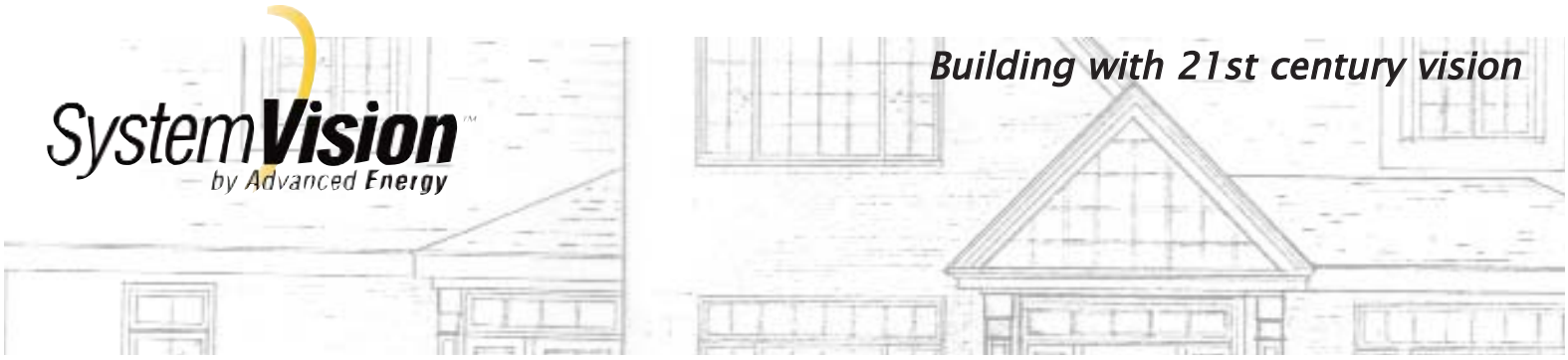

High Performance Homes and the 3C Barrier
by John Tooley

In terms of Building Science, a high-performance home is one that provides the maximum comfort to its occupants, along with maximum energy efficiency. In practical terms, this means a house that heats and cools evenly and comfortably, is free from drafts and excess moisture, and doesn't waste money heating or cooling air outside the living space.

For maximum comfort and efficiency, a house must be adequately sealed to prevent the unwanted movement of air, heat, or moisture, into or out of the living spaces of the home. A high-performance home uses three barriers to protect the home: a thermal barrier (insulation), an air barrier (sheathing, foam core board, house wrap, caulk and gasket), and a moisture barrier (poly sheeting). These three barriers should form a continuous, sealed envelope around the living space of the home, with no open penetrations, gaps, misalignments, or voids.

The engineers at Advanced Energy have coined a phrase for this concept of a sealed, environmental envelope: the 3C Barrier – Continuous, Contiguous, and Complete. Continuous refers to an envelope with no breaks in the air and thermal barriers. Contiguous means that the two barriers are physically touching each other at all times, in all places. And Complete in that the air and thermal barriers together completely contain the living space within the house.

The Basics

Movement of Air, Heat, and Moisture

Air, heat, and moisture can move into and out of a home through openings in the home's envelope. These unwanted guests can play havoc with the comfort, efficiency, and durability of a home. In the summer, homeowners want to keep the hot, humid air outside. Not only is it uncomfortable, but warm, moist air may condense as it comes into contact with cold surfaces within the home, resulting in mold, mildew, stains, and even rot. During the winter, homeowners want to keep all the warm air inside, of course. But they also don't want the moisture present in the inside air to leach out into the exterior sheathing of the house and cause moisture damage.

While each of the three – air, heat, and moisture – are driven by different forces, their movement into or out of a home is often related. Air can move very quickly between spaces, while heat and moisture generally travel much more slowly. Heat and moisture can both be carried along on air currents. But while air and moisture both need an opening to flow through, heat may also be conducted directly through a solid surface.

Air Movement

Air moves from high pressure zones to lower pressure zones, and can change direction quickly. Many conditions can affect the different pressure zones in a home, such as doors opening and closing, the operation of HVAC or vent fans, or even changes in the wind outside. Differences in the air temperature inside and outside a living space also changes the relative pressure, and so causes air currents to flow. With so many different factors to consider, the movement of air through a home may be difficult to predict at times.

