Energy Code Compliance

Montana

Best Practices Newsletter

Fall 2018

Published by MTDEQ and NCAT with funding from NEEA

It should be possible to explain the laws of physics to a barmaid.

—Albert Einstein

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The Building Science of Performance Testing

Building science is a collection of knowledge that allows us to understand the physical behavior of the building as a system and how this impacts energy efficiency, durability, comfort and indoor air quality. Performance testing plays a key role in our understanding of building science today. Building envelope tightness and duct tightness testing are based on physical properties such as air pressure, airflow, the stack effect, the effect of wind, and backdrafting.

Air Pressure

Air molecules constantly bounce off each other and everything around them. The air molecules inside an inflated balloon, ball, or tire are at higher pressure than the molecules outside. The force exerted by these air molecules is called air pressure. Where air molecules have greater density, more tightly packed together, air pressure is high. Where air molecules are less dense, less tightly packed together, air pressure is low. A manometer, a pressure gauge, measures the pressure difference between to different volumes of air.

The earliest manometer was simply and inverted U-shaped hose partially filled with water. Refer to Figure 1 on the next page. When the air pressure at one open end of the hose is different than the air pressure at the other open end, the water level in the hose will change accordingly. The difference in the water level, a measure of air pressure, is called inches of water (inH2O). Another unit of pressure is the Pascal (Pa). Pascals are generally used when working with performance testing since they allow us to work with whole numbers. Working with inH2O would require dealing with decimal values.

In performance testing we speak of the pressure in one area *with reference to* (WRT) the pressure in another area. The three house diagrams in Figure 2 illustrate the conditions that create neutral, positive, and negative pressure in the house WRT the outside. The blue arrows have been added to show the direction of infiltration and exfiltration through the building envelope.

Air Density

Until the 2015 IECC, air density corrections were not required by code. But the 2015 and 2018 IECC require corrections for air pressure differences caused by altitude to be considered when calculating building envelope air leakage rates.

