The air/vapour barrier must die

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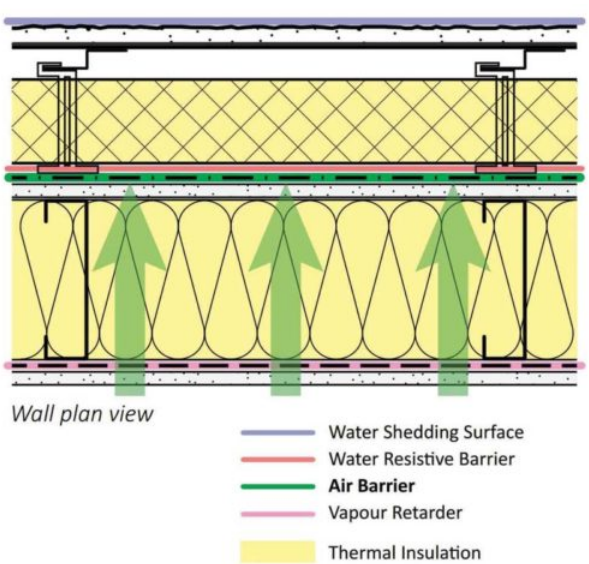
By Juste Fanou

The terms "air/vapour barriers" and "vapour retarder" are perhaps some of the most poorly understood concepts in the construction industry. Most building professionals know they are needed, but often struggle to locate them correctly within wall assemblies. Also, the consequences of installing these materials improperly can result in failures. This lack of understanding of the functions of these assemblies has resulted in simplistic rules-of-thumb prone to misapplication (*e.g.* the vapour barrier is always on the inside and the air barrier is always on the outside). As manufacturers introduce materials with new properties and attempt to push the boundaries of building envelope construction, it is crucial the industry agrees on terminology for communicating the specific functions and purpose of these materials to avoid confusion and costly errors. In this regard, the term "air/vapour barrier" is misleading and should be replaced with more appropriate terminology. This article briefly explores the origins of this term, the discrete functions of air barriers and vapour retarders in building envelopes, and the detrimental effects of incorrect terminology in construction documentation.

A brief history



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Building envelope layers.
Images courtesy Juste Fanou

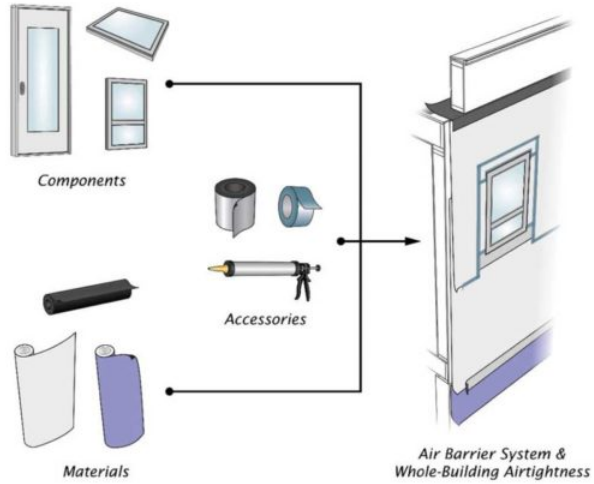
Initial attempts to increase the thermal comfort of occupants in modern North American wood-framed construction date back to the 1800s. The introduction of “building paper” in the form of asphalt-impregnated felt—also known as sheathing membranes or weather-resistive barriers (WRB)—represented an early effort to reduce wetting of wall assemblies and air leakage (Refer to the 2017 book *Building Materials: Product Emission and Combustion Health Hazards* by K. Hess-Kosa.). The industry made further advancements in the field of envelope performance in the 1930s with the rise of insulation in framing cavities and attics (For more information, read the article, “Heat, Air and Moisture Control in Walls of Canadian Houses: A Review of the Historic Basis for Current Practices,” by M. Koniorczyk and D. Gawin, published in the April 2008 issue of *Journal of Building Physics*.). However, the undesirable effects of moisture in insulated cavities soon surfaced. The traditionally painted wood façades began to suffer from peeling, blistering, and other coating failures. As is the norm in the building industry, a “blame game” quickly ensued with insulation manufacturers blaming the paint and vice-versa, while the building paper manufacturers were caught in the middle (Consult the paper, “The rise of the diffusion paradigm in the US,” by W.B. Rose, published in the 2003 book *Research in Building Physics: Proceedings of the Second International Conference on Building Physics,* edited by G. V. J. Carmeliet, H. Hens, and G. Vermeir.). It was not until the late 1930s scientists began investigating moisture movement in building assemblies. Their findings—considered controversial or even biased by some—concluded the transfer of water vapour by diffusion (a process explained later in this article) was responsible for the paint peeling off the siding (Many argue Frank Rowley’s theory of vapour diffusion, which led to the introduction of vapour barriers in wall cavities and ventilated attic spaces, was not grounded in sound science. This study is considered biased by many in the field, because it was funded by the insulation industry as a way to defend itself against claims insulation was responsible for condensation in cavity spaces and peeling paint.). These conclusions resulted in regulation mandating the use of low-vapour permeance membranes in construction projects in the early 1950s. It was the birth of the “vapour barrier,” and the industry celebrated its solution to the moisture problem by lining walls with polyethylene plastic. Ostensibly the issue of peeling paint was resolved, or at least it seemed so.

