2. Building Science and Performance Testing

Since November 2015, building tightness testing has been mandatory for all new residential construction in Montana, both within and outside local code enforcement jurisdictions. Duct tightness testing is required unless the ducts and air handlers are located entirely within the building thermal envelope.

By testing the performance of their houses, builders demonstrate their commitment to energy-efficient, safe, and comfortable home construction. Documented proof of test results provide a competitive advantage by demonstrating attention to detail and added home value. In today's marketplace, performance testing creates a reputation for quality and professionalism.

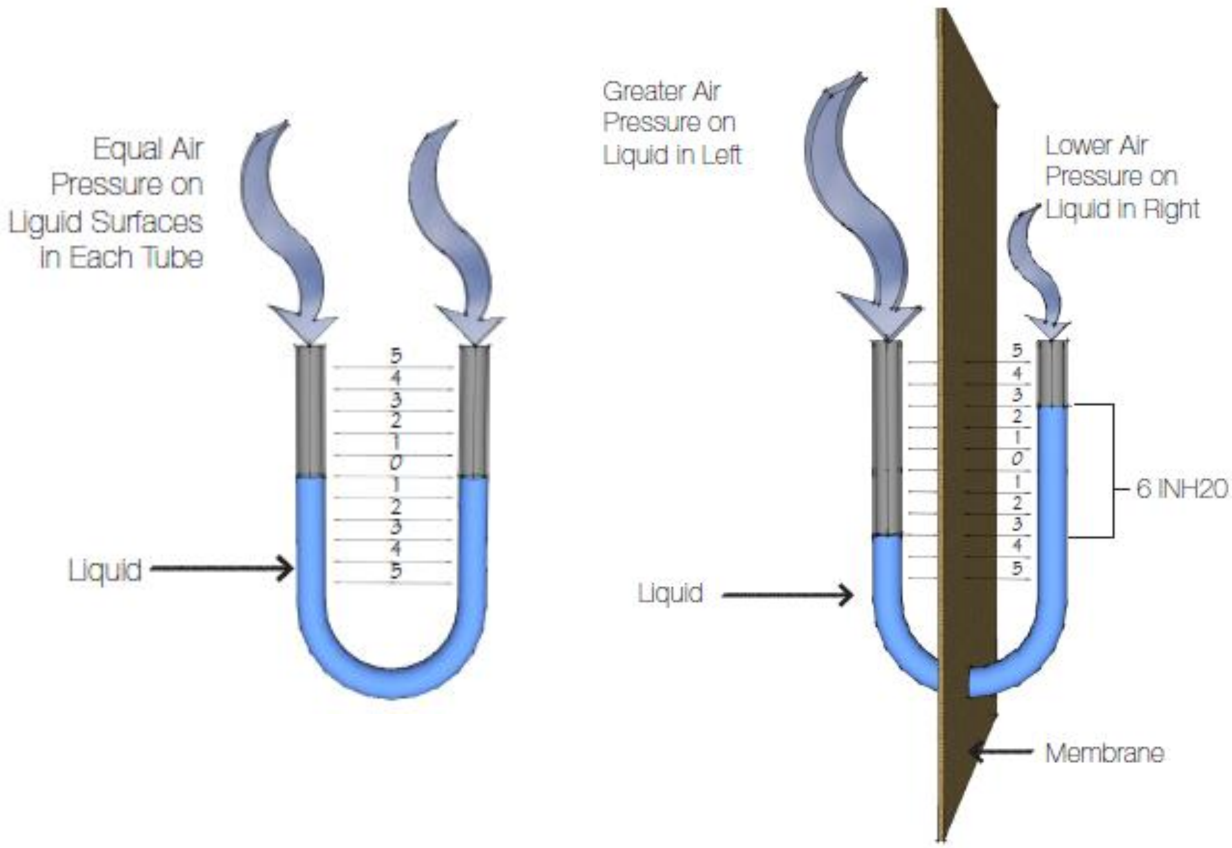
Why Is Duct Leakage Testing Important?

Tightly sealed ducts can reduce utility bills. Tight ducts improve indoor air quality because leaky ducts in attics, unfinished basements, crawl spaces, and garages can allow dirt, dust, moisture, pollen, pests, and fumes to enter the home. When ducts are leaky, heating and cooling systems have to work harder to condition the home. Duct sealing, along with proper insulation, allows the installation of smaller, less costly heating and cooling systems. When ducts are properly sealed, they deliver conditioned air more effectively to all rooms—helping to ensure a more constant temperature and improved comfort throughout the home.

Building Science and 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, stack effect, effect of wind, and backdrafting. These basic concepts are explained below.

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, or pressure gauge, measures the pressure difference between different volumes of air. The earliest manometer was simply an inverted U-shaped hose partially filled with water. 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.