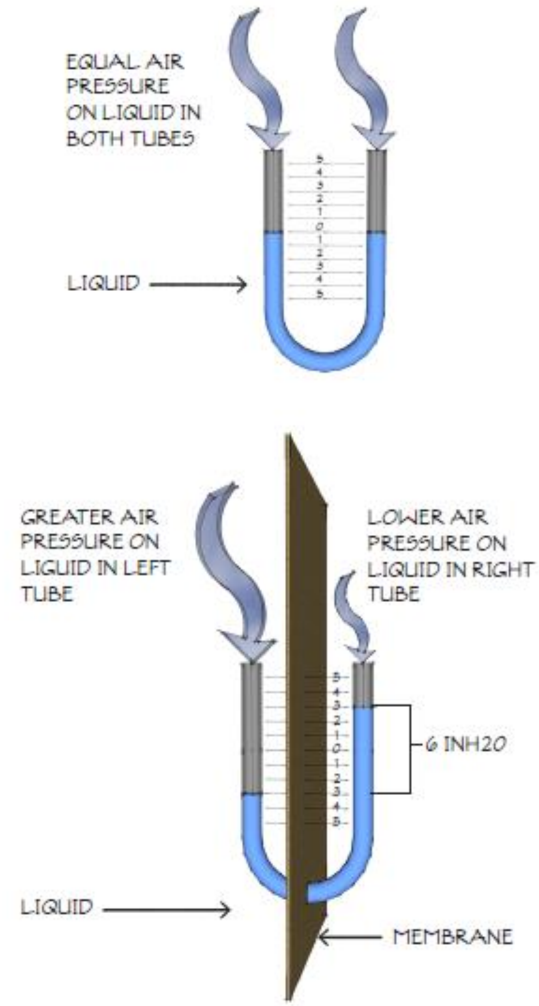

Figure 1 CONCEPTUAL MANOMETER

1 INH20 = 250 PASCALS

6 INH20 X 250 PA = 1,500 PA

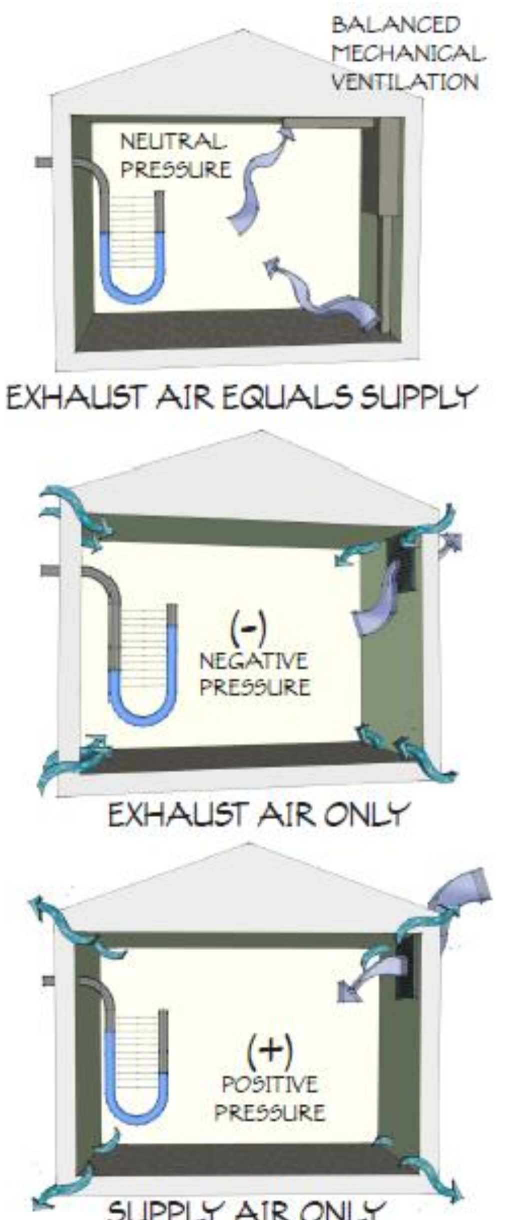

Figure 2
HOUSE PRESSURE WRT OUTSIDE

Atmospheric air pressure and air density decreases as altitude increases because there's less air pushing on it from above. At higher elevations, there are fewer air molecules per unit volume than at lower elevations.

Airflow Basics

Air flows according to basic physics. For our purposes the following concepts are important.

• For air to move, you need a hole and a pressure difference.

• Air always flows from high (or positive) pressure to low (or negative) pressure.

• Air In = Air Out. The same amount of air in cubic feet per minute (CFM) must enter the building as leaves the building.

• When air is added or removed from a single zone building, the pressure in the building with reference to outside changes by exactly the same amount everywhere. For a building to act as a single zone, all interior doors must be open.

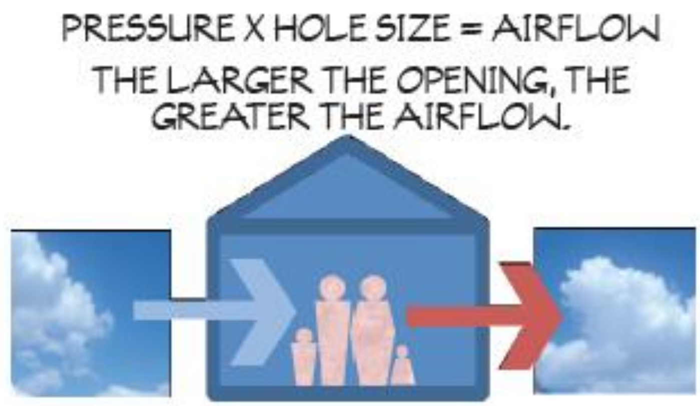

Figure 3 AIR IN = AIR OUT

A FUNDAMENTAL BUILDING SCIENCE PRINCIPLE: IF ONE CFM OF AIR LEAVES A BUILDING, THEN ONE CFM OF AIR MUST ENTER THE BUILDING.

