ENERGY COORDINATING AGENCY

KNIGHT GREEN JOBS TRAINING CENTER

Energy Conservation Training Handbook

Academic and Technical Training for Weatherization and Retrofit Installer

made possible by

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Please work safely when following the procedures outlined in this manual. If you cannot safely complete any of the procedures suggested in this manual, we recommend that you hire a certified professional to do the job, or skip the procedure altogether. *Your failure to comply with this warning could result in injury, death, or damage to your home.* Please perform only those tasks for which you are willing to assume responsibility.

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TABLE OF CONTENTS

Energy Coordinating Agency
Philadelphia, PA

Weatherization and Retrofit Course Curriculum

MANUAL ONE
Weatherization and Retrofit & the Weatherization Assistance Program

MANUAL TWO
Building Science: The House as a System and Principles of Energy

MANUAL THREE
Air Sealing, Insulation and Combustion

MANUAL FOUR
Weatherization Installation: Technical Applications

The purpose of this book
The content of this book and the courses that goes with it are designed to prepare entry-level retrofit installer technicians (RITs) to install weatherization measures in residential buildings. The material will also be useful for incumbent workers who wish to add to or enhance their existing set of knowledge, skills and abilities (KSAs).

This material is based on up-to-date principles of building science, which has decades of scientific research behind it. Modern building science can be applied to any weatherization situation, so all of the KSAs taught in the book can be applied to weatherization work anywhere. However, this book also specifically addresses issues that are unique to the U.S. Department of Energy's Weatherization Assistance Program (WAP).

Students that satisfactorily complete the material in this book and the associated curriculum will be prepared to start an entry-level weatherization installation job.

A Note on Terminology
Weatherization installation is an established industry, but relative to other trades (e.g. carpentry, construction), it is very young. Some states have only recently officially recognized weatherization installation as a bona fide trade. Because of this, there are a number of titles for the type of worker this book will train you to be. You may read or hear workers called retrofit installers, retrofit installer technicians, weatherization installers, weatherization retrofit installers, and depending on the context, simply "installers." Keep this in mind when going through this training and/or manuals, as the book or instructors may refer to the position in a number of ways.

How to use this book
The book is divided into four manuals. It is recommended that the book be used in the order it is written if the student is not familiar with weatherization work. The reason for this is that successful completion of the course requires higher-level KSAs as the manuals progress. The material in manuals one and two is appropriate for nearly everyone, while manuals three and four can only be successfully completed by individuals with experience.

The material may also be used to refresh KSAs of current weatherization workers. Students with some prior knowledge and/or experience may be able to skip to sections of the book as they see fit.

Manuals and Topics
The four manuals are as follows:

- **Manual 1: Weatherization and Retrofit & the Weatherization Assistance Program.** This manual introduces the core concepts behind weatherization and retrofit and introduces the KSAs necessary to become a weatherization retrofit installer, including weatherization tools, materials and processes. It also describes the Weatherization Assistance Program's history and goals, and what it means for workers in the field.

- **Manual 2: Building Science: The House as a System & Principles of Energy.** Modern weatherization practices are based on *building science*. Building science uses scientific principles to describe how conditions in buildings change and can be controlled. The scientific laws regarding air, heat and moisture flow are the most important for weatherization workers to understand, and are the focus of this manual. Health and safety issues related to building science are also touched upon. Basic plumbing applications such as domestic hot water heaters are also covered.
- **Manual 3: Air Sealing, Insulation and Combustion.** The two most effective ways to make a building more energy efficient is to properly air seal and insulate. Manual 3 builds upon the material discussed in manuals 1 and 2 and describes how to properly air seal and insulate homes. There are a variety of techniques and materials used to address a variety of weatherization situations. The material in this manual includes descriptions of a number of these, as well as lab exercises to practice the techniques. In addition, the basics of combustion, combustion safety, and combustion analysis are covered.
- **Manual 4: Weatherization installation Technical Applications.** The final manual in this book describes more advanced weatherization technical applications, such as those dealing with roofs, stairs, walls, windows and doors. The lab activities provided in this manual require a slightly more comprehensive set of KSAs than previous manuals to successfully complete.

It is important that you know that though weatherization work is very hands-on in nature, there are a number of *concepts* and *principles* that are important to understand if you want to be an effective worker. Because of this, much of the information presented in some of the earlier manual does not directly involve hands-on work. Though some of this information may not seem important, keep in mind that *all* of the information in this book is included for a reason. Namely, it will help you become a more effective weatherization worker.

Course Competencies
The U.S. Department of Energy (DOE) describes a weatherization competency as:

> The possession of a minimum level of knowledge and proficiency required to collect appropriate information, make informed decisions, and physically take the needed actions to deliver the high-quality weatherization service in question[1].

Using DOE's definition as a basis, the introduction to each chapter in this book describes the competencies that are required to successfully complete the material in each chapter. The competencies covered in each chapter (to the extent possible) match the ones specified by the National Renewable Energy Laboratory (NREL, a laboratory overseen and funded by the DOE) as

[1] From *Core Competencies for the Weatherization Assistance Program* (2009), p. 2, available at http://www.waptac.org/data/files/training_resources/corecompetencies12022009.pdf.

essential to all retrofit installer technicians. The standards set by NREL are compiled and organized into a job task analysis (JTA)[2], which are seen by the DOE as the authoritative set of standards for all weatherization workers, and will likely be the primary set of standards in the U.S. in the near and distant future. The manuals in this book cover all elements of the Retrofit Installer Technician JTA.

The list of competencies at the beginning of each manual can be used as a checklist for how well you have learned the material in the manual. If you can confidently say that you possess all of the listed items after completing the manual, you have a good handle on the material. By the same token, if you find that you do *not* possess all elements, it is recommended that you review and/or ask questions about the ones you are lacking.

Laboratory Exercises

The "hands-on" components of the manual (the laboratory exercises) are especially important considering the book is meant to prepare workers *in the field*. The lab exercises are meant to be done with the supervision of an instructor with expert knowledge of the material. Many of the tools and materials used in weatherization are dangerous if used improperly.

Additional Elements

The authors have created a number of ways to highlight material that is especially important for students to understand and/or be aware of:

The **Safety Matters** symbol indicates issues and practices that are especially important in terms of safety. Many weatherization practices, materials, and situations pose health and safety hazards if not done carefully.

Carbon Monoxide (CO): a gas that is tasteless, odorless, colorless and poisonous that is a by-product of incomplete combustion of fossil fuels.

Glossary Inserts highlight weatherization-related terms that many people may not be familiar with. Note that these and other terms are in the glossary at the end of the book as

Tools of the Trade

Caulk and Caulk Gun
Caulk is a compound that is used for filling joints, cracks and gaps in house construction. A caulk gun is needed to apply it. It is an inexpensive and effective tool for filling small cracks (less than ¼").

Tools of the Trade info boxes highlight tools and supplies that are essential to installers.

Weatherization may require the use of many different common tools, such as hammers, saws, screwdrivers, and the like. But some tools and supplies are particularly (and sometimes solely) useful to weatherization workers.

[2] The JTA is available for download at http://www1.eere.energy.gov/wip/pdfs/51671.pdf.

Weatherization Matters: Key Concepts

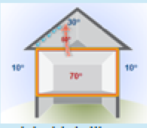
How does condensation occur?

Have you ever had a cold drink in the summer, and wondered where the water droplets on the outside of the glass came from? Do you know that this same phenomenon is an important concept in weatherization?

A cold bottle causes the surrounding air to reach its dewpoint, causing condensation.

Condensation refers to when water in the air (in gas form, called **water vapor**) condenses and turns into liquid water. This occurs when the air reaches its **dewpoint**.

The dewpoint is the temperature air must reach for its water vapor to condense into a liquid. So, if the dewpoint of the air inside your home is 30° F (middle left image), once the air reaches that temperature, water vapor will condense out of the air and form a liquid. This is what happens on the outside of a cold glass or beverage in a warm home. The air around the container becomes cold enough (cooled off by the liquid inside) to reach the dewpoint. When this happens, water condenses on the outside of the glass/container (see image to the left).



A poorly insulated attic can cause warm air from inside the home to reach unconditioned attic space. If it cools down enough (reaches the dewpoint), the moisture in the air will condense into liquid. (Image courtesy of US DOE)

The same thing can happen in a poorly weatherized home. If the attic is not well insulated, warm (moist) air from inside the home can leak into the attic. When this air hits the cold roof, it can reach its dewpoint and cause condensation (see image to the left).

Why is this bad? First of all, moisture is one of the key ingredients in mold formation. Mold can cause allergic reactions and other health problems. Also, moisture can be very damaging, especially to wood – it can cause it to buckle and/or rot (see image to the left). Many an expensive repair has resulted from too much moisture.

Buckling and moldy roof sheathing resulting from condensation. (Image courtesy of US EPA)

Condensation can occur in other parts of the home, especially inside walls and ceilings. This can also result in expensive and dangerous conditions. Much of it can be prevented through proper weatherization.

The **Weatherization Matters** info boxes highlight concepts and processes that are especially important in weatherization.

All of the material in this book is relevant to weatherization, but there are some things that are more important than others to understand if you are going to be a competent weatherization worker.

Lighting Technology

There are three main types of bulbs ("lamps") that are either in use or will be in use in homes:

Incandescent bulbs run electricity through a thin metal coil (the "filament"), which produces heat and light. Incandescent design has changed very little since it was invented in the late 1800s. It is very inefficient – around 90% of the electricity is lost as heat.

Compact fluorescent lamps (CFLs) do not have a filament. CFLs are filled with a gas (mostly neon or argon) that emits ultraviolet (UV) radiation when excited by electricity. UV is invisible, so a coating is put on the inside of the bulb that lights up when UV hits it. CFLs use about 25% of the energy of an incandescent that gives off the same light, and last about 10 times longer.

All images courtesy of US EPA

Light emitting diode bulbs (LEDs) have a series of tiny bulbs that contain a special material that lights up when electricity is run through it. They use about 20% - 25% as much as electricity as incandescent, but last up to 25 times longer. They are much more expensive than CFLs, but are getting cheaper as demand for them increases.

CFLs and LEDs will save the homeowner money! They are more expensive to buy, but since they last much longer and use less electricity, they save money in the long run. Don't be fooled by cheap lighting - think long-term!

Some information boxes are used to better explain concepts, materials and processes more thoroughly.

Many things in weatherization, including materials, scientific concepts, and processes are better explained through diagrams and images. For many of these, enhanced information boxes are provided.

Some concepts and processes are difficult to explain with words alone. To remedy this, a CD has been included (attached to the back cover of the book) that contains animations of some of these concepts.

Numbered icons like the one to the left have been inserted at points in the manuals where these animations can help enhance the material. When you encounter these icons, it is recommended you view the animation. The animations can also be viewed on their own as a standalone learning process.

ENERGY COORDINATING AGENCY

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Manual One

Introduction to Weatherization Retrofit & Weatherization Assistance Program

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Energy Coordinating Agency
Philadelphia, PA

Weatherization and Retrofit Course

MANUAL ONE

Weatherization and Retrofit
&
the Weatherization Assistance Program

Weatherization and Retrofit Course

Energy Coordinating Agency
Philadelphia, PA

MANUAL ONE

Weatherization and Retrofit & the Weatherization Assistance Program

TABLE OF CONTENTS

Appendix B: Manual One Quizzes

Energy Coordinating Agency

Manual One: Weatherization and Retrofit & the Weatherization Assistance Program

Overview

This manual is designed to provide an introduction to weatherization and the U.S. Weatherization Assistance Program, as well as explain the specific skills needed and tasks done by entry-level retrofit installer technicians. It is designed for individuals with little to no prior construction or weatherization experience. Students will learn the basic tools, materials and methods used in weatherization, including the use of blower door diagnostics; the benefits of and basic science behind weatherization retrofit; safe operation of tools and use of materials, including ladder safety and use of Personal Protective Equipment; and the retrofit installer technician's role(s) and responsibilities in weatherization in the context of working in a crew.

The manual will proceed as follows:

- Introduction to weatherization and retrofit and description of the Weatherization Assistance Program
- Discuss the weatherization process
- Practice proper use of Personal Protective Equipment
- Discuss the role(s) and duties of retrofit installer technician on a weatherization crew
- Practice safe operation of ladders
- Discuss weatherization priority lists, and what role considerations – including health and safety and cost – affect weatherization decisions
- Discuss typical weatherization measures
- Handle and discuss typical weatherization materials
- Observe and practice proper (safe) use of common hand and power tools
- Discuss baseload and seasonal load
- Discuss Savings-to-Investment Ratio and how it relates to weatherization
- Discuss, observe and operate a blower door setup
- Discuss and practice following a work order for a weatherization measure

- Seal a band joist using foam board with caulk and/or one-part spray foam
- Discuss codes related to weatherization
- Discuss the benefits of weatherization and the Weatherization Assistance Program
- Discuss weatherization standards and the Building Performance Institute

Learning Objectives

At the conclusion of this manual, the student will have the following competencies:

- Describe the weatherization process
- Describe the benefits of weatherization and the Weatherization Assistance Program
- Define Savings-to-Investment Ratio and describe how it relates to weatherization and the Weatherization Assistance Program
- Describe the basic responsibilities of working as a retrofit installer technician on a weatherization crew
- Demonstrate proper use of Personal Protective Equipment
- Demonstrate safe use of step and extension ladders
- Analyze a weatherization measure priority list and identify high- and low-priority measures
- Describe the prioritization of health and safety relative to weatherization
- Handle tools and materials according to manufacturer specifications
- Identify and explain the basic uses of insulation and air sealing materials
- Describe the basic physics behind air leakage
- Analyze a work scope and explain how it is used before and on a job site
- Set up and use a blower door with manometer
- Explain the basic functions of a blower door setup, and explain the basics of why and how it is used in weatherization
- Explain the difference between baseload and seasonal load
- Demonstrate the ability to attend weatherization training
- Demonstrate basic hand tool use
- Gather materials and supplies for a weatherization application
- Set up tools and materials
- Clean up and organize work area as work is in progress
- Pick up tools and materials, and clean up and close out a job site

Key Terms

- Air barrier
- Baseload
- Batt
- Blower door
- Blown insulation
- Building cavities
- Building science
- Caulk
- Carbon monoxide
- Compact fluorescent lamp (CFL)
- Cost effectiveness
- Cubic feet per minute (CFM)
- Energy audit
- Energy efficiency
- Exfiltration
- Foam board
- Health and safety
- House as a system
- Incandescent
- Infiltration
- Insulation
- Knee wall
- Light emitting diode (LED)
- Manometer
- Natural ventilation
- Pascal
- Poverty level
- Pressure zones
- Priority list
- Retrofit
- Savings to investment ratio (SIR)
- Seasonal load
- Spray foam
- Stack effect
- Thermal envelope
- Two-part foam
- U.S. Department of Energy
- Ventilation
- Weatherization
- Weatherization Assistance Program
- Work scope

Manual One: Weatherization and Retrofit & the Weatherization Assistance Program

Topic 1: Weatherization and the Weatherization Assistance Program

What is Weatherization?

Weatherization can be defined as "the process of reducing energy consumption and increasing comfort in buildings by improving **energy efficiency** of the building" (Krigger and Dorsi, 2009, p. 262). As you will see below, weatherization also improves the health and safety of homes. The weatherization of a home may require the use of dozens of measures, but it focuses on two things: air sealing and insulating, in that order. Air sealing is the process of making a home more airtight by sealing up small or big gaps, cracks and/or holes. This prevents air, moisture and some heat from leaking in and out of the home. Insulation helps keep warm and cool air from leaving and entering the home by preventing heat loss (not by controlling air movement).

Energy Efficiency: using less energy to achieve the same goal or function without changing behavior. Weatherization is a process that achieves energy efficiency - the building uses less energy, and is actually more comfortable, and a change in behavior is not needed.

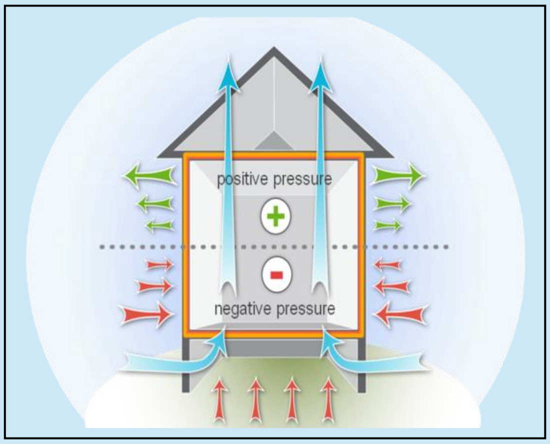
The better a building is air sealed and insulated, the better you are able to control the temperature, moisture and comfort of a home. Throughout this book, you will learn about many of the most common weatherization measures. Air sealing measures like using caulk, spray foam, foam board, and dense-packed insulation; using insulation measures such as fiberglass batt insulation, blown insulation, dense-packed insulation, and spray foam; as well as other measures like replacing windows and doors, furnaces, hot water heaters, electronic appliances, and more.

There is a lot of science behind modern weatherization. Weatherization experts now recognize that a home functions as a *system*. This means that conditions in one part of a home affect conditions in another part of the home (see sidebar below). This may be a difficult concept for people to understand because they are not used to thinking this way. – not many people realize that what occurs in the basement or attic affects conditions in the rest of the home. However, it is extremely important for anyone who is installing or recommending weatherization measures to keep in mind. This concept is called "**House as a System**," and is one of the most important concepts in weatherization.

House as a System: Components of a building are connected to each other and form a single system. For a home to be comfortable and energy efficient, all of the parts must work together.

Weatherization Matters: Key Concepts

House as a System – the Stack Effect



Warm air rising due to the stack effect causes cooler air to infiltrate in lower parts of the building (Image courtesy of US DOE)

Can you find the positive and negative pressure zones in this image? (Hint: look at the white tarp.) (Image courtesy of US DOE)

A very common example (especially during colder times of year) of the "House as a System" principle is the "stack effect." Warm air naturally rises toward the top of buildings. The excess air creates a *positive pressure zone* in the top part of the house, and a *negative pressure zone* is created in the lower part of the building as the air moves toward the top.

Heated air from the positive pressure area eventually finds a way out through small (or large) leaks in the building. All air that leaks out is replaced somewhere else in the house. In this case, it is will be replaced by cold air from outside the home in the negative pressure zone. (Pressure zones will be explained in more detail in manual 2.) In this way, warm air actually causes some cold air to leak in.

Bigger leaks in the top part of the building will cause warm air to leak *out* faster than if the leaks were small. Bigger leaks at the top cause cold air to leak *in* faster in the negative pressure zone. It is important to remember that air movement and building components in one part of the home affects air movement elsewhere.

The U.S. government began to officially support weatherization in the late 1970s and still does today. To make the most of its funding, it focuses on weatherization strategies that make the largest reductions in energy use at the lowest cost. By analyzing costs and benefits, they came up with a "priority list." For example, adding new windows and doors makes a home more comfortable and energy costs lower. However, windows and doors *cost* a lot of money and do not *save* very much money. They are not very "cost effective" (not much "bang for the buck"). Air sealing and insulating, on the other hand, usually save much more than they cost. This is why air sealing and insulating are a high priority in weatherization. This will be discussed in more detail below.

The overall result of using energy more efficiently at home is to be more comfortable at a lower cost. Most homes have small cracks and gaps throughout them, many of which are invisible to the naked eye. Common areas include at the base and top of walls, near windows, in recessed light fixtures, where basements meet the first floor, and in attic floors. When added together, these openings can be equal to leaving one or two windows open, leaking air day and night. If air is accidentally escaping and entering the home, heaters and air conditioners must work harder to keep the home a comfortable temperature. Since these appliances are doing more work, the house uses more electricity and other fuels such as oil and gas. Using more energy means lower higher bills and less money to spend on other needs. The weatherization industry knows it can do a lot of things to make these leaky houses more comfortable and efficient. Many times, it is a relatively easy fix, as long as the person doing the weatherization is well-trained. This book, and the exercises and labs that go along with it, are designed to help you become a competent and effective weatherization installer.

Retrofit Overview

Retrofit means the weatherization of existing homes (as opposed to new homes). The majority of single family housing in the United States is constructed of wood framing, brick and/or stone. Some common housing styles are cape, ranch, townhouse, split, bi-level, and colonial. Today, a great deal of new housing is manufactured (mobile homes). Unfortunately, much of the housing stock was built with methods and materials that created some of the problems that now need to be fixed with weatherization. This is a bad thing because it means that people are less comfortable and spending more money than they have to. This is a good thing for people like you who want to learn how to weatherize, because there is a lot of work that needs to be done!

Even better, weatherization skills are in demand for new home construction as well. Governments and building-related industries are starting to realize the benefit of efficient homes. Because of this, the skills that are needed to *retrofit* are also useful for *new* homes. It is becoming very common for construction workers and managers to be trained in weatherization. This means that the skills you learn in this weatherization course will be useful for other jobs and trades.

Weatherization Works

Weatherization retrofit services benefit people regardless of income, race, nationality, social standing, or any other personal characteristic. No matter what type of home you live in or who you are, everyone benefits from healthier, more comfortable and less expensive living conditions. Learning how to weatherize can help customers, the environment, and for anyone (like you) that is looking for a job in today's building industry.

The Weatherization Assistance Program

The Weatherization Assistance Program (WAP) is designed to do two things: First, to help low-income homeowners and landlords decrease energy consumption and costs. It does this mostly by installing weatherization measures, but also by educating consumers about reducing usage. Second, WAP services target home health and safety problems for low-income individuals. These are often found during the initial inspection of a client's residence. All of these efforts aim to improve comfort, use less energy, save money and benefit the environment. WAP can help non-low income residents as well. It provides energy-saving tips (including weatherization) that are available free to anyone. (Visit the WAP Technical Assistance Program at www.waptac.org for details.)

Two things are considered when figuring out whether or not a household qualifies for WAP: income and household size (location matters only because Hawaii and Alaska have different qualifications). The U.S. government determines income levels that qualify as "low income" (the "poverty level") every year. These may change from year to year because of inflation and other financial issues. In order to qualify for WAP, a household must make no more than twice (200% of), the poverty level. The chart below shows poverty levels for 2011.

Why Weatherization Retrofit?

- **Save money**: Weatherizing and retrofitting homes helps people use less energy. Using less energy means lower energy bills. Lower energy bills means money saved and to be used for other needs.
- **Create jobs**: Weatherization creates jobs in the United States that cannot be outsourced abroad. The green jobs industry is expanding rapidly and there is a growing need for a trained workforce.
- **Design and build healthier and more comfortable homes**: After homes are weatherized, not only are homes healthier and more comfortable but are also less drafty in winter. The air in the house will be cleaner which is especially important for people with asthma and allergies.
- **Protect the environment**: Fuels used to heat and cool homes (mostly oil, natural gas, propane and electricity (electricity is mostly provided by burning coal and natural gas)) are damaging to the environment. Digging for these resources is extremely destructive. Burning them causes pollution, including gases that most scientists believe are causing global climate change.
- **Promote equity**: Low income individuals, especially the elderly, pay a higher portion of their income than people with higher incomes. In other words, people who can least afford it are most affected by high energy bills.

WAP has existed since 1976, and is a project of the U.S. Department of Energy (DOE). Funding for the program is provided in an annual budget passed by the U.S. Congress. As of 2011, over 6.4 million homes have been weatherized by WAP funding. The DOE estimates that in 2010 alone, over $2.1 *billion* will be saved by low-income clients because of WAP services (an average of $437 per family in the first year). These savings tend to increase from year to year, because scientists, designers and builders continue to develop more ways for WAP to save people energy.

	Poverty Level			WAP Qualification (2 x poverty level)		
Persons in Family	48 States and D.C.	Alaska	Hawaii	48 States and D.C.	Alaska	Hawaii
1	$10,890	$13,600	$12,540	$21,780	$27,200	$25,080
2	14,710	18,380	16,930	29,420	36,760	33,860
3	18,530	23,160	21,320	37,060	46,320	42,640
4	22,350	27,940	25,710	44,700	55,880	51,420
5	26,170	32,720	30,100	52,340	65,440	60,200
6	29,990	37,500	34,490	59,980	75,000	68,980
7	33,810	42,280	38,880	67,620	84,560	77,760
8	37,630	47,060	43,270	75,260	94,120	86,540
Add for each additional person	$3,820	$4,780	$4,390	$7,640	$9,560	$8,780

Federal Poverty Level and WAP Qualification, 2011. (*Source: U.S. Department of Health and Human Services*[1])

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Building Science: an approach to weatherization that uses modern technology to study building construction, maintenance, safety and durability in an effort to increase energy efficiency.

There are many weatherization measures that are used by WAP. You will learn about a lot of these throughout the rest of this book. Examples of somewhat major retrofits include attic, basement and crawlspace air sealing, as well as insulation of all these areas and filling voids in walls. There are smaller modifications too, such as caulking around doors and windows, and wrapping hot water pipes and water heaters. Refrigerators, water heaters and furnaces are also evaluated and can be serviced or replaced. Smaller upgrades include adding more efficient light bulbs, changing dryer ducts, programmable thermostats and carbon monoxide alarms. All of these measures and more may be used in the process of weatherization. As mentioned above, which measures are used first depends on how much money they save vs. how much they cost ("cost-effectiveness"). More on this below.

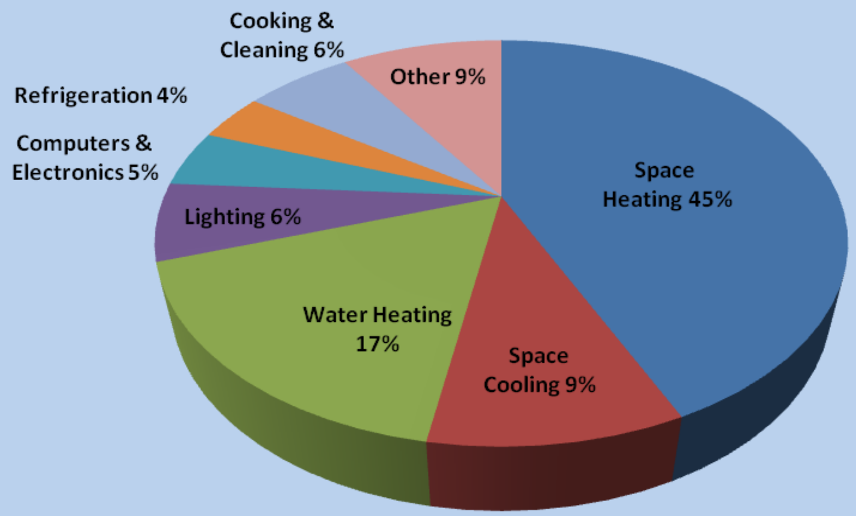
WAP bases all measures in a solid understanding of **building science**, and treats every house as a system of connected parts. Most existing houses have been designed and built by different professionals, builders and tradesmen that do not communicate enough with each other. Architects have been mostly concerned with what the building looks like, mechanical engineers

[1] Available at http://aspe.hhs.gov/poverty/11fedreg.shtml.

mostly with the mechanical systems (heating, etc.), and builders mostly with the methods and cost of construction. Notice that none of these fully address energy efficiency or health. This is because in order for a building to be efficient and healthy, all of the people involved in design need to work together, because all of the parts of a house must work together. Building science helps to solve this problem by treating the house as a system.

WAP also focuses on teaching homeowners to do things that will help maintain a safe, healthy home. Actions such as using fans instead of air conditioners, turning down the thermostat, cleaning furnace filters, and many other things are taught by energy auditors and crew chiefs. This is called "occupant education." By educating the occupant, energy savings can increase.

How do we use energy at home?



Residential Energy End Use in the U.S. in 2010
(Source: US DOE, Buildings Energy Data Book, 2010)

It is important to note that while WAP has been funded and focused on low-income residents, weatherization can help people of any income level. Cost-effective standards (see below) are the same no matter what the income level of the homeowner is.

The Need for Weatherization Assistance
Inefficient homes create problems for people that *don't* live in those homes as well. There are many programs like WAP that offer assistance to people who have trouble paying energy bills. The money to fund these services has to come from somewhere. Where does it come from? Almost always, it comes from small extra charges to other energy customers in the area. This is especially important in states like Pennsylvania, in which income-qualified households pay the same for energy every month regardless of how much they use. As energy costs increase, the burden on everyone else increases as well.

The impact of this has been in check for the past decade or so because of rate regulation, which forces energy companies to charge a certain price for energy. However, *deregulation* (removing rate regulation) is occurring in many states throughout the U.S. When this occurs, energy costs will probably change more rapidly, and high energy costs for people who cannot afford it will be more likely to increase costs for others. As you can see from the poverty chart above, the people receiving energy assistance really need the help. It is important to keep offering energy assistance to them, but as costs keep going up, this becomes harder and harder to do. One way to reduce this cost is by permanently lowering the energy costs through WAP.

Of course, an added benefit of WAP is that saving money on energy costs frees up money for other uses. Many people in poverty in the U.S. are experiencing increasing costs in other areas as well. Housing is becoming more and more expensive, health care costs are skyrocketing, and good-paying jobs are harder to come by (two-thirds of those in poverty are working 1.7 jobs, according to the 2000 Census). In addition, transportation options, healthy food options, and schools and other public services in high-poverty areas are losing funding. The Weatherization Assistance Program is one of the few governmental efforts to consistently affect improvements for the poor over the past 20 years.

WAP is also important because it provides energy and weatherization education to residents that receive services. By explaining the process and benefits of weatherization, it is easier for clients to maintain upgrades. WAP has also recently begun to focus more on educating clients how they can have healthier and cheaper homes *after* the WAP provider leaves. This can be done by changing behavior. Many people do not know how to save energy on their own. WAP hopes to change that, while at the same time lowering energy use without changing behavior. By doing this, WAP hopes that clients will have safer, more comfortable and more efficient homes for the long-term. As explained above, this is important for WAP clients, but also for other people and the environment.

Topic 2: The Weatherization Process

The DOE has over the years determined the best way to provide weatherization services. There are five major steps in the weatherization process:

Step 1: Determining Eligibility

As mentioned above, if a household has income 200% or less of the poverty level for their family size, they qualify for WAP. There are a number of different ways to enroll, depending on where a person lives. Many states and counties have energy assistance and WAP centers and hotlines, and many non-profits are able to help as well (see the box on the next page for ways to contact WAP providers). Once eligibility is verified, the WAP service will be scheduled.

It is important to know that priority may be given to certain households, such as those with elderly residents, high energy bills, children in the home, and so forth. If demand is high, wait times can be a few months or more. It is a free service, though, so it’s hard to justify complaining about waiting a little while. The agency will get to the client as soon as they can. In the meantime, the agency will attempt to gather as much information as they can. Energy bills are very helpful, because they give the agency and the weatherization crew an idea of how efficient the home is, and they will know how much energy is saved after they weatherize.

Step 2: Initial site visit and energy audit

After income is verified, a visit to the house will be scheduled. Most WAP agencies hire contractors to do this. During this visit, an energy auditor will thoroughly inspect the home. They will look for a number of things. One important aspect is a health and safety inspection. The auditor will look for things like lead paint, asbestos, mold, and major repairs that need to be done. If a house is unsafe to work or live in, the WAP provider is not allowed to do any work until the problem is taken care of. This cannot be stressed enough – if a home is unsafe, for the workers or for the resident, **absolutely no work can be done until it is safe**. Examples of this will be given below.

The auditor will also do an energy audit. During the energy audit, the efficiency of the home is investigated by a number of means. Obvious problems like recessed lights, cracks in walls and windows, missing insulation, and missing weather stripping will be noted by the auditor. They will also take note of possible problems like missing baseboard, lack of caulking, attic hatches, and so forth. Most auditors will also use a blower door setup to find out how leaky a house is. You can read more about the blower door in Topic 9 below.

How can a person get WAP services?

There are three main steps in enrolling in WAP:

1) Know that the program exists. This may seem obvious, but many people do not know about WAP. Spread the word! Even if you are not sure someone qualifies, it never hurts to find out.
2) Contact a WAP representative. Though WAP is federally funded, it is run by the states. A list of state contacts can be found at http://www1.eere.energy.gov/wip/project_map/. Local energy providers (electricity, gas and oil utilities) should know who to contact, as should the local housing authority and county and state government.
3) Go through the verification process. Income and household size must be verified to ensure that no one is cheating the system. It may seem intrusive when someone asks for personal information like social security number, pay check stubs, and so forth, but it is essential to make sure people are really in need of help.

Step 3: Work scope development

The auditor analyzes the information gathered in the site visit/energy audit. They may use computer programs and/or refer to the WAP priority list to figure out which weatherization measures should be done. As mentioned above (and below), after health and safety, cost-effectiveness is the most important thing that is considered. After a full analysis is done, the auditor will come up with a "work scope." A work scope is a report that tells the weatherization workers (installers and crew chiefs) what should be done to the house.

Step 4: Implementing the work scope

The weatherization crew takes the work scope to the job site (the home), and weatherizes. (Most of what you will learn in this book would be done in this step.) This is when the home is made more efficient, healthier and more comfortable. Measures mentioned throughout this book, such as air sealing, adding insulation, changing light bulbs and refrigerators, and weather stripping doors and windows are done during this step. Other things may be done as well, such as repairing or replacing furnaces, fixing hot water heaters, and minor electrical work may also be done. Things not in the work scope may be discovered during this step, including major and minor repairs. The crew chief should be consulted before work not in the original work scope is done.

Step 5: Final inspection

First, the crew inspects their work to make sure they did everything properly. This includes the quality of the work, making sure the entire work scope is taken care of, and cleaning up. If a blower door was used before work began, it will be used again to find out how well the air sealing was done. In rare cases, the house is sealed too tightly, making it the home unsafe and uncomfortable. If a house is sealed too tightly, not much air can get in and out. This can be a dangerous situation because of "indoor air pollution." Indoor air pollution is something that is found inside the home and is dangerous to breathe in. Examples include gas from ovens and furnaces, drying paint, and fumes from cleaners. If the house is too tight, extra ventilation needs to be added.

After the contractor's crew inspection is done, the WAP agency will also do an inspection. All agencies are responsible for the work that they contract out for. In other words, if the crew messes up, the agency may get in trouble, even though they did not do the work themselves. There are many examples of agencies getting in trouble and even being shut down because they did not properly inspect the homes.

Step 6: Follow-up and occupant education

As mentioned above, WAP has focused more on educating the occupant in recent years. Usually a crew chief or energy auditor will sit down with the client and discuss two things: the weatherization measures they did, and how the client can save more energy on their own. One of the main goals of WAP is to reduce energy use by as much as possible. Educating the client to save money on their own by changing behavior (turning off lights, turning down thermostat, using less hot water, etc.) can result in significant savings.

Topic 3: Weatherization Retrofit Installer Job Description

Now that the weatherization process has been described, we will zero in on what an installer does. Installers are the front line soldiers of weatherization, and do the bulk of the work in the weatherization process. As indicated above, a retrofit installer's overall task is to successfully fulfill the work sites' "work scope" (or work order). Detailed task include (but are not limited to) installing various types of insulation, applying air sealing measures, window & door repair, and constant attention to the health & safety of the work crew and the building's occupants.

Each installation job has its own work scope. It is the plan of action that the installer follows to improve the safety, efficiency, and comfort of the building. The work scope is prepared by the energy auditor prior to weatherization being done. The auditor usually isn't present on the work site – it is usually the crew chief's ultimate responsibility for implementing all of the work scope on the job site. For this reason, the retrofit installer reports directly to his crew chief with any issues encountered on the job site. In addition, the installers must confirm the tasks indicated in the work scope with the crew chief before they begin the weatherization work. Common issues include preexisting structural conditions, difficulties accessing work areas, accidental spills or damage, broken or lost tools, safety concerns, and approval for moving obstructions that may get in the way of weatherization work. Any personal belongings that are removed and/or moved MUST be returned to their original location prior to leaving the premises. If an Installer has deficient knowledge or needs further instruction while performing his task they should report to his crew chief before moving forward. Installers are obligated to attend and participate in safety meetings, as per company policy. Maintaining a safe work environment for workers is required by law. If you are not clear about what company safety policies are, consult a superior, such as a crew chief.

To be considered a competent retrofit installer the technician must possess two equally important characteristics: (1) knowledge of how to apply weatherization measures, including the knowledge of how the house system works, and (2) the physical ability to apply this knowledge on the work site. The more an installer knows about the science behind weatherization, the more effective worker they will be. Key knowledge-based components of weatherization are basic building science, basic mechanical systems, manufacturer's specifications, industry standards as they relate to work scope, basic math skills, and principles of thermal (heat) energy and air movement.

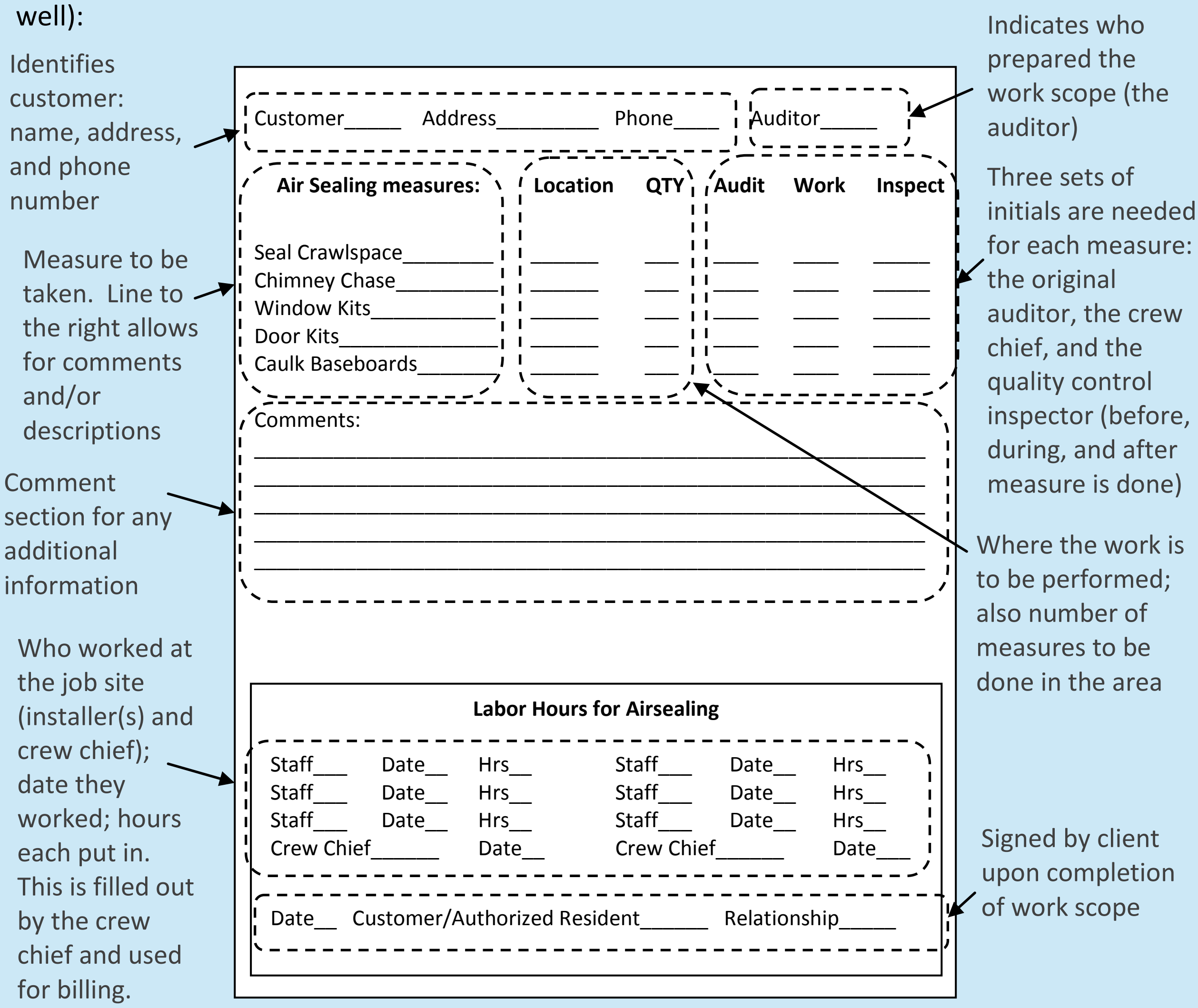
Common physical ability needs for installers include setting up the work area, proper use of safety equipment, locating various work areas and mechanical systems, moving and replacing client belongings, loading & unloading materials as needed, conducting final walk through, and requesting final inspection by the crew chief. All of these physical abilities are more effective with increased knowledge, practice is an essential aspect of being a competent worker.

Work safety is paramount on the work site and should be considered at all times by the retrofit installer and all members of the crew. An installer should possess the ability to identify evidence of leaks, mold, or other work site complications that may pose safety hazards. Tool safety begins with using the proper tool specific for the task at hand, continues with safe tool operation, and ends with proper storage of equipment. Personal protective equipment (PPE) should be worn at all times and fall protection should be worn per OSHA regulations.

Weatherization Matters: Key Concepts

Work Scope

The work scope, or work order, indicates the weatherization measures that the installers must implement. Except under extenuating circumstances (e.g. something in the house changed since the work order was written), the work order **must be followed**. Anything not followed must be clearly indicated on the order, and documentation of the issue must be made. Installers may or may not need to interpret or even see a work order – it depends on the crew you are working on and company you are working for. But since this is such an important document, you should understand the basic components (these may vary by company as well):



Topic 4: Priority List of Energy Savings Measures

When an energy auditor is finished analyzing the weatherization needs of a house, a list of all of the weatherization retrofits and/or repairs is made. The list describes what measures are to be done in what order. Higher items on a list are to be done before items lower on the list. This order is based on certain factors, such as the overall condition of the house, major and minor repairs that must be made, and of course weatherization needs. Each state in the U.S. comes up with a "priority list" of weatherization measures based on maximizing cost-effectiveness (most "bang for the buck"). WAP providers *must* follow this priority list when deciding on which repairs to do first. Not following the priority list can be grounds for suspension of funding.

No matter what state you are working in, health and safety of workers and occupants is considered above everything else. **Work cannot be done on a home if the building is unsafe before, during, or after the work is done**. Problems such as lead

Health and Safety	
Repair/replace furnace as per health & safety protocols in PA WX Standards and Field Guide	
Building Shell Retrofits	
Air seal as per blower door guided protocols Duct sealing as per blower door guided or duct diagnostic protocols	
Insulation Component	**Measure (not existing insulation, unless specified)**
Ducts (in unconditioned spaces)	Add R-11 wrap
Open attic ceilings	Add R-38
Kneewall (in finished attic)	Add R-11 – R-13 batt or fill cavity where dimensions allow
Roof rafter (in finished attic)	Add batts or fill cavity where dimensions allow up to 12 inches in depth
Closed wall cavities (adjacent to unconditioned spaces)	Fill to 3.5 lbs./ft^3 with loose fill insulation where dimensions allow
Open wall cavities (adjacent to unconditioned spaces)	Add R-15 batt and cover with air barrier
Closed floor cavities (adjacent to unconditioned spaces)	Fill to 3.5 lbs./ft^3 with loose fill insulation
Open floor cavities (uncond. basements and crawl spaces)	Add R-19 batt
Closed ceiling cavities (adjacent to unconditioned spaces)	Fill cavity where dimension allow up to 12" in depth
Sill box (rim joist) (conditioned basements)	Add R-11 polystyrene and seal (optional: two-part closed-cell foam to air seal and insulate to R-11)
Open attic ceilings	Existing: R-11; Add R-30
Open attic ceilings	Existing: R-19; Add R-19
Low-e Storm Windows	
Single pane, no storm	Install low-e storm window (glass emissivity (ε) ≤ 0.22)
Metal-framed dual pane clear	Install low-e storm window (ε ≤ 0.22)
Single pane window or deteriorated clear storm	Replace existing clear storm window with low-e storm window (ε ≤ 0.22)
Baseload Measures	
Lighting	Replace incandescent and halogen lamps with CFL lamps as per PA WX Standards and Field Guide
Domestic hot water measures	Add R-11 wrap, pipe insulation and other water heating measures where manufacturer specs allow and as per PA WX Standards and Field Guide
Refrigerator replacement	Replace as per PA WX Standards, using WAPTAC tool
Mechanical Retrofits	
Install automatic setback thermostat with double setback if possible Repair or replace as per efficiency protocols in PA WX Standards and Field Guides Use 90+, if cost effective to replace and structurally possible	
Windows and Doors	
Missing or deteriorated windows beyond repair	Replace windows with R-5 labeled windows (0.22 U or less for operable windows; 0.20 or less for fixed windows
Missing or deteriorated doors beyond repair	Replace with solid core or insulated doors

Example of WAP Priority List. Each state may have a different list of priorities. (*Source: PA Weatherization Field Guide*)

paint, asbestos, toxic air from furnaces and ovens, and major structural problems must be taken care of before work is done. Even if these issues are not a problem yet, but may become a problem in the future, they must be taken care of. When figuring out health and safety repairs, the cost-efficiency is not considered. In other words, it does not matter how much the repair costs – it must be done. However, WAP providers have a limited amount of money they can use for each house. If the health and safety costs are too high, the provider cannot weatherize the house until the issue is taken care of by the occupant.

After health and safety issues are resolved, the rest of the list is based on how much the measures will cost to apply and how much money they will save ("cost-effectiveness"). The table to the left shows the State of Pennsylvania's single family home WAP priority list (there is a different list for manufactured/mobile homes). As you can see, the list is broken down into categories, in order of priority. After health and safety, the order of priority is building shell retrofits (this is just a fancy way of saying "air sealing"), insulation, low-e storm windows, baseload measures, mechanical retrofits (thermostats and furnaces), then windows and doors last.

There are a couple of important things to point out here. Air sealing is nearly always going to be a top priority. Most air sealing methods are very cheap (e.g. caulk), and make a big difference in efficiency. Insulation is also going to be high on the list, because it is essential for keeping air temperature inside of a house under control. One other thing is important, because you will run into this issue in the field. Nearly everyone wants new windows and doors! They look great, and it is a change that a person can really see. Many measures, such as air sealing and insulation, cannot be seen. The problem is that windows and doors are expensive and do not save much energy. In other words, they are not very cost-effective.

Topic 5: Typical Weatherization Measures

Typical weatherization measures address the building shell, insulation requirements, mechanical systems and the **baseload** of a home. Weatherization measures can be generally categorized as one of two types, "old school" and modern. Note that the modern measures are based on building science and what has been learned in the recent years. Because they are based on scientific research, they are usually more of a priority than the old school measures.

"Old School" Weatherization Measures

Many weatherization programs that are poorly managed end up replacing windows and doors in nearly every home. This is not a cost-effective us of money. Old school weatherization would include some air sealing, but it was usually only done with caulk, and did not target specific areas. Attic insulation and weather stripping were also done as well. Common old school measures can be seen in the insert below.

"Old School" vs. Modern Weatherization Measures

Weatherization has come a long way. New measures are based on decades of scientific study, and are much more cost-effective than older measures

Common Old School Measures

- window replacement
- storm windows
- door replacement
- weather stripping
- some attic insulation
- caulk (by the case)

Common Modern Measures

- blower door measurements for measuring and locating air leaks
- attic insulation
- dense-pack sidewall insulation
- heating and cooling equipment repair and replacement
- duct sealing and duct modification
- electric base load measures
- compact fluorescent lamps (CFLs)
- refrigerator replacement
- water heater modification

Modern Weatherization Measures

Modern measures means looking at the whole house as a system: shell, mechanical and energy base load. Doors and windows are highly visible and get much publicity, but replacing them is not typically cost-effective over a short amount of time. The measures that save more energy at lower costs, such as air sealing and adding insulation, are largely invisible but have a much quicker payback than replacement of doors and windows.

Armed with this common knowledge, the WAP program has improved dramatically over the years. Modern measures that provide proven cost-effective savings, based on computerized energy audits, are as follows:

Building Shell and Insulation

These are all acceptable measures under the current WAP and are proven to be cost effective:

- Blower door-directed air sealing. This is generally the top priority (see Topic 9 below for blower door details). Note that this includes sealing of air ducts.
- Insulation – walls, floors, ceilings, attics, and foundations. As mentioned above, insulation is an essential part of an energy efficient home.

Incidental Measures

Incidental repairs are things that need to be done to make weatherization effective, but are not in and of themselves weatherization. These are permitted if they are necessary for weatherization measures to work. An example of this would be to fix a leaky roof. If water drips inside an unfinished attic, insulation can get wet. Wet insulation is less effective. Also, if wood stays wet, it can rot, which can cause major structural damage. Major damage like that makes a house less efficient. For these reasons, a leaky roof needs to be fixed before weatherization takes place. It is an incidental measure. Examples of other incidental repairs:

- Repair of minor roof and wall leaks before insulating attics or walls
- Repair of plumbing leaks
- Minor structural repairs such as reinforcing dropped ceilings, floor repairs, etc.
- Before insulating an attic:
    - Replace missing electrical junction box covers
    - Ensure all wiring splices are contained in junction boxes

Mechanical System Measures

Mechanical systems include plumbing, ventilation, heating and cooling. Typical mechanical measures are:

- Cleaning, tuning, repairing or replacing heating and cooling systems (gas or oil)
- Modifying duct and pipe distribution systems so heating and cooling systems operate efficiently
- Replacing appliances that have standing pilot lights with electronic ignition devices

The following measures are always advised when cost-effective and within the average price cap:

- Install programmable thermostats and HVAC control systems
- Repair or replace water heaters
- Install faucet aerators and low-flow showerheads
- Install insulation on water heater tanks and water heating pipes

Electric Measures

Lighting is a common everyday expense. Reducing the energy needed for lighting by converting incandescent lighting to fluorescent can save a lot of money. Lighting makes up 10% of a typical home's energy bill. If 10% of the annual home energy bill is $200, replacing incandescent bulbs with compact fluorescent lamps (CFLs) can save $150 per year on energy bills. This is because CFLs use 75% less energy than incandescent bulbs – they also last about 10 times as long on average, so the savings are usually better than 75%. Manual 2 will explain lighting issues in more detail.

Replacing refrigerators can also reduce electrical baseload. Refrigerators consume an average of about 4% of all energy in the home. Newer models can be much more efficient and replacement of the old appliance is often cost-effective. Many electrical appliances in the home are part of the baseload. These uses may not seem like "weatherization" issues, but any cost-effective way to save on energy bills is fair game in WAP. Reducing cost is one of the primary purposes of WAP.

Tools of the Trade: Air Sealing and Insulation

Air sealing is one of the most basic and important weatherization measures. The following is a list of some of the most common air sealing tools and supplies:

Caulk and caulk gun

Summary and Uses

Sealing gaps and cracks ¼" or less across. Easy to use, but requires some caution because of toxicity and fumes. Provides very minimal insulation. Good adhesive.

One-part (polyurethane) spray foam

Summary and Uses

Sealing gaps and cracks 1" or less – expands as it cures. Very good insulator, and good adhesive. Easy to use, but requires some caution because of fumes, toxicity, and flammability.

Two-part (polyurethane) spray foam

Summary and Uses

Sealing gaps and cracks 2" or less – expands significantly. Can be applied at a distance of up to 24" – it is under pressure and is a liquid . Very good insulator, and good adhesive. Relatively easy to use, but requires extreme caution because of fumes, toxicity, and flammability.

Fiberglass batt insulation

Summary and Uses

Insulating ceilings and walls between joists (dense pack is better wall insulation). Good insulator, but allows air to flow through freely (does not provide air seal). Very easy to apply, and relatively safe, though fiberglass fibers can be irritating to skin and lungs.

Cellulose (blown) insulation

Summary and Uses

Especially good for insulating *and* air ceiling walls, between joists. Moderately difficult to use, and requires heavy machinery (and two people) to apply. Extremely effective and non-toxic.

Rigid foam board

Summary and Uses

Good for insulating open wall and ceiling areas that are difficult or impossible to use blown or batt insulation. Outstanding insulation properties and good air seal. Easy to install and non-toxic (except when burned).

All photos ©

Topic 6: Deferral of Weatherization Measures

Sometimes, an analyst will determine that a house's weatherization needs to be deferred for various reasons. Usually, these are dangerous situations or conditions either with the property or the occupants. Examples of valid deferral situations are as follows:

Optional (the provider decides whether or not to do work):

- Unsanitary conditions
- Threatening animals
- Illegal activities are being conducted in the house.
- The homeowner or occupant is uncooperative, abusive, or threatening.
- Health concerns and conditions exist that prohibit the installation of weatherization materials.
- Remodeling of the home is going to take place, and has not been coordinated with weatherization.
- The client refuses service

Under the following conditions, weatherization **must be deferred**:

- The home has been weatherized after September 30th, 1994
- The building is vacant
- The building is scheduled to be demolished within the next year
- The building structure, its mechanical systems (including electrical and plumbing), or sewer/sanitary system are in an advanced state of disrepair.
- The house has been condemned, or electrical, heating, plumbing, or other equipment has been "red tagged" by local or state building officials or utilities
- Moisture problems are severe
- The existence of lead-based paint that has not been taken care of (not "remediated")

Topic 7: Baseload and Seasonal Load

"**Baseload**" energy, as explained previously, is energy that is used nearly the same amount year round. Things like lights and refrigerators, lights, TVs, and hot water heaters are used no matter what time of year it is. Some energy uses vary depending on what time of year it is. Air conditioners are only used during warmer times of year, and furnaces are only used when it is cold. These uses vary according to the season, and are called **seasonal loads**.

Base load usage varies slightly throughout the year (lighting and water heaters more in winter, refrigerators and dehumidifiers in summer), but not by much. To save on baseload costs, client education is key. Many baseload energy uses can be reduced by customer behavior, such as turning off lights and TVs when not in use, using less hot water by taking shorter showers and washing clothes with cold water, and getting rid of extra refrigerators.

Seasonal load, on the other hand, is primarily reduced through weatherization measures, and does not require clients to change behavior. After a home is weatherized, seasonal load usually goes down a lot. However, actions such keeping a house cooler in the winter and warmer in the summer can significantly reduce seasonal loads.

Both baseload and seasonal loads are addressed by WAP, though the seasonal load is the primary focus. This is because seasonal loads are usually more cost-effective to address.

Baseload: energy used in the home that does not vary much with seasonal changes in weather. Common base load appliances are washing machines, lights, hot water heaters, and household electronics.

Seasonal load: Energy use that varies depending on the time of year. Space heating and cooling are usually seasonal loads.

Topic 8: Cost-Effectiveness Requirements and Savings-to-Investment Ratio

Each weatherization measure (not including health and safety, as mentioned above) performed or installed in a home must be cost-effective. That cost-effectiveness is measured by the United States Department of Energy Standard of the **Savings to Investment Ratio (SIR)**. There are two parts to the SIR: the cost of the measure **over its lifetime** (the "investment"), and the savings that will result over its lifetime (the "savings"). Both of these numbers need to include incidental repairs.

Once the lifetime costs and savings are determined, the SIR is easy to calculate. As the name implies, the savings to investment ratio is simply the *ratio* of the *savings* to the *investment.* To calculate this, you simply have to divide the savings by the investment. An SIR of one or higher means that the measure is cost-efficient. See the box below for details of this very important concept.

Carbon Monoxide (CO): a gas that is tasteless, odorless, colorless and poisonous that is a by-product of incomplete combustion of fossil fuels. Excess CO in a home can cause suffocation and death.

The SIR is used in two ways by WAP. Each individual measure must have an SIR greater than one to receive funding. Also, all of the measures combined must have an SIR greater than or equal to one (not including incidental repairs).

As mentioned above, energy-related health and safety work (e.g. the existence lead-based paint, **carbon monoxide** and moisture), is not included in the SIR standards. There is no federally-required limit for health and safety funding for projects. However, each state designates a limit in their state plan. Historically, states have set their upper limit around 6% to

7% of a total project budget. With an increase in the amount of Lead Safe Weatherization (LSW) and furnace replacements, that number has gone up.

