial type roof insulation above the deck with a vapor retarder.

MARTHA'S VINEYARD SCHOOL, MASSACHUSSETS

For some unknown reason, the designer of this building created a crawl space under the entire building. In many areas, the crawl space had standing water—small ponds. The structural members were rusted as were the electrical and mechanical items in the crawl space. There was no foundation drain system, water proofing or insulation. There was water dripping down the cold exterior walls as well as water dripping off the rain drainpipes. If the school had been built slab-on-grade, there would have been no problem and the first cost would have been lower. The solution was to install a foundation drain system, waterproof the foundation and insulate it. Next, I recommended eight-mil polyethylene membrane be put on the entire ground area of the crawl space and the rain drainpipes insulated.

NATIVE AMERICAN RESERVATION, MAINE

This housing project down east near the Canadian border was built several years ago by a midwestern contractor. I will give the contractor the benefit of the doubt and say he was not familiar with our New England climate. The tribal council was upset at the persistent problems of mold on the walls and ceilings of the 25 buildings. At times during the winter, ice would appear on the inside of the sheetrock! The problems were many. People had stacks of firewood in the basement with resulted in huge quantities of moisture. Foundations were cracked and leaking ground water. Foundation walls were condensing water as a result of being uninsulated. Wall-mounted bathroom fans had all been covered with polyethylene membrane and duct tape, making these useless. (In this climate, wall mounted exhaust fans allow more cold air in than they are worth.) In the walls and ceilings, it was obvious that several spots had no insulation. The solution was to install one-inch foil-faced insulation board with taped joints inside all of the walls and ceilings, cover it with new sheetrock and add new bath and kitchen exhaust fans. We also suggested they store the firewood outdoors.

KENNEBUNK CONDO—MAINE

This lovely old seaside hotel had been converted into condos. The entire building had a crawl space. Originally, the crawl space had lattice around on four sides to keep out children and let the wind blow through. In the conversion process, the crawl space was enclosed, insulated with fiberglass batts on the walls (no vapor retarder) and heated with electric unit heaters. (The crawl space heaters used 17,000 KW hours in the month of January. Ouch!) The kitchen broiler exhaust units and the clothes dryers were vented into the crawl space (comment censored). The new structural steel beams did not even get a prime coat of paint and in places were buried in six inches of earth. It was evident that ponding water took place in the crawl space frequently. (It was muddy in July.) The crawl space had many bare