Proper Design, Installation, and Field Quality Control for Achieving a High-Performance Air Barrier System

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Abstract

Air barrier systems are different from other building envelope components: You cannot see air leakage. Designers must trust that the contractor’s workers will make all the connections airtight, in an industry that some say is quick to cover things up so one can’t see the quality of an installation. The speaker will detail steps to reduce risk and improve the performance of buildings, and will discuss what might happen if you do not get it right. Many think air barriers simply save energy, but the main reason one installs an air barrier system is to reduce moisture problems—in both warm, moist climates and in cold ones.

Speaker

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Laverne Dalgleish has been in the construction industry for over 30 years. He pioneered a site quality assurance program in the early ‘90s that reduced the risk of problems, kept projects on schedule, and improved installation quality. Dalgleish has written material, installation, and application standards. He was part of the management team that founded the Air Barrier Association of America.
PROPER DESIGN, INSTALLATION, AND FIELD QUALITY CONTROL FOR ACHIEVING A HIGH-PERFORMANCE AIR BARRIER SYSTEM

ABSTRACT

An air barrier system is somewhat different than many of the other components making up a building. You cannot see air leakage. As a designer, you have to trust that the trade contractor and his or her workers will make all the connections airtight. This is in an industry that some say is quick to cover everything up so one can't see the level of quality (or lack thereof) in an installation. This presentation will walk attendees through the steps whereby one can reduce his or her risk in the installation of an air barrier system, thereby improving the moisture and energy performance of a building. The presentation will also cover what happens if one doesn’t get it right. Many think of air barriers as simply saving energy, but the main reason one installs an air barrier system in a building is to reduce moisture problems. This is true not just in cold climates, but in warm climates, as well.

QUALITY ASSURANCE IS RISK MANAGEMENT

The problem with an air barrier system is that air leaks cannot easily be observed without special tools. What you may think is airtight can actually be leaky, and what you would expect to be leaky may actually be airtight. There are ways to detect air leaks by using chemical smoke, or by measuring the airflow rate into and out of the building. A building can never be too airtight, but proper ventilation is still crucial. The goal is to make each building as tight as possible. To achieve this, a risk assessment for each component or person that will be involved in the installation of the air barrier system should be done. By determining the potential for risk and then determining its possible magnitude, the appropriate steps can be taken to mitigate the risk. No single action can be relied on to remove the risks involved in installing an air barrier system. The air barrier is only effective if it works as a system. The author developed a quality circle back in the late ’80s that has worked well in addressing this issue (Figure 1).

INDUSTRY RESEARCH

Air barriers are a relatively new concept across the United States. The Commonwealth of Massachusetts is credited with being the first state that made an air barrier a requirement in its building code, as it added a requirement for air barriers, along with a number of other energy-efficiency requirements, on July 1, 2001. At that time, there were very few air barrier materials, fewer air barrier project specifications, and minimal research focused on air barriers. The connection between air barriers and reduced moisture problems in buildings had not been made. Air barriers were touted as energy-savers, but there was minimal technical support at the time for the claim that 30-40% of the energy used by a building was used to condition the air for the building’s use.

The industry had to conduct research to show that a lack of air barriers in buildings causes major problems, ranging from high energy use to mold, mildew, corrosion, indoor air quality issues, comfort issues, etc. A major industry research project was undertaken in 2006. It was a collaboration among the Department of Energy, Oak Ridge National Laboratory, the Air Barrier Association of America (ABAA), the New York State Energy Research and Development Authority, and Syracuse University to document the energy savings for installed air barrier systems. This research showed the potential for energy savings and pointed out some of the moisture issues. In 2005 the National Institute of Standards and Technology (NIST) also conducted modeling to determine the potential for energy savings through the installation of air barriers in buildings.

There is still a lot of research to be conducted. As the industry has grown and started to mature, there is an increasing need to become much more detailed in the requirements for materials and their installation.