Weatherization Matters: Key Concepts

Savings to Investment Ratio (SIR)

Weatherizing a home makes it more energy efficient, which means energy costs are lower. However, just because energy costs are lower does not mean that a weatherization measure (e.g. adding insulation, installing a new furnace, etc.) is *cost efficient*. All weatherization measures cost money, at least for materials. So how do you know if it's worth the cost of installation? The Weatherization Assistance Program uses something called the **savings to investment ratio (SIR)**.

$$\text{Savings to Investment Ratio} = \frac{\text{Long-term savings from investment}}{\text{Total cost of investment}}$$

If the long-term costs and the savings are known, this is a very easy number to calculate. For example, if it would cost $1,000 to insulate and air seal a home, and the insulation would save $5,000 in heating and costs , the SIR would be:

$$\text{SIR} = \$5{,}000 \div \$1{,}000 = \frac{\$5{,}000}{\$1{,}000} = 5.0$$

In other words, the weatherization measures would save **5 times as much money as they cost**. An SIR of 2.0 means that you get twice as much savings as costs, 1.5 means one and a half times as many savings, and so on.

So why is this useful? The Weatherization Assistance Program uses this equation to figure out if a weatherization measure is worth doing or not. **All WAP measures must have an SIR of more than 1.0**. This makes perfect sense if you think about it. Okay, done thinking about it? Right, in other words, all weatherization measures must save more money than they cost. If this is the case, they are considered cost-efficient.

The SIR is also helpful in figuring out which measures are more important. In terms of cost, something with an SIR of 4.0 is more important than something with an SIR of 1.8 or 2.2. Other results of weatherization may be more important, such as safety and health concerns, but the SIR at least provides a good way to figure out cost-effectiveness.

You will get practice calculating SIR in manual 2.

Incidental repair costs must be included in the overall SIR of an entire package of WAP measures. On a home needing significant repairs, the entire package SIR might be less than one, even though each measure has an SIR greater than one.

Topic 9: Blower Door System

A blower door system is a diagnostic tool designed to measure the airtight-ness of buildings and to help locate air leakage sites. A basic blower-door system includes three components: a calibrated fan, a fabric door-panel system (metal frame and fabric) and a pressure gauge (a **manometer**) to measure airflow, building, and outside pressure. The fan is used to blow air into or out of the house which creates a pressure difference between the interior and the exterior of the house. This pressure difference forces exterior air through all the cracks and holes in the house's shell. See the box below for a more detailed description of this process.

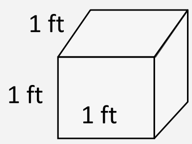
A Basic Blower Door Setup. The manometer (pressure gauge) is attached to the door (middle left in the image). (Image courtesy of US DOE)

There are at least two reasons to conduct a blower-door test on an existing house:

- to determine how leaky a house is
- to help locate holes, gaps and leaks

Pascal (Pa): standard metric unit of pressure. It indicates force per unit area, like pounds per square inch (psi) (1psi is equal to 6,895 Pa)

CFM: CFM stands for "cubic feet per minute." This is the standard unit for measuring movement of air in and out of a building. (European countries measure in cubic meters per minute.) A box whose sides are each 1 foot across would hold one cubic foot of air. A house that leaks 1 cubic foot per minute loses one cubic foot of air every minute.



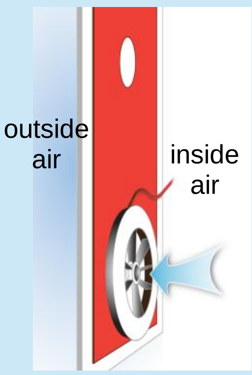
CFM_{50}: The rate of air leakage (in cubic feet per minute, or cfm) through the building shell of a home when there is a 50 Pascal pressure difference between inside and outside the building.

$CFM_{natural}$: The rate of leakage (in cfm) from a building under natural conditions. $CFM_{natural}$ can be thought of as the "breathing" rate of a building.

Weatherization Matters: Key Concepts

What is a blower door, and why is it important?

The blower door is an essential tool in modern energy auditing and weatherization. It is basically a large, powerful fan that is attached with an air tight seal to a fabric door (see the photo to the left). The fabric is attached to a frame that can fit snugly into nearly any size door. When a blower door is properly set up, almost zero air can get through the door except through the fan.

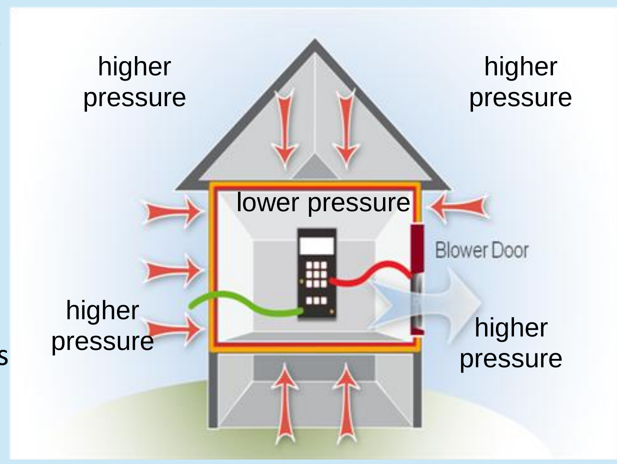


A blower door works by using the fan to blow air from inside the home to outside the home (it can be used to blow the other way around as well). The fan *depressurizes* the house - when air is pulled from the home, it causes a lower air pressure inside the home. **Air always moves from higher to lower pressure**. So, when the *inside* air pressure is lower than the *outside* pressure, air forces its way inside.

Air pressure will be discussed in more detail in manual 2, but the important thing to remember is that for **every amount (volume) of air that *leaves* a home, the same amount must *enter* (from somewhere outside) to replace it**.

Outside air will *always* find its way in if a home is depressurized, otherwise the house would implode. It usually comes in through small (but sometimes large) cracks in the building shell. This is called "leakage." Common leakage areas include where ceilings meet walls, porch roofs, electrical outlets, and many other areas.

Forcing air in through gaps and cracks makes them easier to find. This is the primary reason why a blower door test is so important. It is also an important tool in determining the overall leakiness of a house.



All images courtesy of US DOE

Once the house has been prepped for the test, the blower-door technician starts up the fan slowly to depressurize the house. The fan speed is then turned up until the pressure difference between the indoors and the outdoors reaches 50 Pascals (Pa). The pressure difference at which blower door tests are conventionally performed – 50 Pa – is arbitrary but useful. By establishing 50 pascals as a standard pressure difference, a wide variety of houses can be compared. Depressurization is important because it allows the auditor to figure out where air leaks are - even extremely small ones. Many leaks are invisible to the naked eye, but they still reduce energy efficiency and comfort. It may be impossible to find them under normal conditions unless they are large (e.g. when a room is “drafty”). When a blower is properly used, most of these cracks can be found because air can be felt coming through them. If it can’t be felt, a smoke wand (burning incense works too) can be put next to possible leak areas. If the smoke dances around chaotically, there is probably an air leak nearby.

Topic 10: Air Leaks and Sealing

It is true that air leaking into a home under natural conditions is usually difficult to detect. (Air leaking into a home is called **infiltration**.) But you should know by now that this does *not* mean that leaks are *not* important to find and close. Infiltration is a major source of inefficiency, but can also pose health hazards. Air leaks can be a source of problems like moisture and dust entering the house through cracks and gaps in foundations, crawlspaces, walls, and roofs. Since these areas inside and outside the home can also be contaminated with chemicals, radon, etc., air leaks can be the cause of unhealthy air.

Homes do need some Infiltration and **exfiltration** (air escaping the home) to maintain healthy indoor air. This “breathing” of homes helps to dilute indoor air pollutants like carbon monoxide, fumes from cleaning products and paint, and chemicals like formaldehyde from building materials. Also, if a home is too airtight, it will feel “stuffy” and will become humid (because water in the air has nowhere to go). Eventually, a home that is too tight will have moisture problems.

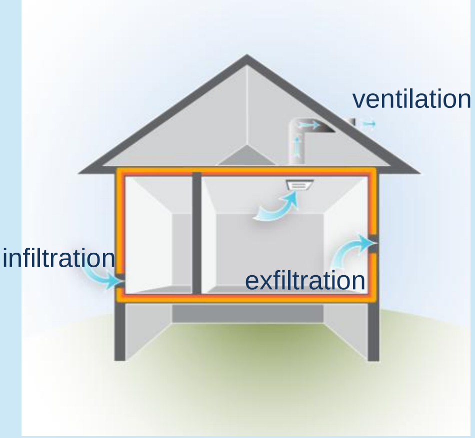
However, it is extremely rare that a house is too tight. If it is too tight, it is much better to add **ventilation**, which is the process of forcing air out of a building, usually with a fan. Bathroom and oven exhaust fans are both examples of ventilation (though these fans are there to force moisture out of a home). It is much better for the air movement in and out of a home to be controlled. Uncontrolled air will cause the home to be inefficient (e.g. warm air escaping in the winter and entering in the summer). It may also cause it to be unhealthy (e.g. toxins coming in the home, moisture problems). These are two of the main reasons why air sealing is so important.

Infiltration, Exfiltration and Ventilation

“**Infiltration**” is air leaking in to the building. “**Exfiltration**” is air leaking out of or exiting the building. “**Ventilation**” is planned and controlled air movement whether through open windows or mechanically drawn from the outside. Technically, ventilation is not leakage.

Controlling the movement of air in and out of the building envelope is extremely important part of having a safe, healthy and energy efficient home.

Infiltration usually results in unwanted heat, cold and/or moisture entering the home. It can also result in dirty or polluted air coming inside. Exfiltration can result in unwanted heat and/or cold loss. Ventilation is an important way to purposely remove unwanted air. Common examples of ventilation include removing damp bathroom air and hot/potentially dangerous air from a stove by using exhaust fans.



Most homes have infiltration, exfiltration and ventilation. (Image courtesy of US DOE)

In weatherization, infiltration and exfiltration are commonly controlled through air sealing. Ventilation may be addressed if the house does not “breathe” enough to be safe.

A high-quality exhaust fan ducted to the outdoors from each bathroom and from the kitchen is crucial for air quality in any house, whether the house is well sealed or not. Stopping air leaks in windows by installing storm windows is important, but it is not enough to close the costly gaps in your home.

Homeowners are much more aware of small openings and cracks around doors and windows, fireplaces or chimneys than they are of air escaping through the attic, crawlspaces or ducts and plumbing. These are in most cases the major source of air leakage and the cause of moisture and dusty air.

Knee wall: wall in a finished attic that reaches from the sloped ceiling to the floor, and is thus shorter than the other walls in the attic.

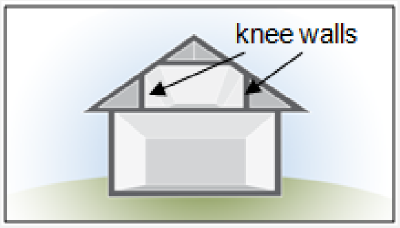


Image courtesy of US DOE

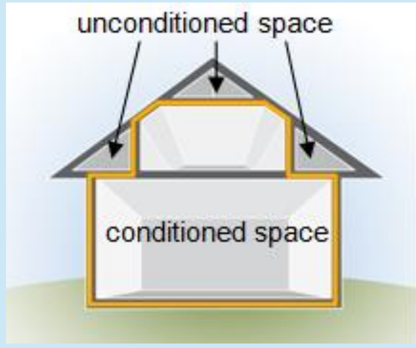
Homes – particularly wood-frame homes in cold and harsh climates – should have a continuous **air barrier** all over the exterior envelope. Barriers are typically a thin ‘skin” that is wrapped around the exterior of a house (four exterior walls as well as the roof/ceiling and basement/crawlspace to retard or prevent air and water vapor from penetrating the building’s exterior. An air barrier is the best way to prevent air from leaking into a house and to get higher energy savings, but it is difficult or nearly impossible to install on millions of existing American homes. Also problematic are air leaks from porch roofs, house additions (where these elements abut the exterior skin of a house) as well as attic **knee walls** and dormers.

Thermal Envelope

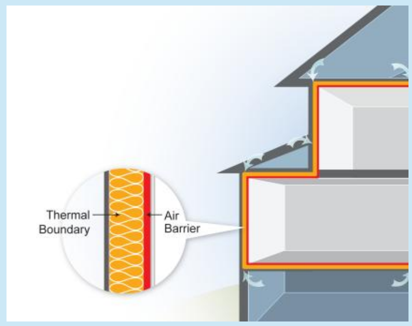
The thermal envelope separates the "conditioned" from "unconditioned" space. The conditioned space in a home is the area that is heated and cooled on purpose. The unconditioned space is more connected to the outside than inside, so its condition depends on the weather.

The location of the thermal envelope depends on the design and condition of the house. Interior walls (if properly sealed and insulated) are a part of the thermal envelope. Most modern homes use drywall for this. *Un*insulated attics, porches and basements are outside the thermal envelope, even if they are "inside" the home.

These unconditioned spaces are inside the *building envelope*, but outside the thermal envelope. Holes and cracks in the thermal envelope (small air leaks, recessed lights, electrical outlets, etc.) can seriously reduce a building's energy efficiency and comfort. Fixing these leaks is an important part of weatherization.



The thermal envelope separates conditioned from unconditioned space. It is indicated in yellow in the above diagram and in red below. (Images courtesy of US DOE)



Wind and other environmental pressures, such as the stack effect, cause air movement through building cavities and air leakage as well as water vapor.

Since air leakage paths are driven by the fact that warm air rises, the attic is the best place to prevent heated air to escape into the outdoors. Unwanted outdoor air may enter into a home through electrical outlets, recessed lighting fixtures, attic pull-down stairs, false ceilings (bathroom and kitchen soffits), the surrounds of bathtubs and shower stalls, floor cavities, and

Air Sealing Materials and Insulation
There are several types of air sealing materials, depending on the dimensions of gaps and openings and their type and location:

- Caulks and Foams:
  To seal the holes, cracks and penetrations in an attic or similar location, use the proper caulks and foams. General purpose foams and caulks may serve most situations, but in

some cases you will need non-flammable materials (chimneys, electrical devices, etc.), very elastic sealants to respond to extremes in temperatures, or expanding foams to fill large openings. Penetrations and holes associated with electrical outlets, recessed lighting fixtures, plumbing connections or chimneys demand specific sealing works and materials.

- Air Barriers:
  To restrict the air leakage in walls, the floor and the ceiling of the attic, use an air barrier to close any gaps to the interior and wall spaces. Depending on the type of construction, thermal insulation or spray foam can be used or seal with a foam and then insulating with a "blown" product.

- Insulation & Fiberglass, Cellulose and Mineral Wool:
  Common attic insulation materials such as fiberglass, cellulose, and mineral wool do not stop attic air from leaking. It is common to find attic insulation materials dirty, which is a clear sign that the insulation layer isn't stopping the air movement. These materials will not stop air leaks without combining them with good air sealing products and methods.

- Plywood, Drywall and other Sheathing:
  Drywall, plywood or other sheathing materials can be effective air barriers and can be used to seal large attic surfaces; however it will then be necessary to add thermal insulation.

- Rigid Sealing Materials:
  Plywood, drywall and rigid foam insulation can be used for surfaces and very large unsealed penetrations. These materials are the core of the continuous air barrier that every home should have (they are commonly known as "sheet goods"), but they can also be used to air-seal large holes, cracks and cavities.

Air Barrier: the parts of the building shell (or exterior wall) that resist air infiltration from the exterior to the interior of a house, or vice-versa.

Building Cavities: voids or empty spaces inside walls, floors and ceilings and between the interior and exterior wood sheathing of a house's envelope (shell).

Natural ventilation: using natural processes (no mechanical or electrical equipment) to remove air from inside a building. Opening windows is one way to achieve natural ventilation

Topic 11: Weatherization Codes

A weatherization installer needs to be familiar with certain codes and regulations. There are many regulatory organizations and codes that are available in assisting a weatherization project. Some are national codes like the International Building Code which are adopted and approved for use in states and local areas. There are also local codes like the zoning code that are adopted in many counties, cities, towns, and small jurisdictions. It is important to know that these exist and where to find out about them. Most local governments include a building and codes, license and inspection, or similar department that administers them. These codes provide rules and guidance to architects, builders, subcontractors, and workers so that houses are safe, structurally sound, and energy efficient.

For the weatherization installer some code issues affect their work directly. The following list reviews some of these areas.

The Jobsite

Local codes affect a weatherization job from the preparation and set-up phase, through the on-going maintenance of a safe, organized site, through to final clean-up and close-up inspections and approvals. The local code may restrict your company's hours or operation, the noise level of your work, sidewalk safety, parking, and trash disposal. Your company will need to be licensed, pull permits, coordinate inspections, and follow any other local rules. Some local areas have special historic or business districts which have their own special guidelines and restrictions. For example, historic districts have rules about the type of windows that can be installed. Local codes play an important part in weatherization work and installers should become familiar with their local building department and its codes.

Air-Sealing Work

The weatherization installer needs to know about fire code safety issues related to their air-sealing work. One is related to installing air sealing measures in attics or basement spaces where chimneys, flue-pipes, and other heat-producing appliances. There are required minimum "clearance distances" that must be maintained around the heat-producing item. That is, no combustible materials (a combustible material is one that can catch on fire) can be located in the clearance space. That is why installers use metal and non-combustible caulk to air-seal at chimneys.

A second issue is related to recessed lights ("can" lights) that are not "IC-rated." Most recessed lights get too hot to allow insulation to touch them. IC-rated lights *can* have insulation touching them, because they do not get very hot. The code requires that insulation must not be within 3" of non-IC-rated lights. That is why installers build air-tight drywall boxes around these fixtures.

A third issue is related to foam insulations which are combustible. Rigid foam boards and large areas of spray foam cannot be left exposed to the interior of the house. The foams must be either covered with an approved fire or ignition barrier, or an alternate approved barrier material must be used. That is why installers often use drywall to cover any holes in closet ceilings facing into the home.

Window and Doors
The installation of windows and doors involves the building code. Issues to be aware of include the required sizes and locations of doors or windows for egress requirements (egress requirements are related to exiting the building), and their energy-related U-value requirements. (U-value indicates how well a door or window insulates.)

Electrical Work
Several codes relate to electrical work such as the exhaust fans which weatherization crews may install. The building and local codes require bath ventilation of a certain capacity, installation, and venting; the fire code relates to safety with the fan and its installation; and the NEC (National Electrical Code) states how the unit should be safely wired. Electrical work is typically done by licensed electricians following the NEC. Installers should be aware that certain electrical issues require them to stop work and report to their crew leader. Examples are live knob and tube wiring which cannot be insulated over, open junction boxes which need to be covered and marked before insulating, non-IC recessed lights which must be kept 3" away from insulation, and deteriorated wiring.

Plumbing work
Several codes relate to plumbing work which is part of a weatherization crews' work scope. Like electrical work and other mechanical trades, plumbing work is typically done by licensed plumbers. The building code regulates the installation of water supplies, drain and vent lines. If new gas-burning equipment such as furnaces or water heaters is being installed the Fuel Gas Code and Gas Fitting Code both apply. These regulate the sizing and installation of the equipment, gas piping, and connections.

Roofing work
Weatherization work often involves roofing repairs to ensure a dry attic before installing insulation or roofing work such as installing roof vents. The building code regulates roofing work including roofing and sheathing materials. Roof ventilation is also regulated by the building code. Many local building codes require permits for any roofing work and have rules about sidewalk safety and debris removal.

A list of important codes and organizations that affect weatherization work follows[2]:

- **ASHRAE** – The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, which develops standards for refrigeration processes and the design and maintenance of indoor environments. Codes available for purchase at www.ashrae.org
- **Building Code**: (See ICC)
- **Fire Code**: The IFC, International Fire Code, is part of the ICC codes. It regulates fire prevention, fire protection, life safety, and storage of hazardous materials. (Also see NFPA)

[2] Source: *DOE Weatherization Assistance Program – Boston Support Office. Northeast Weatherization Field Guide. (no date). Copyright Saturn.*

- **Fuel Gas Code**: The IFGC, International Fuel Gas Code, is part of the ICC codes. It regulates the design and installation of gas-burning appliances including sizing, piping, installation, and chimneys.
- **Gas Fitting Code:** Many local jurisdictions and utilities have their own Gas Fitting Code which regulates the design and installation of gas piping and gas-burning equipment. These codes often are a combination of the International Fuel Gas Code; the Plumbing Code; National Fire Protection Association regulations, and local requirements.
- **IAPMO** – The International Association of Plumbing and Mechanical Officials works with government and industry to implement comprehensive plumbing and mechanical systems around the world. Codes are available for purchase at http://www.iapmo.org
- **ICC** – The International Code Council's codes (**I-Codes**) provide minimum safeguards for people at home, at school, and in the workplace. The I-Codes are a complete set of comprehensive, coordinated building safety and fire prevention codes. Codes are available for purchase at www.iccsafe.org
- **IECC** – International Energy Conservation Code (See ICC). "12 IECC" refers to the code published in 2012. For residential construction, this is the code included in the IRC as Chapter 11; Energy Efficiency.
- **IRC** – International Residential Code (See ICC). "09 IRC" refers to the code published in 2009. Chapter 11 in the IRC is where the information on Energy Efficiency in residential buildings is found.
- **Local Codes:** These are specific to the area where the work is being done (state, county, city, town, etc). These codes control many of the day-to-day operations of a weatherization company regarding permits, inspections, access, parking, site safety, clean-up, and trash disposal. In addition, there are special requirements such as historic district restrictions.
- **NEC** – National Electric Code (See NFPA)
- **NFPA** – The National Fire Protection Association develops, publishes, and disseminates more than 300 consensus codes and standards intended to minimize the possibility and effects of fire and other risks. Codes are available for purchase at www.nfpa.org
- **UMC** – Uniform Mechanical Code (See IAPMO) This code regulates the design, location, installation, and maintenance of HVAC/R equipment. (Heating, Ventilation, Air Conditioning, and Refrigeration)
- **UPC** – Uniform Plumbing Code (See IAPMO) This code regulates the design and installation of safe and sanitary plumbing systems. These systems include the domestic water supply and the DWV (Drain, Waste, and Vent) systems.

These are the codes the most often impact weatherization work. As an installer, it is not your responsibility to know all codes, but it is to your benefit to know as many as possible. Code responsibility falls to superiors and/or code experts within your organization.

The following chart summarizes many of the specific weatherization actions that are affected by code issues. Again, this is not a comprehensive list, but it will give you a good feel for many of the specific code issues involved in weatherization installation.

Issue Faced by Installers	Applicable Codes	What it Says
Insulating over knob and tube wiring	08 NEC 394.12	Do not envelop knob and tube wiring with thermal insulation
Ensuring proper clearance from high-temperature vents to combustibles	NFPA 54 - National Fuel Gas Code: Table 10.7.4.4 Clearance for Connectors.	Table designates required clearance for various vent types.
Replacing doors/windows: egress	06 & 09 IRC 301.1.2 & 3	Minimum 20 in. wide, 24 in. high, 5.7 sq. ft. clear opening[3] area UNLESS…(see below)
	06 & 09 IRC	5.0 sq. ft. clear opening OK with direct grade-level access.
	06 IRC 311.4.4 & 09 IRC 311.2	All egress doors require keyless operation from interior.
Adding required ventilation[4]	ASHRAE 62.1 or	15 CFM/person natural, 0.35 ACH
	ASHRAE 62.2	7.5 CFM/person plus 1 CFM/100 sq. ft. mechanical ventilation
Ensuring indoor air quality/ conducting Combustion Appliance Zone testing	Refer to (trainer-supplied) State Technical Manual and/or (trainer-supplied) State or regional Weatherization Field Guide	
Replacing water heater	09 IRC 2005.2 & 2406.2	Fuel-fired WH prohibited in storage closets.
	09 IRC 2005.2 & 2406.2 and 09 UPC 505.1	Fuel-fired WH prohibited in bedroom, bathroom, or their closets UNLESS WH is a direct-vent type OR separated by a weather-stripped, self-closing door with all combustion air coming from outside.
	09 IRC 2005.1 and 09 UPC 508.27	Outdoor enclosure required unless WH listed for outdoors.

[3] Note: 24 in. x 20 in. = 3.34 sq. ft., meaning one or the other dimension must be greater than the code minimum. Yes, both dimensions can exceed the minimum.

Topic 12: Does WAP Help?

There is no doubt that making a home more energy efficient through weatherization will save money for the occupant. Proper air sealing, insulating, and baseload measures will make a home more inexpensive to operate. But as mentioned above, it is important when using public money that the savings outweigh the costs, i.e. the measures should have a positive savings to investment ratio. Oak Ridge National Laboratory, one of the top energy research organizations in the country, investigated this in 2010. The results were encouraging. They found that the energy improvements alone had an estimated savings to investment ratio of 1.8. The overall benefit to society, which includes things like savings on environmental and health costs, was estimated to be 2.53. Both of these ratios use cost savings projected 20 years into the future.

They calculated that the average home weatherized by WAP in fiscal year 2010 (October 2009 – September 2010) saved $436.65 in heating and cooling costs for the year. They also found that an additional $104 to $174 would be saved due to electric baseload cost reduction. These numbers are scientifically calculated, but use some estimation and assumptions. It is impossible to measure the savings in each and every one of the estimate 100,000 homes that are weatherized through WAP each year. But it is clear that large amounts of savings result from WAP services. This is especially important for low-income households, because they spend a higher percentage of their income on energy than other households. On average, low-income households spend about 10% of their total income on energy costs (about $1800). Non-low-income households only spend about 3.3% ($2,231) on energy. Notice that low-income folks spend less on average than higher-income people. The reason that the percentage is so much higher is because the average income of low-income households is about $18,625, with non-low-income households making an average of $71,144.

The following are some additional statistics from the Office of Energy Efficiency and Renewable Energy (EERE) in the U.S. Department of Energy:

- Low income households served by WAP saved a total of $2.1 billion in 2010.
- The average low-income household reduces their energy costs by 35% after weatherization.
- WAP has served more than 6.9 million homes since 1976.
- WAP provides thousands of direct and indirect jobs nationwide.
- WAP saves the equivalent of 24.1 million barrels of oil each year (EERE, 2011[5]).

The Weatherization Assistance Program has consistently shown positive overall benefits. These benefits can be realized by anyone that wants to weatherize their home. As long as it is high-

[5] All of the information in this topic was provided by the U.S. Department of Energy's Energy Efficiency and Renewable Energy Program: *Weatherization Assistance Program: Saving Money by Saving Energy*. Available at http://www1.eere.energy.gov/office_eere/pdfs/51242.pdf.

quality work and the focus is on measures with a high SIR, all weatherization is beneficial, not just through WAP.

Weatherization and Retrofit
Energy Coordinating Agency

APPENDIX A

Manual One Lab Exercises

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Green Jobs Training Center

Lab 1: Personal Protective Equipment

Weatherization installation always requires the use of safety measures and equipment. At minimum, it usually requires the use of some "Personal Protective Equipment" (PPE). Personal protective equipment provides protection to the installer. It is essential that all weatherization installers know how to *properly* wear PPE.

All materials that installers work with have a MSDS: Material Safety Data Sheet. These should be available on the job. They are often stored in a folder kept in the work vehicle. The MSDS has important information about the safety issues relevant to the tool or material being used. When starting to work with a material, pay attention to MSDS Item #8: Exposure Control/ Personal Protection. Here you will find out about the dangers of the material and how to protect yourself when working with it.

After this lab is completed, you will know the basic components of PPE, how to properly wear PPE and what each piece of PPE is generally used for.

Tools	**Consumables**	**Safety Equipment**
none	Duct tape	Eye protection
	MSDS sheet	Breathing equipment
		Gloves
		Hard hat
		Coverall; Hood; Booties
		Knee Pads
		Hearing Protection

Approximate time needed to complete this lab: 0.5 hours

Procedure

CAUTION:
PPE needs vary according to the action being undertaken. All labs in this manual indicate what PPE items are to be used for the given lab. It cannot be stressed enough how important it is to wear the necessary PPE, and to wear it correctly. If PPE is not properly used, you will not be able to continue with the lab until it is being used properly.

PPE Components and Descriptions

1. Respirator
    a. Can be half-face with dual cartridges that are HEPA-rated for dust, and organic filters for fumes (shown in diagram)
        i. Masks are adjustable – use straps on side to tighten to fit snugly
    b. Can also use a disposable dust mask rated M-95 or M-100
2. Safety glasses or goggles
    a. Rated to AMSI Standard Z87.1 o keep dust particles out, prevent sharp objects from scraping or puncturing the eyes, and prevent damage from chemical splashes
3. Hard hat
    a. Protects the head from falling objects and banging against hard surfaces
4. Steel toe boots
    a. Prevents injury from falling and/or sharp objects
5. Gloves
    a. Protects hands from all types of harm – burns, bruises, cuts, abrasions, punctures, fractures, and chemical exposure
6. Tyvek suit or coveralls
    a. Keeps dirt and any chemicals from coming into contact with the body. Suits come in various sizes, and it is important that the suit fit properly

Proper wearing of PPE

1. The instructor will explain the different pieces of PPE used by weatherization installers
2. The instructor will demonstrate how to properly wear PPE
3. You will retrieve your PPE and demonstrate to the instructor how to properly wear it

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Lab 2: Ladder Safety: Step Ladder & Extension Ladder

Ladders can be extremely helpful to completing necessary work but it is important to know when and which conditions are safe for use. Stepladders and extension ladders are the two most common ladder types and will be explained in detail below.

When this lab is complete, you will know how to safely set up and use a step ladder and extension ladder, and understand the importance of ladder safety.

Tools	Consumables	Safety Equipment
6' Step Ladder	None	Hard Hat
20' Extension Ladder		Eye Protection
		Work Gloves

Approximate time needed to complete this lab: 1 hour, broken out into two half hour sessions

Procedure

CAUTION:

- Never jump, slide down from, or climb more than on rung at a time
- Read all safety information
- Never place ladders in front of doors that open toward the ladder. Block, lock, or guard all doorways
- One person per time on ladder
- Set ladder up on firm level ground, paying special attention to slippery conditions at the base or top support points
- Adjust length of ladder so no climber need to stand on the top rung
- Compare duty rating with total weight of climber and materials, Duty Rating should be higher and never exceeded
- Never use ladders with loose or missing parts
- Always inspect ladder to ensure good working conditions
- High winds and storms will prevent all ladder use
- Never step on a ladder if feeling tired or dizzy, or chance of balance loss
- Always wear slip-resistant shoes when climbing ladders
- Fall protection MUST be used (per OSHA) if going over 6' in height

Set up and use a 6' step ladder

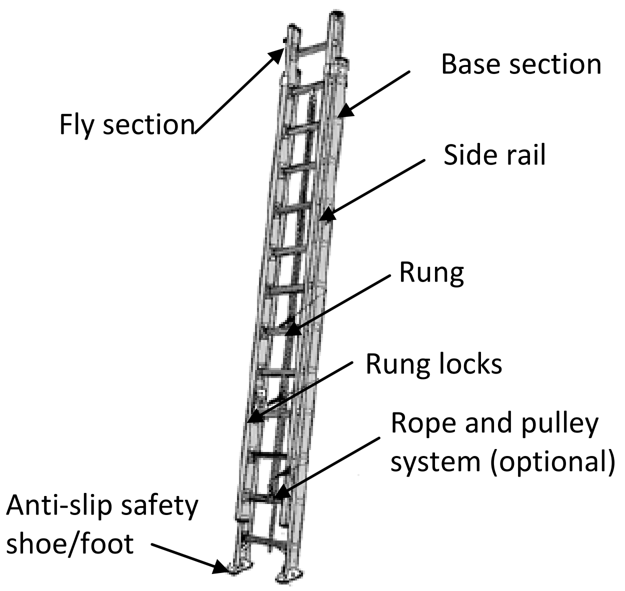
1. Pick proper setup location
    a. Level ground support on all four sides – no exceptions
    b. Prevent over-reaching and ladder tipping by setting ladder up close to the work
    c. Never place step ladder on snow, ice, boxes, barrels, or unstable bases
2. Proper ladder setup
    a. Base must be spread fully open and locked in place with spreaders
3. Proper ladder use
    a. Keep body near middle of steps to keep ladder balanced
    b. Do not attempt to carry items in hands when ascending or descending
    c. Descend ladder before relocating it, never dismount from the side or step from one ladder to another
    d. Rear braces are not meant to be climbed or stood on, unless it is a special two person stepladder with steps on front and rear

Set up and use 20' extension ladder

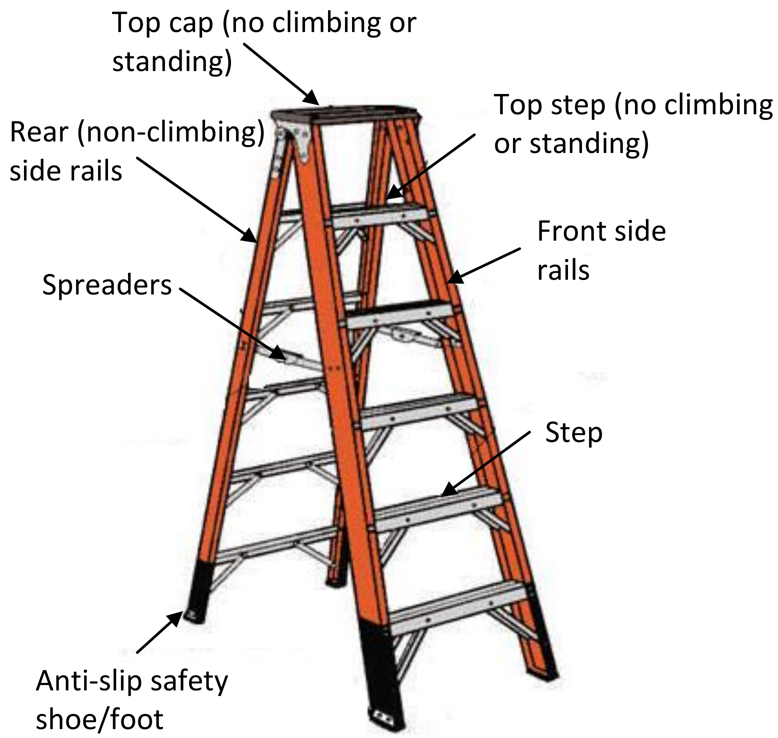
1. Prepare for setup
    a. Determine how high the roof is
    b. Must have rope with a pulley system, with rope minimum breaking strength of 650 pounds
2. Set up the ladder
    a. Ladder must extend an additional 1 to 3 feet beyond climbers' access point
    b. The ladder should be 1 foot away from the wall for every 4 feet it rises (this results in a 75 degree angle
    c. Fly sections and rung locks work together to adjust and extend ladder
        i. Fly sections are permanently attached and held at the base section of the extension ladder
    d. Ladder should never be extended or adjusted when someone is standing on the ladder
    e. Rope should always be tracked correctly in pulley system
    f. If you are going to climb onto the roof, you must use a harness
3. Proper ladder use
    a. ALWAYS face the ladder when going up and down
    b. Use at least one hand to grab the ladder when going up and down
    c. Do not carry anything that may cause you to lose your balance

Special note on fall protection:

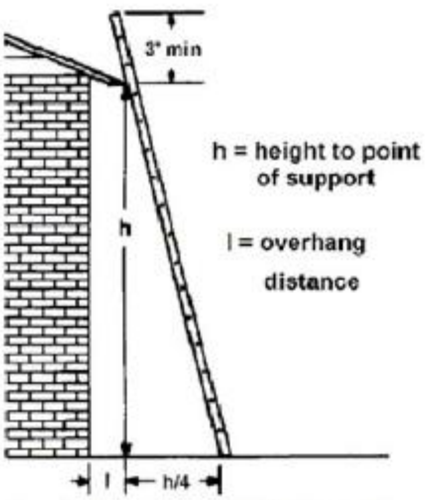
1. OSHA requires fall protection for any work being done 6' or higher
    a. The Personal Fall Arrest System (PFAS) consists of:
        a. Harness – fits snugly on the body
        ii. Can go around legs and waist or just waist
        iii. Lifeline – rope that is anchored securely
        iv. Lanyard – connects harness to lifeline
            1. Lanyard must be capable of supporting 5,000 pounds



Extension Ladder Parts. (Image courtesy of US Office of Compliance, *Fast Facts: Extension Ladders*, October 2010)



Stepladder Parts. (Image courtesy of US Office of Compliance, *Fast Facts: Stepladders*, September 2010)



Proper Setup of an Extension Ladder.   Note the 4:1 (rise:run) angle, and the extension of 3 feet above the surface. (Image courtesy of US Office of Compliance, *Fast Facts: Extension Ladders*, October 2010)

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Lab 3: Weatherization Materials

There are many specialized materials that you will use as a weatherization installer. The quality of weatherization is only as good as the materials used and the skill with which they are applied. You will use many of these on a daily basis, and will become very familiar with what they are used for and how they work as you continue to weatherize homes. **It is important to know that many of these materials have certain health and safety hazards and they must be handled and installed properly**. They also must be compatible with other products and materials they will be used with: for example, certain caulks can only be used with certain products. There are also material tolerances that must be followed such as the sizes of gaps that can filled with caulk or spray foams, or the application temperature ranges. Read and refer to the **Manufacturer's Specifications**. Keep this in mind when using them.

All materials that weatherization workers use have an **MSDS: Material Safety Data Sheet**. These should be available on the job. They are often stored in a folder kept in the work vehicle. The MSDS has important information about the safety issues involved. When starting to work with a material, pay attention to MSDS Item #8: Exposure Control/ Personal Protection. Here you will find out about the dangers of the material and how to protect yourself when working with it.

The purpose of this lab is to introduce you to the primary materials used in weatherization, including how to apply them, what they are used for, and safety considerations to make when you are using them. These materials are available at most hardware stores, unless otherwise noted.

Consumables (Based on Availability)

Drywall (GWB):Gypsum wall board
Plywood
Oriented strand board
Medium density fiberboard (MDF)
Metal air barrier:
Sheet metal; al. flashing
Cement board
Weather stripping
Plastic air barrier
One-part spray foam
Two-part spray foam
Batt insulation:
faced and unfaced
Various caulks
Cotton, rock/mineral wool, polyethylene insulation
Blown cellulose insulation
Blown fiberglass insulation
Bagged insulation
RIGID FOAM BOARDS:
Polystyrene (XPS):
(extruded polystyrene faced and unfaced)
Polystyrene (EPS):
(expanded polystyrene faced and unfaced)
Polyisocyanurate:
(faced and unfaced)

Safety Equipment

Eye protection	Gloves	**MSDS Sheets**
Breathing Protection	Hard hat	**Manufacturer's Specification Sheets**

Approximate time needed to complete this lab: 45 minutes

Air Sealing Materials

Caulks

Caulks are used frequently in weatherization. They are relatively inexpensive and easy to use. They are excellent air sealers and good adhesives, but do not insulate.

Acrylic Caulk

Used for interior applications such as air-sealing of cracks and gaps; sealing around trim like window & door casings, and baseboards.

Safety concerns: Caulks contain chemicals that are harmful if breathed in and/or contact skin. Breathing and skin exposure risk (see above).

Caulk and a Caulk Gun. (Photo © eca)

Silicone Caulk

Silicone caulk is very elastic, and is good to use in areas that will go through relatively extreme temperature changes. It is great for areas (inside or outside) that will be exposed to cold winters and hot summers.

Safety concerns: Breathing and skin exposure risk (see above).

Heat Resistant Caulks

Certain caulks are designed for use in high-heat areas, such as near or around chimneys, hot water pipes, and near electrical devices. Examples are non-combustible caulk which has passed the ASTM-136 test, and high-temp RTV silicone for limited use with gas heating appliances.

Safety concerns: Breathing and skin exposure risk (see above).

Other Materials

Insulation batting in a bag for "stuff and seal"

"Poly-bags" are made up on the job by stuffing fiberglass batt in polyethylene plastic bags. They are then stuffed a wall or floor cavities to serve as an effective block such as when dense-packing balloon framed walls, or when preparing to insulate an attic kneewall area to stop wind-washing from blowing under attic floors. They should be spray foamed to achieve a more effective air seal and to lock them in place.

"Stuff and Seal" in a Joist Bay. (Photo ©)

Safety concerns: Breathing and skin exposure risk with fiberglass. Keep polyethylene bags away from heat-generating areas such as chimney and flue pipes, as well as young children.

Weather-stripping

Weather-stripping is attached around the edges of doors and windows to prevent air from leaking through. It is relatively easy to attach, inexpensive and effective. Effective seals have a vinyl/rubber gasket with a nailing/stapling flange for attaching them.

Safety concerns: None

Plastic air barriers

Polyethylene sheeting that comes in rolls or in temporary weatherization window and door kits. It is used as a vapor barrier over dirt floors in crawl spaces, and as a vapor retarder behind drywall.

Safety concerns: Keep polyethylene bags away from heat-generating areas such as chimney and flue pipes, as well as young children.

Metal sheet (non-combustible) air barrier

Sheet metal or aluminum flashing material comes in rolls of various widths (such as 10"; 14"; 18", and 24") which are cut with metal snips to fit around chimneys and flue pipes.

Safety concerns: Skin protection working with sharp edges (cut metal has very sharp edges). Working around heat-generating areas.

Air Barriers. Polyethylene plastic (above) and sheet metal (below). (Photo ©

Air Sealing/Insulation Combination Materials

Spray foams are very useful in weatherization because they are good air sealers, insulators and adhesives. Most are easy to use and relatively inexpensive.

Expanding spray foams

One-part spray foam

One-part, low-pressure spray foam is easy to apply. It comes in a single spray can with a long, thin tube at the end - all you have to do is shake it up, put the nozzle in the correct spot, and pull the trigger. The key to foam is that it expands after being applied to fill cracks and holes very tightly.

There are a number of different kinds of one-part spray foams available, including non-expanding for doors & windows, triple-expanding for big gaps, and fireblock for sealing penetrations between floors such as in the bottom or top wall plates.

One-Part Foam. (Photo ©)

Safety concerns: Breathing and skin exposure risk. Keep away from heat-generating areas; foam typically is covered with another approved barrier if used facing the interior, or it is not used if it will be left exposed to the interior.

Two-part spray foam

Two-part spray foams offer the weatherization worker an effective air sealing and insulation material in convenient kits of different sizes and densities. These produce higher density insulation and are cost effective. They are sized by the amount of board feet of foam in the kit such as 15 BF; 200 BF; and 600 BF. (1 board foot = 12” x 12” x 1” thick). The kits contain 2 canisters, a double-feed hose, and applicator gun. The 2 components are kept separate until they are mixed in the disposable applicator tips. The foam then quickly sets up, expands, and hardens.

Safety concerns: Breathing and skin exposure risk

CAUTION:

1. When spraying foam, especially in a confined or closed area, follow all manufacturer’s instructions and MSDS guidelines including proper PPE and adequate ventilation.
2. Check with your Code Officials to make sure you know all local requirements. When foam products are used in interior construction or in any confined area, codes usually require them to be covered with a thermal barrier material to provide a fire rating.
3. In some situations, codes call for an alternate covering called an ignition barrier to cover the foam. Check with your local Code Officials.
4. If foam will be exposed to sun or water for long periods of time, it is recommended that a protective coating be applied over the foam to prevent the foam from deteriorating.

Low-density low-pressure foam
This foam is specially designed to be used around doors and windows to prevent frames from buckling. It expands very little and remains somewhat flexible. This is very important as other expanding spray foams cause window and door problems by pushing in on the frames.

Safety concerns: Breathing and skin exposure risk

High-pressure commercial spray foam "manufactured-in-place" two-part foam
Spray polyurethane two-part foam is a high tech product that uses heat and pressure to pump more dense materials. It produces foam with a higher density and a higher R-value. This product costs more than the other types of foam and can only be done by trained technicians using special equipment. This involves a truck with a reactor/proportioner; large drums of the Part A (iso) and Part B (resin); long heated hoses with a spray gun. The high-density product has been used in commercial applications for many years. It provides a strong well-insulated roofing if covered with a protective membrane.

High-Pressure Two-Part Foam. (Photo © eca)

Safety concerns: Breathing and skin exposure risk
1. When spraying foam follow all manufacturer's instructions and MSDS guidelines including proper PPE and adequate ventilation.
2. If foam will be exposed to sun or water for long periods of time, it is recommended that a protective coating be applied over the foam to prevent the foam from deteriorating.

Foam Boards

Foam boards come in many shapes, sizes and colors, and are very useful in weatherization. Foam boards are excellent air barriers, good vapor retarders, and generally have very high R-values (they are very good insulations). They are also easy to customize into nearly any shape, because they are easy to cut.

Rigid insulation board
Rigid ("rigid" means that they are relatively solid, unlike batt insulation) foam boards can be either faced or unfaced. Facing is usually applied to protect the foam, to provide a moisture barrier (some foam board can absorb moisture), or as a reflective surface (foil) to reflect radiated heat.

Rigid Insulation Board (one of many kinds). (Photo © eca)

Rigid foam is often used on the exterior of walls under siding, and on foundation walls. It is also placed under some roofing applications where the thermal envelope is located at the roof. For weatherization work it is often placed in rim joist pockets, used in attic air sealing Applications, and formed into insulating covers for pull-down stairways.

The three main types of rigid foam boards are expanded polystyrene (EPS), known as "beadboard" with R-4/inch; extruded polystyrene (XPS), often seen in blueboard or pink colors with R-5/inch; and polyisocyanurate, known as polyiso or iso-board with R-7/inch. Each of these can be faced or unfaced.

Safety issues: Breathing and skin exposure risk. Keep away from heat-generating areas; foam typically is covered with another approved barrier if used facing the interior, or it is not used if it will be left exposed to the interior.

Insulation

<u>Batts and blankets</u>

Batt insulation comes in large rolls or bundles of pre-cut batts. For weatherization retrofit work, they are primarily used in attics and above ceilings – the insulation can be rolled out in-between joists. They are sometimes used in walls and crawlspaces as well, especially in new wall construction. Batts can be faced and unfaced. Faced batts have paper or foil attached to one side, which acts as a vapor retarder and provides a stapling flange for attaching batts to studs or joists. Unfaced batts have no paper attached.

Installing Unfaced Batts. (Image courtesy of US EPA; original by North American Insulation Manufacturers Association)

Batt insulation is commonly made of fiberglass, but it can be made of cotton, rock mineral wool, or sheep's wool, or polyester fiber as well.

Safety issues: Breathing and skin exposure risk; eye protection

<u>Blown insulation</u>

Blown insulation comes in bags filled tightly with material. It is "loose," though when purchased it is densely packed together. This type of insulation must be put into a machine that shreds up the tightly packed fibers. The machine is attached to a hose that blows out, which allows you to blow the insulation into desired locations. Blown insulation is made of one of two materials: cellulose, which is actually paper fibers (with fire retardant added);

Blown insulation comes packed in bags. (Photo ©)

and fiberglass, which is the same material as in fiberglass batts. Loose fiberglass does not contain the chemical binders used to hold fiberglass batts together.

Blown insulation can be applied in "loose fill," which means it is blown into a loose pile on a horizontal surface. This is common in unfinished attics. Loose fill has a relatively high R-value, but does not prevent air from flowing through it. Or, it can be "dense-packed," which means it is pumped into and used to fill a cavity (wall, ceiling, etc.) Dense-pack insulation is very useful because it offers very high R-value *and* it stops air movement.

Safety issues: Breathing and skin exposure risk; eye protection; hearing protection. For cellulose, maintain clearance distances from heat-producing areas such as chimneys and flue pipes.

Other Materials

There are a number of other materials that are used in weatherization. Many of these, including the ones below, are also used in general construction. It is important for installers to know the weatherizing properties of common construction materials.

Plywood

Plywood is a very useful wood product which improved the construction of US homes starting after WW II (World War II) in the 1940's. It is made of thin layers of wood veneer peeled off a tree by sharp cutting equipment. Alternating layers are held together under high pressure and glued together. Plywood is typically sold in 4' x 8' sheets in thicknesses ranging from ¼ to 1 1/8". It is used for wall and roof sheathing as well as subfloors. Plywood is very strong and stable; it resists cracking, twisting, and shrinkage. For weatherization work, it is a very good air barrier, but is a poor insulator. It can also be used to create insulation dams around attic openings like pull-down stairways.

Safety issues: Breathing, Eye and Hearing when cutting; gloves when handling; Tool Safety

Plywood (top) and OSB (bottom) usually come in 8' x 4' sheets. (Photo ©)

Oriented strand board (OSB)

Oriented strand board, or OSB is made of chips of wood glued together under high pressure. OSB is denser (heavier) than plywood, and is thus harder to work with. It is also not as sturdy as plywood, though it is less expensive. Like plywood, OSB is typically sold in 4' x 8' sheets; its thicknesses ranging from ¼" to 3/4". It is also used for wall and roof sheathing as well as subfloors. Like plywood, it is a good air barrier, but not a good insulator

Safety issues: Breathing, Eye and Hearing when cutting; gloves when handling; Tool Safety

<u>Drywall (GWB: gypsum wall board)</u>

Gypsum wall board (GWB) is the generic name for panel-type wall finishing products that are used for interior wall and ceiling surfaces. Gypsum wall board consists of a noncombustible rock core (the primary component being gypsum) with paper surfaces on the face, back, and along the edges. Commonly used generic names for these products are drywall, wallboard, plasterboard, or Sheetrock™, the latter being a brand name that came into common use.

Drywall is versatile and can be installed using relatively few basic tools. It provides a large surface area that can be made smooth when its joints (seams) and fastener heads are covered with joint compound. It is available in 4' x 8'sheets of thicknesses ranging from ¼" to 1". The most significant drawback of gypsum board is that it has very little moisture resistance. There are special moisture-resistant (MR) drywalls as well as fire-rated (Type X) types.

Drywall also usually comes in 8' x 4' sheets. (Photo ©)

Drywall is finished using joint compound, commonly called "mud," which seals the joints, seams and fasteners. For joints, seams, and corners, paper or fiberglass mesh tape is embedded in the "mud" to reduce cracking. Basic finishing can be done with minimal skills using easily learned techniques; however, expert finishing is a skilled trade that is mastered only with extensive practice.

Safety issues: Breathing protection when cutting and sanding; Eye and Ear protection when installing; Tool Safety

Standard gypsum:

- Paper-faced and backed ¼" to 5/8" inch thick
- Fire-resistant (Type X)

Moisture resistant (MR):

- Coated paper gypsum
- Fiberglass mat layer
- Cement board

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Lab 4: Hand and Power Tools

Tools are used to perform nearly all weatherization measures. There are many kinds of tools and the ones most frequently used in weatherization and basic carpentry are included here.

Maintaining tools (sharpening, replacing worn or damaged parts, etc.) is critical to good job performance. Some carpenters spend nearly 1/3 of their time *looking for tools*. This means that keeping tools well organized will make you a more effective worker. Tools in a truck or shop can be grouped in whatever way makes sense to you. All that matters is that you can find the right tool quickly. It is sometimes helpful to have more than one of the same tool in your toolset. What is important is not the exact system but that it is understandable, that all crew members and users agree on the system, and that that they know how to use it correctly.

The purpose of this lab is to introduce you to the tools that you will be using throughout the course. The instructor will describe the tools, what they are used for in weatherization, and demonstrate how to safely operate them.

By the end of the lab, you will be familiar with tools commonly used in weatherization, how they are used, and how to safely use them.

Tools		**Safety Equipment**
#2 drill bit	Power drill	Eye protection
Chalk line	Pry Bar	Hearing protection
Chisel	Putty knife	Respirator
Circular saw	Reciprocating saw	Gloves
Drywall joint knife	Scraper	Hard hat
Extension cord	Screwdriver	
Hammer	Square	
Handsaw	Table saw	
Miter saw	Tape measure	
Pencil	Tool belt	
	Utility knife	

Approximate time needed to complete this lab: 1 hour

Tool Organization:
The well organized shop or truck has a designated place for every tool and includes an adequate number and variety of tools for the work performed. Time is wasted when two crew members need a certain tool and only one is on hand or when a needed tool is difficult to find.

Different sizes or types of the same tool should be kept near each other such as various blades for the reciprocating saw or sizes of drywall finishing knives. It can also be useful to group tools according to function such as measuring and marking tools, cutting tools, fastening tools, etc. For frequently performed tasks having the entire set of tools for certain jobs or trades in one kit eliminates the step of gathering them each time the task is performed. Examples are a drywall kit, or an attic hatch building set.

On the job site, loss of tools is a major contributor to unnecessary added time and expense. The discipline of returning tools to their proper place at the end of the work day, and wearing a tool belt, are important. Get into the habit of returning every tool to the belt or toolbox after use, rather than putting it down and having to remember its location. These are effective ways of reducing or eliminating tool loss, frustration, and wasted time. Be organized!

Tool Use On-site:
An installer is expected to know how to load and unload the truck each day. Refer to the jobs scope of work to prepare the jobsite. Tools should be grouped by job type and made ready in the order they are needed. Take care to use gloves to help with carrying and unloading. When lifting heavy, bulky items, use proper lifting techniques relying on legs with a straight back, and seek assistance when it is needed.

When setting up power tools, before plugging into power first make sure they are set up right with all attachments, handles, cutting blades, or drills, and all fittings are tightened. Plug in tools as needed to properly grounded power source using an extension cord of adequate rating. **Only outlets with GFCIs should be used!** Have all PPE in place, and be in a supported and balanced position, before starting the tools. Then safely operate and check each tool for proper operation. In there is a tool, cord, or power problem, tag the defective item and store it on the truck to be returned to the shop for servicing.

CAUTION:

Manufacturer's Specifications
Always read and refer to the manufacturer's specifications for all tools. There are important instructions for attaching blades and bits; guidelines for safe operation and maintenance; and information about power requirements and limitations of tools. These "specs" are shipped with the too. They are usually kept in the tool box, in a folder on the equipment truck, or in a file at the company office/garage.

Many tools have sharp edges. In addition, power tools have powerful motors that can cause injury or damage if not used properly. There are basic rules that should be followed in addition to always following instructions, paying constant attention to the task at hand, and using common sense.

- Appropriate personal protective equipment (PPE) should always be worn when using tools. This includes goggles for eye protection, and ear plugs or muffs for hearing protection. Gloves are also important for many tasks to protect the hands from splinters and sharp edges, or toxic materials. Wear enough clothing to protect the skin from flying chips and pieces but avoid loose-fitting clothing and dangling jewelry, and tie back any long hair, as these can get caught. If required, use respirator and practice **EPA lead safe work practices** if creating dust.
- ALWAYS DISCONNECT THE ELECTRICITY to a power tool before even beginning a blade or bit change. THIS MEANS UNPLUGGING THE POWER CORD OR REMOVING THE BATTERY. Don't just check to see that the switch is off as a switch could get bumped or malfunction. Some workers have lost fingers or had other serious injuries by not following this simple but very important rule.
- A dull tool is a dangerous tool. If a blade or bit is not as sharp as it should be the tool and the worker both have to work harder to complete the task. In such cases, the worker has less control and the tool is more likely to kick back, bog down, slip or bind. In addition to the hazards, this can stress the tool and shorten its life and is likely to produce an inferior job result.
- Look ahead. For example, in the board you are cutting, check for any metal such as nails, screws or staples. Remove anything in the way of a cut or hole before beginning. Cords, furniture or other items that can get in the way should all be out of the way.
- Always work against the cutter. Power tools are designed so that the material and the tool move in opposite directions. The reason for this is to avoid the tool pulling the material or running out of control, which could result in serious injury or damage.

Hand Tools

Tool Belt

1. The tool belt can help you keep the basic tools organized and within reach. It is the primary tool organizer for the individual worker. It has loops, holders, and pockets for tools and fasteners and is worn around the waist.
2. It should fit comfortably and not be loaded too heavily with things that are not in use. This way you can wear it throughout the work day.

Toolbelt. (Photo © ECA)

Hammer and Pry Bar

1. The hammer a basic tool, and is used to drive nails and other fasteners. It is also used to pound pieces of wood into place, or in demolition to break apart material or remove fasteners.
2. It consists of a handle and a head. The handle can be of wood, or of fiberglass or metal with a rubber or plastic grip, and is typically 12” to 16” long. The head is always of drop forged machined steel and has a face for striking nails or other objects, and a claw for pulling nails or prying materials apart.
3. Most hammers have either a curved claw or a “straight” claw, which has a much lesser curve. Through the hammer’s head, between the face and the claw, is the eye where the handle is

inserted. The handle is secured in place by wedges, filling the space with a plastic material which hardens, or solidification of the handle material.