Penetrations in the air barrier allow conditioned inside air (or unconditioned outside air) to travel through or around the insulation (or thermal barrier) of a home, a process known as thermal bypass. Thermal bypass reduces the effectiveness of any insulation, and may allow condensation to form on cold surfaces. However, thermal bypass requires openings for the air to flow through. Careful installation of a well-designed and complete air barrier will prevent most

air leakage between the inside and outside of the home

The placement of the air barrier generally determines the position of the vapor barrier and the thermal barrier (insulation). Some modern building materials, such as Styrofoam blue board, act as both air barrier and vapor barrier. Other building designs use plywood, OSB, or sheetrock as the air barrier, with a plastic vapor barrier installed adjacent to the air barrier. Insulation should be installed directly in contact with the air barrier in most cases, to prevent any convection currents from forming, or any air from moving through the insulation. The only exception is when insulation is installed in an airtight cavity, in which case the thermal barrier may be installed on either side of the cavity.

Heat Movement

Heat travels from warm areas to colder ones through two means: conduction (direct thermal transfer) and convection (heat carried by air currents). Conduction refers to the transfer of heat directly through a solid object like a wall or floor. This type of heat loss requires no holes or openings to occur, though for most building materials, conduction of heat is a fairly slow process. Insulation is designed to slow conductive heat loss even further.

Heat transfer via convection uses air currents to carry heat into or out of the living space. The speed and volume of heat transfer obviously depends on the size and speed of the air currents. Holes or other openings in the home's air barrier allow heat to migrate into or out of the home depending on the movement of the air currents – which in turn are often driven by pressure differences between living spaces and the outside.

Conduction and convection heat losses are often related. Cold spots on a wall (caused by conductive heat loss) cool the air on the inner side of the wall, causing the air to fall and convective air currents to begin flowing. These convection currents can then carry the cool air to other parts of the home, resulting in homeowner complaints of drafts or poor heating operation.

In a different scenario, any gap between the air barrier and the insulation within a wall cavity creates an air space that can allow convective air currents to begin flowing. Even if the cavity is airtight to the conditioned space of the house, these small convection currents can carry heat away from the interior wall, causing a cold spot on the wall. As illustrated in the previous paragraph, such a cold spot can then cause convection currents to begin flowing within the living space, transferring the cold to other parts of the home.

Moisture

Moisture in the form of water vapor migrates from wet areas to drier ones, and from warm to cold. In general, this means that moisture tries to move into a house in the summer, and out of a house in the winter. While water in its liquid form is fairly easy to track when it enters a home, water vapor is much more elusive, creeping in through holes in the vapor barrier, and even slowly migrating through insulation, drywall, or other materials. As water vapor enters a home or passes through the walls, it can condense on any cold surfaces, resulting in mold and mildew growth or even rot in wooden structures. A complete, sealed vapor barrier will prevent moisture from traveling through the walls and floor, or otherwise entering a home.

Holes and Bumps

Installing a 3C Barrier in a square box would be relatively easy. But most modern houses are anything but square, with dormer and bay windows that break the plane of walls, dropped ceilings and recessed lighting that break the plane of ceilings, and even sunken living rooms that break the floor plane. For effective performance, a 3C barrier must follow the contours of the living space very closely.

Technically speaking, breaks in the building planes are called either intrusions or protrusions, depending on if they extend into or out of a space. Most features that extend into one space leaves a void on the back side. Building professionals prefer to use the simple terms holes and bumps. Whether a break in the barrier is a hole or a bump depends on your point of view. The term "with reference to," or WRT, is valuable when discussing such features: a recessed light would be a hole WRT the kitchen ceiling, but a bump WRT the attic floor. Similarly, a bay window is a hole WRT the living room, but a bump WRT the outdoors. Holes and bumps are most commonly found in walls and ceilings, but occasionally appear in floors as well.

Enclosed Spaces

Most home designs contain a number of enclosed spaces that are hidden from view. These spaces include strapped ceilings, furred walls, knee walls, floor framing, soffit spaces, chases, and others. Such enclosed spaces, while located adjacent to or even within the living space of the home, are often open to attics and other unconditioned spaces. If these enclosed spaces are not properly framed and sealed, they can allow air, heat, and moisture to bypass the 3C barrier, reducing the comfort and efficiency of the home.

R-Value Killers

Most homes, even well-built homes, are plagued by instances of thermal bypass – breaks in the envelope that allow air and heat to flow around the home's insulation and

air barriers. A properly-installed 3C Barrier prevents thermal bypass. However, any breaks in the barrier will reduce the effectiveness of the home's insulation. For this reason, these problems are often referred to as R-Value Killers.