It has also been recognized that when considering air barriers, one must also consider water-resistive barriers and vapor barriers/retarders. Many materials can provide the air barrier function and also the water-resistive barrier function. The water vapor transmission rate of all air barrier materials must be taken into account to determine where and how they can be used in a building assembly. (See Figure 2.)

Research must be done to determine the extent of moisture issues created when there is not a properly installed air barrier system. Research conducted to date shows a connection between a very airtight building and reduced moisture problems. This needs to be fully fleshed out to actual, quantifiable numbers. The durability of the air barrier materials—especially materials that will be buried in the wall—needs to be determined, and a proper protocol for the accelerated aging of the materials must be developed. Research is needed to show the loads imposed upon buildings and to show how these loads increase when

Figure 1 – Site quality assurance circle.
buildings are over three stories in height. The current loads in the American Society of Testing Materials' ASTM E2357 were developed for the 80% of buildings across the United States that are three stories or less. (See Figure 3.)

The industry needs to understand actual field performance requirements for air barrier materials as new and different types of air barrier materials come on the market. It is easy to say we need a certain value for the air leakage rate of air barrier materials, but what other material characterizations are required to ensure that the material performs over the service life of the building? The industry needs to determine how to characterize these materials by different material properties.

**IMPORTANCE OF STANDARDS AND SPECIFICATIONS**

The original intent of the construction industry, back in 2001, was to simply identify all the standards and specifications that were available at that time, bring all the information together in one place, and then to have everyone working off of the same information. What we found was that this information was simply not available. In 2001, there was no air barrier industry and, therefore, no documents supporting the air barrier industry. When the lack of documentation was identified as an issue, the industry rolled up its sleeves and worked to develop the documentation required.

The first two published standards from ASTM were ASTM E2178, *Standard Test Method for Air Permeance of Building Materials* (Figure 4), and ASTM E2357, *Standard Test Method for Determining Air Leakage of Air Barrier Assemblies*. These two standards have been fundamental in developing acceptance criteria for air barrier materials. The industry has
matured, and now these standards need to be updated with new information and clarification of the existing information. (Figure 5.)

The Air Barrier Association of America (ABAA) has developed material evaluation criteria for the different types of air barrier materials and provides a listed service for air barrier and water-resistive barriers. These material evaluation criteria are then proposed to ASTM to become ASTM material specification standards. Currently, ASTM has not published a standard material specification for any of the air barrier materials. There is one material specification currently in development and out for voting: ASTM WK16958, Standard Specification for Membrane Forming Fluid-Applied Air and Water-Resistive Barrier Materials. There is also a standard practice being developed at ASTM that has just completed the voting process. It is ASTM WK50742, Practice for Assessing the Durability of Membrane-Forming Fluid-Applied Air and Water-Resistive Barriers. This is a good step in the right direction.

Other ASTM standards under development are ASTM WK7774, Terminology for Building Enclosure System Materials, Assemblies and Systems; ASTM WK40552, Specification for Air Barrier Materials – Medium-Density Closed-Cell Rigid Spray Polyurethane Foam; and ASTM WK35913, Test Method for Whole-Building Compliance Enclosure Air Tightness. There is a fairly long list of standards that still need to be developed, including materials specifications, installation standards, test methods (both new and revisions of existing test methods), and guides.

Without proper standards, one cannot compare one material to another, set a bar for the material or the installation, conduct repeatable and reproducible tests, or provide guidance to the industry.

To assist design professionals in identifying key requirements for the installation of air barrier assemblies, there are master specifications for the different types of air barriers. They are available free of charge in MS Word format so that a design professional can customize them for a specific project (https://www.airbarrier.org/specs/index_e.php).

New master specifications must be developed as new types of materials come on the market, and the existing master specifications must be updated and improved, based on the feedback received from the field and the advancements in the industry.

DESIGN IMPACTS ON PERFORMANCE

The air barrier system needs to be designed correctly. If the design is improper or incomplete, or the details are missing, then it will be almost impossible for the installer to properly install the air barrier materials. If you can draw it, it does not mean that you can build it, and in some cases, even if you can build it, it may not function properly. (See Figure 6.)