4. Correct use of the hammer for striking is to hold the handle close to the end for maximum leverage and with the thumb on top, swing from the wrist with only limited motion of the forearm and almost no motion of the upper arm. With practice accuracy can be gained to minimize misses that can damage material and bend fasteners.
5. The flat pry bar is used when the hammer is inadequate for prying or for pulling fasteners. It has a gentle curve at one end and a hooked curve at the other for different situations.
6. Both ends of the pry bar and the hammer claw have a slit for grabbing fastener heads.
7. The hammer can also be used to lift heavy things for a short distance by hooking under them.

Hammer and Pry Bar (not to scale). (Photo ©)

Tape Measure and Pencil

1. The tape measure is needed for both planning and laying out work. This is needed for making accurate cuts and placement of pieces.
2. Tapes are made in various lengths, most commonly 25'.
3. Reading the tape is important for making accurate measurements.
4. Care of the tape includes keeping it dry and avoiding kinks being made by severe bending.
5. The tape and pencil are generally used together and the ability to handle them with one in each hand is an important skill that contributes to efficiency.
6. The pencil needs to be kept sharp. This is usually done with the utility knife.
7. Accurate cutting or placement is impossible without accurate marking. To mark the measurement, a small but distinct tick should be made on the material directly in line with the mark on the tape. To make the tick easily seen, it should have a larger tail or diagonal slash. The tail should be on the side of the tick that will be cut away or will be covered by the material that is added.
8. When marking for fastening a second tail is usually added to make an arrow or another slash can be made across the tail to form an "x."

Squares

1. Squares are used with the tape measure for accurate marking and layout. Squares have numeric measurements that can be helpful. They are also used as cutting guides for cutting materials such as drywall, lumber, and glass.
2. The speed square is usually used for marking wood for a square or diagonal cut. It has a flange that is held against the edge while the square lies flat on the material. A measurement can then be extended across the material by running a pencil along the edge of the square. Care is needed to hold the pencil at the same angle throughout the motion of making the line.
3. For longer cuts, a framing square is used.
4. Both of these squares can also be used to check corners and angles.

Speed square (top) and framing square (Photo ©)

5. A drywall T-square has a 4’ long blade, and can be used to mark sheets of drywall, plywood, OSB, or other material. It also serves as a guide for cutting drywall and rigid insulation board.

Chalk Line

1. A chalk line is a case enclosing a reel of string and filled with powdered colored chalk.
2. The chalk-laden string is drawn through a hole in the case and pulled tight between two marks, then snapped to produce a straight line for cutting or fastening.

Chalk line and refill chalk (Photo ©)

Utility Knife

1. The utility knife consists of a handle and a retractable blade, similar to a razor blade but with angle-cut ends to make a point.
2. The blade can be reversed when it becomes dull and the handle can also hold spare blades.
3. Some utility knives are made without retractable blades, but these are considered unsafe.
4. It can be used for sharpening pencils, cutting drywall and rigid insulation, marking for precise cuts, whittling or shaving wood, and other tasks. It is a very versatile and important tool. REMEMBER: Always cut away from your body.

Utility Knives (Photo ©)

Uses:

1. To sharpen a pencil:
   - cut a sliver off the wood starting at the thick shank just above the existing taper and cut toward the point or the place where a point is wanted.
   - Shave each sliver slightly thicker at the beginning of the cut and thinner toward the point. This is necessary because graphite is more brittle than wood, so to avoid breaking it the cut must be nearly parallel to the shank of the pencil.
   - Continue shaving around the shank until a sharp point is obtained.
2. Drywall and rigid insulation:
   - Use a straightedge held in place with the secondary hand and sometimes the foot.
   - The blade is drawn along the edge to make the cut and the flat surface of the blade should be at a right angle to the surface of the material. For drywall, only the paper facing is cut but for rigid insulation the cut should be as deep as possible.
3. For a precise mark on wood, a utility knife cut is much thinner than a pencil line. As noted above, keeping the blade at a right angle to the wood surface is critical for accuracy.
4. To mark for a mortise, the hardware that is to be mortised into the wood is held in place with one hand while the knife blade is used to carefully trace the outline of the mortise. The mark is actually the beginning of the cut that will be made by the chisel.

Chisels

1. Chisels are another wood cutting tool, used for removing more wood than a utility knife can handle, but where a saw is impractical. They are usually made in widths of ¼” to 1-½”.
2. A chisel consists of a straight handle with a thick stiff blade that is beveled (flattened) at the end to a very sharp edge. Regular

Assorted Chisels. (Photo ©

use of the sharpening stone keeps the chisel in condition for making accurate and clean cuts.

3. The chisel is held in one hand and tapped gently with a hammer or with the heel of the other hand or simply held with one or both hands, to make accurate small cuts. With practice and attention to the grain of the wood, a sharp chisel can make extremely accurate details. REMEMBER: Always cut away from your body.

Other Blades

1. Other blades you may use are the putty knife, scraper, and drywall joint knife. All of these have a straight handle and a flat blade and the main differences are the width and stiffness of the blades and their uses.
2. The putty knife is typically 1" to 1 1/4" wide and is designed for applying glazing compound to a window. It can also be used for small amounts of scraping to free stuck windows or doors and other miscellaneous tasks. A putty knife is also handy for cutting rigid foam insulation.

14" Drywall Blade (left), 6" Drywall Blade (middle) and Putty Knife (right). (Photo ©)

3. The scraper is typically three inches wide and has a stiff blade with an edge that has limited sharpness although it is sometimes sharpened. This very versatile tool can be used for scraping, prying trim or other materials loose, protecting wood surfaces when using another tool to pry or pull fasteners, and other tasks.
4. Drywall joint knives are typically 6", 10", 12", or 14" wide, and are used for applying and smoothing out drywall joint compound ("mud").

Screwdrivers

1. Screwdrivers can either be hand or power driven, Phillips or flat. Most screws are driven with a power screwdriver/drill, and are of the Phillips, or "cross-head" type.
2. The standard size is #2, but #1 (smaller) and #3 (larger) are sometimes seen.
3. A hand Phillips screwdriver is usually only used when access does not allow a power tool or one is not available.
4. Single slot screws ("flatheads") are rarely used today but are frequently encountered in older buildings in which case a flat screwdriver is needed. A worn or abused flat screwdriver can be sharpened or "dressed" using a sharpening stone or grinding wheel.
5. When a single slot screw that is worn must be re-used, the slot can be improved by running it a few times down the blade of a hacksaw. Sharpening a worn Phillips bit, or reconditioning a Phillips screw head is very difficult and generally not practical.

Sharpening Stone

The sharpening stone is used to sharpen chisels and plane irons:

1. Holding the bevel flat against the stone surface, move it evenly back and forth more or less parallel to the blade edge to grind the entire surface of the bevel. A blade that is very dull will take a long time to sharpen in this manner and a grinding wheel in this case is more efficient.
2. In using the grinding wheel, the blade is steadied on a rest and held against the outside of the wheel with the blade edge parallel to the wheel axis and the bevel surface tangent to the wheel. This will produce a "hollow grind" where the bevel curves slightly inward from the blade edge to the top of

the blade. Be sure that the edge remains square to the sides of the chisel or plane iron. The final honing can then be done with the sharpening stone in the manner described above.

Hand Saws

1. Most saw cutting is done with a power circular saw or a reciprocating saw, but there are still times when hand sawing is more practical.
2. There are three common types of hand saws.
   a. The wood cutting type, commonly called a hand saw is a wide blade with teeth on one edge and a "D" type wood or plastic handle. The size and number of teeth is designated in points per inch and the most commonly used is eight point. The more points, the finer the cut.
   b. The hacksaw is used for hand metal cutting and has a narrow blade with very small teeth in tension on a frame with a pistol grip handle.
   c. Mostly drywall is cut by scoring and breaking along a straight line but for other cuts, the drywall saw is used. This is a narrow blade about eight inches long with a straight handle, and fairly large teeth. Because of their softness, drywall and rigid insulation are easily sawn with this tool.

Hand Saw. (Photo ©)

Power Tools

Cordless Drill with battery and Charger. (Photo ©)

Power tools are either corded or cordless. Corded tools have the advantage of more consistent (and often more) power. They have the disadvantage of having to be always connected to a power source by a cord, which can limit mobility and cause tripping or shock hazards. There are 2 ways tools are used safely to minimize the shock hazard, grounded or double-insulated. Grounded tools use a grounding conductor wire in a 3-prong outlet, plugged into an extension cord which is plugged into a grounded power outlet. Double-insulated tools use a non-conductive outer casing/shell that does not conduct electricity through the outside body of the tool.

Cordless tools have the advantage of greater mobility. They have the disadvantage of always needing batteries, which add weight, require regular recharging, and are expensive to replace (they usually wear out a few times during the life of the tool). Usually (but not always), corded tools are used in a shop, and cordless tools are better in the field. Tools requiring a large amount of power are nearly always corded, but this is gradually changing with improvements in battery technology.

Screwdriver/Drill

1. The driver/drill, a combination screwdriver and drill, is the primary tool used for fastening screws and for drilling holes. Cordless drills are very common, and keeping the batteries charged is essential to continued operation.
2. Using a Phillips #2 bit, a wide variety of screws can be driven or removed with this tool. By replacing the screwdriver bit with a drill bit, it becomes a drill.

3. Whether corded or cordless, a safety issue with this tool is twisting of the wrist or arm from the bit binding in a hole, and not releasing the trigger.
4. When drilling, it is important to grasp the tool firmly and steadily while keeping body parts clear from the drilling location. Fingers can easily stray to the exit point and be suddenly in harm's way.
5. Drilling a straight hole at a right angle can be a challenge. A good way to approach this is to look at the angle of the bit from two directions when starting the hole and checking again while the hole is still shallow making adjustment as needed.
6. A *perfectly angled* hole is difficult to achieve. If that is needed, a guide that holds the drill at the correct angle or a drill press should be used.
7. When drilling completely through a material that is finished on both sides such as a door, stop drilling when the point of the bit is just visible on the other side then start from that side in the opposite direction. This way the roughness that occurs at an exit hole is avoided.
8. A different drill bit is used for every size hole. For holes up to ½" diameter, a twist bit is used. Holes ½" to 1 ½" can be bored with a spade bit, and for larger holes a hole saw, which is a saw blade in a circle with teeth parallel to the axis, is needed.

Circular Saw. (Photo © eca)

Circular Saws

The circular saw is a very powerful cutting tool, and operates by the motor spinning a circular saw blade at high speed. In addition to the basic PPE, hearing protection should be worn when using these tools. There are several types of circular saws, three of which are discussed here.

Hand-held circular saw

1. The most commonly used type is the hand-held circular saw, that moves over the work on a flat metal plate called the base plate or shoe. The base can be adjusted for depth of cut, and it is advisable to adjust it so that the blade is only slightly deeper than the thickness of the material.
2. A blade guard is provided, which is spring loaded and in the closed position covers the portion of the blade that protrudes below the base. In addition to the obvious safety precaution of keeping body parts away from the blade, care must be taken not to back up the saw or the blade can get got in the wood, causing "kickback." This can both damage the wood and injure you. The force of the blade against the wood should always be toward the base so that the tool is providing its own resistance, rather than exerting force against the operator.
3. Before beginning the cut, the saw must be fully running. When the blade gets up to speed, the cut is normally started at the edge of the work, which pushes the guard out of the way as the saw is moved forward.
4. A plunge cut can be done with this tool but should only be attempted after considerable experience in basic use. To make a plunge cut, the "toe" or leading edge of the base plate is placed on the work, and the saw moved forward so that the blade guard is rolled back, allowing the blade to gradually penetrate the work. This is not for beginners: this is an advanced and potentially dangerous technique which can result in saw kickback and the saw jumping back toward you.

Table saw

1. Another frequently used circular saw is the table saw, which is a large stationary circular saw. The blade on a table saw faces up (comes up through the table), and the base is the table. The blade stays put and you push the board over it.

2. The table saw is typically used for cutting large pieces of material. Table saws create more accurate and straight cuts than hand-held saws.

Miter saw

1. The motorized miter saw has a narrow table and a stationary fence that are perpendicular to the blade.
2. The blade and motor (called the "head") are on an arm that has a horizontal axis pivot and can be swung down for the cut in a slow even motion. The arm can be swung side to side on its vertical pivot and tightened in place for diagonal cuts called "miters."
3. Some models have a third pivot that is horizontal but at a right angle to the fence to tilt the head sideways for compound miters.
4. Models are equipped sawdust collection as well as a blade brake which stops the blade from spinning when the trigger is released the sawdust collection. Always wait for the blade to stop spinning before raising the head back across the cut wood.

Miter Saw. (Photo ©)

Reciprocating Saw

1. The reciprocating saw is used for cuts not possible with a circular saw such as curved or close to corners or squaring circular saw cuts. It is an essential remodeling tool used for cutting in hard-to-reach areas.
2. Like the hand held circular saw, it has a base, or shoe, that rests firmly against the work. Likewise, the saw should always be running before engaging it in the material to be cut. The reciprocating saw has a blade that moves up and down, rather than spinning like the circular saw.

Reciprocating Saw. (Photo ©)

Extension Cord

1. The electrical extension cord is needed whenever a corded power tool is used farther from an electric outlet than the tool's cord can reach (which is most of the time).
2. The most useful lengths are 25'and 50'. Longer cords are available but are not recommended because of their tendency to become tangled. Shorter cords can be strung together for longer distances BUT MORE THAN 100' IS NOT RECOMMENDED because the voltage drop can damage electric motors.
3. The cord must have a rated capacity that is equal to or greater than a tool's amperage rating. Examples are 14 ga wire for up to 15 amps; 12 ga. Wire for up to 20 amps. The cord must be free of damaged or frayed insulation covering. The male and female ends must both include a third grounding prong connected to the grounding wire.
4. Cords can cause tripping hazards and should not be placed across traffic areas.
5. Coiling a cord for storage is best done by holding the end in one hand and making loops with the other of equal length. The resulting loops can be tied up, or held together by wrapping the two ends around the middle a few times, and plugging them to each other.

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Lab 5: Blower Door

The Blower Door is special equipment that building analysts use when evaluating a home's energy performance. A blower door has a large fan that is placed a house's exterior door opening to measure the overall "leakiness" of the house. The fan is used to depressurize the house by pulling air from inside and blowing it outside. This causes the inside of the home to have a low pressure relative to the outside, which causes air from outside the home to come inside through holes and gaps in the air barrier. Using a blower door as well as other tools, methods and knowledge, an analyst can find the location and estimate the size of the leaks in the thermal envelope.

To do this, the variable speed fan in the blower door measures both the air flow through the fan in cubic feet per minute (CFM), and the pressure difference between the inside and outside of the house in Pascals (Pa). The pressure is measured with a small hand-held instrument called a manometer. A manometer has small ports where small plastic hoses are placed on both sides of the blower door with the air pressure measurements indicated on a digital display.

When this lab is complete, you will know how to set up and run a blower door, and learn how to use a manometer to measure pressure differences in Pascals between the inside & outside of the home, determine overall air leakiness of a home in CFM.

Tools	Consumables	Safety Equipment
Blower door	None	None
Manometer		
Manometer hoses		
Calculator		
Writing utensil		

Approximate time needed to complete this lab: 1.5 hours

Procedure

Make sure the home is safe

When the blower door is used in the field, the following precautions need to be taken:

1. Inspect the home for asbestos or mold. Depressurization can cause mold spores and asbestos particles to become airborne and dangerous. If either is found, do not run a blower door until it is

removed.
2. Cover fireplaces with wet newspaper. If the fireplace has a glass cover, close this as well. Close the damper. Check for other dust or materials that the fan could affect.
3. If there is a drop ceiling, remove at least one of the tiles to avoid collapsing the ceiling.
4. Put the house in wintertime condition by shutting all exterior doors and windows.
5. Open all interior doors including the basement door.
6. Turn off all combustion appliances or turn them to pilot. Turn off all fans.
7. Check for loose items and plaster. Make sure children and pets are away from area.

Set up blower door
1. Select a door that is directly open to the outdoors. Assemble the fan's metal frame on the floor adjacent to the door to fit inside the exterior door frame/jamb.
2. Fit the fabric over the metal frame
3. Lift and place the full frame assembly tightly into the door jamb (without the fan)
4. Thread one of the hoses through the lower hole of the frame assembly to the exterior of the house and locate about 5' off to the side of the fan opening.
5. Insert the fan into the opening of the fabric and secure it with Velcro straps.
6. Make sure the fan cover is left on.

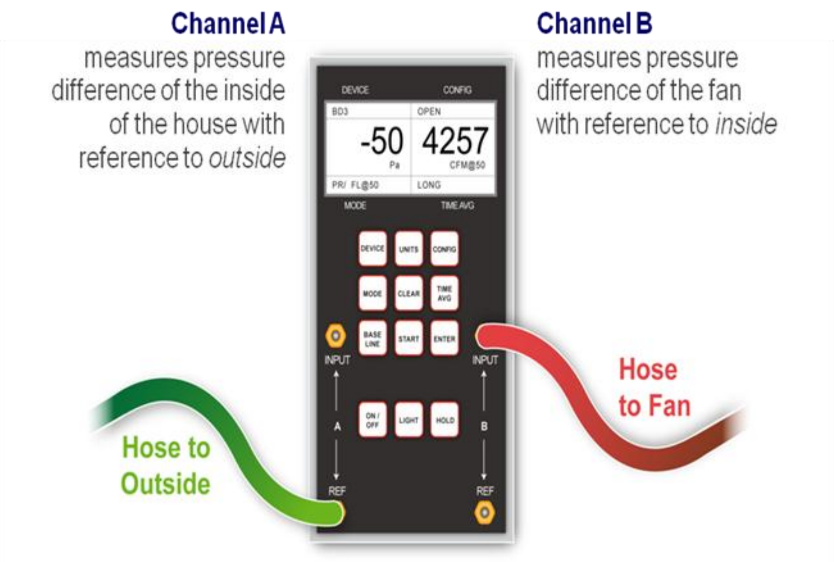
Set up the manometer

The manometer will have two hoses hooked up to it (see diagram below). One hose measures the pressures inside and outside the home, the other measures the pressure of the fan relative to the inside (the manometer uses this measurement to measure the air flow)
1. Set up the fan controller, manometer and holder where it can be easily seen and accessed. Most models should have a Velcro strap that will allow you to hang it inside the doorway.
2. Hook up the 2 hoses as illustrated below. The hose that was inserted through the door should be inserted over the bottom left port of the manometer. The other hose goes from the fitting on the fan onto the top right port of the manometer.
3. Make sure the fan will not be blowing air over the end of the hose that is outside – this will cause false "outside" pressure readings. (Locate it 5' off to the side of the fan opening).
4. Set-up the manometer for the conditions and equipment.
5. Get a baseline pressure reading with the fan cover still on.

Operate the blower door
1. After getting the baseline pressure reading, take the fan cover(s) off.
2. Slowly increase the fan speed until it reaches a reading of -25 Pascal's (Pa) with reference to (WRT) the outside (this should be displayed in the left portion of the manometer screen).
3. In the field, you would walk around the home to make sure everything is secure at this level of depressurization. Check for airborne particles (e.g. ashes) and things such as pictures that look like they may fall. Check for open windows and doors. Take care of any problems that you see.
4. Slowly increase the fan speed until you reach a pressure of -50 Pa. If you cannot reach -50 Pa ("can't reach 50"), add a low-flow plate.
5. If you still can't reach fifty, the home is VERY leaky. Continue to the next step. In the field, adjustments will be made at the end of the blower door test to make up for this.
6. Once -50 Pa is reached (or if you can't reach 50, the highest pressure you can get to), measure the air flow through the fan (the number in the right half of the manometer screen). This is in cubic feet per minute, or CFM. If you have achieved -50 Pa, it is called $CFM_{50.}$

Calculate air changes per hour

1. The CFM number tells you how leaky the house is. The higher the number, the leakier the house. A CFM_{50} of 4000 is high for a small house, but okay for a bigger house.
2. Calculating air changes per hour (ACH) takes the size of the home into account, and is necessary to find out if a home is leaky or not.
3. To calculate ACH, multiply CFM_{50} x 60 (minutes), and divide by the volume of the home. The volume is the length x width x height.
4. This gives you the ACH_{50} value. Generally, an ACH_{50} value of 7 or higher means that the home should be airsealed.



Hose setup for manometer
(Image courtesy of US DOE)

Finished blower door setup
(Image courtesy of US DOE)

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Lab 6: Work Scope

A Work Scope (or work order) is a document created by the Energy Auditor that lists all weatherization measures which will be applied to the corresponding work site. The work scope is used by the retrofit installer as a guide to apply the appropriate measures and as a checklist to determine whether all work has been completed.

Also, it will be important for an installer to become familiar with the “tool list”, which list all the tools and materials which are loaded onto the truck. Depending of your agency’s policy tools may loaded each day per the necessities of that days’ work order or there may be a master list which list all the tools & materials that could be used on any work scope. It is imperative that an installer knows what he has on his truck in order to report missing or deficient tools & material.

After this lab is completed, you will be able to analyze a work scope to identify work site areas, pull the proper tools & materials for weatherization measures, and determine the completion of work scope measures. This lab can be done in conjunction with any of the labs in the retrofit installer technician manual – it is not a standalone lab.

Tools	**Consumables**	**Safety Equipment**
Varied	Varied	Varied

Approximate time needed to complete this lab: additional 30 minutes to associated lab

Procedure

The work scope is reviewed by the crew prior to reaching the work site. The crew chief will sanction individual task to each installer. Upon reaching the work site the crew chief will use the work scope to introduce the home owner to the work areas of the home. During this time the installers pull their task designated tools and materials from the truck. The installer then waits for “start-work” verification from the crew chief. After work is complete the installer will return all tools and unused materials to truck to be inventoried and organized.

Safety concerns

1. Proper care of tools and materials
   - Power tools are somewhat delicate and need to be moved appropriately
   - Hand tools should be carried by the grip or handle

- Materials have manufacture specifications about proper storage (ex. One part foam shouldn't be stored in temperatures above 120^{o} to maintain material integrity and ensure safety)
- Materials and tools also have manufacturer limitations. When these limitations are exceeded it becomes a safety hazard (ex. A chisel is designed to shear wood with its sharp edge, though the sharp edge is flat it should not be used as a flathead screw driver because of the risk of injury)

2. ALWAYS WEAR THE PROPER PPE!

3. Work Area Hazards
    - Low head clearances
    - Rodents/rodent waste, aggressive animals/waste
    - High ambient CO, loose, friable asbestos
    - Illegal activity, aggressive client
    - Obstructions (e.g. client belongings)

Analyze Work Scope

1. Per Crew Chief instruction identify your task and locate it on work scope form
2. Cross check other installer measures
    - Ensure there will not be a conflict in work area space
    - Ensure there are no measures which may need to proceed your task
    - Report any issue to crew chief for further instruction

Pull Tools and Materials

1. Unload tools from truck
    - Find a place to compile your task appropriate tools & materials. This area shouldn't be on adjacent properties or in the path of passersby.
    - Compile your task appropriate tools & materials. Lay the tools out so they are all visible, never one on top of the other.
2. Confirm start-work order and enter work area
    - Confirm start-work order per crew chief
    - Carry tools and materials into work area (Safety First! Never carry more than what feels comfortable. Generally 2 hands = 2 tools.)
    - After all tools & materials are within specified work area apply weatherization measure.

Install Measures

During installation, issues may come up that are not in the work scope. For example, a safety hazard (e.g. broken step) may arise or an additional efficiency problem may occur between the tie the work order was created and given to you. If you feel the work scope needs to be deviated from *no matter how slightly*:

1. Clearly identify the deviation – where it is, why it is a problem, and that it is not in the work scope
2. Report the deviation to the crew chief or supervisor

   a. Unless specifically authorized to do so from the crew chief, do not deviate from the work scope
3. Request direction for modified work scope
4. Implement the modified work scope

Clean Work Area
1. Remove all materials & tools from work area into an adjacent area of the work site. This selected area should not restrict movement throughout the work site.
2. Remove and clean work area of material debris, dust, and dirt.

Load Truck
1. Carry tools to truck, placing each in its designated place. Again a safe carrying method is 2 hands = 2 tools. (prior to organizing tools in truck inventory each tool on tool list)
2. Locate appropriate facilities (per Crew Chief instruction) for dumping of trash, recyclables, and lead hazardous materials.
3. Place materials in appropriate facility or separate and compile materials for site removal.

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Lab 7: Sealing the Rim or Band Joist

The rim or band joists are the wooden boards at the end of the floor joists that wrap around the perimeter of a house. For the first floor of a house, they are found above the foundation and below the subfloor, and can be accessed from a basement or crawlspace. They are usually the same lumber as the floor joists (often 2" x 8", x 10" or 12"). Rim joists are very common points of weakness in the thermal envelope of the home. Many older homes will have no insulation or air sealing on the band joists. Brick masonry homes have the space between the floor joists filled with brick. These spaces need to be insulated and air sealed.

It is important to air seal and insulate rim and band joists because they air movement in and out of the home. This decreases energy efficiency and can cause condensation problems. In addition, without insulation heat loss occurs through the wood or brick.

The best method to insulate and air seal band joists is to use rigid foam board and caulk or expanding spray foam.

After this lab is completed, you will be able to properly seal and insulate rim and band joists using caulk, one-part foam, or two-part foam as an adhesive and sealant.

Work Scope:
Provide air sealing and insulation to the band or rim joist area in the crawl space. Following the work specification, install the air sealing and insulation from the materials listed below using the tools provided. Complete cover and seal the rim joist area located between existing floor joists above the foundation or crawl space wall. Minimize material waste and demonstrate proper safe tool use. Plan for project, prepare, construct, install, test, clean-up, and put equipment and materials away.

Work Specification:
The band or rim joist area will be insulated to an R-10 level using rigid foam insulation cut to fit between existing joists between the foundation and the subfloor above. Foam will be installed tight to, and entirely cover, the band or rim joist. The rigid foam will be secured and entirely sealed with a continuous bead of caulking or spray foam.

Tools
Measuring & Layout
Tape Measure & Pencil
Framing Square or speed square
Cutting & Shaping
Utility knife (or putty knife)
Assembly & Installation
Caulking gun
Clean-up & Disposal
Dust pan and broom

Consumables
Rigid foamboard
Caulk (latex); one-part foam or two-part foam
Rags
Trash bag

Safety Equipment
Eye protection
Breathing protection
Gloves
Hard hat or Bump Cap

Approximate time needed to complete this lab: 2 hours

Procedure

Cutting the rigid foam board to cover the rim joist and fit between the floor joists

4. Measure the rim joist space: the height from the subfloor down to the foundation or sill; and the width between the floor joists (this should be a rectangle).
5. Mark the measurements on the foam board using a pencil and square.
6. Cut the board with the utility knife, or a sharp putty knife. IMPORTANT – when cutting, place the foam board firmly atop a surface (such as scrap wood or a sawhorse) that you do not mind scratching up. The board should be flat against the surface underneath the *entire cut* – in other words, the rigid board should not be resting between two saw horses with a gap in the middle.
7. If sealing with caulking, the foam board should have a tight fit with no more than ¼" gaps.
8. If using one- or two-part foam, larger gaps (less than an inch) are acceptable.

Sealing all around the rigid board to the joists and subfloor and foundation or sill

1. Make sure the area around the board is clean and dry so the sealant with stick.
2. Seal edges with caulk, one- part foam or two-part foam by slowly filling around the *entire* outside of the foam board. The foam or caulk should make a complete seal.
3. Caulk can only be used if the gap is less than ¼".
4. 1-part foam can be used on any gap that is 1" or less.
5. Spray foam acts as insulation, adhesive and air sealant. Caulk is not a good insulator, but does work as an adhesive and air sealant. Neither will be as effective if the seal is not continuous.
6. After a few minutes, both the caulk and spray foam should be completely dry. Check to make sure there are no gaps in the seal.
7. Check for and fill any gaps with more caulk or foam to get a continuous seal.
8. If caulk was used, it is best to remove all caulk from the perimeter and carefully caulk again. Be sure to move slowly enough to make a complete seal.

Clean-up work area and store tools and materials

1. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used as these are usually flammable and could contains VOC's (volatile organic compounds).
2. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.
3. Return any items or personal belongings that may have been moved or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
4. Complete a final check and clean your work area and the work site.

Band joists can best be sealed with spray foam (left) or caulk (right). It is essential to form a *complete* seal around the edges to prevent air leakage. (Photos ©)

Weatherization and Retrofit

Energy Coordinating Agency

APPENDIX B

Manual One Quizzes

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Quiz 1: Blower Door

Name: _______________________________ Date: _______________

Choose the best answer for each question:

1. The blower door test works at its best when _______.
   a. a pressurization difference of 50 Pascal is achieved between the upstairs and downstairs of the house
   b. the weather outside is clear and sunny
   c. a pressurization difference of 50 Pascal is achieved between the exterior and interior of the house
   d. using the model by Minnesota Door.

2. A blower door is a diagnostic tool designed to ______.
   a. measure the total size of all the holes in the building shell
   b. measure the indoor air quality
   c. measure how often the door is opened
   d. measure the air leakage rate of a building

3. A basic blower door set up includes which of the following?
   a. Calibrated fan, pressure gauge and manometer
   b. Calibrated fan, fabric door panel system and pressure gauge
   c. Pressure gauge, manometer, fabric door panel
   d. Metal frame, fabric frame cover, calibrated fan

4. Air flow is measured in ________.
   a. cyclic flow per minute
   b. cubic feet per minute
   c. air changes per hour
   d. cyclic flow per month

5. The blower door is used to guide a contractor in _______ .
    a. air sealing
    b. insulating
    c. finding hazards
    d. fixing doors and door frames

True or False:

6. T / F Blower door testing is the best method to quantify air leakage in a house.

7. T / F The manometer needs to be attached to a hose that runs into the basement and basement/crawl space during the blower door test.

8. T / F You must always set up the blower door in the front entrance.

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Quiz 2: Weatherization

Name: ______________________________ Date: _______________

Choose the best answer for each question:

1. Today, the mission of the WAP program is _____.
   a. to reduce energy costs for low-income families
   b. to ensure the health and safety of low income people
   c. to reduce energy use in a region
   d. A & B above

2. Which of the following is an example of an incidental repair?
   a. Limited roof repair
   b. Replacing the dishwasher
   c. Repairing a toilet drain
   d. Installing weather-stripping

3. Baseload energy does not include which of the following?
   a. Air conditioning
   b. Lighting
   c. Hot water heating
   d. Running the refrigerator

4. Which of the following is not a good air barrier?
   a. Caulk
   b. Drywall
   c. Spray foam products
   d. Fiberglass

5. Which of the following usually reduces energy use the most?
   a. Replacing the refrigerator with new a Energy Star model
   b. Adding insulation
   c. New exterior doors
   d. Air sealing

6. Which of the following group is the highest priority for the Weatherization Assistance Program?
    - a. Attic insulation
    - b. Loose-fill sidewall insulation
    - c. Lighting replacement
    - d. Duct sealing

7. Electric baseload savings do not include which of the following?
    - a. Compact Fluorescent Lamps (CFLs)
    - b. Refrigerator replacement
    - c. Water heater insulation
    - d. Furnace replacement

8. The greatest amount of energy use in the average home is used how?
    - a. Base load appliances
    - b. Home electronics
    - c. Space heating and cooling
    - d. Water heating

True or False:

9. T / F The only goal of WAP is to reduce the energy burden of low-income clients.

10. T / F The goal of calculating the SIR is to find out if weatherization measures will pay for themselves over the lifespan of the measure.

11. T / F Diagnostic testing cannot determine the amount of leakage into a building.

12. T / F Cost-effectiveness is measured by the Savings to Investment Ratio (SIR), which is the amount of energy savings versus the cost to install a measure.

13. T / F The SIR is not considered in matters of energy-related health and safety (H&S).

14. T / F Incidental repairs are those repairs necessary for the effective performance or preservation of weatherization materials, but not actually a weatherization measure.

15. T / F A blower door set is an effective diagnostic tool for determining the volume of a house.

NOTES

ENERGY COORDINATING AGENCY

KNIGHT GREEN JOBS TRAINING CENTER

Manual Two

Building Science: The House as a System and Principles of Energy

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Weatherization and Retrofit Course

Energy Coordinating Agency
Philadelphia, PA

MANUAL TWO

Building Science: The House as a System & Principles of Energy

TABLE OF CONTENTS

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Manual Two: Building Science: The House as a System and Principles of Energy

Overview

This manual is designed to provide individuals who wish to become entry-level retrofit installer technicians with training in the principles related to and analysis of energy, air and water vapor movement in residential buildings; baseload and seasonal load analysis; use, cost and reduction of use of electricity in homes; and basic analysis of domestic hot water heaters and other plumbing installations as they relate to energy efficiency. Training in air sealing recessed lights and installing dense pack insulation will also be provided. The material is designed for individuals with little or no background in construction or weatherization, though experienced individuals who would like a refresher course in the topics discussed will find the material instructional.

The manual will proceed as follows:

- Discuss concept of House as a System, its importance to weatherization and specific house system components
- Discuss and identify framing components in residential housing
- Discuss common moisture-based health and safety hazards in the home and how to identify and remedy them
- Discuss thermodynamics, energy types and sources, and ways to control thermal transfer
- Discuss driving forces of air movement and leakage, and the importance of maintaining air and thermal boundaries
- Install dense pack insulation
- Identify and discuss elements of seasonal load and baseload
- Identify ways to reduce baseload
- Identify basic function, benefits, and drawbacks of different lighting sources

- Calculate energy use and cost of lighting sources and common electronic household appliances
- Identify ways to reduce refrigerator energy use, and common refrigerator problems
- Air seal non-IC recessed light fixtures
- Discuss functions, components, operation, benefits and drawbacks of different types of domestic hot water heaters
- Discuss safety concerns related to domestic hot water heaters
- Identify domestic hot water heater components
- Install low-flow showerheads and plumbing pipe insulation
- Assisting in identification of plumbing hazards
- Air seal plumbing penetrations

Learning Objectives

At the conclusion of this manual, the student will have the following competencies:

- Define House as a System and explain its importance relative to weatherization
- Identify framing components of residential buildings
- Describe common moisture problems encountered in homes
- Describe driving forces of air leakage
- Define thermodynamics and describe the three methods of thermodynamic heat transfer (conduction, convection and radiation)
- Describe the impact of pressure on air movement, and common drivers of pressure in the home
- Describe the difference between baseload and seasonal loads and identify baseload and seasonal load appliances
- Calculate baseload and seasonal load
- Calculate energy use of household appliances and identify ways to minimize home appliance energy use
- Describe operation of domestic hot water heaters
- Identify components of domestic hot water heaters
- Assist in identification of basic plumbing needs
- Air seal plumbing penetrations
- Install low-flow showerheads
- Install insulation on plumbing pipes
- Demonstrate proper use of Personal Protective Equipment
- Handle tools and materials according to manufacturer specifications
- Analyze a work scope and explain how it is used before and on a job site

- Gather materials and supplies for a weatherization application
- Set up tools and materials
- Clean up and organize work area as work is in progress
- Pick up tools and materials, and clean up and close out a job site
- Install dense pack insulation
- Air seal non-IC rated recessed light fixtures

Key Terms

- Air pressure
- Backdraft
- Balloon framing
- Band joist
- Baseload
- Bottom plate
- BTU
- Carbon monoxide
- Celsius
- Compact fluorescent lamps (CFLs)
- Condensation
- Conduction
- Convection
- Cubic feet per minute
- Delta P (ΔP)
- Delta T (ΔT)
- Dense-pack insulation
- Domestic hot water
- Double top plate
- Energy
- Exfiltration
- Exterior wall finish
- Evaporation
- Fahrenheit
- Framing
- Floor joist
- Humidity
- Incandescent lights
- Infiltration
- Kinetic energy
- Knee wall
- Laws of thermodynamics
- Leakage
- Mechanical effect
- Mold
- Platform framing
- Pressure
- Power
- R-value
- Rafter
- Relative humidity
- Radiation
- Recessed light
- Sheathing
- Siding
- Spillage
- Stack effect
- Stud
- Systems thinking
- Thermal boundary or thermal Envelope
- Top plate
- Vapor retarder
- Vapor barrier
- Ventilation
- Wind effect

Manual Two: Building Science: The House as a System & Principles of Energy

Topic 1: House as a System

Overview

As mentioned in Manual 1, treating the house as a single system of connected parts is one of the most important concepts in weatherization. This concept is referred to as "house as a system". Components of a house are connected in one way or another. The house system includes all of the structure (walls, floors, foundation, roof, etc.); the electrical, plumbing, heating and cooling systems; all of the parts in between; the people living in the home; and the environment around the house. It is important to remember that even if one thing does not *directly* impact something else, it is most likely connected in some way.

"**Building science**" is a relatively new approach to weatherization that uses modern technology to study the parts of a house that should work together to create a comfortable, efficient home. Of course, this also means that systems can work against one another, resulting in an *un*comfortable, *in*efficient home. Building science requires an understanding of how individual parts of a house work. This is the traditional way of analyzing home energy efficiency. Unlike the traditional approach, building science also relies on the knowledge that components interact with each other.

Building Science: an approach to weatherization that uses modern technology to study building construction, maintenance, safety and durability in an effort to increase energy efficiency.

There are many possible problems and issues encountered during home inspections and **energy audits** that involve more than one trade. These problems are difficult for a person with a single "traditional" expertise (e.g. carpentry, plumbing, or HVAC) to know how to measure and diagnose. For example, when performing an analysis to discover how air is flowing within a home, *not* thinking of the house as a system will cause confusion. Air movement is influenced by processes throughout the home, as well as by conditions outside the home. In order to properly analyze how and why air is moving, you must "step back" and see how all of the processes in and around the home are affecting each other.

Energy audit: the process of using building measurement tools and methods (such as a blower door) for identifying energy efficiency opportunities at home.

This type of "systems thinking" requires knowledge of, and experience with, many aspects of home construction and operation. This includes construction materials (e.g. wood, concrete, drywall, glass), air and water movement, as well as basic electricity, plumbing and HVAC.

Biological elements such as humans, plants, animals, and insects are often ignored, but must also be considered.

In thinking about a house as a system, remember that the system consists of the building (structure, coverings, connections, and systems), occupants (people, pets, and plants), and the environment within and around the home. You must also remember that each of these influences the others, and they must work *together* to create healthy and energy efficient homes.

Systems Thinking

Systems are all around us, but we usually don't think about them. Common examples of systems include:

- **The human body**: All systems in the body depend on each other for proper function. Have you ever sprained a foot or ankle? Then you know that "favoring" that ankle/foot when you walk can cause the other foot/ankle to have problems because you are walking differently.
- **A car**: If one part of a car malfunctions, the car will not function properly. For example, tires that are not properly inflated cause the engine to work harder and gas mileage (miles per gallon) to decrease.
- **The environment**: The earth's systems depend on each other for proper function. Cutting down a forest to build houses leads to more flooding, which leads to damage downstream like crop and soil loss, and on it goes…
- **A home**: All systems in a home are connected. A poorly insulated and air sealed home will lead to the furnace working harder to keep the house warm, which shortens the life of the heater and increased infiltration of cold air (among other effects).

Components of a House's System

Every house is comprised of a system of interdependent parts such as plumbing, electrical, mechanical and structural components. This means that the operation of any one of these parts affects the other parts in the house. Many of the parts that the average homeowner is familiar with are connected to components that are usually not seen. These parts may be buried within the house's walls, ceilings, floors, or elsewhere. Generally, the only time that these "buried" components are seen by a homeowner is when something goes wrong and a component (e.g. a light fixture, sink, etc.) needs to be repaired.

Mechanical Components and Air Pressure

Mechanical components found in nearly every house provide many services, including water heating, home heating and cooling, ventilation in the bathroom and kitchen, clothes drying, and more. Most people don't realize that these parts of the house system alter the air pressure in the house when they operate. Air pressure is a very important driving force for air and heat movement, so it is a very important thing to consider in weatherization.

If areas with different pressures are allowed to interact, air from the high pressure area will move toward the low pressure area. (This will be explained in more detail later in this manual.) When air moves, it brings moisture and hot or cold air with it.   This happens often in buildings, and many times is caused by the operation of mechanical components. The movement of air because of changes in air pressure is one of the most important factors that affect comfort, safety and efficiency in the home. Again, in order to understand this type of air movement, it is necessary to understand how the home works as a system.

Furnace blowers alter the pressure profile of the home. (Photo ©)

Electricity

When electricity is needed, the only task for the homeowner is (usually) to find an outlet in the wall to plug the appliance into. This ignores many important components of the home.   An outlet will not be functional unless the hundreds of feet of cable in the walls, the breaker panel, electrical connections to and from the outlet, and the wires that come in from outside the home are properly installed.

If a home is not properly weatherized, moisture or pests can affect wiring and other parts of the electrical system. Also, for an outlet to be reliable for specific appliances, other “house system” parts must be considered. If too many other appliances are being used (especially energy “hogs” like air conditioners), the circuit may become overloaded and the circuit breaker may shut off. Further, if access to cables inside walls is necessary, it requires working on other building components such as wall studs, drywall, and insulation. The point is that components of a house have individual functions, but *are always part of a larger system of some kind*. The better these systems are understood, the safer and more effective home modifications will be.

Moisture

Moisture is an important factor in the comfort, safety and efficiency of the home. **Humidity** is an important factor in the comfort of people in the home. Excess moisture in the air or on parts of the home can cause mold to grow, which can be dangerous to human health. If wood is wet for an extended period of time it can rot, which can cause a number of health, safety and efficiency problems. These are but a few of the problems that are caused by poor moisture management in the home.

Humidity: the amount of water in the air. Water in the air is in the form of a gas, and is called water vapor. Air with a high humidity tends to feel very “sticky.”

Relative humidity (RH): a measurement of how much water vapor is in the air compared to how much it could possibly hold. A 100% RH means no more water vapor can fit in the air (50% RH means that the air is half as saturated as it could be).

The movement of moisture is affected by the house’s system. Moisture from one part of the home (e.g. the kitchen when cooking or bathroom when showering) can (and usually does) end up in other areas of the home. If this moisture is not properly managed (e.g. through use of exhaust fans), problems may result (examples are mold, wood rot, and wet insulation).

Topic 2: House Framing

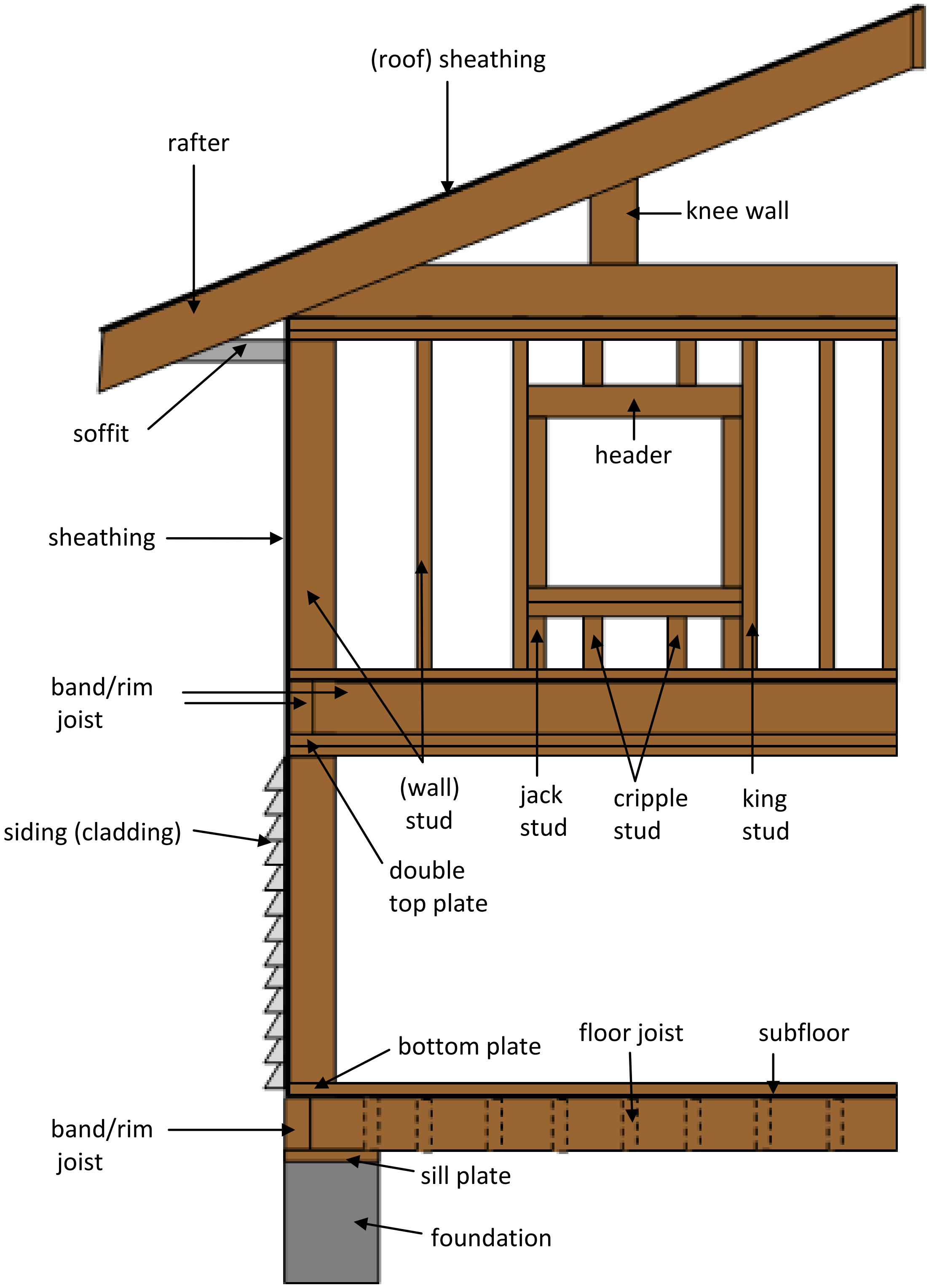
The Hidden Parts of the House (Framing)
All homes are made up of many hidden components, but just because they are hidden does not mean they are not important. The *frame* of a home is a good example of this. In fact, the frame is what really holds the house together and keeps it from falling apart! Also, framing plays a large role in weatherization, especially in terms of air leakage into the home. In short, it is a very important component of the house system.

The frame can be thought of as the "skeleton" of the house. It is made up of many parts, most of them made of wood, such as columns, studs, beams, joists and rafters, all nailed or screwed together to form a structural frame. In almost all homes, there are large air gaps between framing parts. If these gaps are not properly sealed and filled with the right amount of insulation, the home will be extremely inefficient and uncomfortable. Despite this, many fairly modern homes were built with many unsealed gaps and too little insulation. Many older homes have no insulation at all in certain places!

The frame of the house is rarely seen in a finished home. The typical home's frame is hidden by at least two layers of material on the outside. First, the frame is covered by a layer of wood attached to the frame itself ("sheathing"). In modern homes, sheathing is generally made of plywood, or "oriented strand board," known as OSB. OSB is used because it is relatively inexpensive, strong, water resistant, and does not let air through (it is an "air barrier"). Outside of the sheathing is a second layer, such as siding, stucco, brick veneer, or stone facades (a façade looks like stones or bricks, but is actually a thin layer of something that only looks like it). These coverings make up the **exterior wall finish**. Many homes, especially in relatively wet and/or humid areas, have "house wrap" installed over the sheathing of the house. This layer of house wrap sits behind the siding. This helps prevent outside moisture from entering the home. It also adds to the air barrier of the home.

The frame is not usually invisible from *inside* of the home because it is covered by drywall or plaster. Homes built after 1950 usually have walls made of drywall (drywall is also called "sheet rock" or "gypsum wall board"). Drywall is much easier to install, maintain, and customize than plaster. Neither drywall nor plaster is a good insulator – it is essential that the spaces behind the walls are properly insulated. On the other hand, both drywall and plaster are very good at preventing air leakage, so they are good air barriers if properly sealed. Drywall is relatively good at preventing moisture from going into the walls, as long as it is coated with a few layers of paint.

Exterior Wall Finish: layer of material attached to the outside of sheathing, used for air and moisture control, and aesthetic purposes.



Common Framing Elements of a Modern Home. This is a diagram of a "platform" framed home. (See below for more information about platform framing.) Aside from the siding and foundation, these elements are typically made of wood (boards, plywood, oriented strand board, etc.). This is not an all-inclusive list of framing components. (Image © ; based on image by Pennsylvania Weatherization Training Center)

Typical House Framing in an Attic. Roof rafters (at an angle, top left and right) and ceiling joists (bottom) can clearly be seen. It appears that this attic is severely lacking insulation. (Photo courtesy of US DOE)

In the photograph to the right, the attic framing can be seen. The roof rafters (top right and left on an angle) and vertical support braces can clearly be seen in the foreground. Horizontal ceiling joists can be seen at the bottom of the image. Very little insulation has been added to the attic area in the foreground. The insulation that is there is dirty, which probably means that air is leaking through the ceiling below – air often carries dust and other particles, and the insulation acts as a filter when the air passes through. Over time, the insulation becomes dirty because it is constantly filtering leaking air. In the background, it is clear that no insulation is present. This will cause the room below to rapidly leak heat into the attic space during cool months. In the warm months, unwanted heat will be transferred from the hot attic down into the home.

Framing Problems

After a typical house is built, most of its framing system is covered and no longer visible. This can make it very difficult to diagnose problems or issues that are a result of the framing. This is not a good thing, as gaps and cracks between framing components are often major sources of air leakage, heat loss and water problems. In a perfect world, all homes would be put together well, and would be energy efficient. However, this is not the case – many homes were not built with energy efficiency in mind. (Fortunately, many of these flaws can be corrected by weatherization retrofit.)

Framing lumber can last for a very long time – hundreds of years even – if it is kept under the right conditions. Most importantly, it must be kept dry, because wood is very vulnerable to moisture. Wood is both *permeable* (water can get inside) and *porous* (it is filled with spaces called *pores* that can hold water). Wood framing must be protected from outside moisture from excessive humidity and rain. Properly installed siding and house wrap (see above) are two very important ways to prevent outside moisture from getting to the frame.

Moisture from inside the house can also be a problem. Common sources of interior moisture include cooking, showering, respiration from people (your breath has moisture in it), and plants. As

Vapor barrier: any material that allows zero or almost zero moisture through. Common examples in weatherization are plastic, exterior-grade plywood, aluminum foil, and asphalt shingles.

Vapor retarder: any material that slows the diffusion of water vapor through it. Many materials in weatherization are vapor retarders, including drywall and OSB.

mentioned above, drywall and plaster are decent moisture barriers, as long as they have several coats of paint on them. In mild climates without severely cold winters, painted drywall and plaster are usually moisture-proof enough to prevent problems. In colder climates, such as those found in the northern United States and Canada, an extra moisture barrier called a **vapor barrier** may be added *inside* the walls. In warmer climates, such as those in Florida and some of Texas, a vapor barrier should either be added *outside* the sheathing, or not used at all.

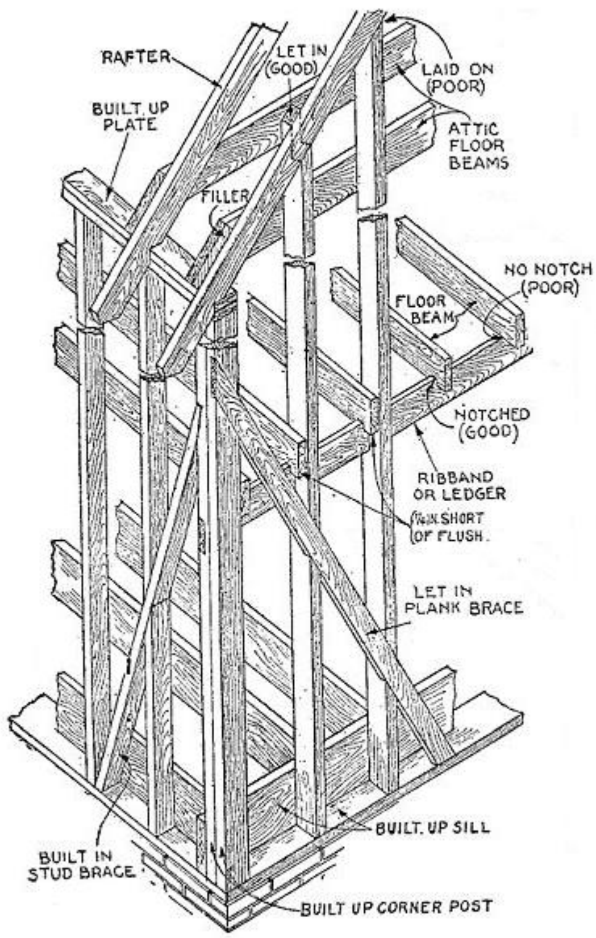
Mold, mildew and moisture that reaches the framing by traveling through the wall's cavities and exterior framing can rot the wood framing over time. Mold growth can also cause a number of health problems (see Topic 4 below). With an occupant's breathing, bathing and cooking, there is so much moisture in a house that it is now a requirement to have ventilation for kitchens and bathrooms. Some newer homes are very tightly sealed, to the point of very little air leakage. If a house is tight enough, the building code requires additional mechanical ventilation to be installed. This helps prevent moisture problems, removes indoor air pollution, and allows needed fresh air to be pulled into the home.

House Framing Types

The two typical framing types for wood construction are called balloon framing and platform framing.

Balloon Framing

Prior to the 1940s, **balloon framing** was the typical method of house construction in the United States. Balloon-framed homes use wall studs that run from the foundation to the roof rafters. The floor joists are attached to the sides of these long wall studs. Subfloors and wall sheathing are usually made of wood boards. (Plywood and OSB were not invented when balloon frames were being built). Modern wall studs are usually only 8 feet, though they can be a few feet longer. Wall studs for balloon frames can be 20 feet or more! This method was easy to use a long time ago, since very long pieces of wood were available from the old growth forests that were available at the time.

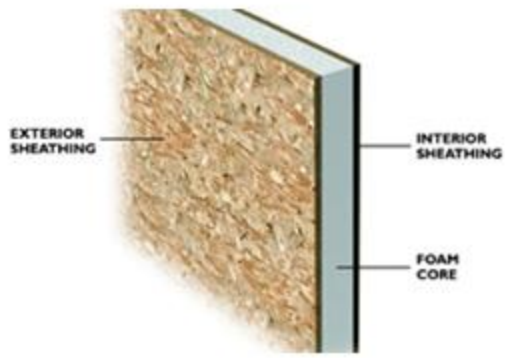


Schematic of a Balloon-Frame House. Note that the studs travel from the base to the top of the house, and the floor joists are attached to a ledger board that is attached to the stud. (Image available publicly at: http://en.wikipedia.org/wiki/File:Balloon_frame.jpg)

Balloon-framed homes have a major efficiency flaw: air can easily travel from the basement to the ceiling (and vice versa). This is because the spaces between the studs provide a continuous open path from the foundation to the roof. Outside air can leak into the attic and basement, and balloon-framed walls provide a path for this outside air to leak into the home.

Platform House Framing
The length and quality of wood that was required for balloon framing is not available today with lumber now being milled from smaller and younger trees. Platform framing uses shorter lengths of lumber for exterior wall studs that are only one floor high. Houses are built one story at a time. The next upper floor deck ("platform") is fastened to the top of the previous lower wall construction. This prevents air from traveling from the basement to the attic. The image on pg. 44 shows a platform framed home. In addition to timber availability being a problem for balloon frames, platform frames are easier to build and can be built faster.

Structural Insulated Panel (SIP) House Framing
Structural insulated panels (SIPs) are pre-fabricated panels that can be used to build walls and roofs. SIPs are unique because they are both insulation and framing in one piece. They come in standard sizes (e.g. 4' x 8'), but can also be custom designed. The panels provide better and more uniform insulation compared to the construction methods detailed above. When installed properly, SIPs also provide a more airtight installation, which makes a house more comfortable and also quieter.