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In performance testing, we speak of the pressure in one area *with reference to* (WRT) the pressure in another area. In the diagram above (to the left), the pressure exerted on both open ends of the tube is equal. The fluid level in both sides of the tube is equal. In the diagram above (to the right) the pressure on the left side of the membrane is positive WRT the area on the right of the membrane. Another way of saying this is that there is 6 inH20 pressure difference between the two columns of fluid.

The diagrams on the following page illustrate the conditions that create neutral, positive, and negative pressure in a house WRT the outside. The blue arrows have been added to show the direction of infiltration and exfiltration through the building envelope.

Airflow Basics. Air flows according to the basic laws of 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.

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 denser 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.

Fundamental Building Science Principles

- Pressure x Hole Size = Airflow Quantity
- The larger the opening, the greater the airflow.
- If one CFM of air leaves a building, then one CFM of air must enter the building.

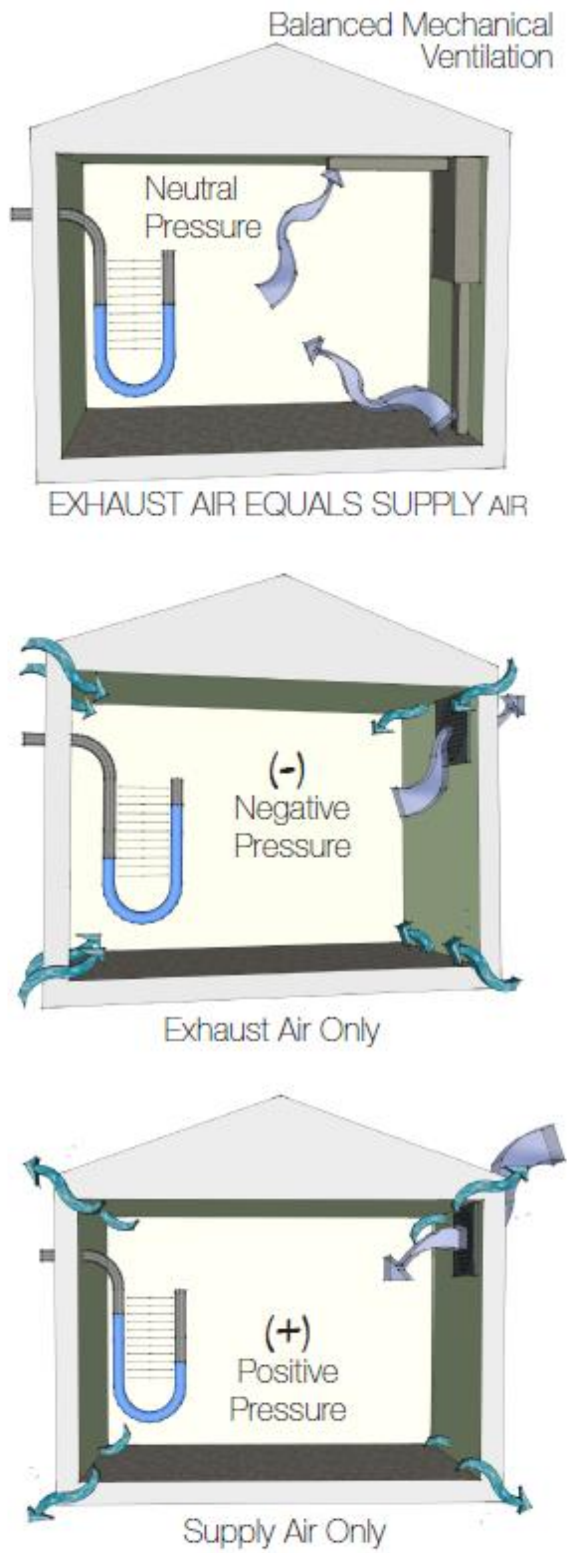

Figure 4-2.
House Pressure WRT Outside

Finally, it is worth emphasizing that the volume of air that is exhausted from the building is equal to the volume of air that enters the building. This is a basic fact of physics and allows us to infer by measuring the air exhausted from a blower door fan how much air is entering the buildind through leaks in the building envelope.

Air In = Air Out

Resources

ENERGY STAR New Homes, U.S. Environmental Protection Agency
www.energystar.gov/newhomes/?s=mega

Volume 12. USDOE Building America Best Practices Series: Builders Challenge to 40% Whole-House Energy Savings in the Cold and Very Cold Climates, Prepared by PNNL and ORNL, 2011. Available online from the Building America website.

Builder's Guide to Cold Climates, by Joseph Lstiburek, Building Science Press, 2006

Prepared by the National Center for Appropriate Technology with funding from the Northwest Energy Efficiency Alliance.