The key to success is to achieve a continuous plane of airtightness. This is easier said than done. One suggestion that has been helpful at the drawing stage is to determine what material is identified as the air barrier material, and then to trace the location of the air barrier through all of the wall, roof, and foundation sections of the drawings. If this can be accomplished without having to lift one’s pencil, that is a good sign. If there are gaps in the drawings, there will be gaps in the air barrier after it is installed.
Figure 7 – An aluminum-framed window set into a CMU backup wall.

The key areas to look for leakage are at the connections. Experience has shown that the roof/wall intersection has been neglected and, in most cases, is where the greatest amount of air leakage occurs. In any building, where a blower door test has not been conducted, there is a high probability that no one has made the connection between the roof and the wall. The next largest air leakage area has been shown to be the wall/window connections.

When designing the connections between different building assemblies and air barrier components, keep in mind the amount of movement there will be between the two materials when subjected to temperature changes and material moisture content changes. As the two different materials will move at different rates, this has to be accommodated by using a flexible connection. An example would be an aluminum-framed window set into a CMU backup wall (Figure 7). The movement between the different materials will be severe and needs a flexible material to keep the seal.

Not all the air barrier components will have been designed or manufactured to provide a flange or other means to make a connection of the air barrier material between—for example—a wall and a window. If there is no "air barrier flange" on the window, the window manufacturer must be consulted as to where the connection should be made and how to keep the window airtight when mechanically fastening the wall air barrier material to the unit, all the while keeping the joint flexible. So, the connections of the different air barrier assemblies and the air barrier components are the first places to look when designing the air barrier system.

Once a strategy for making those connections has been made, how the air barrier materials are to be connected to the penetrations should be assessed. These can be round penetrations (Figure 8), square penetrations, brick ties, penetrations that just protrude through the building assembly, and penetrations that are continuous. The design should detail not only how the installer will make the gap around the penetration airtight, but in most cases, how to keep the connection airtight while the penetration moves—and in some cases, moves significantly. The procedure used to make the joint airtight will need to be flexible, and, depending on the climate zone, may need to be flexible in either very cold or very hot climates.

Finally, terminations need to be designed (Figure 9). This occurs when one air barrier material terminates on another air barrier material. An example of this is when a wall air barrier material terminates on a poured concrete foundation. The poured concrete is the air barrier material for the foundation, so for many projects, there is no need to add an additional air barrier material over the poured concrete. Of course, all joints in the poured concrete should have materials installed that will make them airtight but allow for movement. The termination may need to be mechanically fastened, and a sealant may need to be installed on the edge of the air barrier material. The details will depend on the type of air barrier material that has been used.

Figure 8 – Installing a properly detailed round penetration.
CHOOSING AIR BARRIER MATERIALS

There is no “ultimate” air barrier material. All types of air barrier materials can provide a plane of airtightness. Within each type of air barrier material, there may be numerous different options. There are hundreds of air barrier materials out there (See Figure 9). Many have been evaluated against criteria specifically designed for air barriers.

ABAA has developed material requirements and physical properties for different air barrier types. (See Figure 10.) The requirements include the air leakage rate of the material and the air leakage rate of the material installed into a building assembly. The requirements go beyond simple air leakage tests. They include requirements that indicate if a material will perform as intended and, to some extent, whether the material will be durable over the service life of the building. As many of the materials can also provide the water-resistance function, tests that address water resistance are included. Each material is also tested to determine the water transmission rate and the permeance rating.

Anyone can develop his or her own requirements for an air barrier material, determine how each property will be tested, determine the minimum/maximum requirement for that property, and review each test report (which is sometimes modified from the test method) to determine whether a material is acceptable. In addition to all the time this would take, an additional downside to this is that he or she will then take complete responsibility for the installed performance of the material. That is not a responsibility many design professionals want to take on.

Many design professionals are wary of the manufacturer’s salesperson who says, “Trust me.” It is a lot easier for the design professional to simply go to a website and choose a material for which performance criteria have already been set, the test reports have been reviewed, and the material has been evaluated. Many design professionals will not consider using a material that has not been evaluated in this way.