Nonetheless, moisture problems persisted. Further, research in the mid-1980s suggested uncontrolled air infiltration, and not vapour diffusion, was the largest contributor to moisture accumulation in cavity spaces (Consult R.L. Quirouette’s 1985 technical report, “The difference between a vapour barrier and an air barrier. [3]”). However, by that time the popularity of the now ubiquitous “6 mil poly”—backed by the Canadian General Standards Board (CAN/CGSB) 51.34, *Vapor Barrier, Polyethylene Sheet for Use in Building Construction*—inspired methods to seal the already familiar vapour barrier. The purpose was to turn it into an effective air barrier.

These attempts to seal the vapour barrier may be characterized as the genesis of the “air/vapour barrier,” both as a concept and term. Conceptually, the “air/vapour barrier” was a material purported to address both air infiltration and vapour diffusion issues. Its proponents believed by sealing the joints of polyethylene sheets, a dual-purpose material could emerge ascribing the additional properties of air infiltration control to the already popular “6 mil poly.” This popularity was perhaps responsible for its great appeal and wide adoption in the industry. As time passed, however, the idea of “sealing polyethylene” was quickly abandoned, and construction practitioners explored other materials to provide airtightness. It was clear polyethylene was not a sufficiently durable material to resist the effects of wind gusts and pressures. Moreover, this lack of durability was further undermined by the intrinsic difficulties associated with installing polyethelene in a continuous fashion.

Even if the concept of the polyethylene “air/vapour barrier” slowly faded, the term endured. Coincidentally, as time passed it also appeared as if the general understanding of the functions of these air and moisture control elements was further clouded by this conflated term. These once-distinct materials slowly transformed into abstract dotted lines everyone knew were required on construction details, but no one fully understood where or why.

Differences



[4]
Make-up of an air barrier system from the *Illustrated Guide – Achieving Airtight Buildings*, published by BC Housing in September 2017.

The building envelope performs important tasks. Its primary purpose is to protect conditioned spaces from the adverse effects of heat, air, water, and vapour. In other words, it keeps the outside out, and the inside in. This is achieved through a combination of carefully selected layers designed to stop and/or drain bulk water, insulate against heat loss, prevent or reduce air leakage, and slow down vapour migration. In building science settings, these are referred to as control layers (Read the 2010 article, "The Perfect Wall[5]," by J. Lstiburek.). Air barriers and vapour barriers form part of these control layers.

Air barriers, as their name implies, are intended to stop uncontrolled air from leaking into conditioned spaces. This infiltration is caused by the effects of wind, HVAC systems, and by air buoyancy forces also known as "the stack effect" (Refer to B.C. Housing's 2017 *Illustrated Guide – Achieving Airtight Buildings[6].*). It is critical to stop uncontrolled air leakage, because air can act as a transport mechanism for several other undesirable particulates (*e.g.* smoke and odour). Additionally, air can also carry moisture. However, the maximum amount of moisture air can carry (its saturation point) is dependent on temperature and pressure. In general, cold air can carry less moisture than warm air.

When saturated air encounters a cooler surface, the moisture it is carrying undergoes a phase change and condenses (*i.e.* turns from gas to liquid) on the surface. The temperature at which this occurs is known as the dewpoint. This becomes critical in building envelope design because uncontrolled air leakage can result in air entering and condensing on components of wall cavities in unintended ways, leading to moisture-related problems such as mould, corrosion, and the general deterioration of building materials.

Air barriers are installed to counteract these undesirable effects, and must at a minimum possess some essential properties.

Resistant to air leakage

This resistance is quantified through testing according to industry standards (Underwriters Laboratories of Canada [CAN/ULC] S741, *Standard For Air Barrier Materials–Specification in Canada,* and ASTM E2178, *Standard Test Method for Air Permeance of Building Materials*, in the United States). Air leakage is limited in the *National Building Code of Canada* (*NBC*) to 0.02 L/(s·m^2) (0.004 cfm/sf) of leakage at a pressure differential of 75 pa (1.57 psf).