Stack Effect

The stack effect is the movement of air within a building that leads to infiltration and exfiltration through the building envelope. The process is based on the buoyancy of warm air. Warm buoyant air is less dense and rises. Cooler air is more dense and falls. The difference in indoor-to-outdoor air density resulting from temperature differences drives this process. During the cold months of the year the warm air collects at the top of the building while the cooler air collects lower in the building. During the warm months of the year the warm air collects lower in the building while the cool air collects at the top of the building.

Stack effect is much stronger in cold climates during the heating season than in hot climates during the cooling season. In the winter, when warm air collects at the top of the building, air leaks to the outside high in the building. Infiltration occurs lower in the building. The neutral pressure plane occurs where half of the air leaks are above and half are below. No air leaks occur at the neutral pressure plane since there is no pressure difference between the interior WRT the outside.

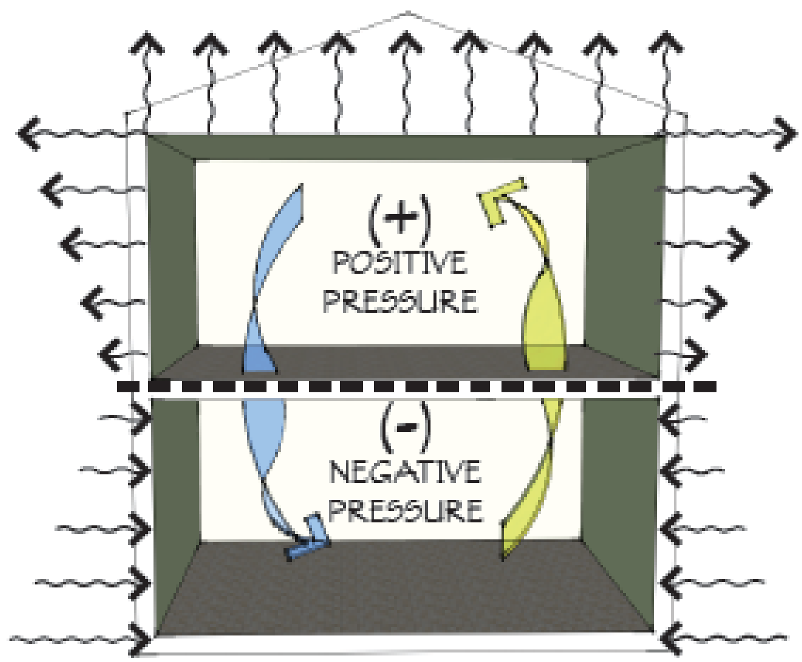

Figure 4 STACK EFFECT - WINTER

IN SUMMER EFFECT IS REVERSED WITH POSITIVE PRESSURE AND EXFILTRATION AT THE BOTTOM OF THE HOUSE AND NEGATIVE PRESSURE AND INFILTRATION AT THE TOP OF THE HOUSE.

Wind Effect

Wind exerts positive pressure on the windward walls of a building, causing air infiltration on the side of the building facing the wind. On the leeward side, negative pressure causes suction that pulls air out of the house through the envelope. Wind creates a greater positive pressure, with reference to outside, in the house interior on the windward side and a greater negative pressure on the leeward side.