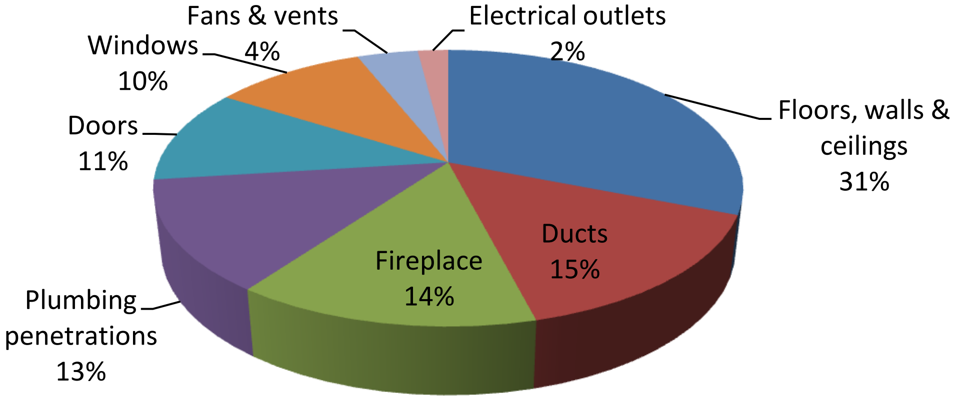
A structural insulated panel (SIP) has built-in insulation. Building with SIPs eliminates the need for much of the typical wall and roof framing. (Image courtesy of US EPA)

SIPs have high **R-values**, as well as high strength-to-weight ratios. A SIP typically consists of four- to eight-inch thick foam board insulation, sandwiched between two pieces of OSB or other type of wood product. Manufacturers of SIPs usually can customize the size, shape and materials based on what customers want. The exterior is glued to the foam under extremely high pressure (or in a vacuum), which creates a very strong and continuous seal. With experienced builders, SIP homes can be built much faster than traditional homes. SIPs are becoming more popular, especially as awareness of the benefits of weatherization is becoming more widespread.

R-value: the ability of a material to resist heat transmission. The higher the R-value, the more heat-resistant the substance is. A material that has a value of R-38 is twice as resistant as R-19. R-values can be added, e.g. two layers of R-15 insulation have a value of R-30.

Topic 3: Air Leakage

Unwanted air leakage into and out of the home is the primary cause of energy inefficiency in homes today. This is the reason that after health and safety concerns are taken care of, air sealing is the number one priority for all weatherization strategies across the country. The pie chart below shows the areas of air leakage from the **conditioned space** in a typical house.



How Air Escapes from a Home. The chart shows how air escapes from the average U.S. home. Most leaks are almost impossible to find without an energy audit and use of a blower door. (*Source: EERE, 2009*[1])

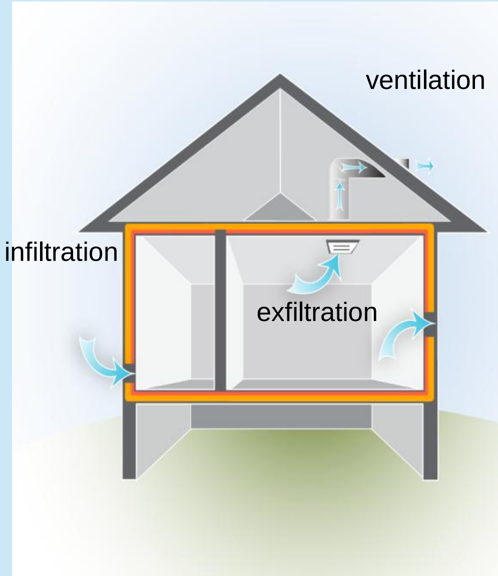
Air can move in and out of homes in a number of different ways. "**Infiltration**" is air leaking in to the building. "**Exfiltration**" is air leaking out of or exiting the building. "**Ventilation**" is planned and controlled air movement whether through open windows or mechanically drawn from the outside. Technically, ventilation is not leakage.

Infiltration, Exfiltration and Ventilation

Controlling the movement of air in and out of the building envelope is extremely important part of having a safe, healthy and energy efficient home.

Infiltration usually results in unwanted heat, cold and/or moisture entering the home. It can also result in dirty or polluted air coming inside. Exfiltration can result in unwanted heat and/or cold loss. Ventilation is an important way to purposely remove unwanted air and bring in needed fresh air. Common examples of ventilation include removing damp bathroom air and hot/potentially dangerous air from a stove by using exhaust fans.

In weatherization, infiltration and exfiltration are commonly controlled through air sealing. Ventilation may be addressed if the house does not



Most homes have infiltration, exfiltration and ventilation. (Image courtesy of US DOE)

[1] Available at http://www1.eere.energy.gov/consumer/tips/m/air_leaks.html

A typical home has many locations that let air and moisture in and out without the resident knowing. No home is completely air tight, even with the most highly advanced building techniques – all homes "breathe" in one way or another. In some ways, this is a good thing: First, all homes have some toxic substances that leak into the air (exhaust from ovens, paint fumes, cleaning products, etc.). This toxic air needs to be diluted and removed. Second, a home needs enough oxygen in the air to keep the occupants comfortable and supply the fuel-burning equipment. Air must come in from the outside for people to breathe and the appliances to work. Third, moisture inside the home (from breathing, cooking, showering, etc.) needs to be diluted and removed or it causes mold and other problems. All houses need to breathe for these and other reasons.

Conditioned space: rooms and spaces in the home that are heated or cooled for the comfort of occupants.

However, most homes breathe *too much.* Escaping conditioned air is the most important source of energy inefficiency in homes today, and often costs a homeowner hundreds of dollars in energy costs per year. According to the U.S. Department of Energy, up to 40% of a home's energy cost is due to air leakage. This is why preventing air from escaping is a top priority in weatherization. It is very rare that a house is too tight, and if weatherization causes the house to be too tight, ventilation can be added to prevent the problems listed above.

Common Sources of Air Leaks. Air leaks are often so small that they go unnoticed. Even if they cause a certain area of the home to be less comfortable, it may be difficult to find their exact location. Added together, these small air leaks result in an overall inefficient home. This can cause hundreds of dollars of extra energy costs per year, make the home less comfortable, and make it vulnerable to pests. (Image courtesy of US EPA)

Barriers

There are many types of barriers in homes that are important in weatherization, though they are not the kind that most people know about. If you ask someone to name some barriers in their home, they would probably tell you about things like fences, outside walls and gates. These are barriers, of course, but for the most part they are not the kinds that weatherization workers need to worry much about. What are the most important barriers used in weatherization?

Air Barrier

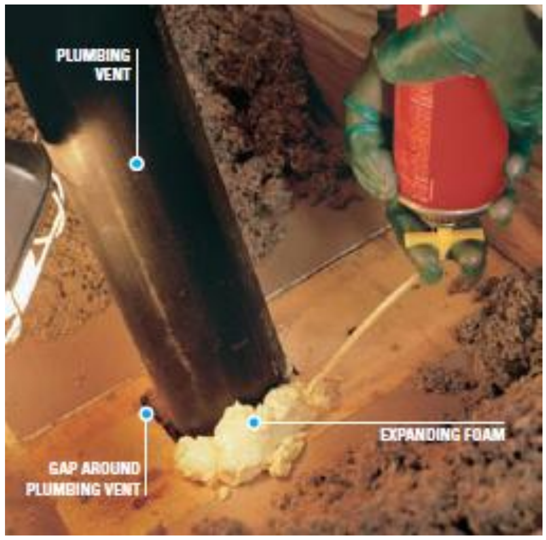
An air barrier is a material that prevents the flow of air. A properly installed air barrier will prevent most air – and also the moisture in the air (humidity) - from escaping and entering a given area. Air barriers also prevent a certain kind of heat flow, namely convection (see Topic 5 below). Air barriers are *extremely* important in weatherization. As mentioned above, unwanted air leakage is very common problem in homes, and is costly and uncomfortable for occupants. Air barriers prevent air leakage if properly installed.

There are many types of air barriers that can be applied in a number of ways. As mentioned in Topic 2 above, painted drywall and OSB are very good air barriers. Drywall is installed inside the home, of course, and so is good at keeping conditioned air inside the home from escaping. Oriented strand board (OSB) is installed on the outside of the framing, and so helps to prevent unwanted air from leaking into the home through the building shell. Plywood is also a good air barrier – plywood is often used on porch and house roofs. Some exterior "house wraps", (also mentioned in Topic 2) serve as air barriers when they are properly taped and sealed. Many of the weatherization materials mentioned in Manual 1 – e.g. rigid foam board, one-part foam, two-part foam, caulking, kraft paper (facing) on fiberglass batting, and properly applied dense-pack insulation – are also excellent air barriers.

Air barriers are most effective if they are continuous. In other words, air barriers are less effective at preventing air flow if there are cracks, rips, tears, or holes in them. To do this, sealants such as caulk and foam need to be used where one part of a room or building meets another. Examples of this include caulking where walls meet ceilings and floors; caulking where walls meet window frames; and putting foam in attics where the tops of walls are connected to roofs.

A home's air barrier is a combination of materials that enclose the conditioned space. It is achieved through various means and limits the airflow between the inside and the outside of a house. In new construction, an air barrier is put in place before the walls and ceilings are finished. In weatherization work, materials are added above, below, and behind existing surfaces and framing to create a continuous sealed air barrier.

An excellent air barrier can be installed using manufactured in-place spray foam insulation. It has a good R-value and provides a complete air barrier at the same time. An alternate method used to provide an air barrier behind existing finished walls is to install **dense-packed cellulose insulation**. The insulation is blown through holes that are drilled into the wall cavities (inside or outside the house) between the vertical studs. This method will effectively control air movement through the wall



Maintaining Continuous Air Barriers. Having continuous air barriers is a very important aspect of weatherization. The picture on the left shows caulking to seal around an electrical junction box. Bigger gaps (more than ¼ inch or so) require expanding foam instead of caulk. The image on the right shows how to use expanding foam to seal around a plumbing pipe. (Images courtesy of US EPA)

Thermal Boundary or Thermal Envelope

17 The thermal boundary, or thermal envelope, of a house is made up of the air barrier and insulation. It is usually located around the outside walls and roof of the home. The thermal boundary limits air and heat flows between the inside and the outside of the
18 conditioned space. The thermal boundary is only effective if 1) it includes both insulation and an air barrier and 2) the insulation and air barrier are continuous and in contact with one another. A full air seal alone will not be effective, because air barriers only prevent convective heat loss. Insulation is very good at preventing conductive heat loss, and helps reduce radiant loss as well. In order to maximize energy efficiency, all forms of heat loss must be minimized. Combining insulation with an air barrier is an effective way to do this (see topic 5 below for explanation of convection, conduction and radiation). The physics behind how insulation and air barriers prevent heat transfer will be address in more detail in manual 3.

Dense-pack insulation: cellulose insulation that is blown into building cavities to a specific density. Dense-packed insulation substantially reduces air leakage and air movement in addition to increasing the R-value of the thermal envelope.

Batt: a narrow (usually 15" – 16" wide) blanket of insulation used to fill the spaces between studs in walls, ceilings and floors. Batts most often come in a large roll and are made of fiberglass.

The location of air sealing and insulation in other building components is critical to insulation's total effectiveness. A small gap in the thermal boundary can let a lot of air pass through the walls and insulation. The gap must be sealed off to achieve an effective, complete thermal boundary for the house.

Common insulation materials for use in the thermal boundary include fiberglass **batts,** rigid and spray foams, and blown-in cellulose. In older homes rock wool and vermiculite may be found. Remember: If the insulation and air barrier are continuous and in contact with each other, air will not pass around and through the insulation to the exterior of the house.

Topic 4: Health and Safety in the House

Overview:
Energy savings add up, and negative health and safety issues are avoided, when approaching the house as a system of interactive parts. For instance, if a house does not have adequate exhaust fans, moisture could build up in the living spaces. If the outside of walls are sealed, but not the inside surfaces, moisture could enter and be trapped in wall cavities. This is a real danger that can occur within just weeks of a cold season in any rooms with plants, unvented cooking, or showering (in other words, in almost any house).

An unvented combustion appliance, such as a kerosene space heater or gas range, creates water as a result of combustion. More importantly, carbon monoxide from burning fossil fuels (oil, gas, kerosene) is toxic, and has no smell. Therefore, there are no certain signs of carbon monoxide poisoning, or even hints of a progressive build-up in a house – except a feeling of lethargy, followed by death.

Comfort, Safety and Efficiency:
Comfort, safety and energy efficiency can be achieved all at the same time if a home is properly weatherized. The Weatherization Assistance Program has determined that a comfortable, safe and energy-efficient home requires a fully insulated thermal boundary with a well-sealed air barrier. These strategies create an efficient resistance to leaking of conditioned air, conserve energy and create good indoor air quality.

Bigger is not better in building science. Larger mechanical equipment cannot completely overcome building leakage. Also, oversized systems in a house that has been air sealed can malfunction. For example, oversized air-conditioners (AC) make a house cold and clammy, and short cycle times (the AC unit turning on and off quickly) produce problems later. The problem is that the mechanical system can lower the temperature before the air inside the home is de-humidified. The moisture in the air can condense on surfaces inside the home instead of the mechanical unit's condenser coil. As with other indoor moisture problems, this can cause mold and rot.

A well-designed and balanced air distribution system is rare even in newer construction. It takes a great attention to detail to properly design duct systems, and to install them without leaks. This takes time and effort (and money), and unfortunately has traditionally been a low priority in the heating, ventilating and air conditioning (HVAC) industry. However, healthy indoor air quality is a key health and safety concern for the emerging weatherization industry, spurred by WAP requirements. This, combined with customer's desire to save energy, has led HVAC installers to think more about properly sized systems. It has also become standard to test for carbon monoxide levels, **backdrafting**, and mold and moisture issues in every house.

Backdraft: combustion gases from household combustion appliances (such as furnaces, hot water heaters and gas –fuelled clothes dryers) that do not exhaust up a house's flue or chimney, resulting in "spillage" of flue gases near the appliance. Excessive backdrafting can be an extreme health and safety hazard.

Moisture

Moisture can easily build up in a house in one or two days when the windows and doors are closed. A typical shower puts half a pint of moisture into the air. Five house plants can add one pint per day. Cooking can easily add two or more pints for each meal. Breathing adds two to three pints per person per day. **Evaporation** through basement floors and crawlspaces can let in an additional 50 to 100 pints a day. Sources of moisture (damp basements, crawl space dirt floors, cooking areas, and bathrooms) need to be controlled to maintain healthy air.

Evaporation: when a liquid changes to a gas (the opposite of condensation). The rate of evaporation increases with warmer temperatures and larger surface areas. Evaporation is a major source of water vapor in a building.

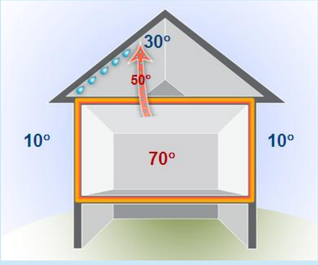
Air movement through breaks in the air barrier and inside wall spaces causes significant moisture movement through a house. In addition, vapor moving through building materials can cause moisture to move into wall cavities. Vapor barriers are now a basic requirement for retrofitting a house to reduce water vapor diffusion. Most houses have one incomplete vapor barrier consisting of a few coats of paint on interior wall surfaces. In extreme northern heating climates, vapor barriers are especially important. Moisture flows with convective currents riding warm air, through breaks in the house's air barrier. When it reaches cool enough surfaces (inside or outside the house, depending on the season) the moisture condenses back to liquid water. This water then causes damage by promoting mold growth, rusting metals, and rotting wood, plaster and drywall (see Weatherizaton Matters box below). This moisture can also drip down onto the ceiling – leading residents to think there is a roof leak. In addition to damaging building materials and breeding mold which can harm residents' health, moisture in the attic also degrades the performance of any insulation.

Weatherization Matters: Key Concepts

How does condensation occur?

Have you ever had a cold drink in the summer, and wondered where the water droplets on the outside of the glass came from? Do you know that this same phenomenon is an important concept in weatherization?

A cold bottle causes the surrounding air to reach its dewpoint, causing condensation.



A poorly insulated attic can cause warm air from inside the home to reach unconditioned attic space. If it cools down enough (reaches the dewpoint), the moisture in the air will condense into liquid. (Image courtesy of US DOE)

Buckling and moldy roof sheathing resulting from condensation. (Image courtesy of US EPA)

Condensation refers to when water in the air (in gas form, called **water vapor**) condenses and turns into liquid water. This occurs when the air reaches its **dewpoint**.

The dewpoint is the temperature air must reach for its water vapor to condense into a liquid. So, if the dewpoint of the air inside your home is 30° F (middle left image), once the air reaches that temperature, water vapor will condense out of the air and form a liquid. This is what happens on the outside of a cold glass or beverage in a warm home. The air around the container becomes cold enough (cooled off by the liquid inside) to reach the dewpoint. When this happens, water condenses on the outside of the glass/container (see image to the left).

The same thing can happen in a poorly weatherized home. If the attic is not well insulated, warm (moist) air from inside the home can leak into the attic. When this air hits the cold roof, it can reach its dewpoint and cause condensation (see image to the left).

Why is this bad? First of all, moisture is one of the key ingredients in mold formation. Mold can cause allergic reactions and other health problems. Also, moisture can be very damaging, especially to wood – it can cause it to buckle and/or rot (see image to the left). Many an expensive repair has resulted from too much moisture.

Condensation can occur in other parts of the home, especially inside walls and ceilings. This can also result in expensive and dangerous conditions. Much of it can be prevented through proper weatherization.

Problems That Can be Seen:

A house will experience problems when its parts or systems do not work together properly. Some problems are obvious, such as condensation on the inside of windows in winter, or the outside of windows in summer. These indicate seasonal issues that affect the building components. Some problems can appear years later, like mold on walls, indicating moisture that has entered into wall cavities. Signs of wood decay or bubbling paint lets you know that water or moisture is trapped inside the wall.

Indications of Moisture Problems. There are many obvious indicators of moisture problems in a home. From left to right: mold on the side of a home, condensation on a glass door, pooled water in the basement, and water damage coming from the attic. All indicate that moisture is being mismanaged inside or outside the home. (All images courtesy of US DOE; original images from PA Weatherization Training Center)

This type of damage needs to be addressed at the source, which may require some demolition and replacement of damaged materials. When these wall problems become obvious, it may mean they have progressed far enough to destroy the framing and wall components. If so, it will require not only solving the source of the problem, but also repairing the sheathing and the house's structure. This can be a very expensive fix.

Problems That Can't Be Seen

Moisture problems can also be invisible, such as damp framing in areas of the home that are rarely visited, such as crawl spaces and unfinished attics. Some may be hidden, but obvious when discovered, such as mold under carpets and behind wallpaper. Problems that are difficult or impossible to see *and* make a heating or cooling systems work harder include uninsulated walls and attics, leaky ductwork located in unconditioned spaces of the house, or indirect air leakage in the house. With more obvious problems, the occupants will likely complain of having cold rooms in winter. They often believe this is a result of drafty windows or doors. However, the causes of cold rooms are usually the hidden problems they cannot see. Many of the unseen problems, such as leaky ducts or slightly underinsulated walls, may only increase energy bills and not be physically noticeable.

Leaky, recessed "can" lighting fixtures in ceilings increase heat loss when air leaks around the fixture's trim or ring and through the fixture itself. Air sealing is required above and around the can fixture housing while leaving enough space for the light fixture's heat to escape without overheating the bulb. This also provides fire prevention by keeping insulation away from the heat of the light bulb.

When warm indoor air leaks into colder attic spaces, condensation can occur and cause problems like mold and rot. In areas with cold winters, leaky ceilings can cause other problems. The heat from the indoor air can cause snow on roofs to melt in the winter. The liquid water can then gather in gutters and freeze, causing an "ice dam." They are called ice dams because they prevent water from draining along the gutter, thus causing water to "dam up." Sitting water can cause the problems listed above, such as mold and wood rot. Problem areas of the roof on the house are evident in the photograph below. When an otherwise snow-covered

Weatherization Matters: Key Concepts

Moisture, mold, mildew and health

Mold problems can be severe or minor, but should always be taken care of. Even a small amount of mold can make a person sick. From left to right: a severe mold infestation after flooding; mold caused by condensation near an air conditioner; and a hidden mold infestation under wallpaper. (Images courtesy of US EPA)

Mold (and mildew, which is young mold) are health hazards that can often be found in homes. Mold requires three things to grow: moisture, heat and a food source. Mold uses organic material for food, which includes building materials such as wood, drywall, carpeting and insulation.

Mold is a fungus, and spreads by airborne “spores.” Mold spores are microscopic (so small that they cannot be seen by the naked eye), and are everywhere! (Mold serves important functions in nature.) You are probably breathing in small amounts of mold spores right now, but there are so few of them that you are not affected. When these spores land on a suitable area (damp, warm with food), they will stay and spread. If something in a home is wet for 48 hours or more, mold may begin forming.

Many people are allergic to mold, and it can cause mild and severe respiratory (lung) problems, as well as skin and eye irritation. It is also a major source of asthma.

Preventing and Cleaning up Mold

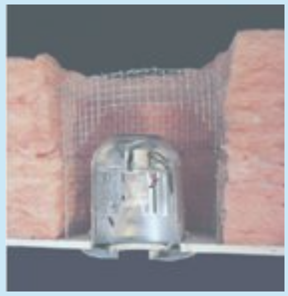
If you find mold in your home, it must be removed. Cleaning it with soap and water (scrub hard!) may work, but bleach (diluted 1 cup to 1 gallon of water) may be used as well. If mold has been present for a while, the item may need to be removed. If it is an extensive mold infestation, consult the local health department. If you remove mold, wear an n95 breathing mask, long sleeves, pants, and rubber gloves, and keep windows open for air circulation.

Prevention is the best way to control mold. Excess moisture is the main cause of mold formation. Exhaust vents in bathrooms and kitchens are important. Also, fix all leaky pipes and windows. Clean up moisture as soon as possible – remember, mold may form in only 48 hours!

For more information about preventing and treating mold, go to the Environmental Protection Agency’s website: http://www.epa.gov/mold/moldresources.html#Homes.

Recessed Lights: Swiss Cheese for Thermal Envelopes





Recessed lights are common features of modern homes. It's hard to deny that they look great (top left picture). Their low profile makes them a subtle way to light a room (top middle).

Unfortunately, they usually cause a major break in the thermal envelope. For all but the newest models, insulation cannot be safely placed within 3 inches of the light (top right). This results in a huge gap in insulation, and a major source of air and thermal leakage (bottom right).

The bad news is that this cannot be avoided – it is a fire hazard to put insulation on top of these lights. The good news is that newer models, called Insulation Contact (IC) rated bulbs, can be in contact with insulation.

Images courtesy of US EPA

roof is bare, it is an almost certainly due to a heating problem such as poor insulation or a leaky duct system.

Topic 5: Principles of Energy

What is Energy, and Where Does It Come From?
Energy is the ability to do work. Work is the transfer of energy. These are of course circular definitions, but it is important to know that work is being done all the time all around us. Any time energy is transferred from one object to another. More than 99% of the earth's energy comes from the sun. Most energy sources on earth (except nuclear, geothermal and tidal) are from daily sunshine or the fossilized remains of plant and animal life that have become coal, oil and gas. Therefore, all energy relies directly and indirectly upon sunlight.

Uneven Melting on a Roof Caused by Recessed Lights. This situation is likely to cause an ice dam, which can cause moisture problems. (Image courtesy of US DOE)

Measurement of Energy

Temperature is the measurement of the vibration of molecules in a substance. It is listed as degrees of either Fahrenheit or **Celsius**. As heat energy is added to any substance, the molecules of that substance (either a solid or a liquid) vibrate faster and the temperature of the substance rises.

Historically, energy has been expressed in several different units. The accepted measurement units of energy include the kilowatt hour (kWh) and the **British thermal unit (BTU)**. A BTU is the amount of heat energy it takes to heat one pound of pure water one degree Fahrenheit.

Fahrenheit (F) and Celsius (C): These are the two temperature scales most commonly used in the world (Celsius is commonly used by scientists and most countries other than the U.S.) Water freezes at 0° C and 32° F, and boils at 100° C and 212° F.

To convert to °C: °C = 5/9 (°F – 32)

To convert to °F: °F = 9/5 °C + 32°

Laws of Thermodynamics

1. The first law of thermodynamics is that energy can neither be created nor destroyed. Energy can be transformed or changed from one form to another. In fact, this happens all the time. Electrical energy in wires are converted to light (in bulbs), heat (heaters, bulbs), mechanical (fans blowing), or any other number of energy types. Oil contains chemical energy that is converted to heat energy when burned. There are nearly infinite examples of energy transfer, many of which relate to weatherization. No matter how the transfer occurs, the total energy of the system is the same after all the changes occur.

British Thermal Unit (BTU): The quantity of heat required to raise the temperature of one pound of pure water one degree Fahrenheit.

2. The second law of thermodynamics is called “entropy.” In layman’s terms, it states that energy always goes from areas of high temperature and energy to areas of lower temperature and energy. This is the most important law for weatherization workers to understand, because heat will always flow from temperature areas to lower temperature areas. As long as there is a difference in temperature (**delta T or ΔT –** “delta” means difference in the language of mathematics and physics), heat will be forced to flow from the higher temperature area toward the lower temperature area.

Delta T (ΔT): difference in temperature. If two areas have a delta T between them and are able to interact, heat will flow from the area of high to low temperature, until both areas are the same temperature.

Energy can be transformed and released. In the process of burning fuels with stored (potential) energy, the result is the generation of heat energy that can be used to do many types of physical work. This released energy can be used to drive machines (e.g. when a gasoline motor propels a car) or to provide a service (e.g. generating electricity). When an internal combustion engine (in a car) converts the stored (potential) chemical energy into heat, the fuel is transformed into kinetic mechanical energy that moves the vehicle (kinetic = movement).

There are many forms of energy, including:

Thermal Energy

Thermal energy is heat. When heat is applied to a substance, the particles of the substance move faster and get warmer. For example, when a pot of water is boiled, heat is added to the bottom of the pot from the flame on the range. This heat is then transferred to the water inside the pot. If enough heat is added, the water molecules can break the bonds holding them in liquid form and become water vapor. This is what is happening when boiling occurs. Thermal energy can travel through substances in three ways – conduction, convection, and radiation. These forms of heat transfer are essential for weatherization workers to know, and will be discussed in more detail later in manual 2.

A candle emits thermal energy. (Image by Matthew Bowden)

Chemical Energy

The energy that is stored in chemicals in the bonds between atoms and molecules. Examples of chemical energy in things we use every day are batteries and fossil fuels like natural gas and oil. In a flashlight, we convert the stored (potential) chemical energy in a battery to kinetic electric energy that is converted to light and heat. In our homes, we convert the potential chemical energy of heating oil and natural gas to kinetic heat energy.

Electrical Energy

Electrical energy is created by the flow of an electric charge (electrons) through a conductor. Electrical energy is transported by a current and has the ability to do work. For example, electrical energy from the coils of an electrical generator in a power station is transmitted through wires to houses and buildings via high tension electrical lines. Electrical current is the flow of an electrical charge through the wires. Electronic devices are items that use electrical power to do their work. This includes all things that are plugged in or require a battery.

Radiant Energy

An example of radiant energy is electromagnetic energy that includes visible light, x-rays, gamma rays and radio waves. All of these forms of radiant energy come to the earth via solar energy. For residential energy, radiant energy usually refers to solar energy from the sun. Radiant energy transfer will occur between any two objects that have different temperatures.

An example of radiant energy is the heat and light emanating from an incandescent light bulb. The light bulb receives electrical energy to make the wire glow. The light's wire (the filament) is heated in the process, making the bulb hot to the touch. Both the light's glow and the infrared heat rays given off are examples of radiant energy. The solar radiation energy that reaches us from the sun on a cold day can provide a warm feeling on the skin. This is an example of pure radiation that left its source, the sun, and traveled through space to warm another surface or object.

Coal and oil mined from the earth come from plants that were grown by the sun thousands of years ago. The existence of these plants was a result of thriving on the sun's radiant heat.

Mechanical Energy

Mechanical Energy is energy that an object has based on its motion or position. If an object is in motion it has kinetic mechanical energy, the energy of motion. If an object is at rest at a position of height or tension, that is mechanical potential energy. A position of height also is called gravitational potential energy. A position of tension is like a spring wound up or a rubber band extended. We use the mechanical potential gravitational energy or kinetic energy of motion to move things. The water stored behind a dam has potential mechanical energy. When the water drops its energy becomes mechanical kinetic energy which turns a turbine that generates electricity at a hydroelectric plant.

A roller coaster illustrates kinetic energy of motion and position. (Image by Stevage)

A roller coaster gives us good examples of each type of mechanical energy. When a rollercoaster climbs high up the first hill, it is building up potential energy. When it reaches the top of the first big hill and stops, this is its maximum mechanical potential energy. When the car speeds down the hill, the mechanical (gravitational) potential energy of the rollercoaster's cars turns into the speeding mechanical kinetic energy of motion, as the image above[2] shows.

Nuclear Energy

Energy stored in the nucleus of an atom as the energy that holds the nucleus together. Large amounts of energy are released when the nuclei are combined (nuclear fusion in the sun) or split apart (nuclear fission in a nuclear reactor).

Heat Transfer Processes

There are more forms of energy than the ones noted above, but the ones listed above (with the exception of nuclear) are the ones you will most likely encounter in weatherization. Of all of these, heat is the most important to understand. It is essential that you remember that heat will always travel from areas with high temperature to areas of low temperature, as long as no additional energy is added. Of course you can make cold air go toward warm air, but you must add energy to the system to do this, for example with a fan. But left alone, heat will always travel from high to low temperature areas. This occurs through three processes: conduction, convection and radiation. Much of what you will be doing as an installer is preventing unwanted heat transfer. It is important to understand these three phenomena.

[2] Image available at http://en.wikipedia.org/wiki/File:Luna_Park_Melbourne_scenic_railway.jpg.

Conduction

Conduction is the most predictable type of heat transfer. Conduction happens through direct contact, when the heat of an object moves through itself and then to another object. Touching a warm surface in winter is a pleasant transfer of heat. Touching hot black asphalt in the summer is considered a painful transfer of heat. Both the pleasant and the painful transfers of heat are the result of rapidly flowing heat when there is direct contact between objects. When we touch a cold metal surface, the heat of our fingers and hand is leaving us and going into the metal. Remember: Hot always moves to cold (more heat goes to where there is less heat).

Convection

Convection is heat transfer through gases (like air) and liquids (like water). Air and liquids are both fluids. Warm areas in the air or water move around or circulate. In this way, heat moves through these substances to equalize the warm and cooler areas. The movement is caused by differences in density. Density is a measure of how much of a substance is contained in a certain volume or space. Warming of air decreases its density (amount of molecules packed together) and creates a rise in temperature. Cooling of air increases its density as its temperature drops. The less dense warm rises through the denser colder air (like oil on water). In building science, the convection of heat causes upward movement of air responsible for the warm air rising in a house, known as the stack effect. The stack effect causes warm conditioned air to be lost through holes and openings in the upper ceiling level (the thermal envelope) of a house. This is why weatherization workers focus on air sealing this upper air barrier: to stop this heat loss.

Convection can also cause pressure forces that cause cold denser air to flow down chimneys (down drafts) and cold attic air to drop into the house below through holes and wall cavities. It also the reason that the supply vents for air conditioning systems are best placed up high near the ceiling level in rooms: the cool dryer conditioned air will drop through the warm humid air causing desired air circulation while also taking heat and moisture as it moves.

Radiation

Radiation is energy that comes from a source and is transferred by traveling through space. It is sometimes called “line of sight” transfer, because it directly moves from one object to another. When you feel the warmth of sunlight on your skin, or when you put your hands next to a hot stove, you are feeling the effects of radiation. The amount of radiation emitted depends on its temperature and on surface characteristics. Higher temperature objects emit more radiation, and more powerful radiation. The only reason sunlight can reach the Earth from 93 million miles away is because it is so hot (and because space is a vacuum and does not absorb heat). When radiation waves reach an object, the energy waves are absorbed into the object, reflected and/or transmitted. The radiation of warm objects is used in infrared technology to allow us to “see” heat. In an infrared camera, heat radiation is converted to a visual screen image where warmer areas are lighter colors and colder areas are darker colors.

Driving Forces of Air Movement

Along with control of thermal movement (thermodynamics), the control of air movement throughout a home is the main purpose of weatherization. In other words, your main job as an installer is (after ensuring a safe and healthy home) is to allow control of air and temperature movement.

> **Delta P (ΔP):** difference in pressure. If two areas have a delta P between them, air will try to flow from the area of high to low pressure.

The forces that drive thermodynamics were just discussed, so what about air movement? Pressure and temperature differences throughout the home, and outside of the home are the main drivers of air flow. Unless forced to do otherwise air will *always* flow from an area of high pressure to an area of low pressure. Different air pressures that are in and around a house constantly try to equalize. As long as there is a difference in pressure (**delta P or ΔP**), there will a force trying to move the air from high to lower pressure. Air movement is a concern between the inside and the outside of a house because conditioned air in the house is constantly escaping or being diluted with unconditioned exterior air, causing the home to be uncomfortable and inefficient. If the air has a pathway (small or large), it *will* find its way into the home.

The bigger the delta P between the inside and the outside of the house, the greater the air flow will be through the exterior walls, roof and foundation, as long as it has a pathway (it will always find a way eventually). Also, a bigger pathway leads to faster and greater flow. There is little that can be done to reduce delta P between the inside and outside of the home, but preventing pathways is a primary part of an installer's job.

Air Movement: Temperature

The temperature difference between the inside and outside of a house is called delta T. Like pressure and air flow, the higher the delta T between the inside and outside of a building, the greater the force is for heat to escape or enter the building. And also like pressure movement, a better pathway for heat (poor insulation, big hole, etc.), the faster the heat will transfer. Combined, the best way to reduce heat loss is to either reduce delta T or minimize the pathways. Unless the occupant wants to be cold in the winter and hot in the summer, controlling delta T will not work. So again, controlling heat movement in and out of the home is a matter of eliminating pathways. This can be done through air sealing and insulating.

> **CFM$_{natural}$:** Amount (volume) of air leakage from a building under natural conditions. CFM$_{natural}$ can be thought of as the "breathing" rate of a building.

The natural air leakage rate of a house in summer might measure 40 cubic feet per minute (**CFM$_{natural}$**), but increase to 120 cubic feet of air per minute ($CFM_{natural}$) in winter. This is because the delta T is generally much higher in the winter than in the summer. In the heart of winter in moderate climate zone, it may be 10 degrees outside. Comfortable indoor temperature is around 65 degrees. Under these conditions, the delta T is 55 degrees. During a very hot summer day in the same climate, it may reach 100 degrees. This results in a delta T of 35 degrees. Thus, the delta T is 20 degrees bigger in the winter than summer – this means that the heat and air transfer is likely to be much more rapid in the winter. This increased delta T is therefore increasing the exfiltration forces as heat moves to cold through any pathway available. This is why the cost-effectiveness of a heating system replacement is generally more cost-effective than for cooling system replacements in regions that have four seasons. The leakage of homes due to heat escaping is the greatest portion of a house's energy waste.

Air Movement: Pressure
Recall from previously that the pressure difference between two areas or zones is written as delta P. The higher the delta P between the inside and outside of a house, the greater the force is for heat or cool air to escape or enter the house. The rate of heat and air transfer through the house's exterior increases as the delta P increases.

There are two especially important things (laws) to remember as installer:

1. The direction of the air flow is from positive (high) pressure to negative (low) pressure.
2. For every CFM (cubic foot per minute) of air that enters a space, one CFM of air must exit to balance out the pressure.

Again, air movement requires two things: a pathway and a delta P on either side of that pathway. The better the pathway and the higher the delta P, the greater the volume of air that will move through the pathway. Pathways do not have to be large for air to flow – in fact, most of the airflow in and out of a typical house are through very small leaks undetectable to the naked eye (see "indirect leakage" below). Pathways in the house's air barrier would not be a problem if there was no pressure difference between one side of the house and the other. However, most of the time there are pressure differences and air movement through the holes and openings.

Air Leakage Rate and Replacement
It is essential to remember that one CFM of air leaving a house requires that one CFM gets into the house. That is, the volume of air that leaks out of a home is replaced by the same volume of air that leaks into the home, usually at a different location. This airflow is measured in cubic feet per minute, also written "ft^3/min" or "CFM." A cubic foot is a "box" of air with each side being one foot. It is a little larger than a standard men's basketball. Air leakage affects energy use because conditioned air leaks out of a house and unconditioned air seeps in. The air that leaks in almost always has a less desirable temperature than the inside air (too hot in the summer, too cold in the winter). This constant leakage increases the total volume of air that must be heated or cooled to maintain comfortable indoor temperatures. This requires that

HVAC equipment be larger or be operated for longer periods of time, meaning there is more energy consumed.

Direct and Indirect Air Leakage

Direct leakage occurs at large, often intentional openings to the outdoors. In these areas, leakage enters and exits at the same location. Direct leakage is typically around doors, windows, soffits and vents. Indirect leakage occurs at smaller openings to the outdoors, and is almost always unintentional. In these areas, the gaps are often isolated behind cavities in the house's exterior. Air enters at one location, then eventually moves through and exits at a different location. Indirect leakage is the most common form of leakage, and is especially a problem in older homes. Unfortunately, indirect leakage sites are very difficult, if not impossible to detect without the use of a blower door. Fortunately, once they are detected, they can often be taken care of with relatively inexpensive measures.

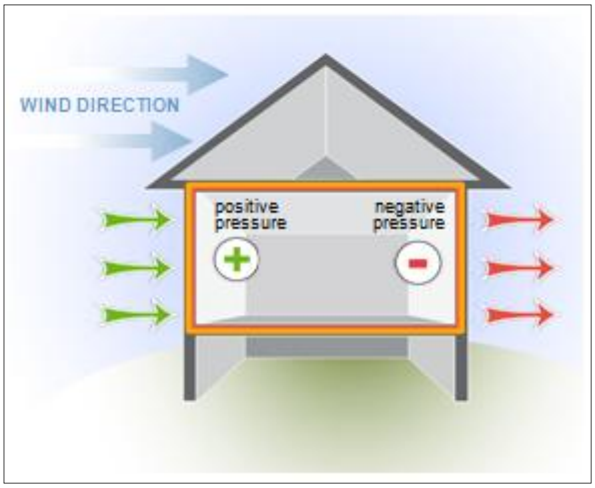
Common Conditions Encountered in the Home

Air movement into or out of a house is caused by the combination of temperature and pressure differences. The primary forces that cause pressure differences in a house are:

- The wind effect
- The stack effect
- The mechanical effect.

Wind Effect

Wind creates pressure effects on a house called the **wind effect**. When wind blows against the side of a house (the "windward" side), it creates positive pressure against the exterior wall of the house. At the same time, it creates negative pressure on the opposite side of the house (the "leeward" side). The effect is infiltration on the high pressure windward side as air is forced in, and exfiltration on the low pressure leeward side as air is pulled out (remember, air goes from high to low pressure areas). The Wind Effect varies considerably depending on where the house is located, the height of the house, and how well protected it is. This is why, during big storms, homeowners can crack the windows open to equalize the pressure. This unequal pressure can be uncomfortable.



The wind effect causes high pressure on the windward side and low pressure on the leeward side. (Image courtesy of US DOE)

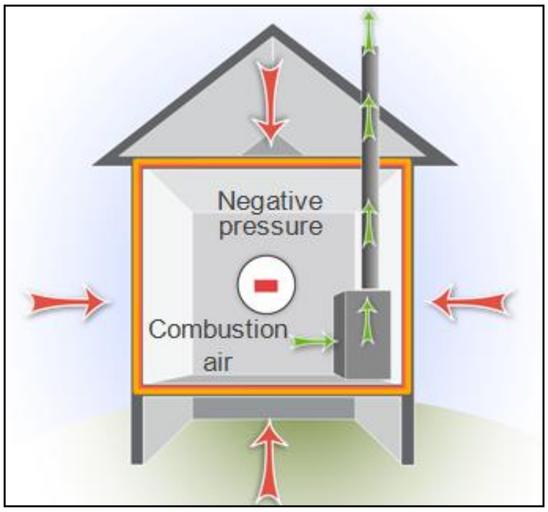
Stack Effect

The **Stack Effect** is a constant force causing air movement in the home. Warmer air rises and escapes out of the top of the house, creating suction that pulls outside air in at the bottom of the house. This is called the stack effect (this was mentioned in manual 1). Air leakage from the stack effect is very predictable. As hot air rises in the house, it creates a negative pressure in the lower portion of the house. Negative pressure creates air infiltration through the house's envelope *near the area of low pressure*. Positive pressure in the top of the house causes exfiltration through weak spots (big and small holes) in the building envelope.

Mechanical Effect

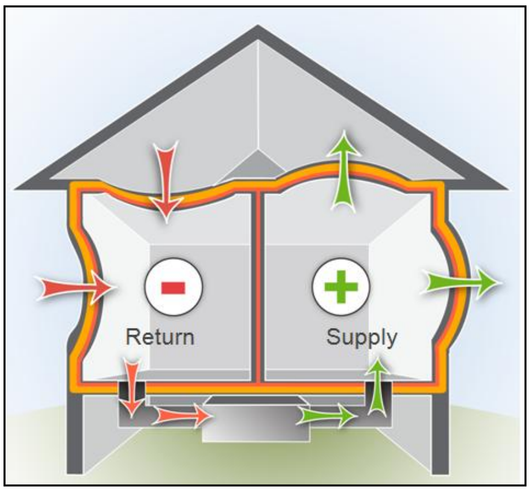
The **Mechanical Effect** is caused by the use of HVAC (heating, ventilation, & air conditioning) equipment in the house. Combustion appliances like furnaces and water heaters along with exhaust fans create negative pressure in the home as they blow air outside. This forced elimination of air leads to a pressure difference that pulls air from the closest sources of paths/gaps available.

Combustion appliances normally take their **combustion air** from inside the home and exhaust air out the **flue**. This creates negative pressure in the combustion appliance zone (CAZ). If there is not enough **replacement air** available, exhaust gases could be drawn back into the house, a dangerous condition known as backdrafting. This could result in unsafe levels of CO (carbon monoxide) in the house. This why it is essential to **always test before and after weatherization work**. Direct-vented appliances are a safer choice because they take combustion air directly from the outside and release flue gases back outside without causing depressurization of interior spaces.



Combustion appliances that draw combustion air from inside the thermal boundary cause negative pressure to occur inside the home. (Image courtesy of US DOE)

Duct leakage and unbalanced duct-based air distribution can create positive and negative pressures in different areas of the house. The pressures associated with duct leaks can be greater than natural air movement, because the driving force of a furnace blower is stronger than the wind on most days. This effect is significant when the leaky ducts are located outside the thermal envelope in unconditioned space like attics and crawl spaces. Closed doors and blocked return vents can also cause pressure imbalances in the house. There are two types of vents in a home: supply vents provide heated or cooled air to the room from a central unit; return vents draw air back into the system. Whatever volume of air goes into a room must go out (remember a CFM out = a CFM in), otherwise the room becomes pressurized. Often upper floor bedrooms have no return ducts. Return air then must



Unbalanced duct systems can cause pressure zones within a house. (The effects of pressure are exxagerated – the walls would not bend so dramatically.) (Image courtesy of US DOE)

Combustion air: air that chemically combines with fuel to produce heat. Oxygen is necessary for combustion to occur. Combustion air supplies oxygen for this purpose. When combustion air is used by the appliance, **make up air (replacement air)** must enter the building. This can be a major source of infiltration, because the makeup air often comes from outside the building.

Flue: a pipe that vents combustion exhaust from an appliance (e.g. furnace, gas-fired hot water heater) to outside of the building.

get under the closed door, travel along the hallway, down the stairs, and eventually into a central return on the first floor. Often these rooms are pressurized with too much supply air, and their return air never gets back to the furnace. It is easy to predict pressure imbalances based on the locations of return and supply vents throughout a home. Use of a blower door and manometer can result in detailed information about these imbalances.

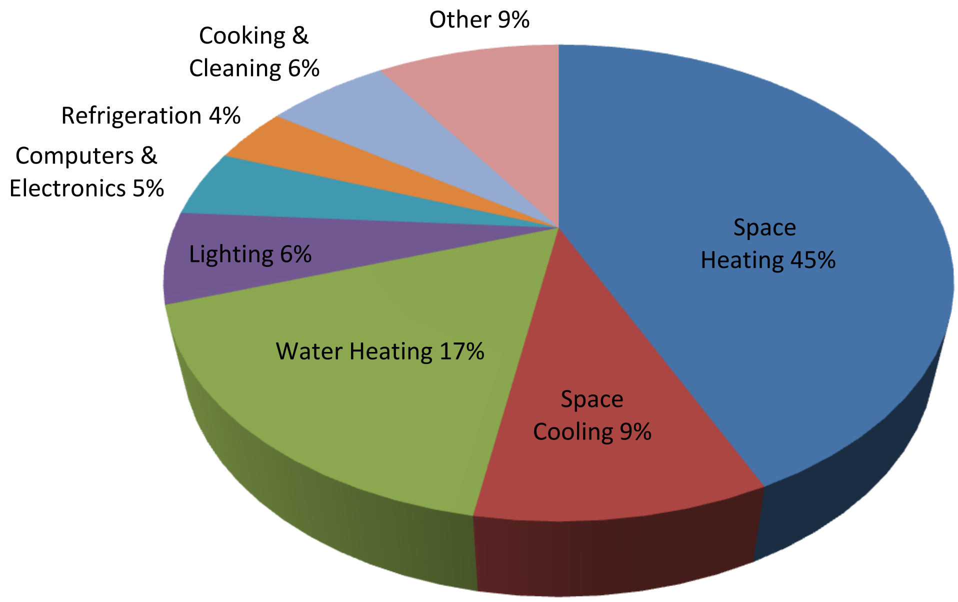
Topic 6: Baseload Energy Analysis

Baseload Overview:
A home's energy use can be divided into 2 major categories: bas load and seasonal. Baseload is the energy in a house that is regularly used by lighting, appliances, electronic devices and hot water heaters. Seasonal use is the energy used for heating and cooling a home's interior spaces, sometimes referred to as space conditioning. Seasonal space conditioning (heating and cooling) uses an average of 54% of the energy in homes, according to the DOE. In this case, the remaining "base load" energy use is 46%. Of this, heating domestic water takes approximately 17%. The remaining energy usage includes the refrigerator, lighting, cooking range, dishwasher, clothes washer and dryer, entertainment equipment, electronic devices, chargers, and "phantom/vampire loads". A phantom or vampire load is energy use that continues after appliances are supposedly shut-off. Many electrical devices like televisions continue to draw electricity while they are stand-by mode. Entertainment equipment (like big screen TV's, DVD players, and game systems), electronic devices (like computers and their peripherals), battery chargers, and phantom/vampire loads are included in the "other" category. This portion of utility use continues to increase as occupants purchase more electronic consumer devices.

Consumer education is important for lowering baseload energy use in a house. It is the essential route to creating baseload savings because baseload energy usage occurs every day. Typical baseload modifications and retrofits include replacing incandescent or halogen bulbs with CFLs (compact fluorescent lamps), and replacing refrigerators and domestic water heaters. The installation of low-flow showerheads and faucet aerators reduces water usage.

Consumption Analysis of a House's Energy Usage:
A house's energy usage can easily be calculated. One method is a consumption analysis that includes three steps:

1. Utility bill analysis: Calculate how much energy is devoted to baseload (see below).
2. Daily energy site survey: Determine what the house's main baseloads are.
3. Reconciliation of the two: Decide if the bills make sense in light of the site survey.



Typical average household energy use, by end-use (2010). Space heating and cooling are considered seasonal loads; the rest are considered parts of the baseload. (*Source: US DOE, Building Energy Data Book (2010)*)

Simple Baseload Analysis Method:
A baseload energy analysis of a house is performed by doing the following:
1. Use a table to arrange a house's utility bills by month. Include all energy bills – oil, natural gas, electric, etc.
2. For each month, note the total consumption of each source. Nowadays, many energy companies provide a bar chart of 12 months or more of energy usage. Use this if it is provided.
3. Find the energy usage for the three lowest months that have little-to-no heating or cooling costs included (spring and fall). Add these three months together and divide it by three. This figure will be the average monthly baseload of the house. This is not 100% accurate, but serves as a very good estimate.
4. To calculate the yearly baseload use, multiply the monthly figure by twelve.
5. The remaining utility usage is considered the seasonal load.

Bill Analysis Example:
The electric bill analysis table below is an example of the utility breakdown for an all-electric house. The critical facts are the month and the amount of kWh used that month. Note that 684 kWh makes up 49% of this house's average monthly energy bill and is considered the baseload usage. The remaining 51% can be separated into suspected heating and cooling loads.

Month	Total Electricity Usage (kWh)	Baseload (kWh)	Seasonal Load - Heating (kWh)	Seasonal Load - Cooling (kWh)
Jan	2,350	656	1,694	0
Feb	2,250	656	1,594	0
Mar	1,244	656	588	0
Apr	682	656	26	0
May	600	656	-56	0
June	992	656	0	336
July	1,327	656	0	671
Aug	1,642	656	0	986
Sept	900	656	0	244
Oct	685	656	29	0
Nov	1,190	656	534	0
Dec	2,044	656	1,388	0
Total	**15,906**	**7,872**	**5,797**	**2,237**
% of Total Energy Usage		**50%**	**36%**	**14%**

Sample Breakdown of Electricity Usage in a Home. Note the distribution and timing of baseload and seasonal loads.

Post-Survey Analysis:
After analyzing consumption, the question is if the baseload energy use can be lowered. The existing lighting, refrigeration, DHW (domestic hot water heater) or other baseloads must be examined to determine if they can be reduced. Some possible ways to reduce baseload are:

- Appliance repairs to increase efficiency
- Using power strips to reduce phantom load
- Replacement with more efficient units like CFL bulbs or a new refrigerator
- Client education to eliminate over-use or misuse
- Client education and improved conservation

There are many factors that affect the energy efficiency of household appliances, including:

- Age: most appliances decline in efficiency each year they are in use.

- Technology: efficiency improvements in lighting, refrigeration and heat have been substantial over the past decade, usually making upgrades worth the investment.
- Standards: federal efficiency standards at the time of manufacture regulate the appliance's maximum energy use. Newer appliances are generally going to be more efficient "out of the box" than older appliances were when they were new.
- Size: bigger usually more energy use.
- Special features: through-the-door ice and water service on refrigerators increase energy usage significantly. Moisture sensors on clothes dryers reduce energy use.
- User habits: occupants leave lights on, stand in front of an open refrigerator deciding what to eat, and run heating and air conditioners with the windows open thereby wasting energy.

The greater the energy being wasted that can be identified, the greater potential for future savings.

Topic 7: Energy Efficiency Strategies for Appliances

Lighting Efficiency

Incandescent Bulbs

Standard **incandescent lamps** (bulbs) have been around for over 100 years. It may be hard to believe, but the technology has not changed significantly since that time. They are the most common and most *inefficient* light source available. These standard incandescent lamps produce light from a tiny coil of tungsten wire that glows when heated by an electrical current. Much more energy is spent creating the heat to make the wire glow than to produce light (only about 10% is used for light; 90% is wasted as heat). Some countries have already phased out incandescent lighting. In the United States, the manufacturing phase out of incandescent bulbs will start in January of 2012. Newer lighting technologies make better use of energy by creating more light than heat.

Compact Fluorescent Lamps

According to the DOE, lighting accounts for an average of 10% of residential energy costs[3]. (Note that lighting is only about 6% of energy *use* – this discrepancy is the result of electricity being more expensive than other forms of energy, on average.) As noted above and in manual 1, compact fluorescent lamps use about 75% less electricity than incandescent. CFLs can be used to replace incandescent without changing the fixture, so they are very easy to use. Just by replacing the all bulbs with CFLs in a home can thus save about 7.5% of the annual energy bill. The average home uses around 12,000 kWh per year, so this would mean a savings of about 900 kWh. At $0.15/kWh, that's a savings of $135! Not bad for replacing a few bulbs. And don't forget, these savings would continue as long as the bulbs stay in place.

Another advantage of new CFLs that you can leave them in longer than incandescent - they can last up to five years, instead of one to two years typical of incandescent bulbs. It is important to note that a general-use CFL is not designed to work with dimmer switches and will cause it to

[3] Source: Building Energy Data Book (2010).

have very short life spans. Dimmable and three-way CFLs are now very easy to find, as are most uses (flood lights, outdoor lights, candelabra, etc.).

Lighting Technology

There are three main types of bulbs ("lamps") that are either in use or will be in use in homes:

Incandescent bulbs run electricity through a thin metal coil (the "filament"), which produces heat and light. Incandescent design has changed very little since it was invented in the late 1800s. It is very inefficient – around 90% of the electricity is lost as heat.

All images courtesy of US EPA

Compact fluorescent lamps (CFLs) do not have a filament. CFLs are filled with a gas (mostly neon or argon) that emits ultraviolet (UV) radiation when excited by electricity. UV is invisible, so a coating is put on the inside of the bulb that lights up when UV hits it. CFLs use about 25% of the energy of an incandescent that gives off the same light, and last about 10 times longer.

Light emitting diode bulbs (LEDs) have a series of tiny bulbs that contain a special material that lights up when electricity is run through it. They use about 20% - 25% as much as electricity as incandescent, but last up to 25 times longer. They are much more expensive than CFLs, but are getting cheaper as demand for them increases.

CFLs and LEDs will save the homeowner money! They are more expensive to buy, but since they last much longer and use less electricity, they save money in the long run. Don't be fooled by cheap lighting - think long-term!

CFLs do contain some mercury, but the amount of mercury in a CFL is very small. It is large enough that it is strongly recommended that they be recycled to capture the mercury and other components. Some home centers that sell CFLs have recycling programs that accept old bulbs. You can also check the Internet website www.earth911.com for other locations. Another option is bring them to municipal disposal sites set up for electronics recycling and disposal. If a bulb breaks, the EPA (United States Environmental Protection Agency) recommends that you get people (especially children and pregnant women) and animals out of the room and open a window to air out the room. Use cardboard to "sweep" fragments up and use tape to pick up smaller pieces. Do not vacuum, as this will disperse the mercury into the air. Put all pieces in a bag or jar. After all visible pieces are picked up; wipe the area with a damp paper towel and dispose of all clean-up materials in a closeable jar or double-bagged enclosure. Clean-up information is also available at EPA website: www.epa.gov/cfl/cflcleanup.html.

LED Lighting

More recent lighting technology is the light emitting diode (LED) light. LEDs are extremely efficient, emitting almost no heat. LEDs last longer, are more durable and offer better light quality than nearly any other type of lighting available. However not all types of bulb replacements are available in LEDs and some are still too costly to make economic sense even though they reduce energy use. This technology is becoming more common and appears to be the lighting of the future. An example of the trend toward LEDs can be seen with computer monitors: The 300 watt CRT (cathode ray tube) computer monitor was replaced by the 150 watt LCD flat screen which is now being replaced by LED screen which can operate at 28 watts. Cost savings can be dramatic if used on a large scale: the city of Portland, Oregon started saving about $400,000 per year in costs by installing around 14,000 LED traffic lights in 2001[4].

Lighting Output [5]	Light Emitting Diodes (LEDs)	Incandescent	Compact Fluorescent (CFLs)
Lumens	**Watts**	**Watts**	**Watts**
450	4-5	40	9-13
800	6-8	60	13-15
1,100	9-13	75	18-25
1,600	16-20	100	23-30
2,600	25-28	150	30-55
Cost per year	**$24 - $36**	**$205**	**$49 - $68**

Comparison of Energy Use and Estimated Cost of Use for Lighting Technologies. Note that the cost calculation assumes the use of ten 75 Watt equivalent light bulbs were used for 5 hours each day, at a cost of $0.15/kWh. (*Source: Design Recycle Inc.)*

In a residential setting, the switch to more efficient light bulbs rarely requires retrofitting fixtures with new parts or replacing entire fixtures. If fixtures do need to be replaced, the cost of the fixture needs to be considered in the Savings to Investment Ratio (SIR). Changing fixtures is more common in industrial, commercial and institutional settings.

