Insight
Leaks and Holes

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To claim that something that has holes in it can act as a water control layer is a pretty interesting argument. It is both true and untrue.

I have it on good authority, that for there to be a leak you need a hole.[1] Holes leak? Who knew? You can argue, and I have (and still do), that it is okay to have holes in assemblies if the amount of water that goes through them can be handled by the assembly. One of my favorite examples of this is old-fashioned "tar paper."[2] We put it up over sheathing with staples and then we nail through it when we attach siding. It works great. How do I know? Look around at old buildings.

It is important to know why that tar paper assembly works of course. No hydrostatic pressure and a high drying potential in both directions (outward and inward). Historically, the traditional tar paper assembly was not very well insulated and the assembly was not airtight. Yes, you heard it here first, or second, or maybe for the thousandth time, air flow tends to dry things more than wet things on balance[3], and poorly insulated walls dry faster than well insulated walls. An air leaky poorly insulated wall without hydrostatic head is hard to beat from a durability perspective. Comfort? Energy? Not so good.

It is ok to have holes but only if there are not too many of them. How do you decide on what is too many? Easy. Experience. When the assembly doesn't work that tells you that there are too many holes. Amazing. We will come back to this.

Here is where it gets interesting. As walls get "tighter" and more heavily insulated the number of holes that you can get away with goes down. So where are we at now? If you do not have hydrostatic pressure acting on your wall as a result of "perched" water (see *BSI-057: Hockey Puck and Hydrostatic Pressure*) and you have back ventilation of your cladding (not a lot, just a little[4]) and you have a high drying potential (vapor open layers) either inwards or outwards – or even better to both sides – you can get away with nail holes and staple holes in building papers and building wraps and fully adhered membranes and liquid applied coatings even with highly insulated airtight assemblies. But you can't get away with building wraps that are "perforated." Not any more. You used to. But not any more. We have too much insulation, too many engineered wood products that are too water sensitive and too many folks have gotten real good at airtightness. This efficiency and sustainability stuff is becoming a real pain. You can't do what you used be able to do.

A little bit of history is in order. Building paper was introduced early in the 20th Century and its function was to reduce drafts in frame assemblies constructed with clapboards and board sheathing. It was not originally intended to be a water control layer (see *BSI-033: Evolution*). The water control function of building paper was introduced in the 1930's and the codes were not

1 Professor John Straube pointed this out to me. He also pointed out to me that joints are the source of all evil, but I am not entirely sure whether or not we were talking about the same thing . .

2 I know that term drives some people crazy, but watching the reaction of these folks is one of the many pleasures that I enjoy immensely . . . The correct term is asphalt-impregnated cellulose fiber.

3 Yes, yes, my Canadian friends, I know that the laws of physics are different in the Great White North... What a bunch of rubbish. I am a Canadian. I am a Leafs fan. I know about air barriers. I am much older than most of you and because of that I have probably seen more than most of you. I remember Bobby Baun scoring that goal with a broken leg in overtime. He blocked Gordie Howe's shot in the third period of game six of the 1964 playoffs breaking his leg. He was carried off the ice on a stretcher. He came back in the same game 30 minutes later for overtime after taping up his leg and popping painkillers. His season should have been over. It gets better. He scores the winning goal in overtime beating Terry Sawchuk forcing a game seven. He beats Sawchuk? The greatest of them all? And gets even better. He refuses to let doctors examine his ankle so he can play in game seven. The Leafs win game seven and Bobby gets to drink out of the Cup. When someone says Bobby to me, Baun is the one I think of, not that youngster from Parry Sound or the guy with the curved stick and the golden hair. So do not lecture me about not knowing about Canada, the home of the air barrier, and how air leakage is so evil and that it is the most serious of the wetting mechanisms. It is not, not even in Canada. It has always been rain leakage. If you don't believe me go visit Vancouver, which is a part of Canada, where they can set you straight. Then go visit Halifax. Even in Canada, air leakage provides more drying than wetting. Of course air leakage sucks on the energy score and we don't like air leakage in that regard. A little bit more about condensation and air leakage, as this footnote is not quite yet long enough, an old guy once pointed out, older than me, that if you are experiencing condensation due to air leakage either make the assembly leakier or tighter to make it go away . . . I wrote about that old guy last time.