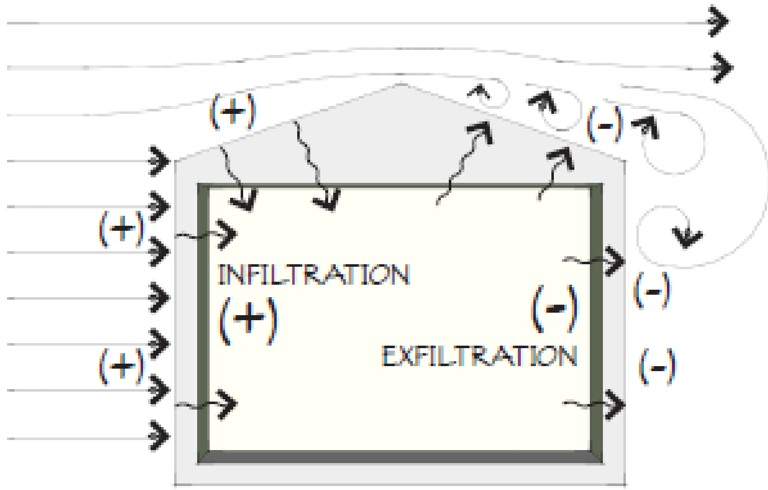

Figure 5 WIND EFFECT

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Backdrafting

The emphasis of this guide is building envelope tightness and duct tightness testing. However every performance testing technician should be aware of backdrafting. Backdrafting occurs when combustion gases are drawn into the living space instead of being exhausted through the chimney or flue.

Atmospherically-vented fossil fuel water heaters, boilers, and furnaces are designed to exhaust the by products of combustion to the outdoors through a flue. These hot gases rise through the flue and exit the home because they are not as dense as indoor air. The pressure difference that drives the movement of combustion gases up and out of the flue can be overcome by exhaust fans, fireplaces and dryers that create a negative pressure in the combustion appliance zone (CAZ). When CAZ pressure is negative enough, combustion gases can be sucked back into the house and may potentially harm or kill building occupants. Carbon monoxide is a dangerous combustion exhaust component because it is odorless, colorless, and toxic. Improperly designed flues or flue blockages can also cause backdrafting.

To understand how backdrafting can occur, in any given home it is useful to know how combustion appliances such as water heaters, furnaces, and boilers expel combustion gases.

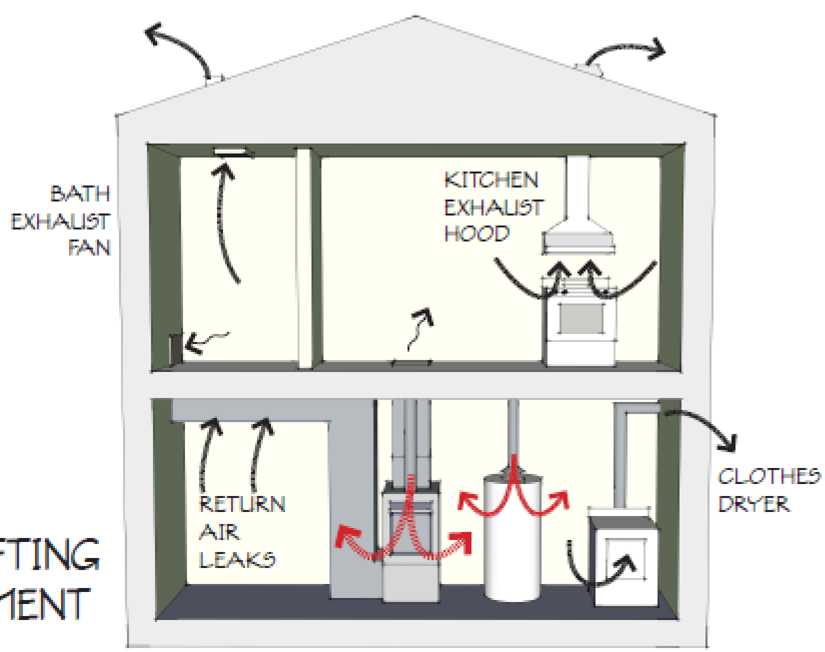


Figure 6
BACKDRAFTING AIR MOVEMENT

Atmospheric Draft. The combustion appliance takes the air needed for combustion from the indoor space where it is located, the CAZ. Combustion gases rise through the flue solely by the force of convection. Most backdrafting is the result of the atmospherically-vented gas water heaters operating in spaces

that have a negative pressure with reference to outside due to the operation of exhaust fans, clothes drier, and other factors.

Induced Draft. This system incorporates a fan that creates a controlled draft. The potential for backdrafting is reduced because the induced draft is usually strong enough to overcome any competing pull from indoor exhaust fans and the clothes drier.