Another way to generate energy reductions and lower lighting use is to use automatic lighting controls (on/off switches). This can be much more efficient than when lights are manually controlled, and often left on when not needed, by the home owner. Some automated lighting controls that are available are:

[4] City of Portland, *LED Traffic Signals = Energy Savings* (2001). Available at http://www.portlandonline.com/bps/index.cfm?a=111737&c=41888

[5] Lumen and wattage output can be found at http://www.designrecycleinc.com/led%20comp%20chart.html.

- Electronic timers that turn lighting on and off on a pre-determined schedule
- Crank timers that are spring driven and go on when someone enters a room then go out after set times
- Photo cells that respond to available natural light (lights dim when natural light inside a room increases)
- Automated dimmers that raise and lower lighting throughout the day
- Sensors that go on when they sense movement and go out after no movement for a set time

Appliances

As discussed above, baseload energy demand in a house comes from domestic water heating, entertainment and electronics, and appliances. The appliances (refrigerators, clothes dryers and dishwashers) can account for a large portion of a house's baseload consumption. It is important to determine the age and condition of the refrigerator, and consider replacing it with a newer Energy Star-rated unit. A portion of the dishwasher's and clothes washer's energy use is for the heating of hot water. While hot water is essential to dishwashing, it is optional for clothes washing – cold water is sufficient for all but the most heavily soiled loads. Energy Star-rated dishwashers and clothes washers are now available. High speed washers do a better job of wringing water out of clothing with their advanced spin cycles. This in turn cuts down of the time and cost of drying clothing. Gas clothes dryers are typically less expensive to operate than electric dryers. They must be properly vented and have an adequate supply of combustion air for the gas to be burned as well as make-up air needed for all dryer exhausts. The cheapest way to dry clothes is to hang them outside, which can be done year round. Many utilities and state governments offer rebates for efficient appliance purchases. Check the Database of State Incentives for Renewables & Efficiency (www.dsireusa.org).

Refrigerator Replacement

Energy usage of a refrigerator can be calculated by using a Kill-a-Watt™ to directly measure the energy use, or by using data from a recognized database available online, such as the Association of Home Appliance Manufacturers (aham.org) or (www.kouba-cavallo.com/refmods.htm). If the refrigerator is an "energy hog", simply replacing the appliance will reduce the energy bill. Comparing the energy cost from the existing appliance to a new version of the same capacity will illustrate the savings. It is also possible to increase energy savings by analyzing certain features and design options that are energy efficient. For example, through-the-door ice-makers and water dispensers increase energy use and lower the efficiency. Side-by-side refrigerator/freezers are less efficient then models with freezers on top. When replacing a unit, all old used appliances need to be decommissioned and recycled to protect the environment. Some utilities offer rebates to customers who turn in an old refrigerator or purchase a newer qualified model.

Calculate the Baseload Savings of Simple Appliances

In order to calculate energy use of electric appliances, three things are needed: the power used by the appliance, the amount of time the appliance is used for, and the cost of electricity. The chart below is a handy way to determine this. This kind of chart is a useful tool for weatherization workers, because they can show occupants how much money they can save by replacing appliances and bulbs, or using them less.

Appliance Name (e.g. light bulb, TV, etc.)	**Replacement Appliance or Use (e.g. low-energy bulb, low-energy TV, using lights less, etc.)**
Power use = _________ W	Power use = _________ W
Hours used per day = __________ hrs	Hours used per day = __________ hrs
Days used per year = __________ days	Days used per year = __________ days
W x Hr x Day = __________ total Watts	W x Hr x Day = __________ total Watts
Total Watts / 1,000 = __________ kWh used per year	Total Watts / 1,000 = __________ kWh used per year
Cost per kWh = $______/kWh	Cost per kWh = $______/kWh
Total cost/yr = _____ kWh/yr x $____/kWh = $ ______	**Total cost/yr** = _____ kWh/yr x $____/kWh = $ ______
Total Energy Cost Savings = $_____ - $______ = $______	

Guide to calculating energy use and cost of electric appliances

Refrigerator Energy Study

A detailed analysis of refrigerator use and energy consumption was conducted by energy analyst Michael Blasnik[6]. Blasnik is a very well-regarded energy efficiency expert. The study found that energy use is often higher than the official rating on the refrigerator label. Different factors were developed to help calculate the actual energy use. Findings from this study have not yet been formally adopted into WAP protocol but they can help building analysts more accurately predict energy usage of household refrigerators based on approved databases. If relying on a refrigerator energy use database for usage estimates, applying the study's findings presents a more accurate picture of how much energy is actually being consumed. Specifically, Blasnik found that if you live in the Northeast U.S., add 11% to the estimated EPA energy rating for any refrigerator used in a living space (e.g. kitchen).

Some simple strategies were developed to reduce waste in refrigerator use include:

- Keeping refrigerators as full as possible
- Opening doors as little as necessary
- Having only one unit per house

Refrigerators are becoming more energy efficient overall, but keep in mind that some newer models actually use *more* energy than older models. This can be due to a number of factors. This can happen when an older top freezer is replaced with a side-by-side or bottom freezer

[6] The full results can be accessed at http://www.cee1.org/eval/db_pdf/394.pdf.

style. Both of these use more energy than an efficient top freezer. Also, water and ice dispensers are very convenient, but waste energy by lowering the insulation value. The following table summarizes the Blasnik survey results:

Factor	Proposed Audit Approach	Notes
Number of occupants	Add an additional 5% per occupant to refrigerator rated use	Only for primary household refrigerators
Anti-sweat switch in "on" position	Add an additional 20% to refrigerator rated use	Expect approximately 15% higher energy cost
Through-the-door ice dispenser	Add an additional 15% to refrigerator rate use	Captures side-by-side effect
Visible gaps in door seal	Add an additional 15% to refrigerator rate use	Related to continuous running of refrigerator
Refrigerator purchased used	Add an additional 20% to refrigerator rate use	Related to continuous running of refrigerator
Average kitchen room temperature	Add an additional 5% to refrigerator rate use if average winter temperature is in low 70's	Annual exterior temperature can be accounted for by adjusting refrigerator usage up or down if average winter household thermostat settings are outside the typical 65° – 70° Fahrenheit
	Subtract 5% from refrigerator rate use the average winter temperature is in low/mid 60s	
Base level usage	85%	Usage estimates if there are no occupant or no through-the-door ice dispenser, the anti-sweat switch is not on, the door seals are in good condition, the unit was purchased new and the household winter thermostat settings are normal

Summary of results from the Blasnik refrigerator study. (S*ource: Blasnik, 2004)*

Topic 8: Domestic Hot Water

Overview:

Domestic hot water heaters (DHWs) are an important modern convenience. Any appliance or system that provides hot water for household uses is considered a DHW. Water heating is a large energy user in the home (~17%, according to DOE) because it is necessary for so many domestic activities, such as cleaning clothes, washing dishes, and bathing. Whether replacing a worn-out existing water heater or looking for the best model for a new house, it pays to choose carefully. Higher efficiency units have features such as better insulation, an electronic igniter to replace a wasteful burning pilot light (for gas heaters), and power venting fans which only allow venting when a gas-fired unit is on. Paying a little more up front can and should result in energy and cost savings down the road.

There are other (cheaper) options for saving energy as well:

- Take shorter and/or fewer showers.
- Replace old showerheads with lower gallons-per-minute showerhead. Replacing a showerhead with a standard flow rate of 3 to 4 gallons per minute with one that delivers 1.75 gallons per minute reduces water usage by more than 50% even if the length of the shower remains the same.
- As mentioned above, wash clothes in cold water.
- Make sure the dishwasher and clothes washers are full when being used.

Domestic Hot Water Heaters

Most domestic hot water (DHW) heaters contain the parts listed in the diagram. Some key parts:

- **Flue/vent pipe**: exhausts combustion gas from the building (only in gas-fired heaters)
- **Draft diverter**: helps gases go into the flue (only gas-fired); prevent downdrafts from entering the tank
- **Temperature & pressure relief valve**: vents steam or water if the pressure inside the tank is too high
- **Insulation**: keeps the heat inside the tank to make it operate more efficiently
- **Dip tube**: delivers cold water (before it's heated) into the bottom of the tank
- **Thermostat and gas valve**: sets water temperature; controls flow of gas into combustion chamber
- **Burner**: heats the water. For electric heaters, a heating element is used (this is a piece of metal that gets hot from electric coils inside) – most electric heaters have a top and bottom heating element.

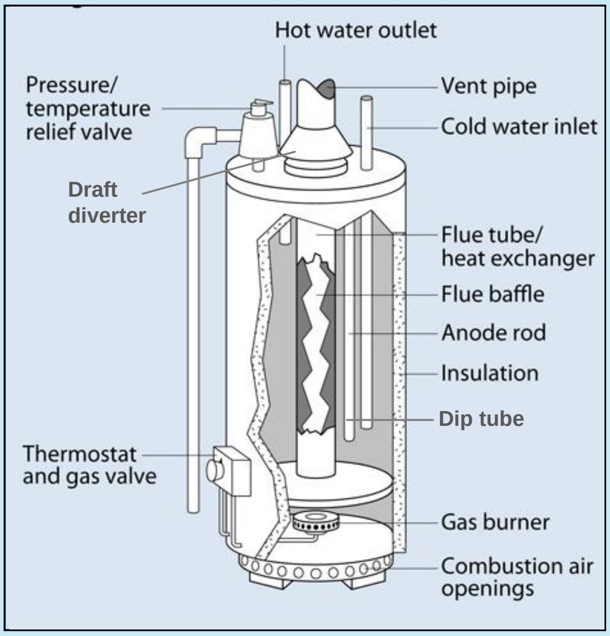


Image courtesy of US EPA

- **Anode rod**: protects the tank from corrosion
- **Gas supply (not shown)**: supplies gas for combustion (electric heaters have power cords instead)
- **Hot water outlet**: where heated water leaves the tank

Hot water heaters use and waste energy in three ways: During demand for water when water is being heated in the tank or heat exchanger; during distribution when water is being used at a faucet and flowing through the pipes; and during standby when the tank is waiting unused but keeping water hot. The demand requirement can be reduced by water conservation or replacement with more efficient units. Distribution losses can be reduced by insulating pipes and decreasing the distance of pipe runs to the plumbing fixtures. Standby losses can be reduced by lowering the thermostat temperature or through the purchase of more efficient units, including on-demand ("tankless") DHWs. On-demand DHWs have no standby losses because there is no tank. On-demand hot water heaters only heats water when a faucet is opened. This type of system works best when the heater can have a direct and short pipe distribution run to the faucet. Tank storage has become more efficient with improved insulation and by making the heat exchange with the tank water more efficient. Note that all of these upgrades have up-front costs associated with them, and careful consideration should be made when purchasing a new heater.

Hazards That Require Hot Water Heater Unit Replacement	
Issue	**Notes**
Excessive tank corrosion has caused irreparable water leaks	Prolonged water can cause floor damage that requires repair
Missing parts are no longer available	E.g. a part replacement cannot be found for a draft hood and the carbon monoxide level cannot be adjusted to acceptable levels with a generic draft hood
The hot water heater is full of corrosion and sediment that cannot be flushed out	When this occurs, the hot water heater cannot provide an adequate amount of hot water due to the corrosion and sediment. Upon inspection, the sacrificial anode has corroded away
Hazards That Do Not Require Hot Water Heater Unit Replacement	
Issue	**Solution**
Combustion byproducts are not venting to the outside properly (CO hazard)	Blocked chimneys, vents terminating inside the living space and backdrafting can be identified and remedied without having to replace the existing hot water heater.
The flame is impinged (CO hazard)	The hot water heater has the wrong burner nozzle for the fuel type. To remedy, the nozzle can be replaced with one appropriate for the current fuel type
Combustion air and gas pressure settings are out of adjustment (CO hazard)	Air and gas pressure can be adjusted to reduce carbon monoxide to acceptable levels
Atmospherically-vented natural gas-, propane- or oil-fired hot water heater is located in a bedroom, which violates the building code	If the hot water heater location prohibits the ability to weatherize a house, the weatherization crew or contractor could move the existing hot water heater for a modest cost.

Common health and safety hazards and solutions related to hot water heaters.

Assessing a Domestic Hot Water (DHW) Heater's Condition:
The condition of the hot water heater can be assessed to determine if a replacement is necessary as a health and safety measure by using the following steps:

- Determine the age and assess the condition of the appliance.
- Test the draft of gas water heaters under "natural conditions."
- Replace the unit if needed.
- If in good working order: Insulate the tank and the first six feet of pipes.
- Check and adjust the thermostat set temperature, ideally to 120 degrees F.

The table above can be used to help assess whether or not a DHW unit should be replaced.

Spillage and Backdrafting
Gas-fired hot water heaters emit toxic fumes (the combustion gases) that need to be vented outside of the home. Some systems use the natural buoyancy of hot air (hot air is less dense than cooler air, and rises naturally) to force the combustion gas out of the home. This is called natural, or atmospheric, venting. When a gas-fired hot water heater is naturally vented, there is a danger that "spillage" can occur. Spillage is the temporary emission of harmful gases such as carbon monoxide escaping into the area around the heater. In order to overcome this, the vent system needs adequate draft. Draft is the upward motion caused by buoyancy of hot gases (draft can be assisted by internal fans as well). In addition, the depressurization around the heater can cause "backdrafting", which pulls combustion gases back into the house rather than venting to the outside. Backdrafting can be caused by other appliance such as dryer and bathroom vents forcing air outside in other areas of the home. When this occurs, it is more difficult for combustion appliances such as gas-fired DHW to properly vent their combustion gases. In essence, the gases get sucked back into the home. This is more likely to happen in homes that are well-sealed. This is a very dangerous situation, and needs to be taken care of immediately if it occurs. (See manual 3 for a more in-depth discussion of combustion hazards and analysis.) Note that there are specially-designed DHW units that prevent this from occurring by using internal fans to increase draft and/or pull in air from the outside, instead of inside the home.

Hot Water Temperature
Many homeowners do not understand the way water heaters work**.** Some turn up the thermostat to the hottest setting and leave it there. This is overheating the water, wasting energy by maintaining unnecessary high temperatures, and shortens the life of the water heater by raising the tank pressure. One way to reduce energy use is to lower the water heater temperature setting to 120°F. This will deliver hot water and limit standby losses. (Also this is considered a safer temperature considering young children or unaware guests could turn hot water directly on and get scalded with hotter water). If a water heater is electric, the energy reduction available from setting the temperature back from 140°F to 120°F can save 343 kWh/yr, or almost $40 per year (at $0.11/kWh). Be careful when setting a water heater thermostat. There are different ways they are marked and spin. The markings usually d o not

have temperatures on them and they are often inaccurate. To check your setting, test the water temperature *at a running faucet or shower* with a thermometer that goes up to 150°F.

Hot Water Tank Insulation

Insulating hot water tanks can reduce standby losses by keeping the tank warmer longer. The minimum recommended hot water system treatment is to insulate the water heater with a fiberglass blanket and cover the first six feet of hot water pipe. It is wise to cover all exposed hot water piping in order to insulate the water already heated for use and waiting in the pipes.

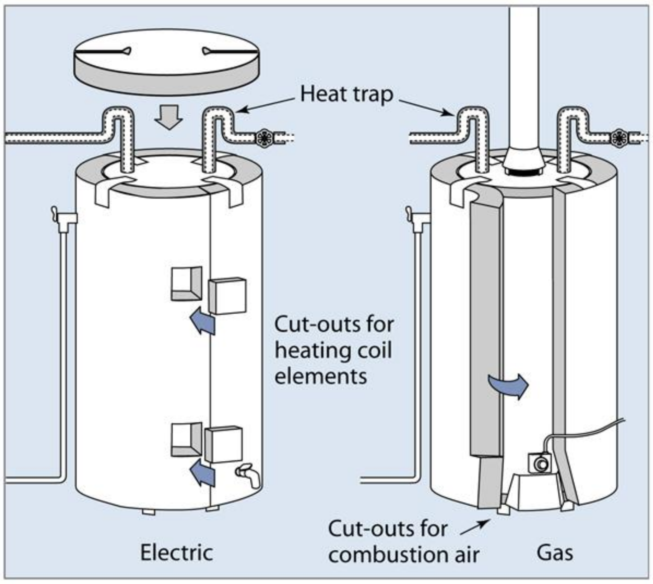


Illustration of how to insulate a gas-fired and electric hot water heater. It is extremely important to not to cover the top and combustion air inlets on gas-fired heaters. (Image courtesy of US EPA)

It is an easy process to apply insulation to a water heater. The step-by-step instructions are on most packages. If the unit is electric, it can be covered entirely, making sure to mark where the access panel is located. If the unit is gas, the sides can be covered but not the top. For a gas unit, the wrap must also be kept away from the gas valve, access door, and above the combustion air inlets. In order to detect leaks easily, don't cover the bottom six inches of the tank.

Hot Water Pipe Insulation

No matter what type of water heater is used, it is always advisable to minimize delivery losses by insulating the pipe runs. This is a low cost, easy first step toward energy efficiency. There are many types of pipe insulation, but inexpensive and very effective wrap can be bought at most hardware stores. It is very easy to apply, requiring only basic coordination.

When installing pipe insulation, simply cover the straight runs with long pieces of insulating sleeves. They can be cut with any sharp knife, and most can be cut with scissors as well. The elbows also need to be covered completely to prevent losses of heat at the point where the water is under pressure at the turn. Install insulating sleeves cut at a 45-degree angle and taped over with insulating tape to cover the joint. On gas water heaters, keep pipe insulation six inches above the flue hood opening and away from the flue pipe. Insulation too close to these hot areas is a fire hazard.

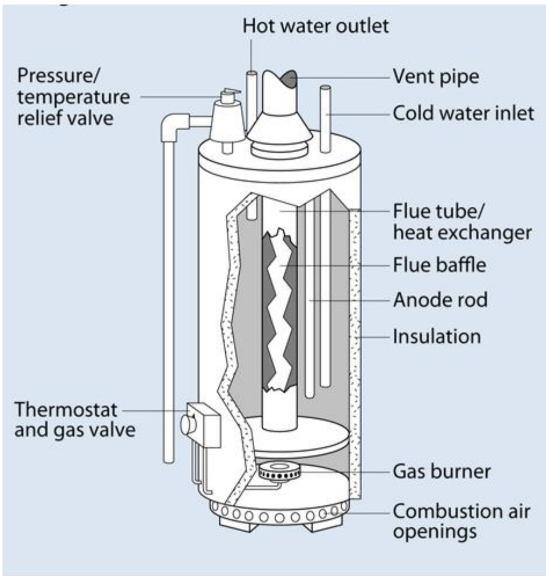
Pipe insulation is very inexpensive and easy to install. (Photos © eca)

Reduction of Hot Water Use
Hot water usage can be decreased by repairing leaks and installing low-flow fixtures. Repairing a hot water tap leaking a mere two drops per minute can save almost $16 a year for an electric hot water heater, based on a cost of $0.11/kWh. Repairing larger leaks save substantially more. Repairing a hot water leak dripping at the rate of one drop per second will save more than $300 a year based on the same energy prices.

Replacing showerheads that have a flow of 3 gallons per minute (gpm) or more with low-flow showerheads of 2 gpm or less can save significant amounts of energy, and do not require any behavioral changes. Showerheads are very easy to install – simply screw off the old showerhead, wrap plumbing tape around the threads, and screw on the new showerhead. Installing faucet aerators in the kitchen and bath are also beneficial and easy to do. Aerators mix air with the water coming through the faucet, which reduces the flow of water without significantly affecting faucet performance. If you are replacing appliances consider Energy Star-rated dishwashers and high-efficiency clothes washers. Finally, the behavior of the homeowner is very important in reducing hot water use. Making sure that dishwashers are full before runs, using warm and cold water cycles on the clothes washer, and taking showers of reasonable time lengths all contribute to hot water energy savings.

Types of Water Heating Units

Storage Water Heaters
By far the most common type of hot water heater in the United States today is the storage type water heater. These generally ranging in water storage capacity from 20 to 80 gallons and can be fueled by electricity, natural gas, propane or oil. Storage water heaters transfer heat from a burner or electric heating coil to water in an insulated tank. Because heat is lost through the flue (except in electric models) and through the walls of the storage tank, energy is consumed even when no hot water is being used.



Schematic of a gas-fired storage hot water heater. (Image courtesy of US DOE)

A new energy-efficient, gas-fired storage water heater is a cost-effective replacement option for current water heaters if there is a gas line in the house. They have high levels of insulation around the tank and one-way valves where pipes connect to the tank substantially reducing standby heat loss.

Newer, super-efficient “condensing” and “near-condensing” gas-fired hot water heaters save much more energy compared to traditional models but are currently niche products and more expensive.

<u>Storage Water Heaters: Closed or Sealed Combustion</u>

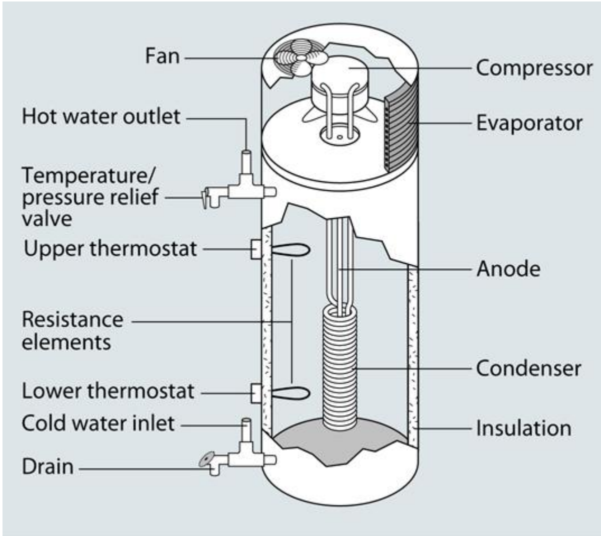
The gas burners of a hot water heater need a source of combustion air which can come either from inside the house or be drawn from the outside. If the burner takes air from inside the house, it competes for this air with other appliances (e.g. exhaust fans and furnaces). In addition, the exhaust gases from all combustion must be discharged to the outside. As noted above, the force of the exhaust (combustion gas) going out of the house can be overcome by other appliances, causing toxic fumes to come back into the home ("backdrafting"). Backdrafting of appliances and fans can cause dangerous, even deadly, gases to build up in the interior of the house. This is why testing is always done before and after weatherization work.

To solve these problems, water heaters and other combustion appliances have been developed that use outside air for combustion. The intake and exhaust piping of a hot water heater can be completely sealed, so no air is pulled in or goes out into the home. All air is pulled in directly from the outside, and exhaust goes directly outside. The piping system can be two separate pipes (requiring two holes through the outside wall), or "co-axial" piping (where one pipe is inside the other), requiring only one hole to be cut through the house's exterior wall. These units are available as power-vented models using electric fans to force draft, or as direct-vent natural draft units. (There are also power-vented units that use combustion air from inside the house that are not sealed combustion units).

A "direct vent water heater" does not have a power fan. It relies on natural air flow for circulation. A direct vent heater draws intake (combustion air) from the exterior through a pipe that passes through an outside wall. It also expels exhaust gases horizontally through the outside wall. Because the direct vent system depends on natural air currents for adequate flow, a gas water heater can only be located a maximum of four feet from the sidewall. If this is not possible, it may be necessary to install a power fan in the exhaust system.

<u>Electric Hot Water Heater</u>

Traditional electric water heaters are efficient and safe, but they can be expensive to operate because of high electricity rates. Though electric models have a higher energy factor than fuel-burning models, electrical resistance is a very expensive way to generate heat. It is less than ideal environmentally, as well, since electricity is only as clean and efficient as the fuel (often coal) that generates it. Before electricity is ruled out, check with the utility company and the fuel cost conditions in your area. It may offer special off-peak rates or options for purchasing renewable power that would make electricity a more attractive option.

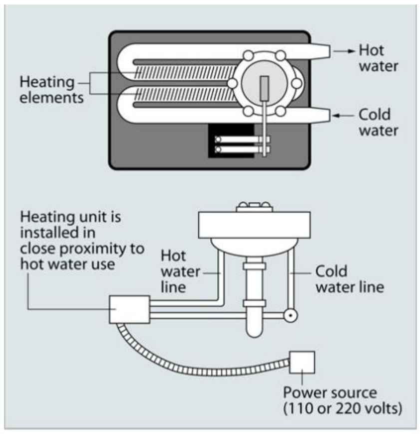


Electric heat pump hot water heaters use a heat pump instead of electric coils to heat the water. (Image courtesy of US DOE)

<u>Heat Pump Water Heaters</u>
Newer electric models that use a heat pump are more efficient because the electricity is used for moving heat from one place to another rather than for generating the heat directly. The heat source is outside air or air in the basement or room where the unit is located. Heat pump water heaters are not very common at this time and costs are considerably higher than more traditional models.

A heat pump water heater uses one-third to one-half as much electricity as a conventional electric resistance water heater. As they use heat from the surrounding air, they may do even better in warm climates. They should be located in a large un-cooled space with about 7 feet of headroom. As more units are installed, these high-efficiency hybrid heat pump units will become more affordable.

On Demand Water Heaters
On demand ("tankless") water heaters do not contain a storage tank. A gas burner or electric element heats water only when there is a demand for hot water. These are small units (a few square feet) that affix to a wall. Cold water goes in through a pipe. When hot water is required, the cold water goes through heating coils inside the unit, and comes out hot on the other side. Hot water never runs out, but the flow rate (gallons of hot water per minute) is limited. By eliminating standby losses from the tank, energy consumption can be reduced by 10% to15% but are not appropriate for every situation, especially when large amounts of hot water are needed (e.g. running multiple hot water appliances at the same time). Because of this, tankless water heater performance is much better when coupled with water efficient devices that limit flow rate demands, such as low-flow faucets and shower heads. Tankless water heaters are very expensive to purchase and install, but can save money in the long run if used properly.



Schematic of On-Demand Hot Water Heater. (Image courtesy of US DOE)

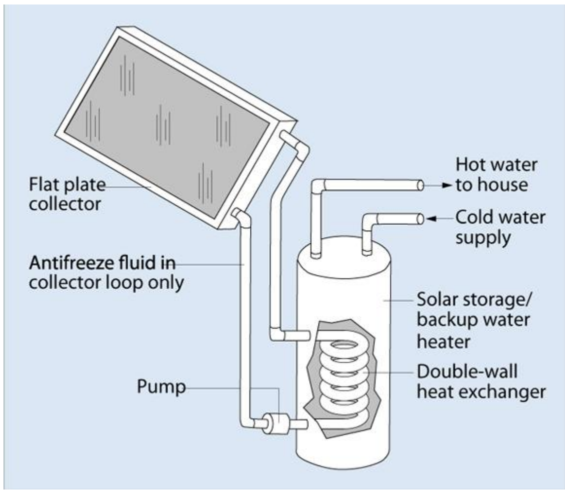
Indirect Water Heaters
If a home is heated with a boiler, ask the contractor about the feasibility of installing an indirect water heater. These use the boiler as the water heater by circulating hot water from the boiler through a heat exchanger, in a well-insulated water heater tank. Older units of this type were known as "summer/winter" units because the house heater runs in the summer to provide hot water. Newer boiler units are much more efficient than older ones. Another option is an *integrated* unit, providing space heat and hot water in one combined unit.

An indirect water heater is an energy-efficient option because it eliminates the tremendous flue losses associated with gas-fired storage water heaters. It also avoids the hassles and extra costs of tankless gas water heaters. When used with a modern, high-efficiency boiler, energy savings can occur even in summer, when the boiler isn't needed for house heating. These systems can be purchased in an integrated form, incorporating the boiler or furnace and water heater with controls, or as separate components. Gas, oil, and propane-fired systems are available.

Solar Water Heaters

Using the sun to heat water is a fundamentally simple concept. The technology has actually been around for thousands of years, though it has advanced considerably since then. Solar water heaters can be a great investment because they offer a virtually cost-free (after installation) and renewable energy source. Solar hot water uses thermal collectors to heat water directly (less common) or heat a fluid that then goes through a heat exchanger to heat tank water. The thermal collectors readily absorb sunlight, and must be placed in a sunny location.

An initial site analysis is needed to assess the feasibility and benefits of a solar water heater for each home. Good and consistent access to direct, unshaded sunlight is essential to efficient operation of the system. The home’s orientation (the direction the roof is facing) and the location of large shade trees or adjacent structures must be considered when considering a system. In addition, the typical seasonal changes of cooler outdoor temperatures coupled with less hours of daylight effects the amount of hot water produced. It takes an expert to know what the costs and benefits will be. As with all solar generation, the investment is in terms of years, but daily use in a good climatic condition for solar water heating can pay off in as little as four years.



Schematic of Solar Hot Water Heater. There are a number of systems available, but the basic components are represented in this image. (Image courtesy of US DOE).

Weatherization and Retrofit

Energy Coordinating Agency

APPENDIX D

Manual Two Lab Exercises

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Lab 1: House Framing

The design and quality of construction of a home plays an essential role in determining how efficient a home is. As a retrofit installer, it is important that you know the basic design and components of houses. All parts are connected in one way or another (remember the home is a system of interconnected parts). Understanding and identifying framing components will help you maximize the effectiveness of weatherization measures.

After this lab is completed, you will be able to identify basic framing components of a home.

Tools	Consumables	Safety Equipment
Writing utensil	None	As needed

Approximate time needed to complete this lab: 1 hour

Procedure

CAUTION:
This lab is best done in the field or in a whole-house mockup (see photo below). If entering a job site, be sure to follow safety protocol and wear appropriate PPE.

Walk the House and Identify Components

1. The instructor will ask you to identify framing components as you walk around, through, and under the home. Write down the name of the component as asked. Try to do this without consulting with your classmates.
2. You may also be asked to identify basic combustion, ventilation, plumbing and other components.

Discuss the Function of Components

1. After all components have been identified, the instructor will lead you through the house again, and discuss the name and function of each component, as well as how it relates to weatherization

Whole House Mockup with Exposed Framing. (Photos ©)

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Lab 2: Dense-Pack Insulation

Cellulose is a popular blown-in insulation material because its small particles fill in the irregular areas of wall spaces. It is made from recycled paper that is treated with a fire-retardant. For weatherizing older buildings, cellulose insulation can be added to existing wall and ceiling cavities. Dense-packed insulation is especially useful because it provides both air-sealing *and* insulation. A properly dense-packed cavity of 3.5 lbs./cu.ft will stop air movement.

Using the blowing machine is one part of the job that will be covered in a step-by-step fashion below. This includes properly using the machine's switches and settings, inserting the hose into the wall, and getting the proper hose movement in the wall and ceiling cavities. Like most weatherization measures, this is made easier with practice. Dense-pack machinery can be dangerous, both to property and your health. Carefully read all manufacturers' safety instructions before using the equipment.

When this lab is complete, you will know how to prepare, drill and probe a wall, and properly fill an uninsulated wall cavity with cellulose insulation. You will also learn about blowing machine set-up, controls, safety, and adjustments. Finally you will learn math calculations that are made to determine cellulose weight per wall cavity, cellulose density, and the number of bundles of cellulose a dense-packing job may require.

Tools
Insulation blowing machine (such as Krendl) & hoses
Drill with Hole saw 2" – 2 ½", or 2 9/16" wood-boring bit
Sponge or rag to seal around hose
Wall probe
Dust pan and broom

Consumables
Bundles of cellulose insulation
Trash bag
For Interior, plaster or drywall: Premade hole plug with drywall compound
For Exterior, wood: Premade wood hole plugs with caulking

Safety Equipment
Eye protection
Breathing protection
Gloves
Coverall; Disposable suit
Hat; Hood;
(Hard hat or bump cap

Approximate time needed to complete this lab: 2 hours

Procedure

Points of caution before beginning – KEEP THESE IN MIND!

1. **In case of emergencies, always push down the red stop button located on top of main control panel**. It will stop all feeding and agitation.
2. Blowing Insulation is an activity that takes getting to know your machine and hoses. You must get a feel for this activity. Be careful of weak walls that may not be able to withstand the pressure of dense packing – continually monitor the area you are working on. Pay attention to how much cellulose material goes into a typical wall section and how long it takes to fill a typical wall section. If your using a lot more material or taking a lot more time than the average, find out where it is going (there must be a hole or opening somewhere). If you are using a lot less material or using a lot less time, find out where it is not going (there must be a blockage and an empty wall cavity).
3. Too much pressure can blow out a wall; on the other hand, not enough insulation with gaps in 15% of the insulation can reduce the effectiveness by 50%. Pack as tightly as is safely possible!
4. **Use a ground fault circuit interrupter (GFCI)** in any damp or highly conductive area and reference NFPA 79, 70E, or OSHA safe work practices when performing energized work procedures.
5. Make sure all guards, hopper bars, and hopper extensions are in proper place before operating the blowing machine. **Hands should never pass below hopper bars.**
6. Make sure blower motor control and remote control hand pendant switch are in OFF position before connecting the power supply to the machine.

Step 1: Prepare for Dense-packing: Locate and Drill the holes for hose insertion

1. The first drilling location for dense-packing is usually several inches in from the corner or end of a wall, and approximately 24” up from the floor. 24” up is also a convenient height for packing a typical 8’ wall and places holes even under typical windows. This location avoids the corner studs and is above electrical outlets and typical wiring for them. Avoid drilling into wood structural parts. If you hit a block or stud, stop drilling, remove the drill, and find a location away from the wood. Some installers use stud finders to locate studs before drilling. Others tap a hammer lightly and listen to changes in tone to determine where structural member locations.
2. Using a hole saw, drill a hole in the center of the wall cavity 2”-2 9/16” in diameter. (Save the cut piece for a plug or use a pre-made plug to repair the wall later).
3. Once the hole is drilled, use a non-conductive probe to determine where framing members are inside the wall. Convenient, inexpensive probes can be made from flexible pieces of vinyl trim like shoe molding. A 10’ length can be cut into a 7’ and a 3’ piece. The 7’ piece allows probing vertically to find any blocks or other obstructions. The 3’ piece allows for probing side-to-side to determine where the studs are located.
4. While you are probing the wall you will also find other items such as plumbing pipes, heating ducts, and electrical wiring. Do not drill into these items. You can pack around sound pipes. Electrical wiring needs to be confirmed for packing, as knob & tube cannot be insulated around. Heating ducts must be avoided. If you find any hazards like mold, asbestos insulation, knob & tube wiring, or insect or rodent infestations, stop and find your

crew leader for direction. Any questions should be brought to your crew leader's attention immediately.

5. Once a block or stud is found. Measure several (3"-4") inches up past the block, or over past the stud, to locate the next hole. Continue with this process to locate all wall cavities and drill one hole per cavity to install dense-packing.
6. Installers must also pay attention to the type and condition of the wall components like the drywall or plaster finish. ¼" drywall is not very strong and can easily be blown off the wall. Cracking plaster is also subject to being blown off walls. If the integrity of any building component is questionable, get your crew leader to evaluate it and determine what needs to be done. When blowing into wall cavities you will continue to monitor the walls and their components.

To keep the blower running properly, make sure (this is specific to the Krendl 500 machine, but will apply to most machines – see manufacturer specs for operational precautions):

1. the hopper is empty of foreign objects before starting.
2. the blower(s) is on when the agitators are running or machine will bind.
3. the blower filter is kept clean and in place when blower is on.
4. the blower is turned off immediately if hose is clogged or else the blower will overheat.
5. the agitator motor is on before adding fiber.
6. pieces of the bag are not left in the machine as this can bind and stall the machine.

Step 2: Prepare the machine for operation (for Krendl 500)

1. Pull up to set the emergency "kill" switch.
2. Turn red main disconnect switch to ON position.
3. Set 4-Position Selector Switch to OFF.
4. Press green start button. Machine will not run unless start button is pressed after kill switch is out and red main disconnect switch is on.
5. Select operating mode on 4-position selector switch from one of the following options:
   a. **Remote:** remote control will control machine. This allows the installer to control the blowing machine while they are filling a wall or floor cavity.
   b. **Off:** machine will not run (overrides remote hand pendant)
   c. **Blower:** only the blower will run continuously (manual control at machine)

The Krendl 500. (Photo ©).

Main Control Panel:

When operating in remote mode, the 4-Position Selector Switch must be set to Remote position. The remote control positions will be selected from the following:

a. BLOWER-FEED: operates both blower motor and agitator-feed motor simultaneously to supply both air and cellulose material.

   b. OFF (middle position): all functions stop. Adjust blower(s) and slide gate to desired settings.
   c. BLOWER: operates the blower motor only supplying only air.

Mechanical Settings:

The control end of the machine contains blower and slide gate controls to adjust the machine for each application and type of fiber. Blower control (air) and slide gate (material feed) are adjusted according to:

   a. APPLICATION: Open blow, retro-sidewall dense-packing, floor dense-packing, and spray-on applications require varying control settings.
   b. TYPE OF MATERIAL: Cellulose, fiberglass and mineral wool have different textures and densities that respond to machine settings.
   c. HOSE: Corrugations or roughness of interior surface, diameter, length and elevation of hose will also require varying adjustments.
   d. WEATHER CONDITIONS: Temperature and humidity may require day to day adjustment of machine settings.

Main Control Panel of the Krendl 500. (Photo ©)

For dense-packing walls with cellulose, the machine blowers are set higher (more air) and the feed gate set lower (less material), than for open blowing insulation is an attic. The added air pressure provides the additional packing to achieve the higher density (more material per volume). The lesser amount of cellulose means that it will take longer to fill a certain area compared to an open blow. Remember for dense-packing: more air; less material.

Step 3: Fill the cavity with insulation

1. Feed the 1 ½”diameter hose up the wall to approximately 6” from the top. (You can run it to the top and pull back 6”, or measure the wall and hose)
2. Block the open space of the hole (the hose is smaller than the hole) with a rag or sponge to prevent blow-back of insulation.
3. Using the remote control, begin by blowing *air only*, to clear the line.
4. Start to feed bags of cellulose into the hopper (the main compartment of the blower).
5. Watch the white part of the hose to see the cellulose flowing through the hose. Pay attention to the velocity that it moves when it is filling the wall. Notice when the velocity slows down and know that you need to make an adjustment. Feel the hose at the wall opening and listen to the machine to determine material movement. When material stops flowing, *switch to air only* and pull the tube back approximately 1’ or until the material in the hose moves.
6. Push the hose toward the top again, to force the material to pack tight. Pull back 6”.
7. Begin to feed material again and repeat the process until the wall is packed from the top down.
8. After you work your way down to the hole where the hose comes out, re-insert the hose down

toward the bottom to pack from the bottom of the wall up to the hole.

9. After the cavity is filled, a smoke test could be conducted to determine if the cavity is well-packed. By using a fan to depressurize a wall prop from behind it, or a blower door to pressurize a house, smoke would be forced into any leaking areas.

This is an activity that takes practice getting to know the machine and the hoses. You must get a feel for this activity. Be careful of weak plaster or drywall that may not be able to withstand the pressure of dense-packing. Always monitor the area you are working on. Always keep checking for cellulose moving through the hose; listen to the blower to see if the hose is backing up. Remember: Pay attention to how long it takes to fill a cavity and how much material you use. This can alert you to problems such as wall blockages or openings.

The loose insulation gets fed into the hopper. (Photo ©)

Step 4: Remove and reseal the hole

1. When the cavity is tightly packed with insulation, plug the hole by either adding caulking or wood glue to the edges of the round plug cut out earlier and inserting it, or use a pre-made plug. For interior work use a plug with drywall compound to patch the area.

Clean-up work area and store tools and materials

3. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used as these are usually flammable and could contains VOC's (volatile organic compounds).
4. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.
5. Return any items or personal belongings that may have been moved or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
6. Complete a final check and clean your work area and the work site.

What the Inside of a Properly Dense-packed Wall Should Look Like. (Photo © Paul Ricker)

Dense-packing Calculations

Installers need some basic math skills to make calculations that are very helpful with dense-packing. The math skills are addition, subtraction, multiplication, and division. An electronic calculator is very helpful in completing these calculations. The amount of cellulose material that is used to fill a wall cavity, or several wall cavities, is very important. If you know how much material by weight you used to fill a wall cavity you can determine the density of the insulation (the weight of cellulose per volume of wall cavity). Dense-packing requires that you achieve a density of 3.5 lbs./cu.ft.

Example

An installer used 30 pounds of cellulose to fill 3 wall cavities. The wall was built with 2” x 4” wood studs, 96” tall, at 16” o.c.
To find how much weight goes in 1 cavity divide: 30 pounds / 3 cavities = 10 pounds/cavity

1. To find the volume of the cavity, mutliply: Volume = L x W x H (length times width times height)
   a. Each cavity of the wall built with 2” x 4” studs, 96” long at 16” o.c. measures: 3 ½” x 14 ½” x 96”
   b. To get the wall volume in ft^3, you need to divide each of the measurements by 12 (12” = 1’).
   c. 3 ½”/12 x 14 ½”/12 x 96”/12 = volume of the wall cavity in ft^3.

2. Now take the cellulose weight figured above (10 pounds/cavity), and divide it by the wall cavity volume you calculated in #1.
   a. 10 pounds/wall cavity volume in ft^3 = cellulose density in pounds / ft^3.
   b. This will tell you the cellulose density (weight/volume) of the cavity. (Remember you want to have at least 3.5 lbs /ft^3 to achieve a good dense-packing job that stops air movement).

3. Now to find how many pounds would be needed to fill 25 cavities, multiply.
   a. Pounds/cavity x # of cavities = Total pounds of cellulose for 25 cavities

4. For this job, the installer also knows that there 30 pounds in one bundle of cellulose.
   a. So take the total pounds you found in #3 for the 25 cavities and divide it by 30 pounds/bundle to find out how many bundles you will need for this 25 cavity job.
   b. Total pounds cellulose for 25 cavities / 30 pounds = Total bundles of cellulose for 25 cavities

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Lab 3: Baseload Energy Use

Baseload energy is the energy that is used in the home at nearly the same rate year round. With some interpretation and calculation, utility bills can be broken down into baseload and seasonal load. In most non-tropical climates, the seasonal load will vary significantly throughout the year. The baseload will remain relatively constant, however.

Examples of baseload appliances include: washing machines, hot water heaters, household electronics (TV, radio, lights, computer, etc.), and cooking appliances.

After this lab is completed, you will be able to estimate baseload from energy bills.

Tools	**Consumables**	**Safety Equipment**
Calculator	none	none
Pen/pencil		

Approximate time needed to complete this lab: 1 hour

Procedure

Assume that a home uses only electricity for energy, including space heating and hot water heating. Baseload can be calculated using the following steps:

1. Get 12 months of electricity bills
2. Find the 3 months with the *lowest* energy use
3. Add these 3 amounts together, and divide by 3
4. This is your estimated monthly baseload

To calculate the yearly (annual) baseload:

5. Multiply the monthly baseload by 12 (12 months in a year).

To calculate the total seasonal load for the year:

6. Subtract the *annual* baseload from the *total* baseload (all electricity combined)

Note that this is not an exact way to calculate baseload, but it is a very good estimate.

Consider the following energy bill summary and calculate the baseload:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Electricity Use (kWh)	1200	1350	850	400	360	470	750	1000	500	440	750	900

1. What are the three lowest energy use months? (Name the months)

_________________ _________________ _________________

2. What is the total energy use in each of these months? (Don't forget the units.)

_________________ _________________ _________________

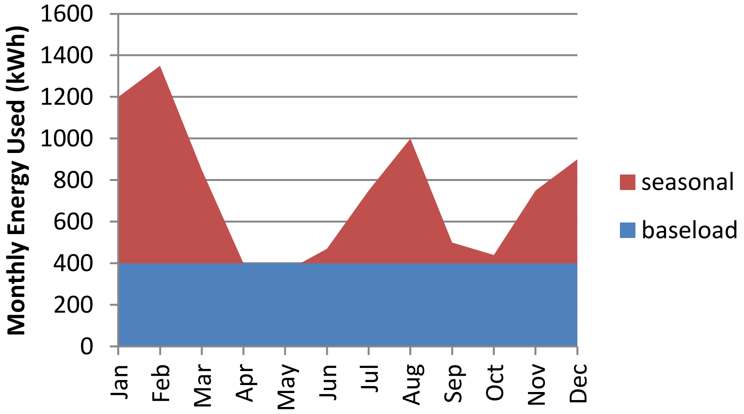
3. What is the average use in these months? (Don't forget the units.) _________________

4. What is the yearly baseload total (hint: there are 12 months in a year.) _________________

5. What is the *total* load for the year? _________________

6. What is the total seasonal load for the year? _________________

The graph of energy use throughout the year is below. Answer the next three questions based on this graph.



7. What do the peaks indicate?

8. Why does the seasonal load peak when it does?

9. Name 4 possible ways to reduce seasonal load (2 in summer, 2 in winter).

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Lab 4: Lighting Efficiency

There are a number of different light bulbs available for use in homes. The two most common are incandescent bulbs (lamps) and compact fluorescent lamps (CFLs). CFLs use about ¼ as much electricity as an incandescent that has the same brightness. CFLs also (usually) last longer – if used properly, they should last about 10 times as long as incandescent bulbs. Incandescent bulbs waste about 90% of their energy on heat.

Light-emitting diodes (LEDs) are slightly more efficient than CFLs, but last about 2.5 times as long as CFLs, and 25 times as long as incandescent. Though CFLs do not get as hot as incandescent, they can get hot if left on long enough. LEDs emit virtually no heat. LEDs are currently too expensive to be worth the cost.

You can calculate the energy and money saving potential of switching bulbs if you know three things: the power of the bulb (measured in Watts), the amount of time you use the bulb (in hours), and the cost of electricity ($/kWh).

Upon completion of this lab, you will be able to calculate the energy cost of lighting technologies.

Tools
Portable lamp
CFL bulb (15 W)
Incandescent bulb (60W)
LED bulb (optional)
Pencil
Calculator
Kill-a-Watt

Consumables
None

Safety Equipment
None

Approximate time needed to complete this lab: 1 hour

Procedure

The goal of this lab is to calculate how much it will cost to use each light bulb for 5 hours a day each day of the year. This lab uses a CFL and incandescent bulbs that produce the same amount of light, but any wattage bulb can be used, including an LED.

CAUTION:

Electricity can be a very dangerous form of energy. Some important precautions when working with household electronics are:

1. Never put bare metal into outlets. It can short, spark, and/or cause a fire.
2. If bare skin is touching metal in an outlet, shock and/or burns can result.
3. Check wires connected to appliances to ensure no frays or breaks.
4. If the insulation is frayed, wrap with a good electrical tape.
5. Frayed wires may be fixed by an experienced electrician.
6. Water is a good conductor of electricity. Do not use appliances that are wet, and never use electrical equipment on wet floors, in the rain, or with wet hands.

Determine Power Use of Each Bulb

Power is the rate of energy use – a higher-power appliance uses energy more quickly than a lower-power appliance. Power is measured in Watts and kilowatts. There are other larger and smaller power units, but you will usually not encounter them in a home.

A Kill-a-Watt is a device that measures the power being used by plug-in appliances.

To determine the power usage of the light bulbs:

1. Plug in the device into a wall outlet
2. Press "Watt" (or press "mode" until the device shows "W" in the display area)
3. Plug the light into the Kill-a-Watt with the CFL
4. Record the power being used by the bulb (in Watts)
5. Repeat steps 2-4 with the incandescent

1. How much power does the CFL use? ________________W

2. How much power doest the incandescent use? (Don't forget the units) ________________

Determine the Energy use of the Bulbs

Electricity is a type of energy. This is important for you to know, but it is important for building occupants to know because electricity costs money to use. The unit of electricity you will most often see is the kilowatt-hr (kWh), though Watt hours (Wh) can also be used. To convert Wh to kWh, divide by 1000. For example, 1000 Wh = 1 kWh (1000 ÷ 1000 = 1).

Power companies measure the amount of electricity you use as it passes through the electric meter, which is located outside the home where the main wires come into the home. They charge you base on how many kWh you use.

To calculate energy use, multiple power x time.

3. If you use the CFL bulb for 5 hours/day, how much energy will you use each day? _______W x _______hr = _______Wh

4. How much energy will the CFL use all year? _____Wh/day x _____days/yr = _____Wh/yr

5. How many kWh will the CFL use all year? ______Wh/yr ÷ 1000 Wh/kWh = ______kWh/yr
6. If you use the incandescent bulb for 5 hours/day, how much energy will you use each day?
   _______W x _______hr = _______ (units?)

7. How much energy will it use all year? _______ x _______ = _________ (units?)

8. How many kWh will it use all year? ________ ÷ 1000 Wh/kWh = __________ (units?)

Determine the Yearly Cost of the Bulbs

To calculate the cost of electricity usage:

1. Determine the cost per kilowatt hour
2. Multiple the total kWh times the cost/kWh

Assume that electricity costs 15 cents per kilowatt hour ($0.15/kWh).

9. How much does it cost to operate the CFL for one year if it is used for 5 hours each day?
   _______kWh x $0.15/kWh = _______/yr (unit?)

10. How much does it cost to operate the incandescent for one year (5 hours each day)?
    _______kWh x $0.15/kWh = _______/yr (unit?)

11. How much money does the CFL save you each year?

12. Assume the whole house uses the same incandescent everywhere as you used in this lab. If you replaced 10 of these with CFLs, how much money would you save each year?

13. For anything that uses energy, you can calculate the total energy use if you know what two things?

14. What two things do you need to know if you want to calculate the total cost of energy?

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Lab 5: Electric Appliance Energy Use

Most homes have numerous electronic appliances. These appliances can be a part of the baseload (e.g. dishwasher, TV, refrigerator) or seasonal load (e.g. electric baseboard heater, air conditioning unit). No matter which load they are a part of, they cost money to use.

There are many efficiency upgrades and conservation measures that can be taken to reduce energy use, and thus cost (and stress on the environment). "Efficiency" is getting the same functionality with less energy. Replacing an incandescent light bulb with a compact fluorescent light bulb is an example of an efficiency measure – the same amount of light comes out (the function of a light bulb is to provide light) with less energy. "Conservation" is the process of using less of something by changing behavior. Turning off lights when not in a room is an example of conservation behavior – it requires a change in behavior (turning off lights as opposed to leaving them on).

Upon completion of this lab, you will be able to calculate the energy use and cost of energy use of common household appliances.

Tools
Pencil
Calculator
Kill-a-Watt
Various electric appliances
(e.g. space heater, air conditioner, microwave, TV, radio, computer)

Consumables
None

Safety Equipment
None

Approximate time needed to complete this lab: 1 hour

Procedure

CAUTION:
Electricity can be a very dangerous form of energy. Some important precautions when working with household electronics are:

7. Never put bare metal into outlets. It can short, spark, and/or cause a fire.
8. If bare skin is touching metal in an outlet, shock and/or burns can result.
9. Check wires connected to appliances to ensure no frays or breaks.

10. If the insulation is frayed, wrap with a good electrical tape.
11. Frayed wires may be fixed by an experienced electrician.
12. Water is a good conductor of electricity. Do not use appliances that are wet, and never use electrical equipment on wet floors, in the rain, or with wet hands.

Calculating Energy Use

In order to measure the energy use of any appliance, two things are needed: power use and time. Power is the rate at which energy is being used, and "time" refers to the amount of time an appliance is being used for. To calculate energy use:

1. Multiple power x time

Note: The following exercises can be used to analyze any household appliance that either a) the power consumption is known or b) the appliance can be plugged into a standard 120V outlet.

The following is a list of common household appliances and their typical power consumption:

Aquarium = 50–1210
Clock radio = 10
Coffee maker = 900–1200
Clothes washer = 350–500
Clothes dryer = 1800–5000
Dishwasher = 1200–2400 (the drying feature greatly increases energy consumption)
Dehumidifier = 785
Electric blanket- *Single/Double* = 60 / 100
Fans
- **Ceiling** = 65–175
- **Window** = 55–250
- **Furnace** = 750
- **Whole house** = 240–750

Hair dryer = 1200–1875
Heater *(portable)* = 750–1500
Clothes iron = 1000–1800
Microwave oven = 750–1100
Personal computer
- **CPU** - awake / asleep = 120 / 30 or less
- **Monitor** - awake / asleep = 150 / 30 or less
- **Laptop** = 50

Radio *(stereo)* = 70–400
Refrigerator *(frost-free, 16 cubic feet)* = 725

Televisions (*color*)
- 19" = 65–110
- 27" = 113
- 36" = 133
- 53"-61" Projection = 170
- Flat screen = 120

Toaster = 800–1400
Toaster oven = 1225
VCR/DVD = 17–21 / 20–25
Vacuum cleaner = 1000–1440
Water heater *(40 gallon)* = 4500–5500
Water pump *(deep well)* = 250–1100
Water bed *(with heater, no cover)* = 120–380

(Source: US DOE[7])

Calculate Energy Use and Cost of Appliances

For all of the following, assume that electricity costs $0.15/kWh (15 cents per kWh).

[7] Available at http://www.energysavers.gov/your_home/appliances/index.cfm/mytopic=10040.

1. Calculate the energy used by a clothes dryer being used on "high" for 1/2 hr. Assume the dryer uses 3000W. How much energy is used in 1 hour?

   ________ W x ________hr = ________Wh

2. How many kilowatt hours is this? _______Wh ÷ 1000 Wh/kWh = _______kWh

3. If the dryer is used an average of once a day all year, how much energy does it use?

   _______kWh/day x _______days/yr = _______kWh/yr

4. How much will this dryer cost to run each year?

   _______kWh/yr x $_______/kWh = $_______/yr

5. If the clothes were hung outside for half the year, how much money would be saved?

6. Is hanging clothes a conservation or efficiency measure?

7. Explain how hanging clothes is a conservation or efficiency measure.

Calculate Energy Use with a Kill-a-Watt

The following exercises may be done as a class, or in small groups.

A Kill-a-Watt measures power use. To measure the power use of an appliance with a Kill-a-Watt:

6. Plug in the Kill-a-Watt into a wall outlet
7. Press "Watt" (or press "mode" until the device shows "W" in the display area)
8. Plug the appliance into the Kill-a-Watt
9. Record the power being used by the appliance

8. Plug in an appliance. What is the power use in Watts? (Don't forget the units!)

9. Decide as a class (or group) for how many hours a day this appliance might be used on a typical day. Based on this number, how much energy would be used each day in Wh?

10. How many kilowatt hours is this?

11. Estimate how many days a year it would be used for. What will it cost to run each year?

12. Name two ways that this energy usage could be reduced:

13. Are the answers to number 12 efficiency or conservation measures?

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Lab 6: Work Scope

A Work Scope (or work order) is a document created by the Energy Auditor that lists all weatherization measures which will be applied to the corresponding work site. The work scope is used by the retrofit installer as a guide to apply the appropriate measures and as a checklist to determine whether all work has been completed.

Also, it will be important for an installer to become familiar with the "tool list", which list all the tools and materials which are loaded onto the truck. Depending of your agency's policy tools may loaded each day per the necessities of that days' work order or there may be a master list which list all the tools & materials that could be used on any work scope. It is imperative that an installer knows what he has on his truck in order to report missing or deficient tools & material.

After this lab is completed, you will be able to analyze a work scope to identify work site areas, pull the proper tools & materials for weatherization measures, and determine the completion of work scope measures. This lab can be done in conjunction with any of the labs in the retrofit installer technician manual – it is not a standalone lab.

Tools	**Consumables**	**Safety Equipment**
Varied	Varied	Varied

Approximate time needed to complete this lab: additional 30 minutes to associated lab

Procedure

The work scope is reviewed by the crew prior to reaching the work site. The crew chief will sanction individual task to each installer. Upon reaching the work site the crew chief will use the work scope to introduce the home owner to the work areas of the home. During this time the installers pull their task designated tools and materials from the truck. The installer then waits for "start-work" verification from the crew chief. After work is complete the installer will return all tools and unused materials to truck to be inventoried and organized.