4 What does "little" mean? As small as $^{1}/_{32}$ to $^{1}/_{64}$ of an inch. Really.

changed to recognize this until after 2000.[5] Yup, they were originally "air infiltration" barriers.[6]

Building paper ultimately evolved into a key element of the water control system of the wall assembly. Lapped shingle fashion and integrated with punched openings became the norm. Not perfectly water tight, but good enough for the time. Not perfectly air tight, but good enough for the time. Being located on the outside of the frame assembly, with the insulation inside the frame assembly meant the building paper had to "breathe." Boy do I hate that term, but that is what we called it in many parts of North America – "breather paper." How much did it have to breathe? Depends. Most of the folks say more than 5 perms less than 100. It is a Goldilocks thing. Not too vapor open and not too vapor closed. Traditional tar paper operated between 2 perms and 80 perms depending on how wet it got (check out *BSI-029: The Perfect Storm*).

So what is wrong with tar paper? It has some pretty neat characteristics. It does not pass liquid water (except at nail holes and staple holes) and it does pass vapor water. Vapor permeable and hydrophobic. But it is tough to work with. It comes in narrow rolls, it blows off easily and it is really difficult to tape it or seal it unless you mastic it. Your only good strategy is to lap it shingle fashion and give up on high levels of airtightness. Now you can achieve airtightness other ways. And many old folks love the stuff and believe me, I revere the old folks. The old folks say, suck it up and demand good workmanship and stick with the tar paper and put it up with cap nails and stop whining and make something else the air control layer. Yeah, but, it is getting really difficult

Photograph 1 (bottom left) – Nice House

Photograph 2 (at right) – Not So Nice

out there and these big wide roll products that let you tape them have a lot going for them.

So we got the wide roll products made out of plastic stuff. You could tape them and print advertising on them. It was great. Except they had to "breathe." Here is

5 You could actually build without any building paper in much of the United States even 10 years ago. Just siding and OSB and you were done. Wow, water must have been getting in. Yes. But things dried. Relax. Of course retrofitting these making them more energy efficient is certainly going to be interesting. Ah, not my problem, the kids will have to figure this one out.

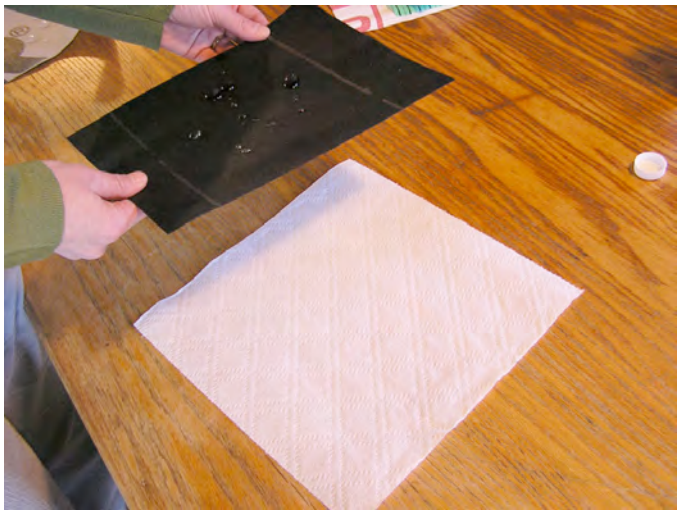
6 Air infiltration" sounds cooler than "draft." That language change came about roughly when "swamps" became "wetlands." George Carlin would be proud.

where it got really interesting. It is hard to make a "plastic" tar paper. Plastic by its nature when it comes in rolls does not have holes in it. So it is great at the water control thing. It lets no water through it. No water in any phase. Not liquid, not vapor, not solid, not adsorbed. None. Big problem. This layer has to breathe if you put it on the outside of the insulation layer which most of the time is in the frame assembly. How do you solve this problem? Easy. Put holes in it. Perforate it. The holes need to be tiny. Very tiny. You want water in the vapor phase to pass through it, but not water in the liquid phase.

Not so easy now. We don't have the technology to make holes small enough to pass only water in the vapor form but stop water in the liquid form. A little bit about the physics of water is necessary now – the "kitchen physics" version. Sort of correct, but not completely correct. More like "engineering physics" – approximately correct.

Water in the vapor form hangs out as individual molecules. Water in the liquid form clumps together in groups of 25 to 75 molecules. The "clumps" are bigger than the individual molecules. Think "golf balls" and "basketballs." The golf balls are the vapor and the

Photograph 3 (top left) – Wet Siding: Water that used to drain and not be absorbed now passes through the field of the building paper and is absorbed. More water is now retained for a longer period of time. **Photograph 4 (top right)** - Tar Paper Test: A teaspoon of water is placed on tar paper placed over a paper towel. Look at how the water beads up on the surface. A beautiful sight.