Misalignment occurs whenever insulation is not installed directly in contact with the adjacent air barrier, leaving a gap between them. Even a gap as small as 1" will allow air to begin to circulate and rise as it heats. Since insulation works primarily by trapping dead air, allowing air to pass through the insulation drastically reduces its insulating ability, turning it instead into an unwanted air filter. Batt insulation rolled over dropped soffit often creates just this type of gap between the surface of the air barrier (soffit) and the surface of the insulation. Gaps such as these should be properly covered and sealed, since insulating down along the contour of the recess is difficult work at best.

Gaps and voids are spots that should contain insulation, but don't. Gaps occur when insulation isn't installed all the way to the edges of the space being covered, typically in corners. Obviously, care must be taken to ensure that the insulation is installed completely. Voids are actual holes in the envelope of the building, such as electrical penetrations, plumbing and ductwork chases, fireplace cavities, and vents. Voids should be blocked whenever possible, and sealed around any penetrations to prevent air infiltration. Insulation should then be installed against the surface of the air barrier.

It's a Team Effort

Installing a proper 3C Barrier isn't a job just for one member of the house-building crew. Rather, it's a team effort, requiring the involvement of the designer or architect, the builder, the framer, the insulator, the plumber, the electrician, the drywall crew, and all the rest. Everyone must commit to the idea of creating a high performance home with a sealed, 3C Barrier to protect it from moisture, air, and heat infiltration.

The list below outlines seven crucial steps required by the various members of the home-building team in order to install an effective 3C barrier. Each member must follow the plan exactly and do a thorough job, since failure to complete any task will prevent the following team member from doing their job, resulting in an incomplete 3C barrier.

7 Steps to a 3C Barrier

1. Designer: Clearly identify the location, materials, and design of the 3C Barrier on the house plans.

2.Builder: Ensure that the plans are followed exactly, regarding the 3C Barrier.

3. Framer: Follow house plans, and establish even planes wherever possible.. Block and seal all enclosed spaces.

4. Mechanical contractors: Install rough-in mechanicals. Flash and seal all air barrier penetrations.

5. Insulation contractor: Install vapor retarder on warm side of insulation.

6. Drywall contractor: Install drywall to follow planes.

.7. Insulation contractor: Follow air barrier, ensuring that insulation and air barrier are in full contact at all points.

Designer

A properly-installed 3C barrier begins with the designer. House plans should clearly state where the air, thermal, and moisture barriers are to be installed by each building trade. The designer should specify not only the exact location of the 3C barrier, but also the materials to be used, as well as how those materials are to be joined at breaks in the floor, walls, and ceiling planes. The location of the 3C barrier must be clearly defined on the floor plan and elevation pages of the house plans so that complex details such as chase ways, stairwells, and dropped ceilings can be easily identified as being inside or outside the boundaries of the conditioned space.

Builder

The builder's job is to ensure that each member of the home-building team understands the building plans, and follows them exactly. The builder should provide guidance to any craft members who are uncertain about the construction techniques used to install a proper 3C barrier. The builder should also ensure that the proper materials are available for each team member to complete their job.

Framer

The framer is responsible for the most critical task in ensuring a proper 3C barrier: establishing even planes (wherever possible) that the other craft can follow. If the framer doesn't do his or her job well, no other craft can make up for it. The framer must adequately seal strapped ceilings and furred walls, and install top plates on all knee walls. In general, wherever a ceiling, wall, or floor plane is broken, the framer is responsible for establishing a sealed plane that the insulator and other craft can follow.

Other Craft

Each craft must follow the design plan and the lead of the framer as they install their various equipment. The insulation crew must install the thermal barrier directly against the air barrier. Plumbers and electricians are responsible for adequately sealing any holes they make in the barriers.

Getting Down to Business

The concept of framing for a 3C barrier is simple enough:

create flat planes; seal all unconditioned spaces; and frame so that the air barrier and thermal barrier can be in constant contact. In reality, accomplishing these goals can be a time-consuming effort, and a bit difficult at times for the inexperienced framer. The following sections provide some suggestions for framing around the more common problem areas.