Safety concerns

1. Proper care of tools and materials
    - Power tools are somewhat delicate and need to be moved appropriately
    - Hand tools should be carried by the grip or handle

- Materials have manufacture specifications about proper storage (ex. One part foam shouldn't be stored in temperatures above 120^o to maintain material integrity and ensure safety)
- Materials and tools also have manufacturer limitations. When these limitations are exceeded it becomes a safety hazard (ex. A chisel is designed to shear wood with its sharp edge, though the sharp edge is flat it should not be used as a flathead screw driver because of the risk of injury)

2. **ALWAYS WEAR THE PROPER PPE!**

3. Work Area Hazards
   - Low head clearances
   - Rodents/rodent waste, aggressive animals/waste
   - High ambient CO, loose, friable asbestos
   - Illegal activity, aggressive client
   - Obstructions (e.g. client belongings)

Analyze Work Scope

1. Per Crew Chief instruction identify your task and locate it on work scope form
2. Cross check other installer measures
   - Ensure there will not be a conflict in work area space
   - Ensure there are no measures which may need to proceed your task
   - Report any issue to crew chief for further instruction

Pull Tools and Materials

1. Unload tools from truck
   - Find a place to compile your task appropriate tools & materials. This area shouldn't be on adjacent properties or in the path of passersby.
   - Compile your task appropriate tools & materials. Lay the tools out so they are all visible, never one on top of the other.
2. Confirm start-work order and enter work area
   - Confirm start-work order per crew chief
   - Carry tools and materials into work area (Safety First! Never carry more than what feels comfortable. Generally 2 hands = 2 tools.)
   - After all tools & materials are within specified work area apply weatherization measure.

Install Measures

During installation, issues may come up that are not in the work scope. For example, a safety hazard (e.g. broken step) may arise or an additional efficiency problem may occur between the tie the work order was created and given to you. If you feel the work scope needs to be deviated from *no matter how slightly*:

1. Clearly identify the deviation – where it is, why it is a problem, and that it is not in the work scope
2. Report the deviation to the crew chief or supervisor

   a. Unless specifically authorized to do so from the crew chief, do not deviate from the work scope
3. Request direction for modified work scope
4. Implement the modified work scope

Clean Work Area

1. Remove all materials & tools from work area into an adjacent area of the work site. This selected area should not restrict movement throughout the work site.
2. Remove and clean work area of material debris, dust, and dirt.

Load Truck

1. Carry tools to truck, placing each in its designated place. Again a safe carrying method is 2 hands = 2 tools. (prior to organizing tools in truck inventory each tool on tool list)
2. Locate appropriate facilities (per Crew Chief instruction) for dumping of trash, recyclables, and lead hazardous materials.
3. Place materials in appropriate facility or separate and compile materials for site removal.

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Lab 7: Air Sealing Non-IC Recessed Light Fixtures

Recessed lights (sometimes called “can lights” or “high hats”) are common sources of both air leakage and heat loss in a home because they cause a break in the thermal envelope, both the air barrier and the insulation. This is an especially big problem because most recessed lights cannot have insulation on top of them because it would result in a fire hazard.

The National Electrical Code (NEC) requires a minimum of 3” of space between recessed lights and insulation, unless they are “IC” (Insulation Contact) rated. Many older recessed lights are non-IC rated, meaning non-Insulation Contact. This makes it even more difficult to have a complete thermal envelope when you have non-IC recessed lights. These are what weatherization installers will usually find in older attics and have to safely air seal around. Often there are existing fire code violations that a retrofit installer finds that need to be addressed. Older non-IC recessed lights might have insulation in contact with them. The insulation needs to be removed and a sealed drywall box built around the fixture. The drywall box stops air leakage and also serves as an insulation dam, keeping insulation safely away from the light fixture.

After this lab is completed, you will be able to safely air seal around recessed lights. This consists of building a 5-sided box (4 sides and a top) around a non-IC recessed fixture.

Tools
Utility knife
Drywall T-square
Tape measure
Drywall Rasp
Drywall saw
Caulk gun

Consumables
Drywall
Metal tape
Pencil
Caulk (latex)
1-part Spray Foam
Paper towel; rags
Trash bag

Safety Equipment
Eye protection
Breathing Protection
Gloves

Approximate time needed to complete this lab: 3 hours

Procedure

Build an air-sealed drywall box (“insulation dam”) around the light
Note: Drywall is an excellent material for this box. The top must be a non-insulating material to avoid excess heat build-up. Do not use metal, rigid foam, or plastic as they can trap moisture.

1. Measure the light fixture and add 4” to all 4 sides for proper clearance around fixture. For the height use the full insulation depth of the attic insulation. R-38 cellulose is about 11” deep, so a 12” height is good; R-38 fiberglass is about 13” deep, so a 14” height is good.
    a. For a 6” wide and 5” tall fixture in an attic to be insulated with cellulose insulation: you would need to build a box that is 14” x 14” x 12” (l x w x h).
2. If you run into a ceiling joist treat the joist as part of the box and measure accordingly. If possible, use the joist as one of the sides of the box.
3. Mark and cut ½” drywall according to your measurements to create 4 sides and a top. Use the rasp to even the edges of your cuts if necessary.
4. Form the box by assembling the sides first. Tape with metal tape on the exterior edges to hold it while you seal it with caulking, or use rated metal tape well adhered.
5. Put a continuous bead of caulk around the top of the box sides and install the top on it. The top can be secured to the sides by using metal tape.
6. To install the box, first clean the area so the sealant will stick to it. Then caulk or use 1-part spray foam where the drywall meets other building materials like the ceiling and joists to form an airtight seal.
7. Check around all edges and at the joists to make sure you have a complete continuous air-seal. If not, install additional spray foam or caulking as necessary. (If working in an attic you could check your work with a smoke test if the blower door was running).
8. Smoke test your prop on the test box with the fan running. Identify any leaks and add additional sealant to achieve a complete seal.

A recessed Light (Looking down from an Attic). Fire code requires insulation to be at least 3” away from the fixture, so a drywall box is build and sealed. Now insulation can be added up to and over the box. (Photos ©)

Clean-up work area and store tools and materials

7. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used as these are usually flammable and could contains VOC’s (volatile organic compounds).
8. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.

9. Return any items or personal belongings that may have been moved or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
10. Complete a final check and clean your work area and the work site.

Attic Insulation around the Non-IC Recessed Light Fixture Box

3. The box will be made tall enough so that full attic insulation can be installed against the sides of the box. No insulation will cover the box.
    a. Example 1: R-38 cellulose is about 11” deep, so a 12” box height is good.
    b. Example 2: R-38 fiberglass is about 13” deep, so a 14” box height is good.

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Lab 8: Basic Plumbing Applications

Per licensure requirements installer are restricted from handing certain plumbing measures. A retrofit installer's job task as it relates to plumbing is to serve as the licensed plumbers assistant and to apply weatherization measures such as installing low-flow fixtures, sealing building penetrations, installing pipe wrap, and repairing the thermal boundary.

To be considered a competent retrofit installer you must grasp certain key elements of plumbing theory such as brazing, gaskets, pipe fitting, venting, pipe slope, plumbing materials, and BPI combustion safety standards.

Brazing is a process used to join two pieces of metal pipe, using a filler metal for adhesion. The filler metal is brought up to a temperature of 450^{o} C and allowed to cool to join the two work pieces. A gasket is a seal which fills the space between two or more mating surfaces, to prevent leakage from or into the joined objects while under compression. Pipe fitting involves installing or repairing piping or tubing systems that convey liquid, gas, and occasionally solid materials. This work involves selecting and preparing pipe or tubing, joining it together, and the location and repair of leaks. Pipe slope is related to proper venting and drainage. Pipes are used to convey certain liquids, gases, and solids each application calls for its own slope requirement; for ex. A flue pipe which exhausts combustion gases must be sloped ¼ inch per foot.

When this lab is complete, you will be able to recognize plumbing components, seal plumbing penetrations, install low-flow showerheads, install pipe wrap, and be familiar with common plumbing hazards.

Tools
2 – Adjustable wrenches
Six-in-One Driver
Utility knife

Consumables
One part foam
Pipe wrap
Fiberglass batt
Metal tape
Teflon tape

Safety Equipment
Eye protection
Respirator
Gloves

Approximate time needed to complete this lab: 2 hours

Procedure

Safety concerns

4. Identify and Discuss Work Area Hazards
   a. Low head clearances
   b. Rodents and rodent waste
5. Tool Safety

Identify Work Site Areas

3. Identify work area hazards
   a. Remove hazards if possible (see safety concerns for example)
   b. Report any irresolvable hazards to Crew Chief
4. Identify basic plumbing components
   a. Hot water pipe
   b. Gas/electric supply
   c. Water Service line
   d. Connections and elbows
   e. Pressure relief valve
   f. Shutoff valve
   g. Water meter
   h. Burner (if applicable)
   i. Drip leg
   j. Tank
   k. Thermostat (behind panel)
   l. Main clean out

Common Components of an Electric Hot Water Tank. (Photo ©)

5. Identify plumbing penetrations
   a. Penetrations can be found by following piping to its destination. Water service lines usually can be followed to the street side of the home. Condensing (high effieciency) furnaces have 2 PVC pipes which will be vented outdoor, follow these pipes to their destination.
6. Identify plumbing chaseways
   a. Plumbing chaseways are easily viewed from the basement and attic. Framing bump-outs are usually a sign of a chaseway, these bump-outs can be found throughout the home.
   b. Chaseways are important to identify because they are often a source of air leakage into the home

Seal Penetrations (Plumbing and Electrical penetrations)

4. Measure gap to be filled.
   a. A measuring tape is usually best when working in confined space.
5. Choose sealing method based on gap measurement
   a. Gaps smaller than ¼ inch can be filled with caulk
   b. Gaps from ½ inch to 1 ¾ should be filled with one part foam
   c. Gaps from 2inches to 3 inches should be filled with one part foam with a backing
   d. Gaps 3 inches and bigger need a rigid material like drywall, cement, or sheet metal

Install Pipe Wrap

6. Identify pipes to be wrapped
   a. Per work order (or)
   b. Per Crew Chief instruction
7. Apply pipe wrap
   a. Pipe wrap needs to be installed so that it is continuous from beginning to end. Elbows and connections present a difficulty that proper cutting can rectify.
   b. Using metal tape secure pipe wrap where ever two pieces meet and approximately every foot.

Install Low Flow Shower Head

1. Identify standard showerhead to be replaced
2. Remove showerhead: Using one adjustable wrench, hold the pipe in place (for polished pipe use a cloth to protect the finish). While holding pipe in position with one wrench use second wrench to spin the fitting which attaches showerhead.
3. Next, remove threading tape and any debris from threading area. Usually a dry cloth is enough to properly clean this area.
4. Apply Teflon tape to threading in a counter clock wise manner. 3 full revolutions is usually sufficient. Too much tape will make a good fit impossible. Too little tape may cause a dripping leak at the fitting.
5. Install Low Flow showerhead: Using the same two wrench method mentioned above replace showerhead. Spin fitting clockwise until it comes to a firm stop.



From left to right: All hot water pipes should be wrapped; all pipe chases should be sealed (foam is useful for fairly large gaps); and low-flow showerheads should be installed in all showers. (Photos © eca**)**

Weatherization and Retrofit
Energy Coordinating Agency

APPENDIX D

Manual Two Quizzes

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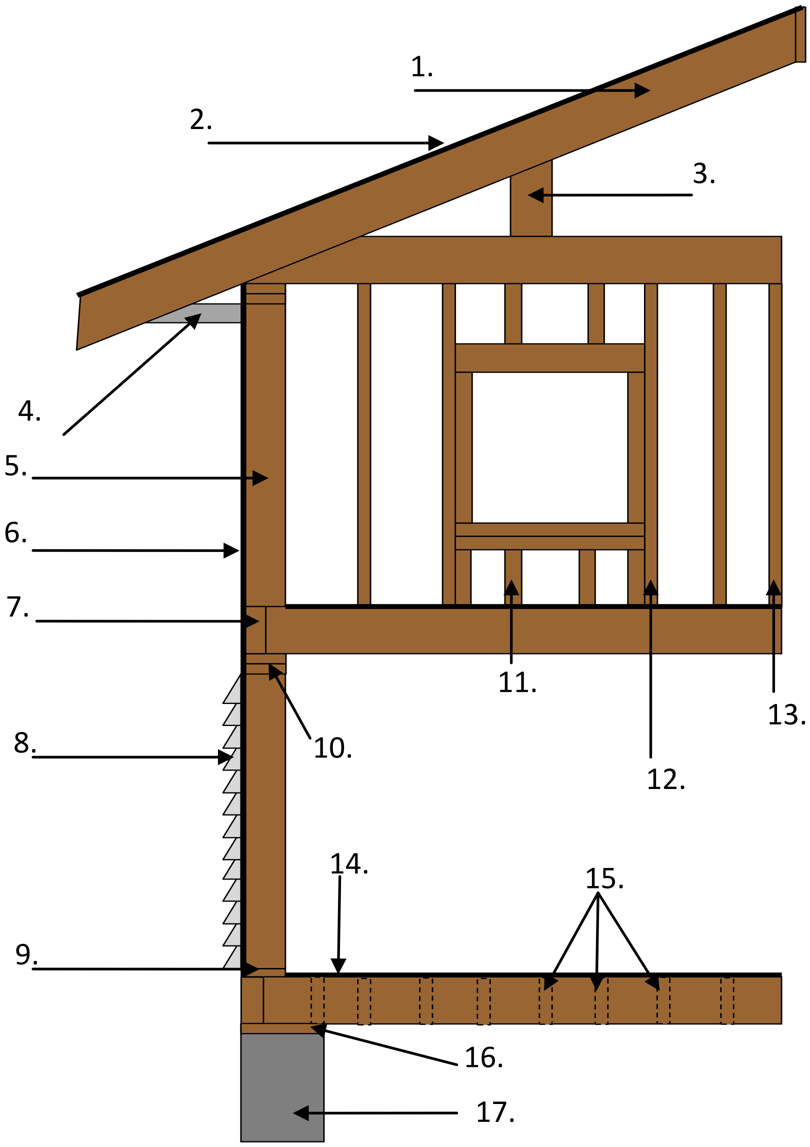
Quiz 1: Building Construction

Name: ________________________________ Date: ________________

Label the basic framing and structural components in the following diagram.



18. The two typical framing types for homes with wood construction are:

    a. Balloon and platform
    b. Studded and framed
    c. Hollow and solid
    d. Closed and open

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Quiz 2: Building Science and House as a System

Choose the best answer for each question:

1. Define the phrase "house as a system." Why is this such an important concept in weatherization?

2. Which of the following are parts of the house system that weatherization installers should take into consideration?
   a. Plumbing
   b. Electrical
   c. Heating, ventilation, and air conditioning (HVAC)
   d. All of the above

3. What is the desired effect of air sealing for building occupants?
   a. Improved air quality
   b. Lowered energy costs
   c. Increased comfort
   d. All of the above

4. What indoor air quality danger may result from excessive air sealing?
   a. Improved comfort
   b. Lowered energy bills
   c. Trapping of toxins within the home
   d. Raise the air exchange rate

5. The most important weatherization strategy across the country is which of the following?
    a. Air sealing measures
    b. Insulating measures
    c. Baseload measures
    d. Seasonal measures
    e. Heating measures

6. To create a proper thermal boundary, the air barrier and thermal barrier must ______.
    a. be continuous and in contract
    b. have a vapor barrier on both sides
    c. be spaced one inch apart for the materials to breathe
    d. be mounted to exterior sheathing

7. An efficient way to save on domestic hot water baseload costs *and* water usage costs is which of the following?
    a. Install low-flow shower heads
    b. Install hot water tank insulation and pipe wrap
    c. Replace existing toilets with more water efficient models
    d. Install a larger hot water heater

8. The stack effect is caused by what?
    a. Too much air sealing
    b. Cold air sinking
    c. Warm air rising
    d. Too much insulation

True or False:

9. T / F Platform construction allows air to freely travel from the basement to the attic.

10. T / F In order for a house to have natural infiltration, it must have an equal amount of exfiltration.

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Quiz 3: Principles of Energy

Name: ______________________________ Date: _______________

Provide the answer for each question:

1. What are the three basic types of heat flow?

2. What does a thermostat sense?

3. What happens if there is a temperature difference between two areas and there is a pathway between them?

Choose the best answer for each question:

4. How does heat flow within fluids?
    a. Conduction
    b. Convection
    c. Radiation
    d. Absorption

5. When walking on hot asphalt, what type of heat transfer is occurring through the feet?
    a. Convection
    b. Conduction
    c. Heating degree days
    d. Radiation

6. Air will flow from areas of _____ pressure to areas of _____ pressure.
    a. low, high
    b. high, low
    c. low, low
    d. high, high

7. Electric energy is typically measured in _______.
    a. Pascals
    b. kilowatt hours
    c. cfm
    d. Watts

8. When standing by a window on a sunny winter day, the feeling of warmth on the face is an example of which of the following?
    a. Convection
    b. Conduction
    c. Radiation
    d. Absorption

Circle True or False

9. T / F If a gas hot water heater is <u>not</u> working properly, it will <u>not</u> affect anything else in the house.

10. T / F Electricity flows along the path of least resistance

11. T / F Air flows through the path of least resistance

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Quiz 4: Baseload Analysis

Name: _______________________________ Date: _______________

Choose the best answer for each question:

1. Which of the following are considered part of baseload home energy use?
    a. Computer
    b. Hot water heating
    c. Gas fireplace
    d. A & B
    e. B & C.

2. Which of the following is *not* considered part of seasonal energy use?
    a. Water
    b. Gas
    c. Electric
    d. Oil
    e. Propane

3. A CFL uses approximately ______% of the energy of an equivalent incandescent bulb.
    a. 5
    b. 25
    c. 75
    d. 95

4. Which of the following types of bulbs uses the least energy?
    a. Incandescent
    b. Compact fluorescent
    c. LED
    d. Halogen

5. Which of the following bulb has the longest rated life span?
    a. LED
    b. Incandescent
    c. Compact fluorescent
    d. Halogen

6. You have a ceiling fan that uses 100 Watts of power. You run this fan for 10 hours each day. How much *energy* do you use each *week* at this usage rate?
    a. 700 Wh
    b. 7 kWh
    c. 7 kW
    d. 700 W

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Quiz 5: Domestic Hot Water

Name: _______________________________ Date: _______________

Choose the best answer for each question:

1. Which of the following are components of a gas storage tank DHW?
    a. Dilution air and flue gases
    b. Combustion air and ambient temperature
    c. Burner, tank and flue
    d. Case, insulation and draft diverter
    e. C & D

2. Which of the following are components of an <u>electric</u> storage tank DHW (circle all that are correct)?
    f. Dip tube
    g. Flue
    h. Burner
    i. Pressure relief valve
    j. Insulation
    k. Cold water pipe
    l. thermostat

3. An unnecessary and wasteful part of older water heaters is:
    a. Flue
    b. Combustion
    c. Pilot light
    d. Insulation wrap

4. Which of the following is *not* a component of a gas-powered DHW?
    e. Flue
    f. Gas pipe
    g. Power cord
    h. Drip tube

NOTES

ENERGY COORDINATING AGENCY

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Manual Three

Air Sealing, Insulation, & Combustion

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Energy Coordinating Agency
Philadelphia, PA

Weatherization and Retrofit Course

MANUAL THREE

Air Sealing, Insulating and Combustion

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TABLE OF CONTENTS

Energy Coordinating Agency

Manual Three: Air Sealing, Insulation and Combustion

Overview

This manual is designed to provide individuals who wish to become entry-level retrofit installer technicians with intermediate training in installation of air sealing and insulation in residential buildings. The material will also be useful for incumbent workers who wish to hone air sealing and insulation application skills, as well as semi- or low-skilled individuals who wish to learn to install insulation and air sealing measures in a non-professional setting (e.g. weatherizing their own home). In addition to air sealing and insulation methods, lab and text components include use of blower door, basic combustion analysis, indoor air quality in regards to attached garages, and basics of heating and hot water systems.

This manual proceeds as follows:

- Discuss driving forces of and principles behind air leakage
- Practice and discuss methods of remedying air leakage
- Discuss combustion science and combustion hazards
- Assist and discuss combustion analysis
- Describe and discuss mechanical ventilation systems
- Rough-in mechanical ventilation systems
- Discuss benefits of using a blower door to analyze leakage rates and locations
- Set up blower door and determine leakage areas
- Discuss and practice air sealing strategies and methods
- Discuss science behind and usefulness of insulation
- Practice and discuss insulation measures

- Discuss dangers associated with attached garages and methods to prevent poor indoor air quality

Learning Objectives

At the conclusion of this manual, the student will have the following competencies:

- Demonstrate a thorough understanding of the principles of and driving forces behind air leakage
- Identify high priority air sealing areas and describe rationale for prioritization
- Identify proper air sealing method(s) for leakage sites
- Install air sealing measures, from small holes to blocking large openings
- Demonstrate proper use of Personal Protective Equipment
- Describe the process of combustion
- Describe the basics operation of combustion appliances and distribution of heat throughout the home
- Identify components of combustion appliances and mechanical systems
- Describe basic combustion safety hazards
- Assist in identification of combustion appliance safety hazards
- Demonstrate proper blower door setup
- Use blower door to identify air leakage sites
- Use and describe air sealing tools and materials
- Apply two-part foam
- Seal and insulate ductwork
- Describe how insulation prevents heat transfer
- Describe and demonstrate how to determine R-value of layers of materials
- Describe uses for various weatherization materials
- Describe potential indoor air quality issues related to attached garages
- Install loose fill insulation
- Handle tools and materials according to manufacturer specifications
- Demonstrate advanced hand tool use
- Analyze a work scope and explain how it is used before and on a job site
- Gather materials and supplies for a weatherization application
- Set up tools and materials
- Clean up and organize work area as work is in progress
- Pick up tools and materials, and clean up and close out a job site

Key Terms

- Air barrier
- Air sealing
- Attached garage
- Attic hatch
- backdrafting
- batt
- Blower door
- Carbon monoxide
- Caulk
- CFM
- Closed combustion furnace
- Combustion
- Combustion air
- Conduction
- Convection
- Damper
- Dilution air
- Direct leakage
- Draft
- Duct
- Duct fan pressure
- Exfiltration
- Flue
- Foam Insulation
- Furnace pressure
- Heat exchanger
- IAQ
- Indirect leakage
- Infiltration
- Insulation
- Loose-fill insulation
- Mastic
- Oxygen
- Polyurethane
- Radiation
- Rigid foam board
- Sealed combustion furnace
- Spillage
- Spray foam
- Stack Effect
- Supply air
- Thermal bridging
- Thermal boundary
- Vapor barrier
- Ventilation
- Wind pressure

Manual Three: Air Sealing, Insulation and Combustion

Topic 1: Air Leakage

Few areas of residential construction are misunderstood as much as air movement within and through houses. Though some contractors still swear that houses need to “breathe,” the new industry of building science and energy efficiency has established the need to seal up leaks and make house “envelopes” airtight.   If you recall the priority list discussed in manual 1, air sealing is the top priority (after health and safety). As discussed previously, this is because it is usually the most cost-effective weatherization measure to take. Air leakage can waste up to 40% of the house’s conditioning (both heating and cooling) costs. Obviously, plugging air leaks can create significant energy savings. Air sealing a house may be the most important function of weatherization, but it can also be the most difficult goal to achieve.

Energy leakage through the building shell (the floor, walls and roof) is very common. While the total cubic feet per minute (CFM) of leakage varies from house to house, the percentage of leakage through a *typical* house’s various construction materials resembles the chart to the right. As you can see, the most leakage (31%) is found in floors, walls and ceilings. The second most (15%) is through ducts. It is no coincidence that these are the top two weatherization measures on many priority lists.

Air Leak Sources in a Home

Floors, walls ceilings – 31%

Ducts – 15%

Fireplace – 14%

Plumbing penetrations – 13%

Doors – 11%

Windows – 10%

Fans & vents – 4%

Electrical outlets – 2%

Common Air Leakage Areas in a Home. The percentages to the right of the image indicate the portion of total air leakage from various source in the average American home. (Image courtesy of US DOE[1])

[1] Fraom the Energy Efficiency and Renewable Energy Program. Available at http://www1.eere.energy.gov/consumer/tips/m/air_leaks.html

Indoor Air Quality (IAQ)

A change in indoor air quality is perhaps the most significant result of proper air sealing, because of the important health impacts polluted indoor air can have. Air leakage may have some beneficial effects for IAQ in some houses by letting in fresh outdoor air. Leakage is beneficial when it:

- Lets excess moisture out
- Provides combustion air for heaters, hot water heaters, dryers, etc.
- Removes or dilute toxic gas build-up from improperly venting indoor combustible appliances
- Replaces polluted indoor air with fresh (non-polluted) outside air

A certain level of natural air exchange must be maintained for safe indoor air. There are standards for how much a house should “breathe,” which is based on the number of bedrooms and occupants in a home. This standard is called the Building Tightness Limit (BTL) or minimum ventilation requirement (MVR). The BTL tells you the minimum amount of air that must be exchanged in cubic feet per minute. For example, if a home has a BTL of 75 $CFM_{natural}$, it means that an average of 75 cubic feet of air or more should be naturally escaping the house every minute. This air is of course automatically replaced by outside air (remember: 1 CFM in = 1 CFM out!).

Homes tend to be rather leaky, especially older ones. It is rare that the BTL is not met, but some new homes or homes that have been weatherized *extremely* well my not meet the standard. If the BTL is not met – in our example, *less* than 75 CFM are being exchanged – ventilation must be added. This will usually be in the form of an exhaust fan somewhere in the home. This ventilation system will supply fresh air for occupants, combustion air for appliances, and make-up air for fans. Fans will help remove water vapor from cooking, bathing, washing clothes, washing dishes, occupants breathing.

Indoor Air Quality (IAQ): refers to the healthiness (or unhealthiness) of air inside of a building; closely related to indoor air pollution. Common sources of poor IAQ include cleaning products, combustion appliances, mold/mildew, and paints and other home improvement materials.

Overall, air leakage is more commonly a *cause* of problems for IAQ rather than a solution as was previously thought. Air leakage changes the moisture level inside a house making it dry in winter and humid in summer. It lets outdoor pollutants into the house.

Air Sealing

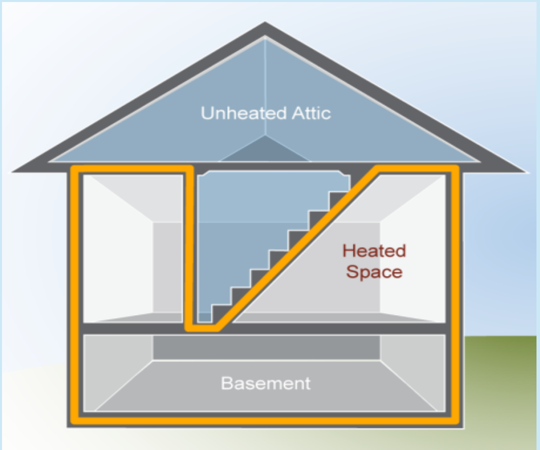
The purpose of air sealing is to make sure that the home’s **thermal boundary** (also called the **thermal envelope**) is continuous The thermal boundary is what separates conditioned space from unconditioned space. People spend a lot of money and effort trying to keep the air in the living spaces of their home a certain way (temperature, humidity, etc.), and preventing outside from leaking in and inside air from leaking out is one of the best ways to do this.

Weatherization Matters: Key Concepts

Thermal Boundary or Thermal Envelope

The thermal boundary, or thermal envelope, separates conditioned space from unconditioned space (basically, inside air and outside air). The thermal barrier is made of two major parts, the air barrier and the insulation. **For a home to be energy efficient, it is essential that these layers be aligned with each other and that they are continuous.** That is, they must be installed next to each other; and there must be no holes, gaps, missing pieces, or open areas.

The initial building analysis will determine where the thermal boundary is located. Weatherization installers doing air sealing work follow a plan to make sure that the air barrier has no holes and gaps, and that it is located next to the insulation.



The thermal boundary separates conditioned air from unconditioned air, indicated by the yellow line in the image above. (Image courtesy of US DOE)

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Breaks in the air barrier allow air leakage to occur under the right (wrong?) conditions. If there is a pressure or temperature difference between two places (e.g. conditioned space and unconditioned space, each on one side of an air barrier), air will naturally want to travel from one place to another. These conditions happen constantly in homes (see below) – air is *always* naturally trying to force its way in or out of a home. The purpose of the air barrier is to prevent this flow. If there are holes in this barrier, air is allowed to pass through. One of the main goals of weatherization is to prevent this flow from occurring.

There are two types of leakage caused by breaks in the air barrier – **direct leakage** and **indirect leakage**. Direct leaks are usually detected easily because they usually cause drafiness in the home. Drafts can be detected simply by putting your hand next to the leak. These can usually be fixed with weatherstripping, caulk and/or spray foam. Weatheriation installers will fix these leaks with relative ease. The real challenge is to find and fix the indirect leaks. Indirect leaks are usually so small that they cannot be detected without specialized equipment. However, just because they are small does not mean they are not important. These leaks add up – most homes have enough indirect leakage points that if you added them all up, it would be equivalent to leaving a window open all year long! This is obviously *not* a good way to have an efficient and healthy home.

Also, *where* the leakage occurs is very important. As discussed in manual 2, the stack effect is a common phenomenon in cold months. The stack effect causes high pressure near the top of the home and low pressure near the bottom. When this happens, warm conditioned air moves up through the house, and if there are indirect leakage points near the top, warm air escapes. At the same time cold air is being drawn into the basement or crawlspace. By sealing the leaks at the top ceiling/attic level and the basement/lowest floor level, major air losses are stopped. This does not mean that air leaks in other parts of the home should be ignored – as a weatherization installer, you should attempt to plug as many leaks as possible. But it is important that you know that some leaks are more important than others.

Direct leakage: occurs where a break in the air barrier of a building allows air to travel in both directions at the same time. Open doors and windows are common examples.

Indirect leakage: occurs when a break in the air barrier of a home is small enough that air can only travel in one direction at a time. Indirect leaks are often difficult to detect without specialized equipment.

There are two critical parts of a successful air sealing project: analysis of building shell leakage, and determining how and where to fill the gaps and cracks. Determining where air leaks are must be done with the aid of a blower door. By highly depressurizing (or pressurizing) the home, the blower door is able to make indirect leakage points detectable. In some cases, leakage points can be sensed by the presence of a draft, but it is best to use an infrared camera or smoke wand (and incense stick will do) to detect small leaks. The air sealing design must include a comprehensive plan to reduce uncontrolled air movement. It must clearly define a continuous and durable air and moisture boundary that encloses the living spaces inside. The attic, side attics, crawl spaces and any other unconditioned spaces must be separated from the living spaces in order to contain the conditioned air.

The goal of a comprehensive air sealing strategy is to control the air flow through a house, not just to stop air leaks. The new field of building science has design strategies to manage air flow, reduce leakage and increase the benefit of ventilation so that the occupants are more comfortable and breathe better air while at the same time using less energy

When evaluating a house's air quality, the sources of the house's problems need to be discovered. The following can assist in locating these problems:

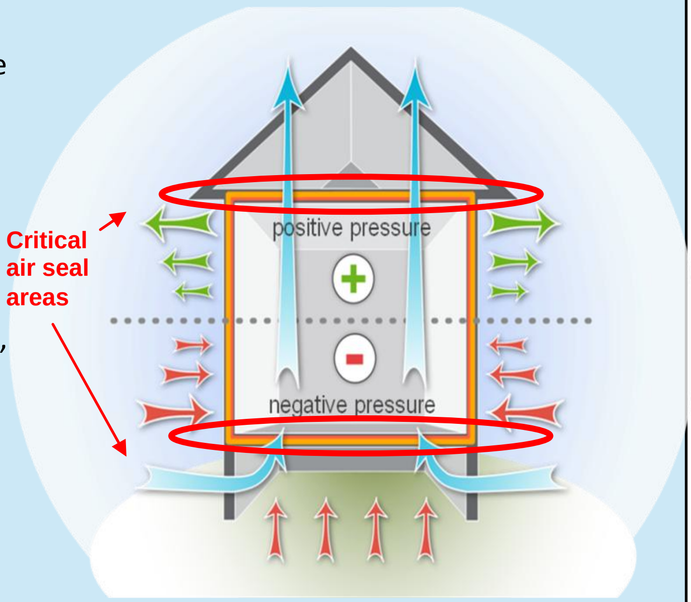
- high energy bills in winter or summer
- icicles, or ice dam buildup after snowfalls
- unexplained winter cold spots
- drafts across floors, walls or window areas

- mold or mildew growing on surfaces
- extremely dry inside air during winter months

The Stack Effect and Air Leakage

When the stack effect occurs, positive pressure increases the higher you go in the house, and the negative pressure decreases the further you go toward the bottom of the home. These areas of extreme pressure are most subject to leakage. As delta P increases, the air tries harder to move from the area of high pressure to low pressure. Conversely, air leakage pressure near the neutral pressure plane is minimal.

Because of this, air sealing parts of the thermal envelope in attics and basements/crawlspaces is especially important. Many of these areas are subject to indirect leakage, so can be difficult to detect. Even if these leaks are small in size, they should be a high priority.



While the stack effect is occurring, air infiltration and exfiltration are likely to be greater as distance from the neutral pressure plane increases. (Image courtesy of US DOE)

Common Leakage Areas

In many homes, the spaces above ceilings and between walls are where plumbing and electrical runs have been cut through. If these gaps are not sealed with caulk or foam, air will leak through, *even if the pipe or wire has a very tight fit*. Some homes, especially older ones, can have very large gaps (inches wide!) where pipes and wires go through. It is recommended that these hidden chase openings be sealed wherever they are found.

The trim around windows can also be subject to leakage if the windows were not sealed well when they were installed. Adding caulk around window trim can help minimize indirect leakage. Door frames can pose similar problems. Also, weather-stripping is an inexpensive and important material for reducing leakage around doors and windows. It is especially important to put weather-stripping in areas where the door closes against the frame, and to install door sweeps on the bottom of doors that open to the outside.

Ducts and fireplaces are also very common sources of air leakage. When the fireplace is not in use, the damper should always be closed. If the fireplace does not have a damper, one should be installed by a trained and certified professional. High-temperature caulk should also be applied where the chimney and/or flue go through the ceiling and roof.

Ducts transport conditioned air from the furnace and/or air conditioning unit to vents throughout the home. Most, if not all, of the ductwork travels through *unconditioned* spaces. Fixing leaky ductwork is thus a major priority for weatherization, because leaking hot or cold air into unconditioned spaces is a waste of energy. For this same reason, insulating ducts is also a high priority. Ducts are most likely to leak at points ("seams") where one section of ductwork connects to another. Leaky ducts also can allow dust and other IAQ-related problems into the house from areas outside of the building envelope. If the leaking ductwork is inside the conditioned space, it is a lower priority because leaking cold air in the summer and hot air in the winter is not too big a deal if you are trying to cool or heat the house anyway. If you want a balanced and efficient heating and cooling system, though, all ductwork should be airtight and well insulated.

Common construction design allows excess air flow. Features such as soffits above kitchen cabinets, recessed lighting fixtures, exterior overhangs and cathedral ceilings provide open channels for air to flow through the walls, ceilings and living spaces. Traditional house siding without air or moisture barriers, unsealed concrete block walls, stairways leading to the outside and crawlspaces that are ventilated or have dirt floors are some of the ways that designs over the past fifty years have made air leakage a common problem.

These pathways permit the infiltration (incoming) and exfiltration (outgoing) of air to occur as the interior and exterior of the house are exposed to changing air pressures and temperatures inside and outside of the house.

It may be difficult to imagine, but indirect leakage also occurs *through* most solid materials. Basically anything in the home not made of metal, glass or solid plastic will leak air. Think about what the average home is made of – it is likely to be mostly wood, with a drywall interior, possibly brick on the outside, and a concrete foundation. All of these materials allow air to flow through. The table to the right shows how rapidly air will leak through certain materials under blower door test conditions (CFM_{50}).

Material	Leakage Rate (CFM)
Air Barriers	
5/8" oriented strand board	0.09
½" Drywall	0.26
1/8" Hardboard	0.37
1" Extruded polystyrene (dense)	1.5
Materials Not Considered Air Barriers	
Standard concrete block	7.9
1" extruded polystyrene (light)	170
6" fiberglass batt	490
1 ½" loose-fill cellulose insulation	1160

This table shows the volume of air that passes through a square foot of each material when a blower door is operating at CFM_{50}. Note that even air barriers are not airtight. (Source: Krigger & Dorsi, (2009), p. 73)

Air Sealing Attics – Construction Flaws

Large breaks in the thermal barrier

The break in the thermal barrier is now sealed and ready to be insulated. (Images courtesy of US DOE)

It is very common in older houses to have very large breaks in the thermal barrier. The images to the left show a view from an attic looking down into the living space of a home. In the top image, you can clearly see the chimney. On one side of the chimney (to the right in the top picture) is the inside of an interior wall. As it turns out, there is a kitchen wall to the left of the chimney. Notice that you can actually see *inside the silverware drawer* of the home (middle picture, chimney on the bottom right)! There is nothing stopping air from flowing inside the home to the unconditioned attic.

These walls are made of plaster and lathe, which was used extensively before drywall was invented. Recall that a proper thermal boundary must have an air barrier and insulation in continuous contact. Plaster and lathe is a good air barrier, but terrible insulation. Does this home have a good thermal barrier, based on these pictures?

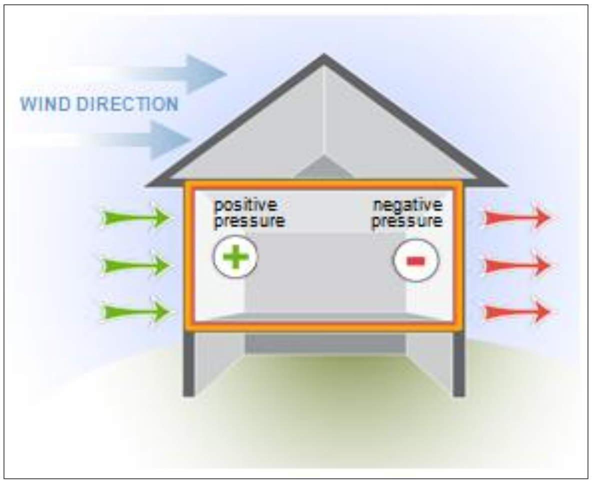
The answer of course is “no.” There is no insulation in this cavity. In order to create a thermal barrier, the installers cut rigid foam to cover the holes and sealed it with spray foam (bottom left image). It will eventually be covered with insulation.

What do you think the white metallic “ring” around the chimney is for? Answer: it is an “insulation dam.” Fire code requires that insulation be at least 3 inches away from chimneys and flues. Insulation is fire resistant, but not fire proof. The insulation dam is fireproof, and will make sure that insulation is not placed too close to the chimney.

It is very rare for a house to naturally be subjected to a 50 Pascal depressurization. But even common pressure changes can force air through some of the solid or semi-solid materials listed above. Small fans, outdoor wind, chimney drafts and furnace blowers are not usually so great as to push a breeze through a concrete block wall, but can cause leakage in many areas. And as noted previously, small leaks can add up to big energy losses. The following are common natural phenomena that drive interior pressure differences.

Stack Effect Pressure
Warm air is less dense than cold air. Hot air rises to the top of a home and cooler air falls to the bottom. As noted above, this means heated conditioned air is being lost near the top of the house (anywhere where positive pressure is) during the heating season (colder months). Just as important, cold outside air leaks in through lower parts of the home (the negative pressure zone). This effect is especially prominent in areas with cold winters. The opposite effect can happen in warmer months as cool air sinks creating a low pressure zone in the lower part of the house. This draws warm air in near the top of the home. As noted above, this is why it is especially important to air seal at high and low points in homes.

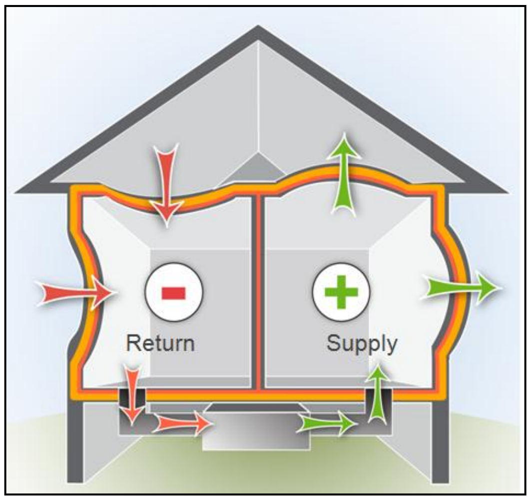
Wind Pressure
Blowing winds create high pressure zones where they push against the face of a house and low pressure zones at the house's corners, as air is drawn away. Significant leaks of conditioned air can occur on the downwind or "leeward" side of the building. The faster the wind hits the side of the home, the greater the resulting pressure is on the inside of the home.



The wind effect causes high pressure on the windward side and low pressure on the leeward side. (Image courtesy of US DOE)

Duct Fan Pressure
In homes with ductwork, the furnace blower is usually the most powerful air mover in the home. The blower is a fan that forces air through ductwork. Just as every CFM that goes out of a home results in a CFM coming into the home, every CFM out of the ductwork must be returned to the ductwork. There are thus two types of vents in ductwork – the "supply" vents blow air out and the "return" vents draw air back in.

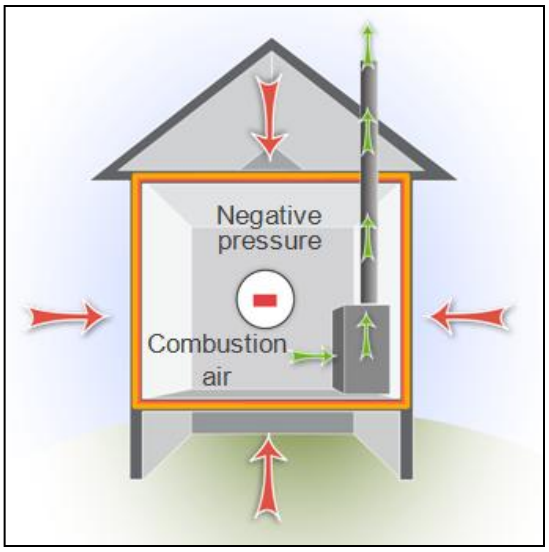
"Balancing" of the air supply and return through the house is necessary for the best energy performance of the furnace. A duct blower assessment is the best diagnostic method for identifying and quantifying problems and for targeting the best sites of repair to balance a forced air system. Unbalanced systems cause positive and negative pressure zones within a house (see image to the left).



Unbalanced duct systems can cause pressure zones within a house. (The effects of pressure are exxagerated – the walls would not bend so dramatically.) (Image courtesy of US DOE)

Furnace Pressure

When a furnace burns fuel – usually fuel oil, natural gas, wood, or propane - the exhaust contains harmful gases and particles that must be sent outside of the home (see Topic 2 below for more details). The same rule applies for this system as any other system in the home – a CFM out means a CFM in. Since the furnace exhausts air outside of the thermal boundary, what must occur? The answer of course is that air must come in from outside of the thermal boundary to replace the exhausted air. This infiltration of air is due to a negative pressure zone that is created inside the home when the furnace exhausts air outside. In the winter, this means the entrance of cold air into the warm house. This is avoided by furnaces that draw combustion air directly from the outside, which are called **sealed combustion furnaces**. **Open combustion furnaces** pull air from the inside of the home, and are the most common type of furnace in the U.S. Combustion will be addressed in more detail in the following section.



Combustion appliances that draw combustion air from inside the thermal boundary cause negative pressure to occur inside the home. (Image courtesy of US DOE)

Topic 2: Basics of Combustion Analysis

Combustion has been mentioned a lot up to this point, but it has not yet been defined. So what is combustion, exactly? Combustion, which is commonly referred to as "burning," is the combination of oxygen and a fuel to produce heat and water (light is almost always produced as well) (see the insert below). The oxygen is usually very easy to obtain, because the air we breathe is about 21% oxygen (it is about 78% nitrogen). This is why a fire needs air to keep burning. The fuel can be any number of things. Most homes are heated with natural gas, heating oil, propane, and/or wood. These fuel sources are made primarily of hydrogen and carbon (they are hydrocarbons). Due to carbon being burned along with the oxygen, carbon dioxide is also produced through combustion. As long as there is enough heat to begin with (e.g. a pilot light or other fire), the oxygen from the air combines with the carbon and the hydrogen in the fuel, and produces water, carbon dioxide, heat and a few minor byproducts.

Sealed combustion furnace: furnace that draws combustion air from outside the home, avoiding depressurization of the building.

Open combustion furnace: furnace that draws combustion air from inside the home. Open combustion causes depressurization and can lead to infiltration.

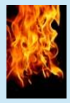
Note that only "pure" combustion results in only heat, light and water being produced. In reality, combustion is usually a dirty process that produces a lot of byproducts like carbon dioxide (CO_2), carbon monoxide (CO), and other pollutants. Of these, carbon monoxide is the most dangerous because it is silent, odorless, tasteless, colorless, and potentially deadly. Too much carbon monoxide can cause suffocation. Because of this, it is important to have furnaces checked annually to make sure they are running properly and safely. It is also important to have a carbon monoxide detector near all combustion appliances. If the alarm goes off on a carbon monoxide detector, the occupants should immediately call a service technician to fix the problem.

What is Combustion?

Combustion is a chemical reaction in which oxygen and hydrogen combine to produce water vapor and heat (and usually light). It requires three things:


Fuel

O_2
Oxygen


Heat

The basic chemical reaction equation for **complete combustion** is:

$$2H_2 + O_2 \rightarrow H_2O + heat$$

In all combustion appliances (except for hydrogen fuel cells), the fuel used (oil, natural gas, wood, propane) contains carbon. This causes carbon dioxide (CO_2) to be produced as well. The basic chemical reaction for **complete combustion of natural gas (CH_4)** is:

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2 + heat$$

Complete combustion is never achieved in home furnaces. Incomplete combustion can occur for many reasons, but the result is a loss of efficiency (waste heat) and dangerous exhaust (carbon monoxide, CO). The basic equation for **incomplete combustion of natural gas** is:

$$2CH_4 + 3O_2 \rightarrow H_2O + CO_2 + CO + O_2 + heat$$

The reason we put combustion appliances in houses is because they produce heat. They are part of the heating, ventilating, and air conditioning (HVAC) system, which also includes any ductwork, venting, and other components that are involved in heating and/or cooling the home and appliances in the home. Furnaces use the heat to heat the home, and domestic hot water heaters use the heat to increase the temperature of the water in the tank. All furnaces use the same basic process to produce usable heat:

1. The fuel is supplied to the burner of the combustion appliance
2. Heat is supplied at the burner

3. Oxygen is supplied (combustion air)
4. Heat is produced and used for heating purposes (usually using a heat exchanger)
5. Exhaust (combustion gas) is produced and released outside of the home through a flue pipe

Fuel Supply and Heat Exchange
Fuel can be supplied a number of different ways: natural gas furnaces use a pipe (usually about an inch in diameter) that runs from a main supply line outside of the home to transport it to the furnace; oil furnaces use a very small (usually about ½" and made of copper) pipe that runs from an outdoor tank; propane is also transported via a pipe from an outside tank; and of course wood is placed inside a furnace by hand. Once the fuel is inside the area, it mixes with air and is ignited, usually by a pilot light or electric igniter. In other words, combustion occurs. The heat that is released by combustion then heats up a heat exchanger, which is inside the furnace. The heat exchanger is made of metal and absorbs the combustion heat. The heat exchanger is surrounded by either air or water, and it provides heat whichever of these fluids surrounds it. (It "exchanges" the heat from combustion into the fluid, which is why it's called an exchanger.)

Heat Distribution
Most wood furnaces simply heat the air around the outside of the furnace, and do not use a heat exchanger. Homes with forced air systems use ductwork to transport the heated air throughout the house. These systems have a blower attached to the furnace, which is simply a fan that forces the air to go through the ductwork. As noted above, the air goes through the ducts, blows air into the home through supply ducts, and air is returned through return ducts. The main duct eventually makes its way back to the furnace. This is the "return air," which helps ensure a balanced system and increases efficiency. It also reduces the negative pressure that would otherwise result if the furnace were constantly pulling supply air from inside the home. Some gas and oil furnaces heat water, which then travels through pipes around the house. These pipes release heat on their way through the home, and eventually return to the furnace. These are called hydronic heating systems. Some furnaces boil water to produce steam, which then travels through pipes until they reach large metal "registers," where the steam condenses into liquid water and releases heat.

The combustion air can be supplied a number of ways, but most furnace use open combustion, as mentioned above. Open combustion furnaces draw air from inside the home. This depressurizes the area near the furnace (called the combustion appliance zone, or CAZ). This can cause infiltration in other parts of the home (CFM in = CFM out). Closed combustion uses air pulled in directly from the outside through a pipe, which prevents this problem from happening.

Draft
Draft is the force that causes air to be pulled into the combustion chamber and propels the combustion gases away from the combustion process and out the flue. The primary driver of draft is the buoyancy of the combustion gases. Hot air rises through colder, air – that is to say, the hot air is buoyant. Some furnaces have fan-assisted draft, which means that a fan with an

26

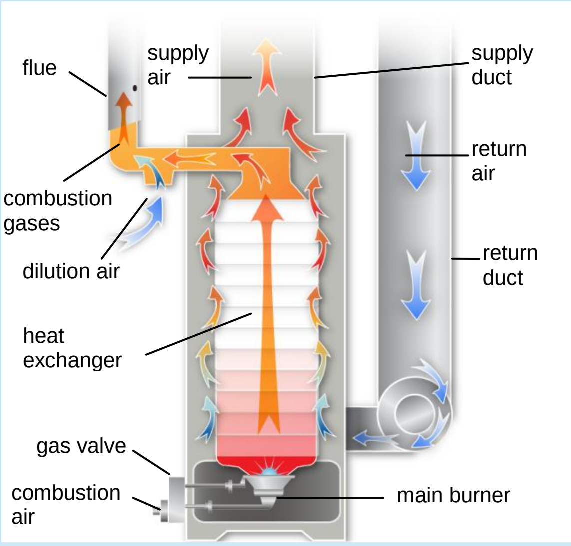
electric motor helps the draft along by blowing the combustion gases out the flue. This is especially important in higher efficiency furnaces, which have lower combustion gas temperatures. Some open-combustion furnaces have a draft diverter or barometric damper, which supplies extra air to the flue if necessary (dilution air). Sometimes a gust of wind or negative CAZ pressure pulls the draft the opposite way down the flue. The draft diverter prevents these negative drafts from blowing out the pilot light. Sealed-combustion appliances do not need diverters, because they use fan-assisted draft, which both maintains a proper draft and prevents negative drafts from occurring.

Weatherization Matters: Key Concepts

Combustion Appliances

The diagram to the right shows the basic functioning of an open-combustion, forced air gas furnace. The basic process is as follows:

1. The fuel is supplied to the burner (in this case, natural gas).
2. Combustion air is brought into the combustion chamber. This provides oxygen, which is necessary for combustion to occur.
3. In the combustion chamber, the heat from the burner combines with the oxygen and the fuel to create heat and combustion gases (i.e. combustion occurs).
4. The heat goes through the heat exchanger. The heat exchanger heats the surrounding air, which goes into the ductwork (the supply air). It is then carried throughout the house and released through vents.
5. The exhaust (combustion gases) go up the flue and out of the building.



Basic setup and functions of a natural gas furnace. (Image courtesy of US DOE)

6. The ductwork goes throughout the home and reconnects to the furnace. This is the return air.

The process is similar for other combustion appliances, though there are many possible differences. Different fuels may be used, water may be heated instead of air, blowers may be used to assist draft, and more.

Having a proper draft is an essential component of the combustion process, both from a safety and an efficiency standpoint. First of all, draft is the force that supplies combustion air to the burner. Without a proper supply of oxygen, combustion will not adequately occur. Insufficient oxygen is rarely a draft problem. A problem that *can* frequently occur in homes - especially ones with open-combustion furnaces - is having too little draft to fully exhaust the combustion gases from the home. This can occur when the CAZ is depressurized by other things in the house. If other appliances are exhausting air to the outside, such as dryer vents, bathroom exhaust fans, hot water heaters, and so forth, the inside of the home can be depressurized. These systems can be pulling air away from the furnace, while the furnace is trying to pull air in and exhaust it. Essentially, they are fighting for the same air. Other draft issues may occur if the combustion gases are not hot enough to be rise quickly through the flue, high winds, and a blocked or obstructed chimney.

All of these can result in **spillage**, which is the temporary exhaustion of combustion gas into the home through a diverter or damper. Spillage is temporary, and is not much of a concern. **Backdrafting**, however, is a concern. Backdrafting is continuous spillage – when backdrafting occurs, combustion gases are being constantly emitted inside the home. Combustion gases contain a number of dangerous pollutants, including carbon monoxide and other things that can cause respiratory problems.

Spillage: the flow of combustion gases from a household combustion appliance that does not exit through the flue or chimney but rather inside the building.

Backdrafting: spillage of combustion gases for an extended period of time. Generally, spillage is considered backdrafting if it lasts for a minute or more.

Combustion Analysis

Energy auditors perform combustion analysis as part of the audit. This is done because combustion appliances can be dangerous, and even deadly, if they are not operating properly. This is also done to figure out how efficiently the furnaces are operating. Some of the key components of the combustion analysis are as follows:

1. Look for ambient CO. Ambient CO is the CO that is in the air before and after the combustion appliance is running. This is tested throughout the home.
2. Create a "worst-case" CAZ depressurization. All exhaust fans throughout the home are turned on, HVAC system is run, doors are opened and closed, and anything else that depressurizes the CAZ is done. This is called the "worst case" depressurization because it creates the strongest possible competition for furnace air.
3. For natural gas furnaces, the piping is checked for gas leaks. A "sniffer" is used for this purpose. The sniffer is a handheld device that is able to detect even very small concentrations of natural gas.
4. Test for spillage. Spillage levels are tested after the appliance has been running for at least 1 minute. Spillage is common within the first minute, because the combustion gases are heating up and may not be hot enough to create a good draft right away. Spillage after 1 minute is evidence of insufficient draft and backdrafting.

5. Test of draft strength. After the appliance has been running for at least 5 minutes, the flue is tested for draft. A draft probe is inserted into the flue through a hole that is drilled. There are minimum draft standards based on the type of furnace and outdoor temperature.
6. Test for CO in undiluted air. The CO content of the combustion air inside the furnace is tested to see if combustion is occurring properly. For sealed combustion appliances, the test is done where the flue exhausts outside. Too much CO is not only dangerous, but a sign that the furnace is not operating properly. CO is the result of insufficient combustion, and can point to a number of potential causes.
7. Test for efficiency. The amount of oxygen present in the combustion gases is determined. Higher oxygen content means lower efficiency. This is also tested by the draft testing probe.
8. Check for flue slope. The flue pipe should *never* be on a down slope. Specifically, all flues should rise at least ¼" for every foot of length. A negatively-sloped flue can decrease draft. Also, flues for smaller appliances (e.g. hot water heaters) should connect to the main pipe above where the large appliance flue enters. This also helps prevent draft problems.

There are more possible combustion analyses to do, and they all vary based on the type of appliances (closed-combustion, open-combustion, age, efficiency, fuel type, etc.). Regardless, combustion checks should always be done for all combustion appliances, both in worst-case and natural conditions.

Fireplace Chimneys and Dampers
Chimneys are generally used for fireplaces (gas or wood-burning), though many existing chimneys have been retrofitted with furnace flues. They are usually made of brick or stone, and the flue runs through them. The natural convection of a good chimney causes air to flow up an out of the chimney, even when no fire or appliance combustion is burning. Conditioned air that flows out of a chimney throughout the year is a total waste, but can be reduced significantly with the installation of chimney dampers (also known as flue dampers). A chimney damper is a movable cover (usually made of metal) inside of the chimney or flue. It can swing open and shut as needed. Dampers should be closed when the fireplace is not being used, otherwise leakage will result. Dampers need to be properly checked and maintained or they will quickly fail.