Photograph 5 (above left) – No Wet Spot: If the water beads up and does not wet the paper towel – it passes Joe Test 1.
Photograph 6 (above right) – Nice House Gone Bad Stuff: In the case of the house we were looking at, the sample product removed from the wall failed Joe Test 1. Most products pass Joe Test 1 before they are installed. But all products that fail in the field seem to fail Joe Test 1.

basketballs are the liquid. An ideal product would be a "screen" that has holes big enough to pass the water golf balls but small enough to stop the water basketballs. That product would be liquid water closed but vapor water open.

Now it gets a little bit more complicated. These miserable water molecule golf balls are really like tiny magnets – they have a positive and negative side – they are polarized, much like the Republic. Now picture a screen that may or may not have an electrical charge to it. If the screen has an electrical charge to it and more of these crazy ass water golf balls show up the electrical charge on the screen pulls them through the screen. The more of them that show up at the screen, the more of them that get pulled through. Bastards. This complicate things more than things need to be complicated. This means that some materials increase in vapor permeability as the relative humidity goes up. How crazy is that? It is tar paper crazy.

Now it can get ugly. When the water golf balls get together and form a gang of basketballs and become a liquid they tend to behave badly as gangs typically do. The basketball gang sometimes goes and hangs out with other gangs. One of the most miserable gangs out there is the surfactant gang and the most vicious members of the surfactant gang are the soaps. These soaps not only get your whites whiter than white, but they have tattoos, date your daughters and drive big Harley hogs. Worse, they make the screen wires slippery. And slippery is worse than charged. They grease the skids on the screen and basketballs just pour through.

So we need a plastic sheet product that passes golf balls but not basketballs and handles gangs with surfactant members. There are only a couple of ways to do this. None of them involve punching holes in sheets. The most common is to start with big holes that get filled in. You can't start with no holes and add holes because we don't know how to add small enough holes through mechanical perforation.[7] The holes that need to be added are so small no mechanical perforation process can make them small enough. A water golf ball is 3 x 10 (-10) m. The smallest holes that we know how to make using mechanical perforation are about 100 microns – the thickness of a dollar bill – the limit that an eye can see without magnification – about 1 x 10 (-4) m – or 100,000 times bigger than a water golf ball and 1,000 times bigger than it should be. If you can see the hole it is too big. Trouble is some of us can't see even big holes.

Tar paper starts with a bunch of cellulose fibers that are smushed together so that the gaps between them are about the size of water basketballs. The fibers are then coated with bitumen that makes the gaps smaller than

Photograph 7 (above left) - Joe Test 1 in 1995: It was not very predictive with new materials but pretty conclusive with field failures. That is my daughter helping me out. **Photograph 8 (above right) – Failed Material:** Weathering it seems was also important. Stuff seemed to be getting on to the stuff changing things . . .

7 You can start with no holes and stretch a film that has particles imbedded in it until it begins to tear where the particles are. Clever eh? The particles initiate the tears. If you stop stretching it at the right point the tears and gaps that are left are small enough to pass only the water golf balls. These materials are more formally called micro-porous films.

water basketballs – in essence "clogging" up the screen. The bitumen also makes the surface hydrophobic – it repels the little water bastard basketballs. The old guys love this product for good reason.

You can take tiny plastic fibers rather than cellulose fibers, fibers that are even smaller than cellulose fibers, and do pretty much the same thing. And if you choose the right plastic with a little chemical engineering magic you can make the surface hydrophobic without coating them with anything. This type of product is called polymeric fibrous. In essence, a plastic tar paper. This product rocks.

You can also take much bigger plastic fibers that create a structural screen mat that supports a thin plastic film that loves water. Something similar to nylon that adsorbs water, then absorbs water and then desorbs water. Think of something that likes to slow dance with the water golf ball but ultimately turns down the golf ball and the golf ball then leaves the ballroom. Typical promiscuous water golf ball. Tries to get lucky but doesn't. Comes in one side of the dance hall, slow dances and then leaves out the other side. The botanists call this "transpiration" and amazingly enough the chemical engineers like it as well. I call it being turned down. The formal name for this type of product is a non-porous permeable film. This product rolls.

You can also do it the way the second to last footnote says. But you can't do it by punching holes in something.

So how do you tell if you have got something that actually works? Something that rocks and rolls? A plastic that works like tar paper but does not blow off that you can tape and that handles surfactants? Well you need to run the "Joe Tests." Specially developed just for this purpose. They can be run in a kitchen since they use "kitchen physics."