Be continuous

As shown by research, air leakage is a critical factor when it comes to ensuring proper building envelope performance. Therefore, *NBC* mandates materials employed to preserve the airtightness of building assemblies must be installed in a continuous fashion.

Act as a system

Contrary to popular belief, the air barrier does not manifest itself as a single material. Even if there is a primary air barrier material (usually referred to as the air barrier membrane), it is the combination of this primary material and various other components (*e.g.* doors and windows) as well as accessories (*e.g.* sealants and tapes) performing in unison that truly guard the building against the deleterious effects of air leakage. This systemic approach is recognized in CAN/ULC S742, *Standard For Air Barrier Assemblies–Specification,* as it attempts to mimic actual field conditions (*e.g.* penetrations, laps, and reinforcements) rather than evaluate the performance of materials in isolation (Read the blog "Do You Know the Canadian Air Barrier Standards CAN/ULC-S741 AND S742?[7]" by Jean-François Côté.).

Vapour retarders (or vapour barriers) serve a much different purpose than air barriers. They are designed to stop (or slow) the movement of water in its gaseous form from travelling through wall assemblies. This process, called vapour diffusion, is the motion of water vapour molecules from an area of high concentration (higher humidity) to an area of low concentration (lower humidity) across a gradient (vapour permeable material). This movement is driven largely by kinetic forces at the molecular level and is governed by temperature and relative humidity (RH), not air pressure.

Permeance ng/s•m²•Pa (perm)	Term	Class
< 5.72 (< 0.1)	Vapour impermeable	Class I Vapour Retarder (or Vapour Barrier)
5.72 – 572 (0.1 – 1.0)	Semi-impermeable	Class II Vapour Retarder
572 – 5721 (1 - 10)	Semi-permeable	Class III Vapour Retarder
> 5721 (10)	Vapour permeable	

[8]

Figure 1: Classification of materials according to their vapour permeance referenced from a Building Science paper by J. Lstiburek.

Vapour permeance (colloquially referred to as "perm rating") is a measure of a material's ability to allow the passage of moisture by diffusion. This measurement is expressed in ng/s●m^2●Pa (nanogram per second per square metre per pascal) or in perms, and is often evaluated in accordance with ASTM E96, *Standard Test Methods for Water Vapor Transmission of Materials*. U.S. building codes have classified materials according to their vapour permeance on a scale ranging from "vapour impermeable" to "vapour permeable" and assigned them to "vapour retarder classes" ranging from I to III (Refer to J. Lstiburek's 2011 paper on "Understanding Vapor Barriers."). In principle, only materials meeting the requirements of a "Class I Vapour Retarder" should be called "vapour barriers" (Figure 1).

Diffusion rates through wall assemblies have been shown to be generally slow. All things being equal, breaches in the vapour barrier result in significantly lower quantities of moisture migration as a result of diffusion rather than the quantity of moisture transported through the same material due to air movement. As such—despite what many often assume—vapour barriers need not be continuous in wall assemblies, and may, at times, (depending on climate) be omitted altogether.

Different meanings

Term	To an architect	To an engineer
Air-conditioning	Any cooling system – probably comfort cooling	One particular system that is cooled, heated, humidity-controlled and ducted. Not comfort cooling
Contractor	Builder	Plumber or electrician
Duct	Anything needed for hidden services	A galvanised steel air-distribution system to HVAC publication DW142
Low-energy structure	Wood-framed, lightweight structure with turfed roof	Concrete structure with exterior insulation and heat exchanger
Natural ventilation	Windows	The passive passage of air through grilles, chimneys, stacks and exposed mass
Pipe size	The actual size of the pipe with everything else included, such as insulation	The mean diameter of the pipe itself – excluding insulation thickness

Source: Dadji (1988).

[9]

Figure 2: Differences between the jargon employed by architects and mechanical and electrical engineers from *Communication in Construction – Theory and Practice* by Andrew Dainty, David Moore, and Michael Murray.

The importance of effective communication in the construction industry cannot be overstated. However, barriers (no pun intended) exist that can impede or distort effective communication and result in failure or undesirable effects. Amongst these barriers, the use of jargon is often cited as a leading cause of communication breakdown. Specifically, in the construction industry—due to its fragmented structure, technical nature, and the adversarial tendencies of its stakeholders—the lack of terminology standardization has engendered different terms and meanings that are understood differently by various people. Figure 2 illustrates how misunderstandings can occur between two professionals interpreting technical jargon differently. Unfortunately, these complex and ambiguous terms, often well-understood by discrete groups, but prone to misinterpretation by others, plague the industry.

