Principles of Building Science and Diagnostic Testing in SimBuilding

Building Science

Nature loves equilibrium. If there is an imbalance, natural forces will attempt to balance it. Heat moves from hot to cold. Air moves from high pressure to low pressure. Moisture moves from wet to dry. These are the principles that inform Building Science. Why? If they are all about nature coming into equilibrium, what do they have to do with building? A building is a structure in the middle of nature attempting to block out all those natural forces and create an unnatural space that is very much out of equilibrium.

A building's walls, roof, and foundation are intended to serve as an envelope that creates an artificially conditioned indoor environment—one that differs greatly from the outdoor unconditioned environment. We expect our buildings to be warm when the outdoors are cold, cool when the outdoors are hot, dry when the outdoors are wet, and flora and fauna free, except of course for those that we expressly invite inside. While buildings need a certain amount of airflow and venting to prevent issues with humidity and mold, this venting should be based on intentional ventilation systems put in place during construction. Unfortunately, many buildings suffer from excessive air leakage either due to construction that pre-dates an awareness of building science concepts, lacking workmanship in the present era, or perhaps well-intended but poorly informed renovations and modifications over time.

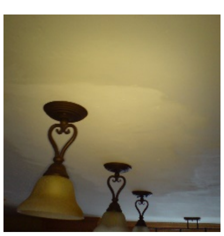
In order to create a stable and comfortable indoor environment, then, it is the responsibility of the contractors to be alert to building science principles, such as proper methods of insulation, air sealing, and ventilation. A stable indoor environment is not just more enjoyable for those that inhabit it, but limiting fluctuations in temperature and humidity go a long way toward limiting high energy demands and unnecessary renovation costs.

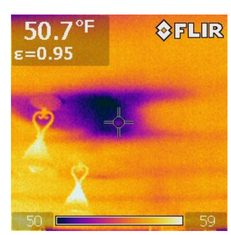
For many buildings, the cost of heating and cooling is driven up by air that is leaking from the conditioned to the unconditioned environment and vice versa. Heat moves to replace cold. We pump heat into our homes in the winter to have a percentage of it leak into the attic, down into the basement or crawlspace, or out cracks around our doors and windows. In most states across the USA, there are Weatherization Assistance Programs in effect for low-income, disabled, and elderly citizens in order to lower energy demand, and in turn lower energy bills. These programs, under the guidance of the DOE, retrofit homes with consistent higher r-value insulation in walls, ceilings, and floors, air seal or replace windows and doors, install lower energy-demand heating appliances, properly seal heating and a/c ductwork, and ensure that the ventilation is functioning correctly.

Before these retrofits are completed, Energy Auditors run diagnostic testing on homes to determine where work is needed. Quality Control Inspectors will come back after the work is complete to verify proper installation. In both these cases, as well as on new construction, a series of diagnostic tests, including running a blower door, using infrared thermography and combustion analyzers, as well as moisture sensors, can determine a home's energy-efficiency and how well the principles of building science were adhered to. This is a growing field in the green building industry. Contractors, Retrofit Installers, Auditors, Inspectors, and HERS-raters, as well as Architectural and Mechanical Engineers all have need to understand these concepts.

Infrared (IR) Thermography and Blower Door Diagnostic Testing

To test how energy efficient a home is, in addition to checking up on how good a job the contractor did of insulating, air sealing, and installing proper ventilation, a variety of diagnostic tests can be utilized. These include blower door pressure diagnostics, duct testing, infrared thermography, and combustion analysis. For the purposes of SimBuilding, the focus is on IR thermography and blower door pressure diagnostics.





IR Thermography reads the heat coming off various surfaces to show what temperature they are. Cooler zones will appear in darker "cold" tones (blues and purples) while warm zones will appear in brighter "warm" colors (oranges and yellows). Interpreting these different zones is the job of the auditor or diagnostician. With IR thermography, a person can see cavities inside walls, water leaks from hidden plumbing, drafty breezes as they cool or warm a wall or ceiling, and heating ducts as they move through a floor. In other words, they can show exactly how air is moving in a house. When partnered with a blower door, which places the house under pressure by typically pulling air out of a house (simulating an outdoor 20mph wind), it can aid in diagnosing where a house has the most critical energy losses and indicate what priorities should be made in creating a work order for the home.

Some points to know for IR thermography and blower door pressure diagnostics:

- Blower door depressurization and infrared thermography are tests best run when there is a significant temperature differential between the indoor and outdoor environments—at least 18 degrees Fahrenheit.
- Always keep in mind which environment is warmer—thermography uses color to show what is warm vs. cold. If interior materials are reading cold, when the interior is supposed to be the warmer environment, then those spots are problem areas. However, if the materials are reading cold when the exterior is the warmer environment, this may mean those locations are performing perfectly.
- In green building, there's a lot of talk about r-value and u-value. R-value is a quantified level of resistance to heat transfer. In IR thermography, this is clearly visible because different materials will appear different colors due to their levels of heat transfer. In particular, wooden studs have a higher r-value than air, so they will not transfer heat as much as air will.
- U-value and r-value are inverse properties. Higher r-value translates to better insulation. Higher u-value means higher leakage. Windows, by default, have higher U-values (i.e. lower r-values), even when double-paned and insulated, in comparison to nearly any wall material.
- Blower door depressurization can highlight areas where insulation has not been evenly and consistently distributed throughout air cavities, as there will be signs of air leakage through the wall. Properly installed dense-packed insulation hinders air flow through walls, ceilings, and floors.
- Notorious areas for air leakage/convective heat loss due to poor air sealing and improper insulation installation: Around windows and electrical outlets; access points for attics, garages and basements; recessed lighting; duct vents; and connection points for garage and porch roofs. Again, running the blower door can highlight air leakage.
- Air leakage appears as feathering of a contrasting color when using infrared thermography. When exterior temperatures are lower, feathering will appear in shades of deep purple to indicate cold air is infiltrating. When exterior temperatures are higher, feathering will appear in shades of light yellow to indicate hot air is leaking through the cavity.
- Attics can show evidence of moisture infiltration when bathrooms are not vented to the outdoors.
- In IR thermography, roof and plumbing leaks look exactly like what they are—irregular shapes of water pooling and soaking through a building materials, in the dark blues and purples of cooler temperatures.

- Thermal bridging is the conductive phenomenon where heat transfers via construction members (e.g. studs) from interior to exterior, or vice versa. Picture a snow covered pitched roof in winter, with evenly-spaced melted gaps where the roofing trusses are located.
- If a wall looks the same through IR thermography both with and without the blower door running, then there is no change in air leakage—typically this points to an insulation job well-done.
- Not all air leakage can be blamed on contractors and inattentive building practices. In some cases, air leakage can be the unwitting fault of the homeowner themselves from doing DIY repairs, or pest intrusion and nesting can cause issues as well.

Now, can you apply what you've learned? Go to SimBuilding.info and test your knowledge in the SimBuilding game.