Holes and Bumps

In general, it is easier for an insulation contractor to follow flat planes and cover holes rather than bumps. For proper installation of the 3C Barrier, the insulation should follow the contours of the air barrier, and be in direct contact with the air barrier at all points. But for some features (dropped ceilings, for example), following the exact contours of the air barrier simply isn't practical. In the example of a dropped ceiling, rather than having the 3C Barrier follow the contours of the hole, it is better to simply cover the hole with a rigid material (plywood, OSB, etc.) specified by the designer. This material then becomes the air barrier, and the attic insulation can be installed as if the hole did not exist.

Treating bumps is often a much more difficult task than handling holes. A tray ceiling in the living room of a home is a bump WRT to the attic. For adequate coverage, the 3C barrier must follow the contours of this bump exactly. Unlike the example with the dropped ceiling, creating a flat plane even with the top of the tray ceiling isn't practical, since such an air barrier would require extensive knee walls to be installed where the new plane intersected the roofline. In this case then, the best solution would be to install the 3C barrier along the surface of the tray ceiling.

Enclosed Spaces

All enclosed spaces within the 3C barrier must be properly blocked and sealed to prevent unconditioned air from entering the home. Large spaces, like knee walls, are easily recognized and sealed with a top plate. But smaller framing details may be overlooked as breaks in the 3C barrier. Even relatively small spaces – like those within a strapped ceiling – can allow air leakage and convective heat losses if not properly sealed against unconditioned space. The guidelines below provide some advice for handling some of the trickier enclosed spaces.

Furred Walls/Strapped Ceilings

Furred walls should be capped with a horizontal strip of wood at both the top and bottom. Strapped ceilings should be blocked and sealed at the end with solid sheathing.

Garage to Basement

It is extremely important that any connections to an attached garage be completely sealed. Otherwise, unwanted air movement may carry automobile exhaust or vapors from stored chemicals into the home. Wherever floor joists or trusses are connected to the garage, the floor or framing should be held back enough to allow room for a rim joist, band, or ribbon to be installed. This will ensure an airtight seal between the garage and the home's living spaces.

Interior Room Partially Cantilevered over a Garage

The junction between the garage and the floor of the room overhead must be blocked and sealed against air movement. If I-beams are used, the blocking must fill the entire opening between the garage and the floor system. If web trusses are used, an upright 2x4 should be engineered into the truss at the point where the truss crosses the exterior wall, to allow the floor system to be blocked and sealed.

Exterior Cantilever

Any floor cantilevered out over an exterior wall should be blocked and air sealed at both ends. This seals the floor from any unconditioned air present in the walls either above or below.

Corner Chase

All corner chases must be capped with sheathing. Any vent pipes located within the corner chase and penetrating the corner sheathing must be flashed and sealed to prevent air leakage.

Chimney Chase

Chimney chases and vertical shafts must be capped with sheathing during framing. After drywall is installed over the sheathing, this surface will create an even plane for installation of the 3C barrier. Failure to adequately seal chimney chases and other vertical shafts allows conditioned air to rise directly from the living space into the attic, bypassing the 3C barrier.

Soffit to Unconditioned Space

Interior soffit spaces may be dropped from ceilings to contain ductwork, or simply for aesthetic design. This soffit presents a hole WRT the unconditioned attic space, and must be capped to create a flat plane for the 3C barrier. The framer should install a cap of plywood, OSB, or thermo-ply sheathing over the soffit space, so that the insulation can be installed flat against it. Without an airtight cap in place, the void between the air barrier (the drywall) and thermal barrier (the insulation) could allow convection currents to flow, and warm air to rise up through the insulation.

Floors to Sidewall Attic

Traditional framing methods often leave the floor framing open to the sidewall attic spaces. Unless the framing is properly blocked and sealed, unconditioned air from the attic is free to flow through the floor. This unconditioned air can then enter the living space around lights, ductwork, or other penetrations in the ceiling below. Note that insulation (alone) is often placed over the ends of the floor fram-

ing. Without the presence of an air barrier, though, the insulation does little to prevent air movement, acting only as a filter rather than an effective air barrier.

Wrapping It Up

When building a high-performance home, no one's job is more important than the framer's. The rest of the building team will take their cue from the framer for the location of the air, thermal, and moisture barriers, as well as the various utilities. By creating as many flat planes as possible, sealing all enclosed spaces, and using the techniques illustrated above, the framer sets the stage for the installation of an effective, 3C barrier. And with a properly-installed 3C barrier in place, a home can live up to its designed performance goals, combining a comfortable living environment with low energy bills.