You might also need to know when a product does not work. Remember I said I would come back to this? One of the first signs that a product does not work is that your house smells musty or the paint is beginning to fall off your siding or both. Check out **Photograph 1** – nice house. Now look at **Photograph 2** – not so nice. The sheathing is almost gone. **Photograph 3** shows the back of the siding. Wet. I think we can pretty much conclude that this assembly is not working. Joe Test 1 is shown in **Photograph 4**. It is run on tar paper in this example. A teaspoon of water is placed on tar paper placed over a paper towel. If the water beads up and does not wet the paper towel – it passes Joe Test 1 (**Photograph 5**). In the case of the house we were looking at, the sample product removed from the wall failed Joe Test 1 (**Photograph 6**). Most products pass Joe Test 1 before they are installed. But all products that fail in the field seem to fail Joe Test 1.

I first started doing Joe Test 1 in 1995 (**Photograph 7** and **Photograph 8**). It was not very predictive with new materials but pretty conclusive with field failures. Weathering it seems was also important. Interesting. Needed to add to the Joe Test method. I mean once it has failed it is pretty much too late, eh?

Joe Test 2 was a pretty impressive add. It was a variation on the old "tent test." Ever been camping and in a tent when it starts to rain and some misbehaving little rat[8] puts his finger against the side of the tent and it starts to leak? **Photograph 9** demonstrates Joe Test 2. How long do you leave your finger in the water? Until you get bored. With me, that is about 3 minutes. Four minutes tops. Lots of perforated housewraps began to fail Joe Test 2 in the late 1990's prior to exposure. I was definitely on to something. ASTM eat your heart out.

I began to notice that when I held failed housewraps up to the light they were darker in some spots than others. They would fail Joe Test 1 in the dark areas and pass Joe Test 1 in the non-dark areas. It became very obvious with lighter colored housewraps (**Photograph 10**). What caused the discoloration? That part was easy. Wood sugars and tannins. Water-soluble extractives. "Weak" surfactants by another name. This lead to Joe Test 3 and Joe Test 4.

Both Joe Test 3 and Joe Test 4 involve boiling water. So this should not be done at home without adult supervision. Take a half dozen cedar chips ("mulch") and boil in water for 30 minutes and allow to cool to room temperature (**Photograph 11**). Go have a beer while you wait. Then use a teaspoon to drop this weak surfactant solution on the sample (**Photograph 12**). This is Joe Test 3. Failure is pretty dramatic when it happens (**Photograph 13**). It should fail in less than 60 minutes if it is going to fail.

8 That would be my then 12-year-old son who apparently understood intuitively that breaking the surface tension of water results in wetting of the surface and subsequently a leak.

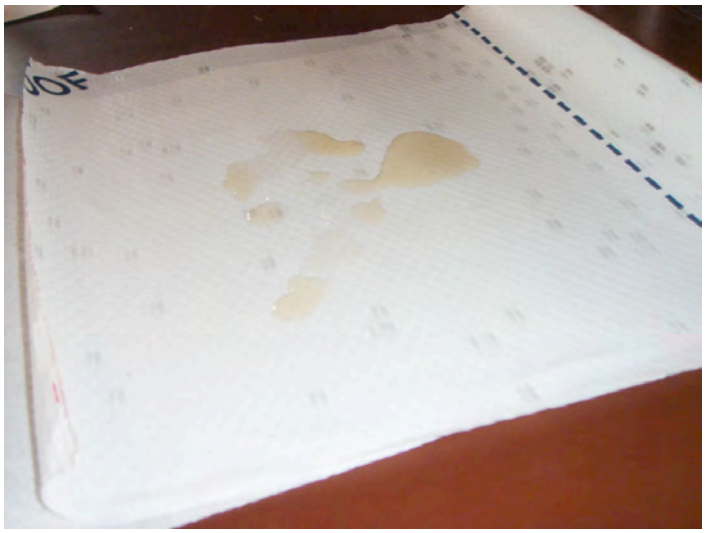
Photograph 9 – Tent Test: Breaking the surface tension to wet the surface. Joe Test 2.

Photograph 10 – Wood Sugars and Tannins: I began to notice that when I held failed housewraps up to the light they were darker in some spots than others. They would fail Joe Test 1 in the dark stained areas and pass Joe Test 1 in the non-dark areas. It became very obvious with lighter colored housewraps. What caused the discoloration? That part was easy. Wood sugars and tannins. Water-soluble extractives. "Weak" surfactants by another name.

So what is Joe Test 4? Ah, if the product sample passes Joe Test 3 let the water evaporate leaving a stain on the surface. Wait for the stain to dry. Then add a droplet of water to the dry stain and see what happens. Joe Test 3 involves the surface energy of the liquid. Joe Test 4 involves the surface energy of the surface.