If the fireplace is used at all, the chimney needs to be fitted with a good flue inside of it. This could mean repairs to the original damper. Many older fireplace chimneys, which were originally used only during the heating season, have been altered to permit furnaces and water heaters to vent all year long. A replacement damper for the fireplace burner box or a top-mounted damper could be installed if needed.

Top-mounted dampers are both spring-loaded and counter-weighted to remain in the open position for safety. They are simple devices that come in kits and are easy to install, but is best left to someone with training and experience. The top is a closable cap mounted on top of the chimney. There is a spring at the end of a cable that is pulled to close the cap when the fireplace is not being used. These are inexpensive options for fireplaces that are only used a few times a year and are worth having even if only to stop summer time conditioned air losses.

Chimney Drafts
A natural draft chimney is one that does not use any implements (fans/blowers) to force exhaust fumes out of the flue. The only dependable driving pressure in a chimney operating on natural draft is produced by the temperature difference between the house's interior and exterior. Air is invisible and makes diagnosing wind-induced chimney failure difficult. Despite the fact that wind flowing over a chimney can produce a driving pressure, it cannot be completely depended upon for the performance of a combustion appliance (a furnace, boiler, hot water heater, etc) since it is variable and unpredictable.

The effects of wind acting on leaks in a house's envelope can cause wild fluctuations of the pressure inside. This explains many venting failures of heating system flues and chimneys. Therefore, it is important to look at the entire house and not just the chimney when diagnosing venting failures.

Topic 3: Advanced Air Leakage Diagnostics

The most accurate and comprehensive means of pinpointing building leakage is a blower door test and full energy audit conducted by a professional energy analyst. These analysts have training and experience inspecting, calculating and evaluating building tightness and locating leakage sites. With the current equipment available, this is a reliable and effective means to assess the building. In the right hands, the blower door can be used to prescribe effective and targeted retrofit measures. An energy audit is a comprehensive analysis of the health and safety and energy efficiency of a home. In this section, the parts of an energy audit that focus on air sealing will be examined.

The Energy Audit
A visual inspection is the first step in an energy audit of a house to find air leaks. The attic is checked for gaps and cracks in the floor and the ceiling underneath. Lifting up the attic insulation and looking underneath can expose gaps that have not been sealed, but were hidden by insulation. The flues, plumbing vents, wire pathways, gaps around recessed lights, fans and chimney penetrations that extend through the roof are found. These will need to be sealed where they come up through the attic floor.

Signs of air leakage in the attic Include but are not limited to the following:

- Discolored insulation (on the warm side, at edges, or in the middle) is an important clue that means dirt and dust are being filtered by the insulation through air movement indicating a significant air leak nearby.
- "Heat tape" on pipes or signs of water leakage, which are good indications that some work to reduce air leakage that is chilling pipes is needed. Pipes generally freeze because cold air blows across them.

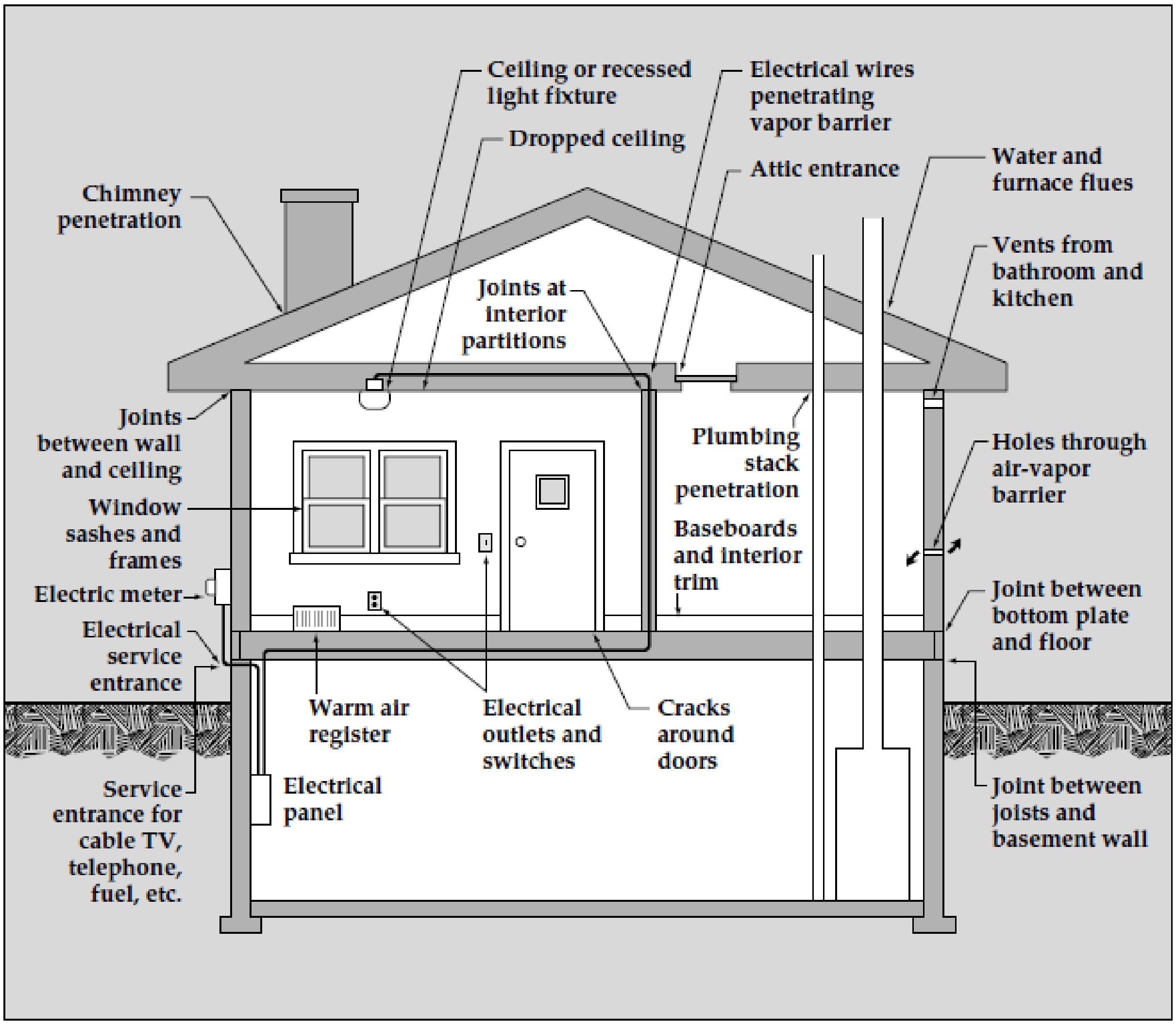
- Icicles and ice dams at the eaves of the roof are a sign of possible air leaks from the house to the attic. Snow melting in small areas or patches on the top of the roof the day after snowfall is an unmistakable visual display of air leakage patterns in the top floor or attic.
- Evidence of moisture such as frost underneath the roof, rusty nails, stained or rotting wood, and mold growth

After the visual inspection is complete, and trouble spots noted, the house is prepped for the blower door test, and the blower door test is performed. (Refer to manual 1, topic 9 for blower door details). Recall from manual 1 that a blower door consists of a powerful fan added to an airtight frame, which is fit snugly into a door that leads outside the home. The setup is connected to a manometer, which measures air pressure and the rate of airflow through the fan. The fan is most often used to depressurize the home by blowing air outside at a high rate. When this is done, air is forced to come in through the various leaks in the building shell, even very small leaks that cannot be detected under natural conditions. The best way to detect almost all leaks in the house is with the aid of an infrared camera. An infrared camera can detect subtle changes in temperature, which results in a color-coded picture that shows areas of different temperature. Energy auditors can also use smoke wands, incense, or other smoke generating devices to find air leaks. Smoke may be difficult to use when depressurizing, because there can be a lot of air movement inside the home, which affects your ability to pinpoint individual leaks. Many times, even small leaks can be detected by putting a bare hand near likely trouble spots (outlets, windows, plumbing chases, etc.). The ability to detect small and indirect leaks is what makes a blower door test so valuable for air sealing.

A blower door test is used to diagnose how leaky a house is, and to assist in finding leakage sites. In this image, the energy auditor is holding a manometer, which is used to determine pressure differences and leakage rates. (Image courtesy of US DOE)

Using a blower door fan test to *pressurize* rather than depressurize a house can be very helpful in locating areas of significant leakage. Smoke-generating devices are very useful in combination with pressurization. Smoke will be sucked outside through even small leaks, and with careful inspection, leaks can easily be found.

Advanced diagnostics can also incorporate zonal pressure in the house between rooms or other areas of the house that can be closed off from each other. Zonal tests can determine if a room or area is significantly leakier or tighter than other rooms or the rest of the house, and how well connected it is to the rest of the house. In addition, a pressure pan can be used to test how well sealed the ductwork in a home is.



Common leakage sites in homes. Many of these can be fixed easily, but diagnosing them can be difficult without a blower door. (Image source: National Renewable Energy Laboratory and US DOE[2])

Tracer Gas

Another less-used method to diagnose air leakage is tracer-gas testing. This method of building analysis is more expensive and time-consuming than the blower door. It can yield very accurate leakage rate information because it tests the building under natural conditions rather than changing building pressures like the blower door does. The testing consists of the release of a gas that is not harmful inside a building. Periodic air samples are taken and then tested to see how much gas is in the air at different times. The leakier the building the less gas will be contained in the samples as some gas leaks out of, and other air leaks into, the building. This test is sometimes used to diagnose special problems or in large buildings.

[2] Available at http://www.nrel.gov/docs/fy01osti/28039.pdf

Regardless of the methods used, after the energy audit is complete and all leaks have been detected, it is time to air seal. There are many air sealing methods. The most common ones used by installers are described in the following section.

Topic 4: Air Sealing Methods

The purpose of air sealing is to provide a **continuous air barrier** between a home's conditioned and unconditioned spaces. Much of the work is usually done in an existing accessible attic, side attic, crawlspace or other buffer zone between the interior and exterior of a home. The goal is to create a single pressure boundary, established where it is most practical. A combination of air barriers (plastics, foam board, etc.) and sealant materials (caulk, spray foam, etc.) is used to close holes and bridge gaps between airtight sections of existing construction. The most typical sealants used are caulk and spray foam.

Caulk

Caulk is a compound that comes in tubes that are loaded into the "caulk gun." Caulk comes out as a gel-like substance that dries (loses its stickiness) in about 30 minutes to a few hours, depending on the type of caulk. Most caulk will fully "cure" (fully dry) after being exposed to the air for a day to a few days.

Caulk forms a flexible seal for cracks, gaps or joints less than 1/4-inch wide. A caulking compound can be used to seal air leaks in a variety of places throughout a house, including around windows and door frames. This is a great way to realize simple and inexpensive energy savings. One tube of caulk can be used to over a hundred feet of cracks, and costs a few dollars. With practice, every window and exterior door on an average home (1,500 square feet) can be caulked in about four hours.

In addition to sealing air leaks, caulking can also prevent water damage inside and outside of a house when applied around faucets, ceiling fixtures, water pipes, drains, bathtubs and other plumbing fixtures. A word of advice when using caulk in this way: for caulk to properly adhere to surfaces, it must be applied to dry areas.

Finally, it is important to note that caulks can be used in high-temperature areas such as chimneys and flue pipes. However, *only use high-temperature or fire-rated caulk in these areas.*

Spray Foam

There are a number of spray foams that are commonly used in weatherization. Spray foams have a couple of advantages over caulk. First, foams expand after they are applied. This is very convenient when air sealing, because when applied correctly, foam will expand to tightly fill holes and gaps. Spray foam is also an excellent insulator, unlike caulk. Spray foams actually have a higher r-value than blown or batt insulation. Finally, because they expand, foams can fill larger holes and gaps than caulk.

Small cracks and holes – up to 1” wide, but up to 4” if a backer, such as foam board, is used – can be sealed with expanding one-part polyurethane spray foam, which comes in a hand-held can. Hand-held cans usually come with a plastic spray tube that can be attached to the nozzle for (relatively) precise application. The can of foam pictured to the right has an applicator gun with a metal tip. This will allow for more precise application than a plastic tube, and unlike the plastic tube, the metal gun allows the can to be reused more than once.

Two-Part Spray Foam. Spray foam is an adhesive, insulator and air sealant. (Photo ©)

For larger areas and bigger gaps – up to 2” alone, and up to 6” with a backer - it can be cost-effective to use two-part foam. Two-part foam comes in large canisters (usually a few square feet) that have hoses and variable spray tips attached to them. These hoses and tips can be used to produce a bead of foam, or a few square inches of coverage, as needed. These produce higher density insulation and are cost effective.

Spray polyurethane two-part foam is a high tech product that requires the use of heat and high pressure inside the canister, because the materials inside the canisters are fairly dense. It produces foam with a higher density and a higher R-value than the foams mentioned above. This product costs more than the other types of foam and can only be done by trained technicians. However, it is a highly effective way to cover large areas.

Two-part spray foam can fill holes up to 2" alone, or 2" - 4" if a backing is used. (Photo ©)

To be effective, the materials, sealants, connections and attachments used in air sealing must meet all of the following conditions:

- Be continuous on all edges and across all gaps
- Be strong enough to support expected loads
- Be durable enough to maintain airtightness over time
- Be impermeable to airflow, typically 0.004cfm/sq ft @75pa for barriers and sealants.

Other Common Air Sealing Materials

Flexible films and sheeting:

- cross-linked polyethylene film (Tyvek, etc.)
- self-adhesive films, which are becoming more available

Thin panel barrier materials that can be left exposed in certain attics and crawlspaces (Check for Code Compliance. For example, they need to be limited access utility service-only spaces, separate from the residence with NO storage and no heat-producing equipment):

- certain foil faced polyisocyanurate (e.g. ESR-1864 TSX8500, NER 681 Thermax)
- certain extruded polystyrene(XPS) insulation boards (e.g. ESR 2142 Dow Styrofoam)
- foil faced bubble wrap (flame spread 25X)

- radiator reflector board

Barrier materials that can be left exposed to interior and to cover chases to interior:
- gypsum board
- plywood
- oriented strand board (OSB)
- 26 ga. sheet metal
- foil faced polyisocyanurate (e.g. ESR-1864 TSX8500, NER 681 Thermax)
- flame spread 25 faced batts and duct insulation when supported
- rigid duct board with flame spread 25 facing

Pliable materials to fill gaps that are sealed over:
- extruded foam gaskets
- fiberglass in plastic wrap

Mastic: a thick, pasty substance used to seal seams and cracks in building materials. It is heat resistant, mostly air tight and easy to apply. It is often used to seal ductwork.

Non-combustible barriers:
- galvanized sheet metal
- aluminum flashing on roll
- cement board

Non-combustible sealants:
- fireblock sealant meeting ASTM E 136 (all chimneys)
- for gas vents only: 600F RTV silicone
- furnace cement

Materials that can be installed by blowing:
- cellulose loose fill insulation meeting ASTM C739, 16 CFR 1209, 1404
- specific cellulose ICC ES reports required for fire rated details
- ESR-1996 US Greenfiber, ESR-2217 NuWool
- mineral fiber batt and blanket insulation meeting ASTM 665
- mineral fiber loose fill insulation meeting ASTM C764
- fiberglass wool engineered for air resistance tested to draft BPI standard using ASTM E2178, C522

Sprayed-on air barriers and insulation:
- Insulating foam (bulk, truck-mounted)
- Two component open cell foam listed for uncovered use in attics and crawlspaces

Air Sealing During Renovations

In cold climates it is best to seal exterior wall air leaks from the house's interior, which establishes a thermal boundary at the inside surface of the exterior walls and the top story ceiling. The most common method is to blow dense-packed blown-in cellulose through holes drilled in each stud cavity (see below for more dense-packing details). Depending on the housing type, the holes may be drilled through the interior drywall or plaster, or the exterior wall sheathing after the siding is lifted up. If proper technique is used, blown-in cellulose insulation will tightly fill any wall cavity. With a well-packed wall with a cellulose density of 3.5 lbs./ft^3, the walls are not only insulated, but also air sealed.

When the opportunity arises to air seal as part of an interior renovation, air seal and insulate before the floor and wall finishes have been replaced. In other words, air seal when the interior of the walls are exposed. This allows easy access to wall cavities, ceilings, floor wall joints and the back of exterior walls which are all common sites of air leakage. Exterior renovations also present a great opportunity to air seal. Re-roofing is a good example of this, and can be an opportunity to install continuous sealing along structural connections and sheet materials on walls and roof surfaces that combine air and vapor barrier properties. Any time any renovation offers an opportunity to access parts or areas of a home that are usually not accessed, weatherization retrofits should always be considered.

Duct Sealing Strategies and Methods

Solving ductwork problems provides another opportunity to improve a home's energy performance and maintain the health and safety of a home. Common ductwork problems are air leakage at joints and seams, poorly insulated ductwork that goes through unconditioned spaces, joints coming apart after installation, and poor system designs. These can cause direct losses of conditioned air, conduction losses of heating or cooling, condensation moisture problems, and air pressures that are out of balance. All of these can compromise efficiency and health and safety in a home.

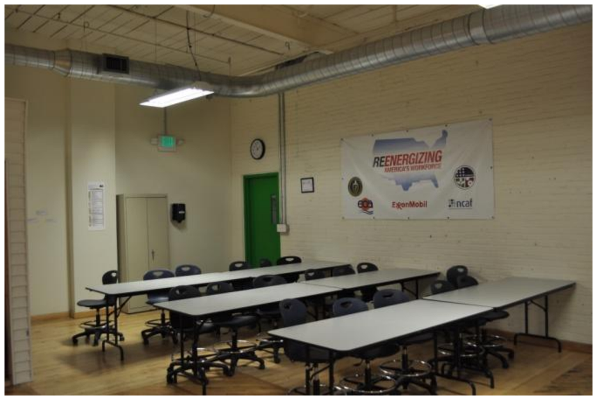
Mastic is an easy and effective material to use to seal ductwork. (Photo © eca)

Airtight ductwork connections and joints are critical. It is especially important to seal near the air handler as the plenum and other duct parts near the blower fan sustain the highest pressures and are the most susceptible to significant air leakage. In addition to energy loss via hot and cold air leakage, leaky ducts can alter the pressure balance in a home. When air leaks into one area of the home, a high pressure zone can be created. This of course can result in air exfiltration, and consequently air infiltration. Both of these represent uncontrolled air movement, which is one of the primary ways a home's energy efficiency is reduced.

Installers must take care to find wall and floor cavities that are used for return duct runs (i.e. they take air back to the blower). These are inherently leaky and made of porous materials that cannot be effectively sealed. These leaks in the return are of greatest concern if they are near the furnace blower, because they can depressurize the surrounding area and draw combustion gases into the supply air. Proper installation of duct take-off fittings in main ducts, reinforced by duct **mastic**, will make a tight lasting connection.

For flex duct, seal the inner liner with mastic and then use strap tie clamps to connect both the inner liner and then the outer insulation wrap.

Where ductwork is exposed to view inside the home, it can be sealed with caulking silicones or with mesh tape and duct mastic. Mastic comes in low VOC varieties and solvent mixes, which are safer for application in living spaces. To do this, apply some mastic, wrap the duct joint or seam with the mesh tape, paint or smear duct mastic to cover and imbed the tape. After the proper tack drying time (two to six hours), the materials usually require a 12 to 20 hour curing time before the duct system can be pressurized. It is essential that you wait until the mastic is completely cured! Incomplete curing can cause total failure of the duct sealing work, permitting the leakage to continue. If this happens, you must start the sealing process over again.



When ductwork is inside the conditioned space, ductwork does not need insulation. (Photo © eca)

Attics, Crawl Spaces and Basements

Attics, crawlspaces and basements require different materials and methods to seal off air and manage moisture than the rest of the house. The air sealing work includes inspection of attics and crawlspaces to be sure they are in good condition and ready for sealing. If signs of moisture are present, sealing should be delayed until the moisture problem is corrected. Standing water or muddy crawl space floors are obvious signals of moisture, as well as white or black mold, water stains, rust on metal parts, and rot. Once all conditions are addressed, a complete vapor or moisture barrier along with insulation can then be installed.

Too Much of a Good Thing?

It is possible to perform too much air sealing on a house, wasting money in the process. If a second blower door test after retrofitting indicates that there is still a little bit of leakage in the house, finding these secondary leaks leads to diminishing returns. That is, this work will usually not save much additional money, but may cost a lot in terms of time and labor. Barring any major errors in work scope, the most important leaks will have been taken care of after the first weatherization.

More importantly, too much air sealing can threaten occupants' health. All houses must "breathe" at least a little bit. Allowing fresh air in is essential to prevent buildup of toxins in the home from common household pollutants like furnace exhaust and cleaning materials. Some of these toxins, such as carbon monoxide from combustion, can be deadly. Also, a house that is too tight will be "stuffy" and uncomfortable, a result of too little fresh air being let in. The U.S. Department of Energy has guidelines for how well a home should breathe, which is the Building Tightness Limit (BTL) mentioned previously in this manual.

A tight building can also make spillage and backdrafting problems worse. When a building is leaky, it can be easy for the combustion appliances to find combustion air, because air can easily come in from the outside to replace air being sucked out. If the building is tight, it is harder for outside air to come in, so the appliances are fighting for the same air. Building analysts must check for this problem in the CAZ both before and after weatherization work.

Topic 5: Insulation

For a house to be efficient and healthy, it must have a good thermal boundary. As mentioned previously, a good, continuous *air* boundary (which can be achieved by good air sealing) is only half of what is needed for a *thermal* boundary. The other component is insulation. Why are both elements essential? The most important qualities of an efficient, comfortable and healthy home are 1) control of air and moisture flow and 2) control of thermal (heat) flow. Air barriers are very good at helping to control air and moisture movement. In terms of thermal flow, recall the three types of heat flow from manual 2 – conduction, convection and radiation. Air barriers prevent convective flow. Insulation is very good at preventing conductive heat transfer, but also convective and radiant transfer.

Even without an air barrier, Insulation helps to slow heat loss wherever present. It is useful to install insulation anywhere you wish to control heat flow, whether in the building shell (e.g. walls, attics, floors) or wrapped around hot water pipes, DHW tanks or around furnaces. Insulation is also used to prevent heat flow into cold areas – it keeps homes cool in the summer, and is inside the walls of refrigerators and freezers. Because of this ability to prevent heat transfer, adding insulation improves the effectiveness of space conditioning (heat and air conditioning). Incidentally, it also reduces noise and can help prevent pests from entering the home.

How Insulation Works

Insulation's ability to prevent heat transfer is measured by "thermal resistance," better known as R-value. All materials have an R-value, which indicates how well a material will resist thermal transmission. Higher R-values indicate better resistance to heat transfer, and R-values can be added. For example, if an inch of fiberglass batt (about R-3) is lain on top of an inch of expanded polystyrene (about R-4), the result is an R-value of 7 (3 + 4). R-values are commonly measured in R-value per inch of material – in fact, weatherization workers use the terms interchangeably. If someone tells you on the job that something has an R-value of "3" or "4," they mean 3 or 4 per inch.

R-value: the ability of a material to resist heat transfer. Higher R-value means better thermal resistance.

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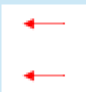
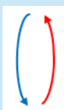
Weatherization Matters: Key Concepts

How does insulation work?

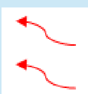
Insulation prevents all three types of heat transfer:



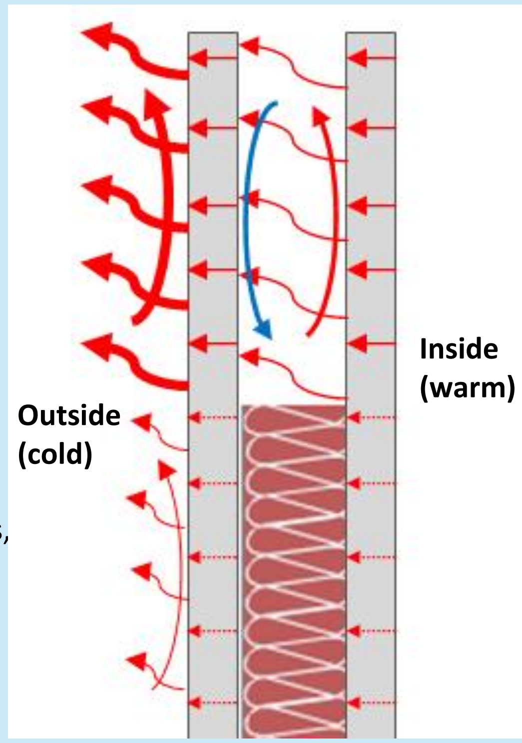
Conduction
Insulation keeps the inside of the wall warmer, which slows conduction of heat from inside the home. Insulation itself is a very poor conductor, so conduction is minimized inside the wall as well.



Convection
Open walls allow air currents ("convective loops"), which create convective heat transfer. Insulation only has tiny air pockets, which prevent this from happening.



Radiation
In an open cavity, there is nothing to stop radiant heat transfer between the hot and cold walls. With insulation, radiant heat travels within air pockets. Delta T is minimal with these pockets, so radiation is minimized.



Insulation reduces all three types of heat transfer. (Image ©

As mentioned above, insulation works by preventing all types of heat transfer, but primarily through conductive resistance. The key to a good insulator is having a lot of small air pockets. The air pockets prevent conductive flow because air *cannot conduct heat*. Heat can conduct between and within the solid materials in insulation (fiberglass fibers, foam, etc.), but it conducts much more slowly than if the whole material were solid. In addition, the material inside insulation prevents convective flow because air movement is minimized. Imagine an empty wall cavity – air is free to move within it, and thus convective heat flow can occur. Insulation prevents this. Radiation is limited by virtue of the material inside of insulation not allowing other forms of heat to flow. Radiant heat flows faster with greater temperature differences, and the material inside of insulation does not allow great temperature variation. All of these factors combine to make insulation work.

It is important to know that the effectiveness of insulation is affected by other factors aside from R-value. For instance, putting a metal screw through foam insulation board creates a "thermal bridge" that can conductively transfer cold and heat through the insulation. **Thermal bridging** permits rapid heat transmission through conductive materials that are in contact with each other. The conduction of heat and cold is easier through steel, aluminum, masonry, and wood, than through insulation. The low R-values for these structural materials reduce the overall R-values for the entire wall well below the R-value of the wall insulation. Moisture can also reduce R-value by compressing air pockets. Also, water allows heat to transfer through it via convection. Extremely wet batt or blown insulation can in fact have a near-zero R-value.

Thermal bridge: material that allows rapid conductive heat transfer, found within a larger area of higher thermal resistance, e.g. wood framing within an insulated wall.

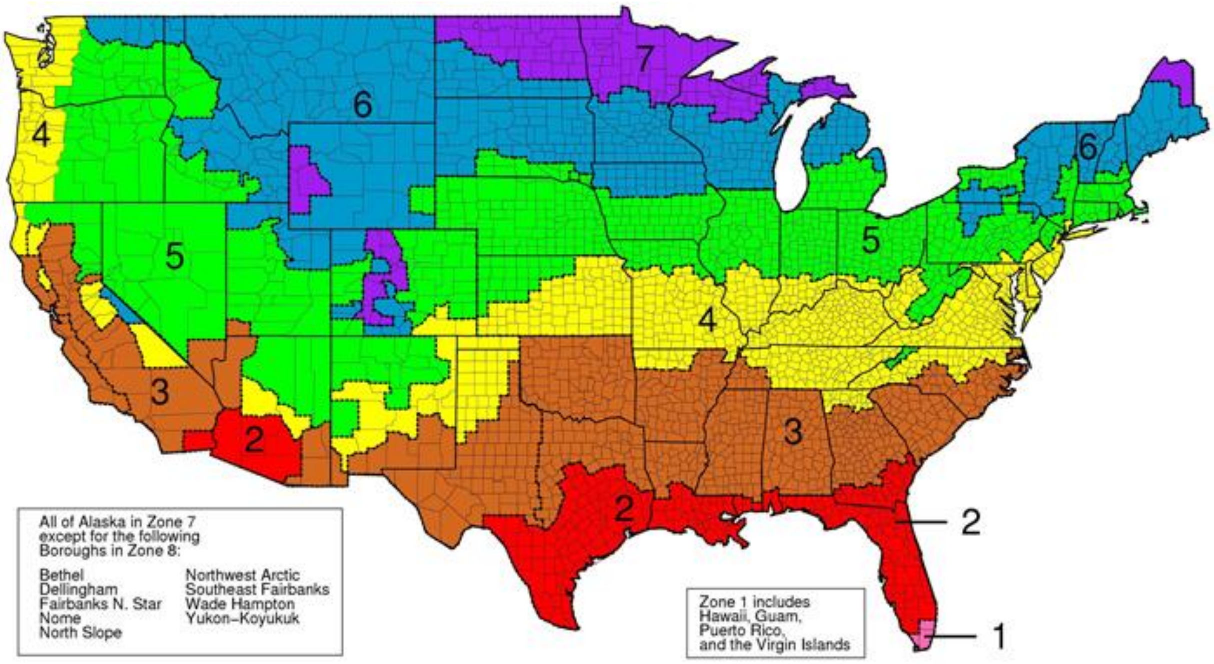
Natural air pressure and flow can cause air to travel around and through insulation. Small gaps of less than 5% around the edges of fiberglass batt insulation can reduce the effective R-value of the insulation by up to 30% by allowing convective flow. A strong breeze or air current can blow right through fibrous insulation such as (unfaced) batt and loose-fill cellulose, carrying cool or warm air through it. This demonstrates another reason why a good thermal barrier requires insulation and an air barrier.

Types of Insulation

Insulation is made of materials that trap air. Spun fibers work well and there are a variety of spun fiber products made of minerals and plants. These are found as loose-fill, batts and blankets. Batts and blankets can be "faced" or "unfaced" with paper or foil and used for filling gaps in walls, floors and ceilings. Loose fill insulation is blown through a hose and can be installed in wall, attic and ceiling cavities.

There are also rigid board materials such as foam products and fiberboard that are fitted between studs and beams or applied to structural members. Many of these materials, such as polyiso and polystyrene, are also air barriers. Like other insulation, thermal bridges and compression can negatively affect the R-value of these materials, though dense materials like polyiso are very difficult to compress.

It is important to know the R-values of different insulations and the building-code required levels of insulation required in different climate zones. Consistent, well-installed insulation throughout a house, combined with a continuous and effective air barrier, keeps the house and its occupants warmer in winter and cooler in summer. Poor installation of insulation can compromise R-value and lower its performance by as much as 50%. A good installation covers a surface completely and to a consistent depth without any gaps, folds or wrinkles. Minimum recommended R-values for typical homes in the U.S. are indicated in the list and chart below.



Zone	Add Insulation to Attic		Floor
	Uninsulated Attic	Existing 3–4 Inches of Insulation	
1	R30 to R49	R25 to R30	R13
2	R30 to R60	R25 to R38	R13 to R19
3	R30 to R60	R25 to R38	R19 to R25
4	R38 to R60	R38	R25 to R30
5 to 8	R49 to R60	R38 to R49	R25 to R30

Wall Insulation: *Whenever exterior siding is removed* on an

***Uninsulated* wood-frame wall:**

- Drill holes in the sheathing and blow insulation into the empty wall cavity before installing the new siding, and
- Zones 3–4: Add R5 insulative wall sheathing beneath the new siding
- Zones 5–8: Add R5 to R6 insulative wall sheathing beneath the new siding.

***Insulated* wood-frame wall:**

- For Zones 4 to 8: Add R5 insulative sheathing before installing the new siding.

Recommended levels of insulation depend on the climate. This map shows the recommended levels of attic, floor and wall insulation in each county of the United States, according to the U.S. Department of Energy. (Source: US DOE[3])

Fiberglass and Mineral Wool

The most common insulation materials used in houses are fiberglass and mineral wool. These are made from processing glass, rock and slag (the byproduct of metal and glass refining). The fibers are manufactured into batts, blankets and boards with the addition of fire-resistant

[3] Available at http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table

chemicals. Fiberglass is most commonly used currently. Mineral wool is rarely used in modern weatherization, but is often found in existing houses during retrofit jobs.

The standard fiberglass insulation is R-3 per inch, but higher density products are available. The medium density batts are R-3.8 per inch and the high density batts are R-4.3 per inch. As indicated above, the thermal performance of the insulation is achieved only if the products are installed correctly, making contact with the surrounding surfaces and air barriers.

Fiberglass is not combustible but the resin binder can burn, so the final product is fire resistant but not fireproof. The main advantage of fiberglass is that it is affordable and easy to find. Some newer mineral fiber products that resist fire and moisture are coming on the market. These may be considered for areas such as damp crawl spaces.

Insulating materials are also available with shorter chopped fibers to be used as blown-in insulation. When blown in, the R-value is higher than in batts and blankets because the short fibers do not align in channels, and thus air pockets are increased and more irregular. Blowing fiberglass is a good insulator for closed cavities as in exterior walls between 16” on center studs, where it can be packed under pressure. The ideal application for blown fiberglass is the insulation of manufactured homes because the walls of manufactured homes are more susceptible to breaking under high pressure. The packing pressure is lower for fiberglass than for cellulose, another common type of blown-in insulation.

Fiberglass insulation is easy to install but performance is very dependent on the quality of the installation. Batts are intended for use in cavities between ceiling joists or wall studs. Blown cellulose can be used to loose-fill spaces, but it tends to perform poorly in open attics because it is very susceptible to air movement.

Faced batts are the most common type of insulation used in homes today. They are usually fitted between wall stud bays and other framing. The facing can be paper to provide some vapor and air resistance, and foil can be added create a reflective barrier to prevent radiant heat transfer. Unfaced blankets can be used in attics, the exterior of metal buildings, duct and tank insulation and sound insulation. They do not insulate well if wet, but will regain the R-value when the fiber dries.

When using fiberglass insulation of any kind, it is very important to wear safety goggles, a breathing mask, and cover your body with clothing (including gloves). Fiberglass fibers can be very irritating to lungs, skin and eyes, and can cause respiratory problems with too much exposure.

Blown-in Cellulose

The most common blown-in insulation is recycled cellulose, which is ground-up wood chips and paper treated to be fire retardant. This insulation is easy to work with and achieves good density results. Large jobs require the use of special equipment (see below), but the machine is relatively easy to operate, and effective at delivering large amounts of insulation.

The primary disadvantage of cellulose fiber is that it can absorb a lot of water. This can become a problem if it gets wet due to wall leaks and in warmer areas where the humidity is high for a long period of time. Also, water will rinse out the fire retardant treatment. This not only reduces the fire resistance but it is a corrosive chemical that causes rusting of any metal it contacts.

Insulation blowing machines have the ability to break up compact bales of materials, fluff it and draw the fiber into a chamber. The chamber is fed by compressed air that blows the material and air through the hose and into the wall cavity. Most products add moisture to the dry material, either in the blower chamber or from a separate spray nozzle, which allows the material to adhere to the dry material's surface on contact. The machines can be plug-in or powered by a gas engine. High volume machines are gasoline- powered that blow more insulation and grind more bales on the hopper per fill. Smaller units blow the insulation but will take longer to deliver the product.

Blown insulation is very useful for filling joist bays in unfinished attics. (Photo ©)

Machine controls adjust the flow of the fill to avoid blowing out the wall's finishes. A variety of hoses and connections are available and many crews have created their own (from PVC pipe and other materials). Most blowing machine operation creates a floating dust that requires the use of a respirator, skin protection, and goggles.

Rigid Insulation Panels

There are a variety of rigid foam insulation panels made for diverse applications. Foam board insulation is good for creating a thermal break and a very good air barrier when properly installed. XPS closed-cell foam board resists penetration by water and water vapor, and is an excellent choice for insulating foundations. Boards with foil facings are effective vapor barriers.

Foam works well in many retrofit applications not only because of the types of foam but because of the variety of laminated coverings available. The most common sheet goods are 4x8 foot panels in widths from 1/8 inch to 4 inches. Different rigid boards are made for insulating foundations, ductwork, pipes and concrete and steel building components. In addition to residential applications, they are also valued in manufacturing environments because they can insulate against high operating temperatures, let water drain, and do not grow mold if wet. These types need to be properly caulked or taped around the edges and at seams. They also should be protected from ultraviolet light and physical damage.

Expanded polystyrene foam (EPS) is typically used for insulated concrete forms. It is the cheapest and least used foam board product on the market. This product typically has an R-value of 3.6 to 4.0 per inch of thickness. EPS is similar to the foam used for "packing peanuts" and does not have much structural strength.

Extruded polystyrene foam (XPS), known as “blue board” or “pink board,” comes in many different thicknesses and edge profiles and is the most widely used foam board insulation product in the residential construction industry. XPS has an R-value of 4.5 to 5.0 per inch of thickness and is used to insulate the outside of foundation walls and under slabs. It is a mid-priced construction product.

Polyisocyanurate is commonly known as polyiso, and is seen in all kinds of building applications. Polyiso is typically used with a foil facing but is also available for roof applications. It has an R-value of 7.0 to 8.0 per inch of thickness and has a higher price to match. A laminated reflective foil facing makes it an excellent insulation board when radiant heat is involved. The foil facing also makes it very easy to seal with good quality foil faced tapes.

Blown insulation comes in large bags stuffed with material. The material is dumped into a machine (left image), which chops it up and sends it through a hose. It can be applied as “loose fill” (usually in attics) or “densepack” (usually in walls). The middle image shows densepack being applied through an exterior wall. Densepack will fill a cavity tightly, and acts as an insulator an air barrier (right image). (Images courtesy of US DOE)

It is important to know the various code requirements when installing foam products. Typically, they cannot be left exposed inside the home or in any spaces that face the interior. They need to be covered with an approved fire or ignition barrier. They are sometimes allowed in certain limited-access and limited-use attics and crawl spaces. These spaces are separate from the residence and have no storage and no heat-producing equipment. Installers need to be familiar with the requirements of their local building codes and the manufacturer of the products they are installing.

SAFETY MATTERS

Spray Polyurethane Foam

Foams used in the field that start out as a liquid or are called “manufactured-in-place foams.” Spray foam is self-adhering to metal, gypsum board, wood and plywood, concrete and masonry. Spray foam products are separated into two categories: low-density or high-density foams.

One-part spray foam can fill small gaps and large cracks in a wall with a low-density foam very efficiently. The foam is activated by moisture, and when drying it produces an unpleasant (but not toxic) odor. Gloves should be worn for protection.

Two part portable foam kits are becoming commonplace and provide good results. There is a need for caution with any direct contact with the freshly sprayed product and the vapors that off-gas within the first half hour. A respirator is required in areas of good ventilation and an air-breathing apparatus is recommended in close spaces like attics and crawlspaces. Occupants of the house also have to be protected from contact with the vapor from two part foam.

Two part spray foam comes out of the canister as liquid, but "cures" to become a rigid material. (Photo ©)

High-density sprayed polyurethane foam (SPF) insulation sticks to most other materials, adds structural strength, provides air sealing, and has a high insulating value of R-7 to R-8 per inch. It can be sprayed on the interior and exterior of buildings with heat controlled systems or two-part foam portable tanks. It has a long life expectancy when covered over by wall finishes or coated properly with certain roof coatings. High pressure heated spray rigs produce a superior foam product but have a significant start-up cost. In addition to being the highest quality air barrier, it is the only foam that also adds structural strength.

Open- and closed-cell spray foams have the advantage of being one product, able to solve multiple concerns. Closed-cell spray foam insulation is the only type of insulation that is a Federal Emergency Management Agency-approved vapor barrier. It prevents mold, adds structural strength, prevents wind damage and uplift, and provides the most efficient option for insulation available today.

Low-density polyurethane foam is also spray-applied using pressure and temperature controlled professional equipment, or portable tank two-part systems. The air sealing properties are equal to high-density foam, but the R-value is usually below R-4 per inch. Because of this, more space is required to achieve the same R-value of high-density foam. There are some low-density foam systems that will not stress the wall with over-expansion (bulge out the wall's plaster or wallboard finish). These are currently expensive to use but are an effective combined air barrier and insulation.

Polyurethane foam is very versatile. Uses of polyurethane one- and two-part foam include air sealing, insulation, roofing, roofing adhesive, construction adhesive, insulation for spas, cavity filling and refrigeration insulation.

Older Insulation Materials

Mineral wool, vermiculite and perlite insulation are products that have historically been used in older housing stock around the country but have been replaced by newer insulation types. In some new construction applications, vermiculite and perlite are used as poured insulation to fill the voids in concrete block walls. The older types were often mixed with asbestos, so when found, it needs to be left in place and covered and encapsulated by safer insulation products.

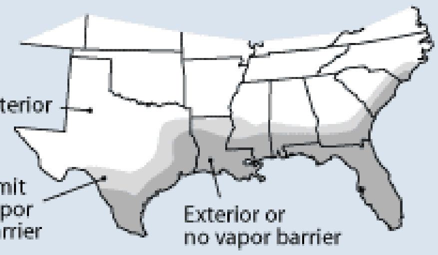
Facings and Barriers

Barriers of different types and materials installed in exterior walls are required for weather resistance, air sealing, vapor and moisture prevention and fire resistance. Barriers can have either foil or paper facings (found on the face of insulation blankets and boards) and can also be used as sheet goods.

Facings applied in the factory to insulation products offer excellent performance and ease of use. The paper facing on rolls of insulation provides an air barrier while also providing tabs used for stapling the material in place. Foil facings add a reflective layer to the paper backing, providing an air and vapor resistant barrier to the insulation.

Vapor Barrier Placement By Geographical Location

In most cold climates, vapor barriers should be placed on the interior(warm-in-winter) side of walls. However, the map shows that in some southern climates, the vapor barrier should be omitted, while in hot and humid climates, such as along the Gulf coast and in Florida, the vapor barrier should be placed on the exterior of the wall.



Perm Ratings of Different Materials
(Rating of 1 or less qualifies as a vapor barrier)

Asphalt-coated paper backing on insulation	0.40
Polyethylene plastic (6 mil)	0.06
Plywood with exterior glue	0.70
Plastic-coated insulated foam sheathing	0.4 to 1.2
Aluminum foil (.35 mil)	0.05
Vapor barrier paint or primer	0.45
Drywall (unpainted)	5 0
Drywall (painted - latex paint)	2 -3

Vapor Barrier Placement. Interior vapor barriers should only be used in cooler climates. (Image courtesy of US DOE)

Weather resistant barriers stop moisture from soaking building components in a house's envelope. Most weather barriers are applied over exterior sheathing, or behind exterior brick or siding. The weather barrier is important because sheathing and siding materials do not fully prevent water, wind or humidity from entering a wall. Exterior sheathing can provide an air barrier if the seams are sealed tightly with appropriate taping.

Vapor barriers retard the flow of vapor through an exterior wall. Seasonal differences can make an impermeable vapor barrier a bad idea. A completely impenetrable barrier can trap moisture inside the house and wall, causing moisture-related problems. The movement of water vapor changes direction through a wall depending on the season, especially in a four-season climate. A semi-permeable vapor retarder allows for some gradual drying of wall cavities should they become wet.

Vapor barriers are not recommended for both sides of a building shell because moisture would be trapped inside the wall between the barriers. This can cause a number of problems, not the least of which is mold. In a heating climate (a cold climate), the vapor retarder is typically placed facing the interior. In a cooling climate (warm climate), the vapor retarder is usually placed on the exterior side of the walls. Vapor retarders can be Kraft paper insulation facing, paint primers, and "house wrap."

Insulation Type	R-value/Inch		Density lb/f^{t3}		Air Barrier (Y/N)	Vapor Barrier Permeable? (Y/N)
	Low	High	Low	High		
Cavity Materials						
Batts	3.2	3.8			No	Yes (very)
Loose fill	2.2	2.9	0.5	1.0	No	Yes (very)
Cellulose						
Loose fill	3.1	3.7			No	Yes (very)
Dense-pack		3.2		3.5	Semi	Yes (very)
Moist-spray	3.4	3.7	2.8	3.8	Semi	Yes (very)
Open-cell Foam						
Icynene pour fill		4.0			Yes	Yes (very)
Icynene spray		3.6			Yes	Yes (very)
Foam Board Stock						
Expanded polystyrene	3.8	4.4			Yes	Semi
Extruded polystyrene		5.0			Yes	Semi
Polyisocyanurate (foil-faced)	7.0	7.5			Yes	No

Typical R-Values for Commonly Used Weatherization Materials.

Fire barriers (also called thermal barriers) have become a requirement of building codes around the country. These create partitions that will resist the spread of fire throughout a building for one or more hours. An ignition barrier that covers flammable materials such as foam may be required. Weatherization installers need to be familiar with local building code requirements. Locate areas and materials that may need to covered and notify a supervisor who can check with local code officials.

Topic 6: Attached Garages and Indoor Air Quality

There is a source of pollutants in homes that has recently been getting increased attention because of the dangers it poses: automotive pollution from attached garages. Any attached garage can be dangerous, whether it is on the side of a house, under the second floor living space, or part of the basement.

Garages are usually attached to homes in one of three ways: from left to right, attached to the side of the house, below grade (part of the basement), and below a second floor living space. All of these configurations can lead to toxic indoor air without proper air sealing. (Photos courtesy of Dan Kasper)

An attached garage is a good place to park a car and store things but it can also create a health hazard for everyone living in the house. Starting up a car or driving a car into the garage and closing the door fills the garage with harmful carbon monoxide. Items commonly stored in garages, such as fuels, chemicals (pesticides, herbicides, etc.), fertilizers, and paints also generate harmful fumes. If a garage is attached and not properly sealed from the rest of the house, these pollutants can enter the living space. Carbon monoxide can be deadly, and many of the other fumes present in garages can make occupants sick. Some also pose fire hazards.

When a cold car engine starts up in the garage even with the garage door wide open, it can generate up to several hundred parts per million of carbon monoxide gas in the garage. Once the car has left and the garage door is closed, the garage may still hold a relatively high carbon monoxide concentration for hours. This can obviously pose a problem if it enters the home.

Houses with attached garages usually have measurable concentrations of benzene (a gasoline-related pollutant) in their indoor air, compared to houses without attached garages. Benzene is a highly volatile chemical that can cause a number of uncomfortable and dangerous health problems if excessive exposure occurs. Other sources of garage pollutants are gas-powered lawn equipment, such as chain saws and lawn mowers. Their emission systems are similar to those found in automobiles. As an engine and its environment cools, **off-gassing** from a variety of compounds takes place. Even discarded items and trash that are often kept in the garage can give off noxious organic vapors.

How Garage Air Gets into the House

Usually the migration of garage-based pollution is the result of a pressure imbalance between the living space and garage. This is especially prevalent in the winter when a stack effect is occurring in the home. As you know, the stack effect (and other pressure imbalances) forces infiltration. Air from an attached garage can infiltrate into the home, like any other exterior air source. The garage is not sealed to the outside and roll-up doors are often very leaky, so the garage pressure is often nearly identical to the outside.

Garages are often filled with more things than cars, many of them toxic. (Photo courtesy of Dan Kasper)

1One of the problems with garage-to-house air movement is that it is not always obvious when or why it occurs – it can be a very subtle process, just like other forms of infiltration. Some of the air routes may be visually evident, but it takes a blower door test and leakage detection equipment to find and quantify all of the infiltration and exfiltration points. In order to prevent infiltration from happening, the garage needs to be *completely* sealed off from the rest of the home. In other words, the garage should be entirely outside of the home thermal envelope, and a completely intact air barrier should be between the home and garage.

Air sealing and insulation of the garage's envelope is similar to the treatment of exterior walls in the home. The door from the attached garage to the house should have effective weather-stripping and a spring, or closer, to hold the door shut tightly. The door should be metal or other fire-rated material and preferably insulated like an exterior door.   Air can move through small cracks in the walls between the house and the garage and through the garage ceiling. Most houses have many holes, cracks and openings that permit this air exchange to take place. All of these need to be sealed, after a blower door is used to diagnose leakage areas.

Preventing Garage-to-House Pollution Transfer
It can be difficult to prevent air movement from a garage to the living areas in an existing house. Leakage areas are often hidden, but safety standards dictate a fire barrier between the garage and the living space. This fire barrier (in the shared walls and ceiling) can also serve as an air barrier.

Where the fire barrier is continuous, holes – or penetrations such as found at switches, outlets, light fixtures, pipes or wires – have to be sealed using standard methods of air sealing and drywall or plaster patching. Plaster is typically applied to the walls to form a tight joint with the concrete floor. However, if the fire barrier is drywall, the floor-to-wall joint should be caulked. If the vertical gap or joint is wide, a bead of caulk is used at the top and bottom of the gap. Cracks in plaster should also be caulked. In many houses, ductwork passes through the garage and careful sealing and insulation of any ducts is needed using standard methods.

In houses where there is no living space above the garage, the garage's ceiling fire barrier may be missing, or a hatch or pull-down stair exists. Both the garage and the home's attic are typically outside of the house's thermal and pressure envelope. Thus, there is no energy saving benefit in treating this garage-attic boundary, although a fire barrier is strongly recommended. The garage may have its own attic or in some cases, or the garage attic may be continuous with some or all of the house's attic. In this

Garage-access doors must be well-sealed to prevent leakage of toxic fumes. (Photos courtesy of Dan Kasper)

case, the garage wall finish should be sealed to the framing at the top adjacent to the underside of the roof and any penetrations in the wall's top plate should also be sealed. Where a garage wall extends upward to form a second floor wall, principles of adequate air sealing and insulation between the living and attic spaces typically apply.

Combustion appliances located in the garage are a serious fire hazard and need to be relocated or isolated from the garage with an airtight fire-rated wall. If possible, all such appliances should be located within the house's conditioned space. If relocation is not practical, the house's thermal/pressure envelope should be extended to include appliances in the garage, by insulating and air sealing the surrounding partition.

Weatherization and Retrofit
Energy Coordinating Agency

APPENDIX E

Manual Three Lab Exercises

Knight

Green Jobs Training Center

Lab 1: Using Portable Spray Foam

One-part and two-part spray foams are easy to use and gives quick results. Using spray foam to fill cracks, gaps, and holes is an effective air sealing and insulating approach to weatherization work. It expands to several times its original volume, which allows it to form a complete, air tight seal in large cracks. Another benefit of spray foam is that it is also a relatively strong adhesive, so can be used to install foam board and other rigid insulating products. This has the triple benefit of holding the board in place, providing insulation, and forming a long-lasting air barrier. As a house expands and contracts, the foam insulation will expand and contract with it. This maintains the air seal and eliminates the occurrence of new cracks and gaps.

When this lab is completed, you will know how to use two-part foam to insulate and seal air leakage sites in a home, both with and without backing board.

Tools

Utility knife
Staple gun

Consumables

Spray Foam MSDS
Spray Foam Manufacturer's Specifications
Spray Foam kit/box
Spray gun tips (round & fan)
Petroleum jelly
Utility knife blade
Staples
Plastic sheeting roll

Safety Equipment

Eye protection
Respirator
Rubber gloves
Coverall; hood; booties
(Hard hat)
Plastic sheeting (for floor)
Ventilation; fans

Approximate time needed to complete this lab: 1 hour

Procedure

CAUTION:

1. When spraying foam **follow all of the Manufacturer's Specifications and MSDS guidelines** including proper PPE and adequate ventilation. This is especially important when spraying in the confined and closed areas typically found in weatherization work.

2. Check with your Code Officials to make sure you know all local requirements. When foam products are used in interior construction or in any confined area, codes usually require them to be covered with a thermal barrier material to provide a fire rating.
3. In some situations, codes call for an alternate covering called an ignition barrier to cover the foam. Check with your local Code Officials.
4. If foam will be exposed to sun or water for long periods of time, it is recommended that a protective coating be applied over the foam to prevent the foam from deteriorating.

Prepare two part foam kit

Photo ©

1. Open a box and organize the contents. If you have not used the product recently, review the Manufacturer's Specifications booklet and the MSDS (Material Safety Data Sheet).
2. Set up the box for use, inserting the hose through the sides.
3. Put a dab of petroleum jelly on the gun in the dispensing area to protect any cross over that might happen when you pull the trigger, and to lubricate the spray tip seal.
4. Choose the type of tip for the work planned, and snap it in place on the dispensing area of the gun. Push in firmly until you hear a "click." The nozzle is now firmly secured. Make sure the trigger safety lock is set on.
5. Make sure the foam material is at 70 degrees F (cold material makes poor quality foam and wastes material left in the canisters). Shake both the Part A and Part B canisters to mix the materials well. Turn the top valves on both canisters all the way on.
6. To make sure the system is working, and to become familiar with the rise of the foam from this kit, perform a one-second test spray.
    a. Disengage the safety and aim the gun with mixing nozzle attached into a waste container.
    b. Dispense foam at full pressure. Watch the foam rise and check the color to make sure it is a good product mix and hardens within 2 minutes.
7. If you pull the gun trigger and the foam is not mixed well, or it does not spray evenly, change the tip. To do this, remove the current tip, wipe the gun dispensing area with a clean paper towel and put more petroleum jelly into the area. Select another clean tip and snap it into place.

Applying the spray foam

Tips for proper application (read all of these before you begin foaming):

1. It is recommended that the gun be held 18 to 24 inches away from the surface to be foamed. If you wish to move closer to avoid splatter, pull the trigger very lightly.
2. You will control the velocity of the flow of chemical by how hard you pull the trigger. BEGIN BY PULLING THE TRIGGER VERY LIGHTLY. Slowly increase the pressure until you get a feel for how strong the flow is. BE CAREFUL NOT TO PULL THE TRIGGER 100% RIGHT AWAY, ESPECIALLY WHEN THE KIT IS NEW.
3. Pull the trigger back at least 25% for a good surface texture.

4. Even coverage is best obtained by moving the gun steadily back and forth and applying a constant trigger pressure. Filling the area with a regular pattern. Spray up against your previous pass with a regular steady fill pattern and avoid crossing over previous foam. The foam will expand several times its original volume. Be careful not to apply too much in one pass. Each pass should be around ½" to 1" (2" maximum).
5. Once the foam is cured, and you see that you need heavier coverage, you can apply another layer of foam on top of the previous layer.
6. IF YOUR APPLICATION REQUIRES A THICKNESS IN EXCESS OF 1 INCH, WE RECOMMEND YOU APPLY IT IN MULTIPLE PASSES. Applying too much foam in one pass will result in a very uneven surface. The foam will sag and may even drop off before it cures.
7. The pressure in the tanks decreases as they empty. As you are dispensing, adjust the trigger pull to a position that gives you a desired spray pattern.

2-part foam was used to seal the band joists in this crawlspace. (Photo courtesy of Paul Ricker)

Filling up a large void

1. Depressions or voids can be filled up with several passes. The void should have a bottom or a backer material needs to be installed for support. Each pass should be around ½" to 1" (2" maximum). We strongly recommend that you do not spray more than four inches of foam in one application.
2. If you are filling up a large hole, allow each layer to cure, and add foam to the top of it. One layer of foam will bond completely to the next.

The installers in these photos used spray foam and backing board to seal a *huge* space in the attic. Note the insulation dam in the photo to the right, which will keep the insulation the required 3" away from the chimney. (Photos courtesy of US DOE)

Sealing across a large gap

1. 2-part spray foam can fill gaps up to 2" wide. Gaps that are between 2" to 4" should have a backer materials like fiberglass batt installed first to provide support for the foam. Gaps and openings over 4" need a solid air barrier material installed first. Run a bead of foam into the cavity. Place the tip of the mixing nozzle at the edge of the cavity and slowly pull the trigger. Remember that foam will expand several times its original volume.
2. If foam cures, and you have not filled the cavity enough, you can always add more foam. One layer will bond to the other.
3. If you dispense too much, you can trim away the excess with a sharp serrated knife.

Storage and reuse

Tips for storage and reuse:

1. Unopened systems are guaranteed up to the expiration date stamped on the carton (13 months from the date of manufacture).
2. Once the kit is opened, it is warranted for 30 days.
3. Use the kit a minimum of once per week to keep fresh chemicals in the lines. Otherwise you may need to purchase a new gun and hose assembly.
4. Store the kits in an environment of 40°F to 100°F (5°C-38°C) whether they are opened or unopened. Remember they should be at 70 degrees when you spray.