The design professional still needs to choose the type of material. Technical support is available from firms and associations during the design process.

Corporations who have had their material evaluated through a site quality assurance program will normally be obligated, under a written agreement in the program, to provide material with the same properties and characteristics as the material submitted for evaluation. The agreement will normally also obligate the manufacturer to work with the owner and the trade contractor to resolve any site issues, including replacement of material when that is warranted.

The objective of the site quality assurance program is to resolve site issues before they go to litigation. The site quality assurance program also allows the manufacturer to take steps to correct issues without admitting anything. They simply take the position that the only reason that they are taking the action is because the site quality assurance program has directed them to do so.

WORKING WITH A GENERAL CONTRACTOR

There are a wide variety of general contractors who can have completely different philosophies. They range from really looking out for the customer’s interest to a “slap it up, cover it up, and move on” attitude.

The very first ABAA chairman worked for a general contractor who specifically had set a goal of zero growth. When I first heard that, I was mystified. It took me a while to get my head around not going for double-digit growth. However, as I examined the company and its philosophy, what I saw was a company that did very well financially, that was able to pick and choose its jobs, put its customers’ interests first, charge for its work accordingly, and had a long list of repeat customers… and a lot fewer headaches. Rather than beating the bush for the next contract on a daily basis, it was able to focus on constant improvement and efficiency. Not a bad way to run a construction company.

Whatever types of general contractors you end up working with, spend the time to help them understand that you want your investment in a building to be a worthwhile investment, and you do not want to
be constantly repairing the building. The air control layers, the liquid water control layers, the water vapor control layers, along with thermal insulation, all impact the building’s performance.

The general contractor needs to understand that “good enough” is not good enough, and that the control layers dealing with air, water, and heat need attention and they need to be done right. Construction documents should set out all objectives and include a consequence when not performed as indicated.

As an example, I received a call from a general contractor who had taken on a project where there was a performance requirement for the maximum air leakage rate of the whole building. As with a lot of general contractors, he seemed to have taken the “what can be different with this requirement” attitude, having never been required before to meet a performance requirement at the end of construction. When he called, he was in a panic, as his customer wanted a check from him in an amount that would cover the increased cost for the energy used resulting from the building not meeting the project’s performance requirements for air-tightness for the next 25 years. That’s not a bad way of writing up a contract.

**FINDING A QUALIFIED SUB-TRADE**

For most building projects, it is not the general contractor who does the work. Most, if not all, of the work will be completed by a specialty contractor. The general contractor must understand the importance of the air barrier and the water-resistance barrier, but the actual air barrier and water-resistant barrier contractors really needs to know their stuff. In most cases, an air barrier contractor is a legal entity. This entity will have a number of employees, but the entity will sign contracts, agree to performance levels, and be legally bound to provide the materials and services stipulated in the contract. The subcontractor’s workers need to have the understanding of how to execute all of the details required to make all six sides of the building airtight. In most cases, these entities are comprised of a number of people.

A site quality assurance program will accredit the air barrier contractor. If someone or something is accredited, that means that it has the ability to do something. The requirements can include having the qualified workers, equipment, processes, quality control, etc. Air barrier contractors can then hold themselves out as having proved that they have been reviewed by a third party. That third party has confirmed that the contractors have everything in place to carry out the work properly. The site quality assurance will also have the accredited contractor sign an agreement that will include requirements that they use trained and certified installers, that they use the specified evaluated material and do not substitute it without prior written approval, that they will document their work, that they will conduct daily testing and inspection, that they will correct any deficiencies, and that they will work with the manufacturer and the installer to resolve any site issues.

**IMPORTANCE OF A TRAINED AND CERTIFIED INSTALLER**

The installer is the person who actually performs the work. That person is sometimes looked upon as being the lowest person in the chain of command. In some areas of the United States, that person could have been picked up in the morning and then made responsible for the installation of the air barrier materials and accessories without any training whatsoever. Remember, air leaks are invisible. When an air barrier system is installed by someone without training, the building is likely to have moisture problems.