The term "air/vapour barrier" is an example of such ambiguous terminology. The ambiguity of this term is inherent in its use of the slash (/) punctuation mark. In English, the slash can be used to either denote the conjunction "or" or the conjunction "and." Therefore, in theory, the term "air/vapour barrier" can be interpreted as "air or vapour barrier" or "air and vapour barrier." In general context, however, it is safe to assume most people use it to refer to the latter. Yet, as it has been discussed previously, the term "vapour barrier" is itself a subset of the term "vapour retarder" (*i.e.* only a Class I vapour retarder is considered a vapour barrier). Should the term "air/vapour barrier" then be restricted to materials meeting the requirements for air barrier materials and Class I vapour retarders? The advent of materials having various levels of permeability (*e.g.* spun-bonded polyolefin, silicone, and vapour permeable polyurethane foam) clearly show such a restriction would prove overly exclusive.

Term	Air Leakage Rate - $L/(s{\cdot}m^2)$	Permeance - $ng/s{\bullet}m^2{\bullet}Pa$ (perm)
Vapour Impermeable Air Barrier	0.02	< 5.72 (< 0.1)
Semi-impermeable Air Barrier	0.02	5.72 – 572 (0.1 – 1.0)
Semi-permeable Air Barrier	0.02	572 – 5721 (1 - 10)
Vapour Permeable Air Barrier	0.02	> 5721 (10)

[10]

Figure 3: Proposed system for labelling air barrier materials.

Any alternative to "air/vapour barrier" should reduce ambiguity while reflecting the current trends of the industry. At present, it is crystal clear the benefits of controlling air leakage far outweigh the control of vapour diffusion. Therefore, "air/vapour barrier" should be replaced with a term describing an air barrier material, which also has some vapour-retarding characteristics. As the permeability of materials has already been standardized in building codes, it is perhaps most appropriate to borrow this terminology and apply it to our problem. See Figure 3 for a proposed system with four distinct designations and associated properties.

Conclusion

It is no secret the construction industry is plagued by a chronic productivity problem. A 2015 report by McKinsey & Company showed that while productivity rates in the manufacturing sector nearly doubled over the 20-year period spanning from 1995 to 2015, productivity rates remained painfully flat, or even worsened, in the construction industry (Check out the 2015 article, "The construction productivity imperative[11]," by C. Sriram, A. Mohammad, and Mark van Nieuwland.). Factors such as the fragmented structure of the industry, the cyclical nature of construction activities, and poor or inadequate communication have all been suggested as contributors to this lack of productivity growth. Moreover, these sluggish gains may also be reflective of the industry's unwillingness to embrace change.

The future is, however, not all bleak. Recent years have shown consultants and contractors alike embracing new technologies such as building information modelling (BIM), drones, and prefabrication to increase output and reduce errors. Accordingly, the language used in construction today must express and reflect the current state of affairs. Terms and materials no longer serving their purpose should be replaced with new ones illustrating advancements in research and practice.

Thus, the term "air/vapour barrier" should be replaced by terms illustrating both the air leakage and vapour permeance properties of these materials. Ultimately, the biggest challenge to any term proposed will be to overcome the inertia forces associated with the construction industry's fear of change.

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Endnotes:

1. [Image]: https://www.constructioncanada.net/wp-content/uploads/2018/07/bigstock-Background-Of-Concrete-And-Gla-230098453.jpg
2. [Image]: https://www.constructioncanada.net/wp-content/uploads/2018/07/Illustration-3.jpg
3. The difference between a vapour barrier and an air barrier.: http://nparc.cisti-icist.nrc-cnrc.gc.ca/eng/view/object/?id=db9bccc2-eff6-4249-8a3f-0d2224dc30db
4. [Image]: https://www.constructioncanada.net/wp-content/uploads/2018/07/Illustration-1.jpg
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7. Do You Know the Canadian Air Barrier Standards CAN/ULC-S741 AND S742?: http://blog.soprema.ca/en/do-you-know-the-canadian-air-barrier-standards-can-ulc-s741-and-can-ulc-s742
8. [Image]: https://www.constructioncanada.net/wp-content/uploads/2018/07/Figure-1.jpg

9. [Image]: https://www.constructioncanada.net/wp-content/uploads/2018/07/Figure-2.jpg
10. [Image]: https://www.constructioncanada.net/wp-content/uploads/2018/07/Figure-3.jpg
11. The construction productivity imperative: http://www.mckinsey.com/industries/capital-projects-%20and-infrastructure/our-insights/the-construction-productivity-imperative
12. [Image]: https://www.constructioncanada.net/wp-content/uploads/2018/07/headshot.jpg
13. jfanou@jmfservices.net: mailto:jfanou@jmfservices.net

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