To my knowledge no product that has passed the four Joe Tests has failed in the field. To my knowledge no mechanically perforated product has passed the four Joe Tests. All the ones that I have tested this way fail Joe Test 3 and Joe Test 4. The polymeric fibrous, the non-porous permeable film and micro-porous film products all pass the four Joe Tests along with old fashioned tar-paper.

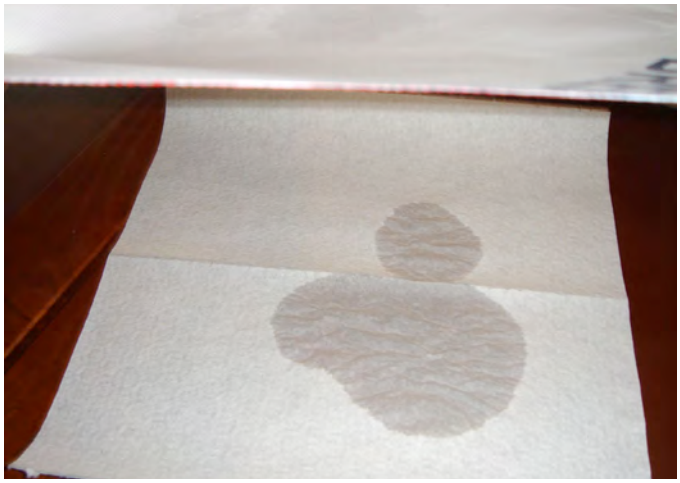
Photograph 11 – Boiling Water and Mulch: This should not be done at home without adult supervision. Take a half dozen cedar chips ("mulch") and boil in water for 30 minutes and allow to cool to room temperature.



Photograph 12 – Weak Surfactant: Use a teaspoon to drop this weak surfactant solution on the sample. This is Joe Test 3.

What if you are in a hurry and you don't want to boil water and you can't find any mulch? Do a variation of Joe Test 3 by adding a bit of detergent to the water. Just a "wee bit." Find someone Scottish to explain this metric. This is like wood sugars on steroids. This is not a realistic test. This is an over the top test. If the product

passes this enormous stress after a couple of minutes you are good to go. If the product fails take a valium and do the longer test as you pretty much beat the crap out the product. I mean who would ever spray soap and water on his wall? Amazing as it seems, folks like to power wash their siding with soap and water and sometimes even bleach. Wow. Why don't you just take a gun and shoot yourself. This is very, very bad.



Photograph 13 – Wet Spot: Failure is pretty dramatic when it happens. It should fail in less than 60 minutes if it is going to fail. The water solution just stays there for a long while and nothing happens. Then, all of a sudden, it goes through. More exciting than watching paint dry.

It gets worse, many paints have detergent in them as dispersion agents to keep the pigments and polymers in suspension. And many stuccos have detergents in them as workability agents. We have soap all over the place.

Ok, so what am I saying? Back in the day, a half century or more ago you didn't have to do much of anything. Not even have a water control layer.

Then a decade or two ago, if you had an air gap between your cladding and your water control layer it didn't mater much what kind it was.

Now, even the air gap will not save you. You need a water control layer that isn't perforated. You can still live with nail holes and staples. But given time and the direction we are going in the future, even this might change.

Note that this refers to low rise residential construction. You go up a bunch of stories and the loads get much bigger and things get ugly real fast. How tall can you go? Talk to the folks in Vancouver.

THE FOUR JOE TESTS SIDEBAR

Joe Test One
Drop a droplet of water on a product sample placed over a paper towel. If the water beads up and does not pass through the product sample to wet the paper towel the product sample passes **Joe Test 1**.

Joe Test Two
Drop a droplet of water on a product sample placed over a paper towel. Put your finger in the droplet of water to break its surface tension. Leave your finger in the droplet of water pressing against the product sample for 3 to 4 minutes. If the water does not pass through the product sample to wet the paper towel the product sample passes **Joe Test 2**.

Joe Test Three
Take a half dozen cedar chips ("mulch") and boil in water for 30 minutes and allow to cool to room temperature. Take a droplet of this water-soluble extractive solution and drop on a product sample placed over a paper towel. If the water does not pass through the product sample to wet the paper towel after about 60 minutes the product sample passes **Joe Test 3**.

Joe Test Four
Take the solution in Joe Test 3 and place on a product sample and allow the water to evaporate leaving behind the residue. Allow the residue to dry. Place the product sample with the dried residue over a paper towel. Take a droplet of water and drop on the dried residue. If the water does not pass through the product sample to wet the paper towel after about 60 minutes the product sample passes **Joe Test 4**.