Decades ago, there was a good apprenticeship system for many of the traditional trades in the construction industry. Today, much of this work of training and apprenticing installers has fallen to organized labor groups. A lot of the trade schools have dropped construction programs due to low enrollment. So when insulation became an industry in the ‘60s and ‘70s, and air barriers became an industry in the ‘90s and 2000s, there was no infrastructure to simply add the additional training onto. Therefore, specialized training had to be developed and delivered.
If an installer has never been trained, he or she cannot be expected to do it right. Installers need training not only on the how, but also on the why. If they understand the why, then they will know how to address details they may have not seen before. Installers need training on each of the types of air barriers that they will be installing, and then also on the specific brand of material they are installing. They need to understand the environmental conditions that are acceptable, the requirements for how to prepare the substrates, where and how to start the installation, how to deal with the different penetrations and terminations, where the material should be installed in the building assembly, what a good installation should look like, how to test their installation to determine if there are air leaks, and how to complete documentation on their installation. They also need to be trained on how to correct defects. They need to understand that a site audit on their work is done to improve the quality of their installation by providing them with additional training, not simply to show up their mistakes. A supplementary quality assurance provision (SQAP) program will include additional hands-on training during a project inspection where the installer learns not only what needs to be corrected, but also how the defect can be corrected.

The air barrier installation will perform or not perform, depending on the knowledge, skills, and abilities of the installer. Well-trained installers can correct, in some cases, bad designs and make the material work in a particular detail. Qualified installers are fundamental, and a cornerstone to any site quality assurance program.

Each individual learns differently. People learn by hearing things, seeing things, and doing things. For some, classroom instruction works, and they can translate what has been taught to real-world conditions on the construction site. However, for the majority of people, they learn the best and retain what they have been taught by doing things (Figure 12). A good training course combines some classroom time with hands-on instruction.

Training without certification is meaningless. To simply attend a training program and receive a certificate does not indicate that the installer has been taught anything. It simply means he or she was there—a warm body in a chair. Certification is confirmation that one has the knowledge, skills, and abilities to actually do a job.

Both training and certification begin with Task Analysis. This is fundamental to any training program and any certification program. Tasks are organized into groups or functions. Some organizations then go on to develop learning objectives for each of the tasks. Developing learning objectives is a requirement for developing a training program, but I have found that it also helps in the development of the certification scheme.

For certification, prerequisites that a person needs to be able to complete for that particular job must be identified. The function/task listing outlines the work that needs to be completed. It must then be determined whether each task requires knowledge, a skill, or an ability to accomplish it. For some tasks, it could be two of them or all three. When you have identified the knowledge, skills, and abilities necessary for each task, you then develop a test instrument to confirm whether the person has the required knowledge, skill, or ability.

For tasks that require knowledge, written test questions must be developed. They should always be multiple-choice questions with one completely right answer and three completely wrong answers or distractors. Long-answer questions are too subjective, and true/false questions are not good indicators of knowledge, because even if one doesn’t know the answer, he or she has a 50% chance of getting the answer right. Misleading/trick questions also do not give a proper assessment. Once the tasks and the learning objectives have been established, questions that would confirm their knowledge can be crafted.

For tasks that require skills, one still would use a written exam, but move to a problem-solving methodology. As an example, a skill that could be required is to determine the number of pails of material that are required for a particular job. The assessment would give the parameters: Each pail covers 100 square feet, and the wall to be covered is 40 feet long by 12 feet high. Then leave it to the installer to determine the number of pails needed on the jobsite.

Figure 12 – Hands-on training at a training course.
For tasks that require an ability, the installer is no longer in the classroom. He or she is either in the field or in a “mock-up” environment. The installer is provided with the requirements for this task and needs to complete it without direction, guidance, or any other support of the person proctoring the exam. The pass/fail criteria for certification needs to be plainly set out ahead of time.

The risk involved at the installation level has dropped significantly. A person who has been trained and who has had his or her knowledge, skills, and abilities evaluated should be able to complete the task.