Sealed Combustion. In sealed combustion appliances the combustion air intake and the exhaust venting system are completely sealed off from household air. Combustion air is drawn in from the outdoors through a pipe that is designed for that purpose. The potential for backdrafting is nearly eliminated because the rate of ventilation is not influenced by indoor air pressure, and the vented gas has no pathway into the home.

Combustion Appliance Zone Depressurization Test

Combustion appliances such as natural gas, propane, and fuel oil water heaters, furnaces, boilers, and fireplaces need to exhaust their combustion by-products to the exterior. One way to assure that backdrafting is not a problem is to exclude fossil fuel appliances or to install only sealed-combustion appliances. If atmospherically-vented appliances are present it is a good idea to test the house to see if conditions in the home can create backdrafting. Such a test, called a CAZ Depressurization Test, is detailed later in this guide.

The worst case CAZ Depressurization Test creates negative pressure in the room or space in which the combustion appliance is located. All exterior windows and doors are closed. Every device in the home that contributes to a negative CAZ pressure with reference to outside is activated. Interior doors are positioned to create the most negative pressure in the CAZ.

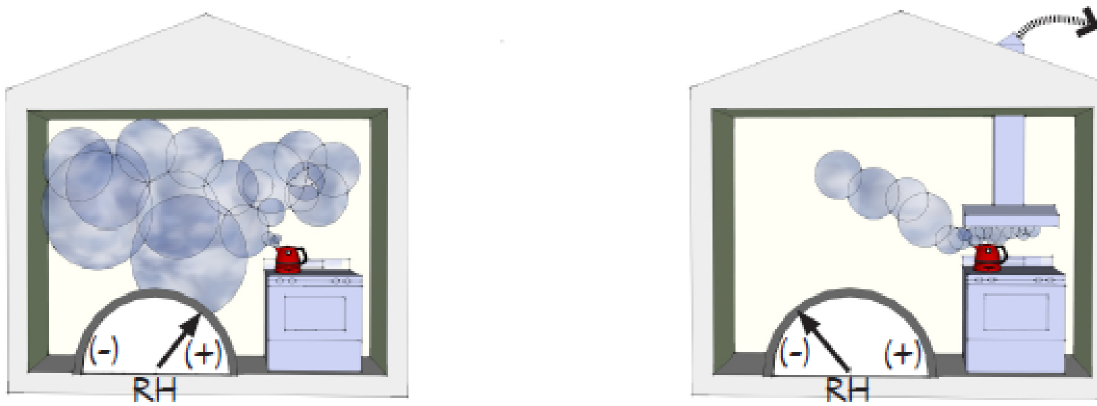
Air handlers can depressurize the CAZ if the return duct is leaky. The air handler fan must be activated to determine if it contributes to a greater CAZ negative pressure. Once the exhaust appliances and interior doors are configured to achieve the most negative pressure in the CAZ with reference to outside, that value is evaluated according to the characteristics of the installed appliances. If the CAZ worst case pressure is more negative than the allowable limit then actions should be taken to mitigate the problem. Those actions might include adding makeup air to the house, removing the atmospherically vented appliance, reducing the exhaust flow of over-sized exhaust equipment, sealing air leaks in return ducts, and sealing leaks in supply ducts located outside the building thermal envelope.

House Tightness and Humidity

Humidity in a home is important because too much humidity can lead to condensation on cold surfaces such as windows and closet walls. Condensation can lead to mold and resulting health issues. Building material degradation is another problem caused by excessive humidity. Relative humidity levels between 30% and 50% are commonly recommended for homes. When water vapor enters building wall and ceiling cavities condensation and mold can occur without being seen until significant damage is done.

If a relatively leaky house is made tighter, the relative humidity will increase if the amount of water vapor being added to the house air remains the same. Adding exhaust ventilation can significantly reduce the relative humidity in the home if the outside air drawn into the home is relatively dry.

Figure 7 EXHAUST VENTITLATION CAN REDUCE HUMIDITY LEVELS



A blower door test determines the tightness of the building envelope.

An infrared camera can help identify leaks in the building envelope.