The certification organization also needs someone to check on them. Make sure that the certification organization has been accredited to ISO 17024 by ANSI/SCC.

**SPECIALIZED AUDITS VS. PROJECT INSPECTIONS VS. SURVEILLANCE AUDITS**

There are many different types of inspections/audits. Each has its purpose for conducting the inspection/audit, and each has an outcome.

One of the requirements of ISO 17024 is to have surveillance audits conducted on persons who are certified. This is to confirm that the person is completing the task properly on an ongoing basis. If only a surveillance audit is being conducted, then it is restricted to the person, as only the knowledge, skills, and abilities of that person are being confirmed. It has been found that conducting the certification surveillance audit in a mock-up environment may be the best. The mock-up can be constructed in a real-world situation where the person can demonstrate his or her abilities. This can also be done on the construction site as long as all the details are available.

Another type of inspection is a project inspection. Normally, this inspection is conducted by a third-party firm or individual who has the credentials for these types of inspections. Most project inspections are broad-based, where the inspection can include the complete building envelope, as an example, or, in other cases, different parts of it. To be proficient in all the different types of roofs and roofing materials, all the different types of cladding assemblies, all types of wall construction, as well as all types of foundations and waterproofing materials, is normally more than what a single person can provide. More likely, these inspections will be conducted on individuals who specialize in the various parts of the building.

Specialized inspections or audits are where focus is placed on a specific part of the building. Of course, just because the air barrier is being inspected doesn’t mean the water-resistant barrier should be ignored. A specialized inspection, like an air barrier audit, does focus on the details of that particular part of the building enclosure (Figure 13). With a specialized activity, the person conducting the audit would have had more exposure to both good and bad installations of that particular type. It is not unusual for a project inspection firm to hire a specialized firm or individual to provide a specialized audit on its behalf.

**HOW PROPER CONFLICT RESOLUTION FITS INTO THE PICTURE**

Every site quality assurance program (QAP) needs to have a conflict resolution
component. Potential risks should be identified, and steps should be taken to mitigate these risks, but at the end of the day, there will sometimes be problems on the construction site. Discussion in advance on who is doing what, who is responsible for what, and how to coordinate among trades will reduce conflicts on the jobsite, but it will not eliminate them.

To conduct an inspection on a project, write up a report, hand it to the owner or the owner representative, and walk away does not help anyone. In a site quality assurance program or (sometimes called a site performance program), identifying the conflict and then dealing with the conflict is critical, and a key component to the success of the program.

The site QAP will have legally binding agreements with the manufacturer for the material, and the trade contractor for the installation. There must also be an agreement with the installer, who would be subject to losing his or her certification if he or she did not follow the requirements of the program. This puts the QAP organization in a position so that they can dictate, if required, that corrective action be taken and what that corrective action will be (Figure 14).

The site QAP will already have helped to keep the project on schedule, as it will have provided trade contractors who know what they are doing, trained and certified installers who will do the installation right the first time, and an audit to find anything that has fallen between the cracks but can be corrected in a short period of time. The general contractor is left with a project that runs smoothly and remains on schedule and on budget.

With a conflict resolution component in a site QAP, there is a process in place to make corrections in the shortest amount of time possible, should things go wrong.

**HIGH-PERFORMANCE AIR BARRIER SYSTEM ACHIEVED**

No single component by itself will provide a high-performance air barrier system (Figure 15). Only by having all the components and by making sure they work together will a high-performance air barrier system be achieved.

For a building to perform as designed and for the construction process to run smoothly, we must take a holistic approach. Without having taught the installer how to install the materials and confirmed his or her knowledge, skills, and abilities through a certification program, one cannot expect a quality air barrier system installation. Without proper standards and specifications, how can differences concerning installation be resolved? How can materials be expected to perform if test methods and performance levels have not been determined in advance? The questions go on and on.

Single actions, like project inspections only, will not give the results needed. A complete QAP is needed where all the risk factors are addressed and a good communication system is enacted with all the related parties. Build the quality (performance) in during construction, rather than trying to inspect for quality after construction.