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Lab 2: Air Sealing Holes, Cracks, and Large Openings

There are many possible hole locations in the upper thermal envelope of a house which need to be closed and sealed by a retrofit installer technician. These include holes for plumbing and electrical penetrations, cracks along the top of wall plates, and gaps where different materials meet. There are also large openings in attics that must be closed and air-sealed. These are often found over open chases or shafts built into the home for running plumbing, electrical, and HVAC mechanical work between floors. There may also be open areas over soffits and dropped closet ceilings. Finally, there is nearly always space around the chimney or flue pipe. A lot of conditioned air passes through these hidden thermal bypasses. The weatherization installer must know the right air barrier materials and sealants to use to close and seal these openings.

After this lab is completed, you will be able to safely air seal holes, cracks, and large openings, including a chimney and flue pipe.

Tools

Utility knife
Drywall t-square
Tape measure and pencil
Drywall Rasp
Drywall saw
Caulk gun
Awl
Marker or grease pen
Metal snips
Pliers
Cordless driver/drill
Smoke stick
Test Box w/fan

Consumables

Large hole prop
Heat pipe prop
Drywall
Pencil
Caulk (latex)
Foam backer rod
Loose fiberglass batt
1-part spray foam
Sheet metal or
Al. flashing
Fire-rated caulk/cement
AA Batteries for Smoke stick
Fluid for Smoke stick
Self-tapping screws
Paper towel; rags
Trash bag

Safety Equipment

Eye protection
Respirator
Gloves

Approximate time needed to complete this lab: 2 hours

Procedure

CAUTION:
The retrofit installer technician needs to know about certain code issues related to closing openings and sealing around chimneys. A retrofit installer technician also needs to be checking for fire code violations that already exist and working to remedy these. If you encounter an unsafe or questionable condition, such as a fire code violation; stop work and contact your crew chief for further direction.

When air sealing an opening that faces into the interior of a building such as into a closet or room, only certain barrier materials can be used. Acceptable materials are drywall, plywood, OSB (oriented strand board); sheet metal; or special rated products like fiberglass duct liner or Thermax ™. Fire code rules do not allow rigid foam boards to be used facing the interior unless they are covered with an approved fire or ignition barrier material.

Another important fire code and safety issue related to air-sealing around chimneys and flue pipes. To avoid fire hazards, there are code required clearance spaces for different types of masonry and metal chimneys. Within the clearance space only non-combustible products can be used. Keep all combustibles away from these heat-producing areas. For example, the min. clearance space for a masonry chimney is typically 2”. To air seal around the chimney within 2”, use a non-combustible air barrier like sheet metal, aluminum flashing, or cement boards. To seal the chimney air barrier use non-combustible ASTM-136 caulk, furnace cement, or high-temperature silicone caulk for gas-only appliances.

Air-seal cracks, gaps, and holes
1. Using latex caulk, seal any crack up to ¼”. These are often found along the wall plates at the tops of walls in the attic. For larger cracks and gaps first use either a foam backer rod to support the caulking, or use 1-part spray foam. Make sure to clean and prep the area so the caulk or foam sticks to a clean solid edge or surface. The caulk or foam needs to fill the crack or gap and extend out onto the surrounding surface to get a good seal.
2. To air-seal holes, use 1-part spray foam. 1-part spray foam closes holes 1” or less. If the hole is between 1” and 4”, install a backer to support the foam. Stuff some fiberglass batt in the hole or opening first. Then install 1-part spray foam using an even steady spray fill pattern. Do not go over previous foam, spray each pass up against the previous to get even coverage. Make sure the foam overlaps the surrounding surface 1” all-around the hole to get a good seal.

Air-seal large opening
1. For large openings, a solid air barrier material such as drywall is needed to cover it. (If the hole is larger than 24” across, additional framing support must be added first). Now measure the hole and add 2” to each dimension. This will give extra material to extend 1” onto the solid surface around the hole, and provide support for the barrier.
2. Using the drywall T-square and a utility knife cut the drywall to your dimensions.

3. Prepare for sealing the opening by clearing away any dirt and dust to get clean surfaces and edges. Then install a continuous ¼" bead of latex caulk all-around the edge of the hole.
4. Now install the drywall barrier centered over the hole so it is evenly supported on all sides. Press it down onto the caulking to get a good seal. Using the driver/drill, secure the barrier with drywall screws at the 4 corners. Keep the heads of the screws flush with the drywall surface; do not drive them below the surface of the drywall.
5. Smoke test your prop on the test box with the fan running. Identify any leaks and add additional sealant to achieve a complete seal.

The combined use of two-part foam and foam backer board made sealing this large space possible. (Photos courtesy of US DOE)

Air-seal opening around chimney or flue pipe

1. For large openings around a chimney or flue pipe, a non-combustible air barrier and sealant must be used. Around chimneys, installers typically use sheet metal or aluminum flashing for the air barrier and fire-rated caulk for the sealant. (If the opening is larger than 24" across, additional framing support must be added first). You will need 2 pieces of metal that overlap in the center. Each piece will have a ½ circle cut out to fit against the circular flue pipe. (If you were air sealing around a rectangular chimney, your pieces would be cut with straight sides to fit against it).
2. Measure side-to-side across the opening and add 2" to get the length of each metal piece. This will give extra material to extend 1" onto the solid framing surface and provide support for the barrier. The piece should be wide enough so that it runs about 1" past the center of the pipe to allow for the pieces to overlap.
3. For the ½-circle (semi-circle) cuts, use a round template such as a container lid or small paper plate to trace the shape on your metal piece, centered on the pipes location. The hole needs to be a little deeper than ½ the flue pipe's diameter so it will slide past enough to overlap the other piece. (For tracing or marking on metal use a metal awl to scratch lines or write with a marker or grease pen).
4. Cut the metal with metal snips and adjust as necessary to fit within ¼" of the pipe and overlap onto the framing. Any gaps over ¼" at the pipe will need to be covered with a small piece of metal first and then caulked. The metal pieces need to fit well, including overlapping each other so you can make a good seal.
5. Prepare for sealing by clearing away any dirt and dust to get clean surfaces and edges. Install a continuous ¼" bead of fire-rated caulk all-around the edge of the hole. Install the first piece of metal pushing it down into the caulking.
6. Then install additional caulking across the edge of the 1st piece where they will overlap. This will seal the lap. Now install the 2nd piece metal pushing it down into the caulking.

7. Secure the pieces with self-tapping screws at the corners and middle of each side. Be sure to keep the metal flat and even. (On larger pieces, additional bends are added to edges to provide added rigidity, strength and to provide a flange for securing).
8. Now that the barrier pieces are secure, install caulking to seal around the pipe. All gaps at the pipe should be ¼" or less, or they will have to first be covered with a solid piece of metal, and then caulked.
9. Check around all edges and at the pipe to make sure you have a complete continuous air-seal. If not, install additional fire-rated caulking as necessary. (If working in an attic you could check your work with a smoke test if the blower door was running).
10. Smoke test your prop on the test box with the fan running. Identify any leaks and add additional sealant to achieve a complete seal.

Air Sealing a Vent Pipe. From left to right: cut metal to fit snugly around the pipe; seal with fire-rated caulk (make sure the gap is no greater than 1/4"; add an insulation dam to provide at least 1" of space between insulation and the pipe. (Images courtesy of US EPA)

Clean-up work area and store tools and materials

1. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used as these are usually flammable and could contains VOC's (volatile organic compounds).
2. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.
3. Return any items or personal belongings that may have been moved or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
4. Complete a final check and clean your work area and the work site.

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Lab 3: Basics of Combustion Safety and Analysis

Combustion appliances in the home include furnaces, gas-fired hot water heaters, and gas dryers. It is important to verify that these appliances are operating properly, because improper function can have dangerous and/or expensive results. Combustion gases in the exhaust can be toxic, and even deadly in the case of carbon monoxide. Heating bills are usually one of the highest energy costs in the home, so efficient operation is also important.

Combustion analysis entails the sampling of combustion gases that are exhausted from fuel burning appliances, the sampling of draft within the flue pipe that exhaust these gases, and the measurement of air pressure where the appliance is located under normal depressurization conditions and the worst conditions possible.

After this lab is completed, you will be able to assist an certified Auditor in a combustion safety analysis. You should be able to perform all of the actions with the assistance of an expert analyst.

Tools	**Consumables**	**Safety Equipment**
Ambient CO detector	Soap Bubbles	Eye protection
Gas leak detector		Respirator
Combustion Analyzer		
Manometer		
Drill		

Approximate time needed to complete this lab: 2 hours

Procedure

Visual inspection precedes each action within this lab exercise. Combustions gases can be extremely harmful when inhaled, so the health and safety of the work crew and the client is paramount. Though we use several testing tool an installer's best inspection tool is his/her senses (sight, smell, etc.).

CAUTION:

1. Identify Asbestos hazards
2. Locate electrical disconnect (Service shutoff switch)
3. Ambient CO detection (monitored throughout entire test)

   a. Bring the portable CO tester with you at all times. Ambient CO should never be above 35ppm
      i. If it is above 9ppm, stop and determine the source of the problem
   b. If ambient CO in the CAZ is above 35ppm, stop the test and repair the equipment before proceeding
4. Test for and Locate gas leaks
5. Identify missing or frayed wires

Inspection of Gas lines

1. Using gas leak detector test all accessible connections and fittings
   a. Inspection of entire gas line should begin at the fuel burning appliance
   b. Gas leak detection should be tested 360 ^{o} around all fittings and connections
      - Move detector at a rate of 1” per second – do not move too quickly
2. Use bubble solution to confirm leak when detector alarms
   a. Apply bubble solution using sponge brush
   b. To confirm leak look for bubbles that grow in size and “fizz” up

Identify System Components

1. Identify Combustion Appliance Zone
   a. Locate combustion appliances
   b. Locate zone boundaries (the door, walls, and windows that separate CAZ from other house zones)
2. Determine overall system condition
   - Visually inspect all accessible system components looking for: dirt, rust, dents, disconnected wires, frayed wires, and missing components.
3. Identify safety issues
   a. Combustible products
   b. Frayed wiring
   c. Volatile Organic Compounds
4. Identify system type
   a. Gas, oil or electric
      - Gas: has a galvanized steel supply line to the burner
      - Oil: has a copper supply line to the burner
      - Electric: has an electric power cord and does not have a flue
   b. Open or sealed combustion
   c. Atmospheric draft or fan assisted draft
      - Atmospheric: has a draft diverter (gas) or barometric draft control (oil)
      - Fan assisted: has a draft fan
   d. Efficiency
      - 70%: has a draft diverter, no draft fan, standing pilot light, non-condensing, indoor combustion and dilution air
      - 80%: has a draft fan, no draft diverter, electronic ignition, indoor combustion air, no dilution air
      - 90%: has draft fan, electronic ignition, outdoor combustion air, PVC vent pipe

5. Identify key parts
   a. Gas supply lines or oil supply lines
   b. Pilot
   c. Supply plenum
   d. Return boot
   e. Commonly vented appliances
   f. Orphan

Setup Natural Conditions

1. Put house in winter mode (exterior windows and doors closed; interior windows and doors open)
   a. Remove at least one tile from all dropped ceilings
2. Record base pressure using manometer
   a. With “outside” manometer hose outside and fan lid still on, record the pressure WRT the outside. This is the base pressure

Setup Worst Case Conditions

1. Turn on all exhaust fans. (Check for greatest depressurization of CAZ by opening & closing doors.)
2. Turn on air handler. (Check depressurization.)
3. Record depressurization reading
4. Note what the *most negative reading* was
5. Subtract the base pressure from this number – this is the worst case pressure reading

Draft Testing

Draft test is not necessary for sealed combustion furnaces

1. Drill test hole (if necessary)
   a. Do not drill a test hole in PVC!
2. Configure combustion analyzer to read draft
   a. The analyzer must be inserted parallel to the draft direction
3. Record reading

A combustion analyzer is used to test draft (left photo) and for carbon monoxide content of undiluted combustion gases (center photo). A hand-held Ambient CO detector should be carried at all times (right photo) (Photos ©)

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Lab 4: Basics of Mechanical Ventilation Systems

Mechanical system replacement or repair is a common work scope measure. Due to city, state, and federal licensure requirements certified electricians, plumbers, and HVAC technicians must handle most areas of the mechanical system; the retrofit installer serves as this certified person's assistant.

An installer's knowledge of framing, building penetrations, sheet metal work, duct sealing, duct insulation, air flow, condensate piping, and fuel sources are all key to be a competent assistant.

After completing this lab the installer will be able to identify relevant plumbing, electrical, and fuel system components. The installer will also have the physical ability to cut rough openings, assist in installation of combustion vent systems, and insulate & air seal duct work.

Tools	Consumables	Safety Equipment
Utility knife	Duct insulation	Eye protection
Pry bar	Duct mastic	Respirator
Reciprocating saw	Sheet metal screws	Gloves
Drill & self tapping bit		
6 in 1 driver		

Approximate time needed to complete this lab: 1.5 hours

Procedure

When working with mechanical systems the retrofit installer should keep two things in mind. First, the installer is only an assistant to the certified individual and should adhere to his/her instruction. Second, the installer should keep in mind the energy efficiency scope as it relates to protection of previously installed insulation, thermal boundary, and other basics of Weatherization.

CAUTION:

6. Asbestos Hazards
7. Tool safety
8. Electrical Disconnects (Service shut off switch)
9. Structural Integrity

Identify Work Site Areas

3. Identify plumbing components
    - Hot water pipe
    - Water service line
    - Connections & elbows
    - Pressure relief valve
    - Copper pipe, PVC, Lead pipe
    - Shut off valve
    - Expansion tank
    - Main clean out
    - Water meter
4. Identify electrical components
    - Service shut off switch
    - Electric pilot
    - Wire conduit
    - Thermostat
    - Bathroom exhaust fan & wiring
    - Range hood Exhaust fan & wiring
5. Identify fuel system components
    - Fuel supply line
    - Oil filter
    - Pilot
6. Locate building penetrations
    - Water service line penetration
    - Waste water line penetration
    - Condensing furnace flue & combustion air stack penetrations
    - Supply and return registers

Combustion Appliance Zone. This CAZ has a gas-fired hot water heater (center of picture) and a gas-fired furnace (to the left of water tank). (Photo © eca)

Uncrate Equipment

6. Locate proper work site area per equipment
    - Combustion appliance zone
    - Bathroom exhaust fan
    - Range hood exhaust fan
7. Check specifications on box, verify against work scope
    a. Report deficiencies to Crew Chief
8. Using utility knife (or pry bar) open box
9. Unpack protective wrap, paperwork, & equipment

Rough in Mechanical System

1. Cut rough openings within building shell (only applicable to non-load bearing walls)
    a. Request start work order from Crew Chief
    b. Cut specified measurement using reciprocating saw (pay special attention to blade selection per material to be cut)
2. Piece together equipment (with the exception of electrical connections)
    - Never connect electrical components!

- Per manufacturer's instructions installers should piece together venting

3. Cut combustion vent exhaust to proper length
   a. Notify Crew Chief that combustion vent is cut and ready to be installed

Replace Furnace Filter

1. Cut off system service switch
2. Locate filter (on return side of system)
3. Remove old filter from unit
4. Verify new replacement filter size and rating
5. Slide new filter into filter slot

Replacing the Furnace Filter (Photo ©)

Duct Insulation & Air Sealing (As Needed)

1. Identify complete installation of duct work
   a. Verify completion with HVAC tech or Crew Chief
2. Repair/Replace missing/loose screws
   a. If ducts are insulated they be exposed to seal leaks beneath insulation
   b. Duct screws (sheet metal screws) can be tightened with a hand driver but need to be drilled for initial application
3. Air seal all joints & connections using mastic
   a. Apply duct mastic at all seams and venting connections
   b. Apply mesh tape on top of mastic for gaps over ¼ inch (repeat previous step to cover mesh tape)
4. Insulate ducted distribution system
   a. Only after the completion of air sealing duct, insulation can be applied
   b. Ducts should be wrapped with a minimum of R8
   c. Duct wrap should be fastened with zip ties or metal tape

In the photo to the left, the joints of a duct have been sealed with a thick layer of mastic on top of mesh tap. The photo to the right shows installed ductwork, with the main duct (square-shaped) wrapped in insulation. Foil tape covers the cut edges, and can be seen in the right part of the image. (Photos ©)

Identify Completion of Work

1. Check work order and review air sealing and insulation measures
2. Notify Crew Chief of completion of work

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Lab 5: Blower Door

The Blower Door is special equipment that building analysts use when evaluating a home's energy performance. A blower door has a large fan that is placed a house's exterior door opening to measure the overall "leakiness" of the house. The fan is used to depressurize the house by pulling air from inside and blowing it outside. This causes the inside of the home to have a low pressure relative to the outside, which causes air from outside the home to come inside through holes and gaps in the air barrier. Using a blower door as well as other tools, methods and knowledge, an analyst can find the location and estimate the size of the leaks in the thermal envelope.

To do this, the variable speed fan in the blower door measures both the air flow through the fan in cubic feet per minute (CFM), and the pressure difference between the inside and outside of the house in Pascals (Pa). The pressure is measured with a small hand-held instrument called a manometer. A manometer has small ports where small plastic hoses are placed on both sides of the blower door with the air pressure measurements indicated on a digital display.

When this lab is complete, you will know how to set up and run a blower door, and learn how to use a manometer to measure pressure differences in Pascals between the inside & outside of the home, determine overall air leakiness of a home in CFM.

Tools	Consumables	Safety Equipment
Blower door	None	None
Manometer		
Manometer hoses		
Calculator		
Writing utensil		

Approximate time needed to complete this lab: 1.5 hours

Procedure

Make sure the home is safe

When the blower door is used in the field, the following precautions need to be taken:

1. Inspect the home for asbestos or mold. Depressurization can cause mold spores and asbestos particles to become airborne and dangerous. If either is found, do not run a blower door until it is removed.

2. Cover fireplaces with wet newspaper. If the fireplace has a glass cover, close this as well. Close the damper. Check for other dust or materials that the fan could affect.
3. If there is a drop ceiling, remove at least one of the tiles to avoid collapsing the ceiling.
4. Put the house in wintertime condition by shutting all exterior doors and windows.
5. Open all interior doors including the basement door.
6. Turn off all combustion appliances or turn them to pilot. Turn off all fans.
7. Check for loose items and plaster. Make sure children and pets are away from area.

Set up blower door

1. Select a door that is directly open to the outdoors. Assemble the fan's metal frame on the floor adjacent to the door to fit inside the exterior door frame/jamb.
2. Fit the fabric over the metal frame
3. Lift and place the full frame assembly tightly into the door jamb (without the fan)
4. Thread one of the hoses through the lower hole of the frame assembly to the exterior of the house and locate about 5' off to the side of the fan opening.
5. Insert the fan into the opening of the fabric and secure it with Velcro straps.
6. Make sure the fan cover is left on.

Set up the manometer

The manometer will have two hoses hooked up to it (see diagram below). One hose measures the pressures inside and outside the home, the other measures the pressure of the fan relative to the inside (the manometer uses this measurement to measure the air flow)

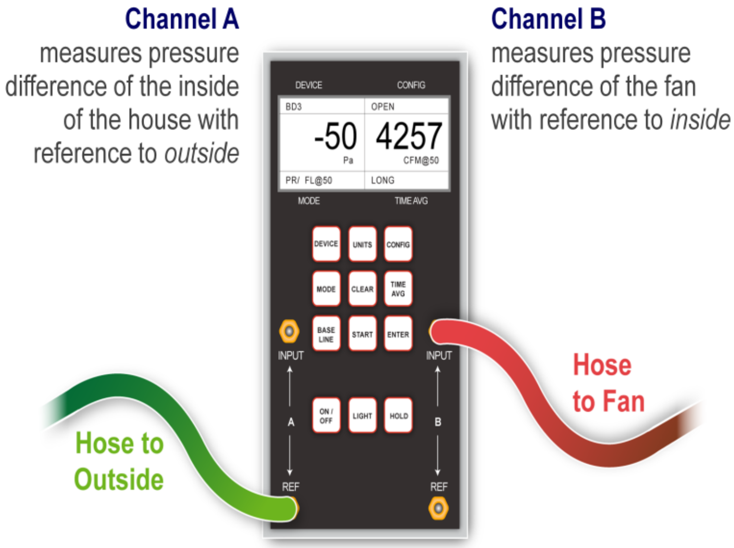
1. Set up the fan controller, manometer and holder where it can be easily seen and accessed. Most models should have a Velcro strap that will allow you to hang it inside the doorway.
2. Hook up the 2 hoses as illustrated below. The hose that was inserted through the door should be inserted over the bottom left port of the manometer. The other hose goes from the fitting on the fan onto the top right port of the manometer.
3. Make sure the fan will not be blowing air over the end of the hose that is outside – this will cause false "outside" pressure readings. (Locate it 5' off to the side of the fan opening).
4. Set-up the manometer for the conditions and equipment.
5. Get a baseline pressure reading with the fan cover still on.

Operate the blower door

1. After getting the baseline pressure reading, take the fan cover(s) off.
2. Slowly increase the fan speed until it reaches a reading of -25 Pascal's (Pa) with reference to (WRT) the outside (this should be displayed in the left portion of the manometer screen).
3. In the field, you would walk around the home to make sure everything is secure at this level of depressurization. Check for airborne particles (e.g. ashes) and things such as pictures that look like they may fall. Check for open windows and doors. Take care of any problems that you see.
4. Slowly increase the fan speed until you reach a pressure of -50 Pa. If you cannot reach -50 Pa ("can't reach 50"), add a low-flow plate.
5. If you still can't reach fifty, the home is VERY leaky. Continue to the next step. In the field, adjustments will be made at the end of the blower door test to make up for this.
6. Once -50 Pa is reached (or if you can't reach 50, the highest pressure you can get to), measure the air flow through the fan (the number in the right half of the manometer screen). This is in cubic feet per minute, or CFM. If you have achieved -50 Pa, it is called $CFM_{50.}$

Calculate air changes per hour

1. The CFM number tells you how leaky the house is. The higher the number, the leakier the house. A CFM_{50} of 4000 is high for a small house, but okay for a bigger house.
2. Calculating air changes per hour (ACH) takes the size of the home into account, and is necessary to find out if a home is leaky or not.
3. To calculate ACH, multiply CFM_{50} x 60 (minutes), and divide by the volume of the home. The volume is the length x width x height.
4. This gives you the ACH_{50} value. Generally, an ACH_{50} value of 7 or higher means that the home should be airsealed.



Hose setup for manometer (Image courtesy of US DOE)

Finished blower door setup (Image courtesy of US DOE)

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Lab 6: Duct Sealing and Insulation

In houses with forced-air heating and cooling systems, ducts are used to distribute conditioned air throughout the house. In a typical house, about 20 percent of the air that moves through the duct system is lost due to leaks, holes and poorly connected ducts. The result is higher utility bills and difficulty keeping the house comfortable. Obviously, well-sealed ducts are an important part of an efficient building. Duct sealing is usually one of the top priorities in weatherization.

After the ducts are sealed they need to be insulated. This is especially important when the ductwork is running through unconditioned spaces. Insulating duct wraps improve energy savings by cutting down on conductive losses of winter heat and summer a/c. The insulation also minimizes ductwork condensation problems. Air-sealing and insulation of ductwork are important skills to have.

When this lab is complete, you will be able to effectively install, air seal, and insulate ductwork. These leaks include joints, seams, fitting connections, holes, and gaps.

Tools
Utility Knife
Putty Knife
Cordless Driver/Drill
#2 Phillips Screw Bit
Screwdriver, flat
Metal snips

Consumables
Ductwork & fitting
Mastic (or DW compound)
Mesh Tape
2” Paint brush
Disposable gloves
Sheet metal
Self-tapping screws
1” x 3” furring strip
Ductwrap insulation
Metal tape

Safety Equipment
Eye protection
Respirator
Rubber Gloves

Approximate time needed to complete this lab: 2 hours

Procedure

Installation of Ductwork

1. To install metal ductwork, all sections and fittings must be mechanically fastened using self-tapping screws.
2. Take your straight length of metal ductwork and slide the fitting over the crimped end.

3. Now using the driver/drill fasten the fitting to the duct using 3 self-tapping screws spaced evenly around the fitting. Check to see if the fitting is now securely fastened.
4. (Installers sometimes have to install flex duct which is a plastic lined ductwork with an insulating outer layer. The procedure for this includes sealing with mastic and attaching with zip strap ties).
5. When the metal ductwork is hung in a building, it must be supported at intervals using metal straps screwed to farming such as the joists above. The spacing of supports varies according to the size of duct, manufacturer's specifications, and the Mechanical Code. For horizontal metal ductwork, typical supports are spaced between 4' to 8'. (For flex duct the typical max. horizontal spacing for supports is 5'.)

Sealing Ductwork

The best practice for ensuring ductwork energy efficiency is to seal to each and every joint in the ductwork with UL 181-rated mastic. For gaps from ¼" to ¾" also install reinforcing mesh tape embedded in the mastic.

Mastic

Mastic is a flexible sealant that expands and contracts as the duct expands and contracts allowing longer lifespan and higher effectiveness. Mastics are water-based products, which are safer and easier to clean. They may come in cartridges, tubs and buckets and can be applied with a brush, a trowel or a gloved hand.

Mesh Tape

Mastic used alone can only be used on cracks up to ¼ inch wide. To seal wider joints and gaps fiberglass reinforced mesh tape also has to be used. In this case, apply a thick layer of mastic and then one or more layers of fiberglass mesh tape topped by another layer of mastic. The mastic should cover the mesh entirely and extend 1" past it on all sides. The mastic and the mesh tape produce an effective ductwork seal.

Prepare the ductwork

- Make sure the joint area has been wiped clean to remove particles and dust before applying mastic. If the joint isn't clean, the mastic won't create a tight seal. A slightly damp rag, or a rag with rubbing alcohol, can be used to clean and prep the duct area.

Seal the ductwork

1. Apply enough mastic to form a continuous coating on the surface of the duct. Use a brush, trowel, gloved hand or caulking gun to apply the mastic. A cheap paintbrush can work well, but it is faster and easier to simply use hands to scoop out mastic. If using this method, heavy rubber gloves need to be worn that won't tear if pressed against a sharp edge of sheet metal duct.
2. Work the mastic into the joint or crack and press lightly to get an even coating. There should be at a 1" overlap around any joint, crack or hole in the duct.
3. Use a mesh tape to reinforce the mastic coating on areas where there's a gap of ¼" to ¾". This is especially important if the area being sealed is a joint that will be under stress.

It's always important to make sure the tape used for sealing the joints is designed specifically for mastic being applied. Completely cover the mesh tape with another coat of mastic extending the mastic 1” past the tape.

4. Gaps and holes over ¾” need to be first covered with solid sheet metal. Cut a piece to cover the hole and then fasten it with self-tapping sheet metal screws. Then seal all edges of the metal patch using mastic and mesh tape.

Insulating Ductwork

Insulating attic ducts after sealing them increases energy savings considerably. Half of duct energy losses are from conduction in unconditioned spaces. They lose heat like any warm surface. Insulating all the ductwork saves considerable energy by reducing: 1. conduction heat loss in winter; 2. conduction a/c loss in summer; 3. condensation/sweating on outside of a/c duct in summer; 4. condensation/drips on inside of duct in winter.

1. To insulate ductwork use ductwork wrap insulation. Wrap insulation comes in different sizes and R-values, usually ranging from R-7 to R-11. Check to make sure your wrap meets the specs for your work order and area. The wrap is made up of fiberglass insulation held inside an outer protective layer, usually of aluminum foil. Use metal tape to attach it around ductwork.
2. You need to determine where to cut the insulation pieces. Roll out a section of insulation wrap and lay the ductwork on it. Pull the insulation around the pipe until the 2 sides meet. Hold this place or mark it so you will know where to cut the insulation.
3. To cut the wrap, roll it out on a flat surface you can cut on. Get a 1” x 3” furring strip and press down the insulation along the line you want to cut. Using the furring strip as a guide, use your utility knife to cut the insulation. Holding the blade at about a 45 degree angle, cut all the way through the insulation while running the knife along the wood.
4. Now take the insulation and wrap it around the ductwork. Using metal tape, tape it where the 2 ends meet at the seam. Tape all along the long seam.
5. Now cut another piece and wrap it around to meet your 1st piece. One again, tape the long seam, then tape the seam where the 2 pieces of wrap come together. Use this procedure to wrap the entire ductwork length and fittings. The wrap should be smooth and tight; all seams should be completely taped.

In the photo to the left, the joints of a duct have been sealed with a thick layer of mastic on top of mesh tap. The photo to the right shows installed ductwork, with the main duct (square-shaped) wrapped in insulation. Foil tape covers the cut edges, and can be seen in the right part of the image. (Photos ©

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Lab 7: Work Scope

A Work Scope (or work order) is a document created by the Energy Auditor that lists all weatherization measures which will be applied to the corresponding work site. The work scope is used by the retrofit installer as a guide to apply the appropriate measures and as a checklist to determine whether all work has been completed.

Also, it will be important for an installer to become familiar with the “tool list”, which list all the tools and materials which are loaded onto the truck. Depending of your agency’s policy tools may loaded each day per the necessities of that days’ work order or there may be a master list which list all the tools & materials that could be used on any work scope. It is imperative that an installer knows what he has on his truck in order to report missing or deficient tools & material.

After this lab is completed, you will be able to analyze a work scope to identify work site areas, pull the proper tools & materials for weatherization measures, and determine the completion of work scope measures. This lab can be done in conjunction with any of the labs in the retrofit installer technician manual – it is not a standalone lab.

Tools	**Consumables**	**Safety Equipment**
Varied	Varied	Varied

Approximate time needed to complete this lab: additional 30 minutes to associated lab

Procedure

The work scope is reviewed by the crew prior to reaching the work site. The crew chief will sanction individual task to each installer. Upon reaching the work site the crew chief will use the work scope to introduce the home owner to the work areas of the home. During this time the installers pull their task designated tools and materials from the truck. The installer then waits for “start-work” verification from the crew chief. After work is complete the installer will return all tools and unused materials to truck to be inventoried and organized.

Safety concerns

10. Proper care of tools and materials

- Power tools are somewhat delicate and need to be moved appropriately
- Hand tools should be carried by the grip or handle

- Materials have manufacture specifications about proper storage (ex. One part foam shouldn't be stored in temperatures above 120^o to maintain material integrity and ensure safety)
- Materials and tools also have manufacturer limitations. When these limitations are exceeded it becomes a safety hazard (ex. A chisel is designed to shear wood with its sharp edge, though the sharp edge is flat it should not be used as a flathead screw driver because of the risk of injury)

11. ALWAYS WEAR THE PROPER PPE!

12. Work Area Hazards
    - Low head clearances
    - Rodents/rodent waste, aggressive animals/waste
    - High ambient CO, loose, friable asbestos
    - Illegal activity, aggressive client
    - Obstructions (e.g. client belongings)

Analyze Work Scope

7. Per Crew Chief instruction identify your task and locate it on work scope form
8. Cross check other installer measures
    - Ensure there will not be a conflict in work area space
    - Ensure there are no measures which may need to proceed your task
    - Report any issue to crew chief for further instruction

Pull Tools and Materials

10. Unload tools from truck
    - Find a place to compile your task appropriate tools & materials. This area shouldn't be on adjacent properties or in the path of passersby.
    - Compile your task appropriate tools & materials. Lay the tools out so they are all visible, never one on top of the other.
11. Confirm start-work order and enter work area
    - Confirm start-work order per crew chief
    - Carry tools and materials into work area (Safety First! Never carry more than what feels comfortable. Generally 2 hands = 2 tools.)
    - After all tools & materials are within specified work area apply weatherization measure.

Install Measures

During installation, issues may come up that are not in the work scope. For example, a safety hazard (e.g. broken step) may arise or an additional efficiency problem may occur between the tie the work order was created and given to you. If you feel the work scope needs to be deviated from *no matter how slightly*:

1. Clearly identify the deviation – where it is, why it is a problem, and that it is not in the work scope
2. Report the deviation to the crew chief or supervisor

   a. Unless specifically authorized to do so from the crew chief, do not deviate from the work scope
3. Request direction for modified work scope
4. Implement the modified work scope

Clean Work Area
1. Remove all materials & tools from work area into an adjacent area of the work site. This selected area should not restrict movement throughout the work site.
2. Remove and clean work area of material debris, dust, and dirt.

Load Truck
1. Carry tools to truck, placing each in its designated place. Again a safe carrying method is 2 hands = 2 tools. (prior to organizing tools in truck inventory each tool on tool list)
2. Locate appropriate facilities (per Crew Chief instruction) for dumping of trash, recyclables, and lead hazardous materials.
3. Place materials in appropriate facility or separate and compile materials for site removal.

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Lab 8: Loose-Fill Insulation

Weatherization installers often work in unfinished attic spaces above the thermal envelope. This is one of the key areas for improving the energy performance of a home. After air sealing work is completed, preparations are made to install insulation. Insulation is usually installed between, and covering over, the exposed ceiling joists of an open attic. This insulation is usually fiberglass batt or loose-fill/blown-in fiberglass or cellulose.

For weatherizing older buildings, cellulose insulation is a popular insulation material. It can be blown-in to fill open attics or it can be dense-packed in existing wall and ceiling cavities. It is made from recycled paper that is treated with a fire-retardant. For installing loose-fill cellulose, a blowing machine is used to quickly disperse the material to a desired thickness.

Using the blowing machine is covered in a step-by-step fashion below. This includes properly using the machine's switches and settings, and the precautions that need to be taken when working in an attic space. Like most weatherization measures, this is made easier with practice. Insulation blower machinery can be dangerous, both to property and your health. Carefully read all manufacturers' safety instructions before using the equipment.

When this lab is complete, you will know how to identify a work-ready attic. You will also know how to prepare a space for loose-fill insulation and properly fill an open attic cavity with cellulose insulation. You will also learn about blowing machine set-up, controls, safety, and adjustments. Finally, you will learn math calculations that are made to determine the needed thickness of the cellulose to reach a desired R-value, and the number of bundles of cellulose a loose-fill job may require.

Tools
Insulation blowing machine (such as Krendl) & hoses
(Work lamp; head lamp)
(Walk-planks)
6' Step Ladder
Tape measure & pencil
Calculator
Dust pan and broom

Consumables
Bundles of cellulose insulation
Wall netting membrane
Trash bag
Pencil and paper

Safety Equipment
Eye protection
Respirator
Gloves
Coverall; Disposable suit
Hat; Hood;
(Hard hat or bump cap)

Approximate time needed to complete this lab: 2 hours

Procedure

CAUTION:

1. **In case of emergencies, always push down the red stop button located on top of main control panel**. It will stop all feeding and agitation.
2. Blowing Insulation is an activity that takes getting to know your machine and hoses. You must get a feel for this activity. Be careful of weak ceilings that may not be able to withstand the added weight – continually monitor the area you are working on. Pay attention to how much cellulose material goes into a typical ceiling section and how long it takes to fill a typical ceiling section. If your using a lot more material or taking a lot more time than the average, find out where it is going (there must be a hole or opening somewhere). If you are using a lot less material or using a lot less time, find out where it is not going (there must be a blockage and an empty cavity).
3. **Use a ground fault circuit interrupter (GFCI)** in any damp or highly conductive area and reference NFPA 79, 70E, or OSHA safe work practices when performing energized work procedures.
4. Make sure all guards, hopper bars, and hopper extensions are in proper place before operating the blowing machine. **Hands should never pass below hopper bars.**
5. Make sure blower motor control and remote control hand pendant switch are in OFF position before connecting the power supply to the machine.

Step 1: Prepare for Loose-Fill

The job work order will give details of the scope of work. The work order typically includes a basic floor plan showing the areas to be loose-filled with insulation. To draw a basic floor plan, an outline of the outside walls and boundaries is first drawn. Interior walls, stair openings, and chimneys along with the outside dimensions are added. This gives the installer an understanding of the space that will be filled and how much material is needed to complete the job. The insulation requirements are based on the weatherization program, local codes, available space, and the manufacturer's specifications for the installation.

1. USE CAUTION: When open blowing an attic, close attention must be paid at all times to where you place your feet. Whenever possible planks should be laid in place across the ceiling joist to create a moveable floor. When space and access won't allow for this temporary floor application, close attention must be paid to walking on the ceiling joists. The first danger in this is the integrity of the joist themselves, all building components need to questioned and inspected. The next danger is mistakenly placing any amount of your weight on the drywall or lathe & plaster. Drywall and lathe & plaster cannot support weight and will be damaged when weight or force is applied.
2. The preparations for loose-fill include health & safety items; air-sealing; and insulation prep.
3. Health and safety items include roof repairs to address all leaks; fire code violations such as combustible materials located against chimneys; repairs to defective chimneys and flue pipes; removal of rodents; termination requirements for venting and flue pipes (the specifications related to materials and installation where they exit the building), and needed electrical work. The electrical work can include the removal or replacement of knob and tube wiring and the covering of all open junction boxes. Remember: No insulation can be installed over live knob & tube wiring. If you find knob & tube, stop work and contact your crew leader for further direction.

4. Inspect attic floor and walls for penetrations, chaseways, and holes. The attic MUST be properly air sealed prior to insulating. Air sealing includes all the work needed to close all opening, gaps, and holes to provide a complete, air-tight, continuous pressure boundary. This work includes approved air barriers over chases and soffits, air sealing around chimneys with non-combustible materials; spray foam or caulk in cracks along wall plates; and proper air-sealing at fixtures and mechanicals. These include bath fans, recessed lights, pull-down stairways, plumbing vent pipes, and ductwork. Check and make sure that all exhaust fans are ducted to the outside with insulated flex duct or add duct wrap to insulate them and other ductwork after it is sealed.
5. After air-sealing work is completed and confirmed, the attic needs to be prepared for loose-fill insulation. Insulation dams are built to maintain required clearances by keeping insulation away from heat-producing items like chimneys, flue pipes, and recessed lights. These dams are also used around access hatch doors and pull-down stairways to allow the insulation to be full-height right up to the opening and to keep insulation from falling into the opening.
6. Insulation dams can be made from various materials like plywood, OSB, drywall, sheet metal, aluminum flashing, rigid foam, and even faced fiberglass batt. Make the dam at least 4” higher than the insulation to be installed. For fire safety around a chimney, the dam must be placed so that there is the min. required clearance space. For masonry chimneys the clearance space is typically min. 2”.
7. Another prep item is to install markings or flags where items such as junction boxes will be covered. Tag all electrical wiring, HVAC equipment, plumbing runs, and lighting fixtures which may be covered by the insulation. These tags should be stapled directly above the corresponding fixtures. This allows them to be located later for repairs or maintenance.
8. If there are vented soffits, soffit vent chutes and wind baffles need to be installed in the lower roof eaves between the rafters. The vent chutes maintain a 1” roof ventilation channel under the sheathing so fresh air can continue to move up to the ridge or other roof vents. The wind baffles block outside air from penetrating under the vent chutes through insulation and taking heat away from the conditioned areas. The chutes and baffles also keep loose-fill insulation from falling into the soffit vent area.
9. Finally, insulation depth rulers with R-values are stapled to rafters or any studs you may find to provide adequate depth measurement. These depth markers come from the cellulose manufacturer and are rated according to the corresponding insulation. These rulers act as a guide for the installer to apply the proper depth of cellulose evenly throughout the attic and offer the inspector the opportunity to report depth without compromising the insulation’s integrity by climbing over it.

To keep the blower running properly, make sure (this is specific to the Krendl 500 machine, but will apply to most machines – see manufacturer specs for operational precautions):

- the hopper is empty of foreign objects before starting.
- the blower(s) is on when the agitators are running or machine will bind.
- the blower filter is kept clean and in place when blower is on.
- the blower is turned off immediately if hose is clogged or else the blower will overheat.
- the agitator motor is on before adding fiber.

- pieces of the bag are not left in the machine as this can bind and stall the machine.

Step 2: Prepare the machine for operation (for Krendl 500)

1. Pull up to set the emergency "kill" switch.
2. Turn red main disconnect switch to ON position.
3. Set 4-Position Selector Switch to OFF.
4. Press green start button. Machine will not run unless start button is pressed after kill switch is out and red main disconnect switch is on.
5. Select operating mode on 4-position selector switch from one of the following options:
    - **Remote:** remote control will control machine. This allows the installer to control the blowing machine while they are filling a wall or floor cavity.
    - **Off:** machine will not run (overrides remote hand pendant)
    - **Blower:** only the blower will run continuously (manual control at machine)
    - **Agitator-Feed/Blower:** both the blower and the agitator-feed will run continuously.

The Krendl 500. (Photo ©)

Main Control Panel

When operating in remote mode, the 4-Position Selector Switch must be set to Remote position. The remote control positions will be selected from the following:

- BLOWER-FEED: operates both blower motor and agitator-feed motor simultaneously to supply both air and cellulose material.
- OFF (middle position): all functions stop. Adjust blower(s) and slide gate to desired settings.
- BLOWER: operates the blower motor only supplying only air.

Main control panel of the Krendl 500. (Photo ©).

Mechanical Settings

The control end of the machine contains blower and slide gate controls to adjust the machine for each application and type of fiber. Blower control (air) and slide gate (material feed) are adjusted according to:

- APPLICATION: Open blow, retro-sidewall dense-packing, floor dense-packing, and spray-on applications require varying control settings.
- TYPE OF MATERIAL: Cellulose, fiberglass and mineral wool have different textures and densities that respond to machine settings.
- HOSE: Corrugations or roughness of interior surface, diameter, length and elevation of hose will also require varying adjustments.
- WEATHER CONDITIONS: Temperature and humidity may require day to day adjustment of machine settings.

- For open-blowing with cellulose, the feed gate is set higher (more material), than for dense-packing cellulose in a wall. The added material provides for a faster, lighter fill which gives more R-value (more insulating air pockets per volume). Remember for open-blow insulation: more material.

Step 3: Fill the attic cavity with insulation

1. Through attic access panel, bring the 3 inch hose and blower remote switch into the attic. Pull the hose into deepest area of attic, where work will begin. This application is very similar to painting in the respect that you do not want to paint yourself into a corner! Start at the deepest point of the attic and back your way out.
2. Using the remote control, begin by blowing *air only*, to clear the line. Turn remote switch to blower/feed and as insulation begins to flow create a mound at the first R-value ruler to achieve desired depth. From this point hold the hose at waist level and use a side-to-side swaying motion to blanket the attic floor using the first mound and the R-value ruler as a depth guide.

Blowing in Loose-Fill Insulation. (Photo courtesy of David Dennis)

3. As you fill the space you are standing in, begin to back up paying attention to the placement of your feet. When the planks need to be moved turn remote to OFF setting and move planks to blanket the next space.
4. Watch the white part of the hose to see the cellulose flowing through the hose. Pay attention to the velocity that it moves when it is filling the ceiling. Notice when the velocity slows down and know that you need to make an adjustment. If the material stops flowing, *switch to air only* and pull the tube back approximately 1' or until the material in the hose moves.
5. Communicate with crew members who are tending to the blowing machine. They will feed bags of cellulose into the hopper (the main compartment of the blower) as needed, and could turn the machine off or adjust the hose if it gets caught.
6. Continue steps 2 through 5 until all areas of attic have achieved proper depth.
7. At the end of a proper installation you should be back at the access panel and the insulation should appear to blanket the floor evenly up to the specified installed height to get the needed R-value. Remember that the insulation settles over time, so the installed insulation height is always greater than the final settled depth you need for the R-value. There is

usually a table on the cellulose bundle package which gives different installed and final settled heights for different R-values.

8. Attic access panel should be insulated to the same R-value of the attic floor. Attic Hatch lab will cover this in more detail

Joist bays should be completely filled with loose insulation when you are done. (Photo ©ECA)

This is an activity that takes practice to get to know the machine and the hoses. You must get a feel for this activity. Be careful of weak plaster or drywall that may not be able to withstand the weight of the insulation. Always monitor the area you are working on. Always keep checking for cellulose moving through the hose; listen to the blower to see if the hose is backing up. Remember: Pay attention to how long it takes to fill an area and how much material you use. This can alert you to problems such as openings.

Step 4: Fill a wall cavity with insulation

Sometimes loose-fill is installed in vertical applications such as attic kneewalls.

1. Prepare the wall by applying the netting material over the exposed wall studs and framing. This material holds the cellulose in the wall cavities while allowing air to escape. Measure the wall and add 4” to 6” extra to ensure coverage. The extra can be trimmed off after the wall is covered. Cut the netting with a utility knife or scissors. Staple the netting every 4” to 6” along each stud so the netting is smooth and tight.
2. With the utility knife cut a small hole about 6’ high where then blower hose will be inserted. Keep the hole small so there will be a tight fit around the hose and the cellulose material will be kept inside the wall.
3. Bring the 3 inch hose and blower remote switch to the wall area where work will begin.
4. Using the remote control, begin by blowing *air only*, to clear the line. Turn remote switch to blower/feed and as insulation begins to flow watch to see that it fills the wall cavity evenly from the

bottom up.

5. Remember to pay attention to the placement of your feet. If in an attic and the planks need to be moved, turn remote to OFF setting and then move and reposition the planks and ladder.
6. Watch the white part of the hose to see the cellulose flowing through the hose. Pay attention to the velocity that it moves when it is filling the ceiling. Notice when the velocity slows down and know that you need to make an adjustment. If the material stops flowing, *switch to air only* and pull the tube back approximately 1' or until the material in the hose moves.
7. Communicate with crew members who are tending to the blowing machine. They will feed bags of cellulose into the hopper (the main compartment of the blower) as needed, and could turn the machine off or adjust the hose if it gets caught.
8. Continue steps 2 through 5 until all wall cavities are evenly filled with no voids and the membrane even with face of the studs. Do not overfill or the membrane could pull away from the studs.
9. Follow all clean-up procedures and check with crew leader for final instructions and inspections.

Loose-fill/ Blown-in Calculations

Installers need some basic math skills to make calculations that are very helpful with insulation. The math skills are addition, subtraction, multiplication, and division. An electronic calculator is very helpful in completing these calculations. The amount of cellulose material that is used to fill an attic area is very important. If you know the R-value that should be in the attic, you can determine how much cellulose material by height you use to fill that area.

1. For example: An installer needs to insulate an attic space with cellulose to get an R-38 insulation level. How many inches need to be installed? Cellulose has an R-value of 3.2/inch.

To find the height of insulation needed, divide:
Total R-value / R-value/inch: 38 / 3.2 = _____number of inches

2. Another calculation that is made for loose-fill, blown-in insulation is the number of bags of cellulose needed for a certain sized attic.
To find the number of bags needed, you need to determine 2 things: the size of the attic and the R-value needed.
If an attic measures 30' x 42', how many bags will you need to get an R-38 insulation level?
For this exercise, 47.9 cellulose bundles will cover 1000 Sf of attic.

To determine the area of the attic, multiply length x width: 42' x 30' = _______ SF
Divide the area of the attic / 1000 Sf: __________ SF / 1000 SF = _______ factor
Multiply 47.9 bundles/1000 SF x factor to get number of bundles:
47.9 bundles x factor = __________ bundles needed

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Lab 9: Batt Insulation and Dry Crawlspace

Batt insulation is commonly used to insulate between ceiling and floor joists, between wall studs to insulate walls, and sometimes between roof rafters. It comes in widths to fit between 16" or 24" o.c. (on-center) framing. It is supplied in bundles of pre-cut 8' batts or in long rolls that are cut to fit on the job.

Batt is usually made of fiberglass, though other materials such as mineral wool, polyester, and cotton, and even sheep's wool are available. It may come unfaced or faced with a paper or foil layer attached to the outside. Facing is useful because it is a vapor retarder and partial air barrier, and can be used to attach the insulation to the studs, joists, or rafters. If adding a layer of insulation atop an existing layer, use unfaced insulation to avoid trapping moisture in between the layers of insulation.

Batt insulation is available in a wide array of R-values, which indicate how well the batt insulates (a higher R-value means more insulating ability. Remember R-value is a measure of resistance to heat loss). The R-value depends on the thickness and type of material. Remember that fiberglass batt does not stop air movement. Air barriers and air sealing are still needed.

After this lab is completed, you will be able to hang batt insulation to the floor joists of a crawlspace, and install it between wall studs. Another crawl space weatherization measure that installers complete is the installation of a vapor barrier. This prevents water vapor from entering the crawl space through an uncovered dirt floor. After completing this lab, you will also be able to install a vapor barrier in a crawlspace.

Tools
Tape measure
Power drill with #2 Philips bit
Driver sleeves
Utility Knife
Stapler
Dust pan and broom

Consumables
Fiberglass batt (R-19, faced)
Fiberglass batt (R-13, faced)
1" x 3" furring; 3'; 8'
Screws (1 ¼" sheetrock screws)
Twine, or insulation wires
Duct or masking tape
House-wrap or Construction Tape
Poly sheeting 6 mil
Staples
Trash bags

Safety Equipment
Respirator
Gloves
Coverall; Tyvek™ w/Hood

Approximate time needed to complete this lab: 1 hour

Procedure

Weatherization work often includes measures in an uninsulated crawl space. Often the space is unconditioned and the floor above needs to insulated. For this part of the lab, you will learn about insulating a floor above.

Installing floor insulation

1. Measure the space between the floor joists to determine the spacing. Usually for a floor the floor joists will be 16” apart (16” o.c on-center). The fiberglass batt will be available for installation between 16” or 24”o.c. framing.
2. For installation in a floor above, you need to hold the insulation up and secure it against the subfloor boards. If the batt has a facing, you will need to place the facing up against the subfloor, because you want the vapor barrier to face the warm, moist inside conditioned air. This means you cannot use the facing to attach the batt to the joists.
3. To attach the insulation you need to set up alternating rows of screws 16” apart and 5 ½” down from the subfloor along both sides of the joists. You will attach twine to the screws in a diagonal crossing pattern as you put up the insulation to hold it in place. (An alternate method to hold up the insulation is to buy pre-cut insulation wires. These are strong thin springy metal rods which can be pushed up between the joists. The sharp ends of the rods stick into the joists and hold the rod in place).
4. Start at one end of the floor and tie some twine to the first 2 to 3 screws to provide support to get started. Gradually work your way along the joists bay, holding the insulation up and then tying twine under it around the next screws.
5. If the joist bay is not a standard width, you will have to cut the insulation. Lay it on a smooth solid surface with the insulation up/ facing down. Get a 1” x 3” furring strip and press down the insulation along the line you want to cut. Using the furring strip as a guide, use your utility knife to cut the insulation. Holding the blade at about a 45 degree angle, cut all the way through the insulation while running the knife along the wood.
6. If you encounter electrical boxers, pipes or other fixtures, you must notch the insulation around them. Do not compress or crush the insulation. Fit the insulation so it is tight and even along the joists. You should have insulation behind the fixture and tight around it. Above, below, and to the sides of an electrical box, the insulation should be full depth. Remember the quality of the installation is critical to getting good insulating R-value.

Installing wall insulation

Weatherization work often includes measures to insulate uninsulated walls. For this part of the lab, you will learn about insulating a wood-frame wall with fiberglass batt insulation.

1. Measure the space between the wall studs to determine the spacing. Usually for a wall the studs will be 16” or 24” apart (16” o.c on-center). The fiberglass batt will be available for installation between 16” or 24”o.c. framing.

2. For installation in a wall, you need to hold the insulation up and secure it against the studs. If the batt has a facing, you will need to place the facing toward you into the house, because you want the vapor barrier to face the warm, moist inside conditioned air. If you are inside the house insulating a wall without drywall or plaster finish, you can use the facing to staple the batt to the studs. (If you are in an unconditioned attic behind a kneewall, the unfaced fiberglass side will face you. You will have to place the facing against the back of the drywall or plaster, and hold it place with a tight fit).
3. To attach the insulation you need to place it tight against the top plate of the wall and work your way evenly down the stud stapling the facing flange across the stud at about every 12”. The insulation should be smooth, even with the face of the stud (not pushed in), and against the full length of the studs (no gaps). When you use more than one piece in a stud bay make sure they fit snugly against each other (no gap between them). Remember the quality of the installation is critical to getting good insulating R-value.
4. If the stud bay is not a standard width, you will have to cut the insulation. Lay it on a smooth solid surface with the fiberglass up/ the facing down. Get a 1” x 3” furring strip and press down the insulation along the line you want to cut. Using the furring strip as a guide, use your utility knife to cut the insulation. Holding the blade at about a 45 degree angle, cut all the way through the insulation while running the knife along the wood.
5. If you encounter electrical boxes, pipes or other fixtures, you must notch the insulation around them. Do not compress or crush the insulation. Fit the insulation so it is tight and even along the studs. You should have insulation behind the fixture and tight around it. Above, below, and to the sides of an electrical box, the insulation should be full depth coming right out to the front of the stud.

Batt insulation should fit snugly between studs. (Photo ©ECA)

Installing vapor barrier

Weatherization work often includes measures in a crawl space. Often the space has a dirt floor which allows moisture to enter the crawl space. For this part of the lab, you will learn about installing a vapor barrier over the dirt floor. If you find bulk moisture such as wet walls and puddles on the floor that indicates either a plumbing leak or water entering from the outside. There is often a grading issue that needs to be addressed where the yard outside slopes back toward the house. This causes water to always drain against the building and run along the foundation and enter the basement or crawl space.

Vapor Barrier Set Up in a Crawl Space. (Photo courtesy of Paul Ricker)

1. Prepare the dirt crawl space for coverage by removing large rocks and flattening high/rough areas.
2. Measure the crawl space to determine the length of the 6 mil poly sheeting pieces to be cut. Add 1’ to 2’ to the length of each long piece to allow for a 6” to 12” lap up onto the foundation wall. (Note there are heavier sheet materials available you could use for a crawl space vapor barrier).
3. Install the first length lapping both on the ends and side.
4. Install the length lapping it 12” over the first piece. Using a quality housewrap-type tape or construction tape, seal the entire length of the lap. (An option for sealing laps is a quality construction adhesive or acoustical sealant).
5. Proceed with next pieces, laps and tapes until the final length is lapped up on the opposite foundation wall.
6. Prep the foundation and attach the lapped poly to the foundation with furring strips/lumber, construction adhesive, mastic, or spray foam.

Clean-up work area and store tools and materials

1. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used as these are usually flammable and could contains VOC’s (volatile organic compounds).
2. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.d or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
3. Complete a final check and clean your work area and the work site.

Batt Insulation in a Crawlspace. The floor joists can be seen in the photo to the left. Note that the first floor has a plywood subfloor on top of the joists. Band joists sealed with caulk and foam board can be seen in the background. In the photo to the right, the nylon stringer held up with screws can clearly be seen. (Photos © eca)

Weatherization and Retrofit
Energy Coordinating Agency

APPENDIX F

Manual Three Quizzes

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Green Jobs Training Center

Quiz 1: Air Leakage & Air Sealing

Name: ______________________________ Date: _______________

Choose the best answer for each question:

1. What is the main goal of air sealing?
    a. Reduce loss of conditioned air
    b. Increase indoor comfort
    c. Reduce energy use
    d. Increase insulation value
    e. All of the above

2. Which of the following is a *benefit* of a leaky house?
    a. It reduces loss of conditioned air
    b. It increases indoor temperature control
    c. It reduces build up of toxic air
    d. It reduces energy bills

3. Which of the following group is the most common air sealing strategy?
    a. Spray foam gaps and cracks
    b. Increase attic insulation
    c. Buy windows
    d. Install radiant barrier in the attic

4. The purpose of air sealing is to _______.
    a. reduce carbon monoxide
    b. increase indoor air quality
    c. create a thermal bridge
    d. reduce air leakage

5. Which of the following are air barriers and insulation?
    a. Fiberglass batting
    b. Spray in place polyurethane foam
    c. Dense pack blown cellulose
    d. OSB
    b. B & C

6. Duct sealing is most valuable for leakage where?
   a. Through conditioned basement
   b. Outside conditioned space
   c. High pressure in return ducts
   d. Plenum leakage at the furnace

7. Winter home heating conditions are most likely to increase __________.
   a. infiltration in the attic
   b. exfiltration in the basement
   c. the stack effect
   d. blower door test readings

8. Which of the following is not a common air leakage problem location?
   a. Platform framed interior walls
   b. Basement stairways leading to the outside
   c. Unsealed concrete block walls
   d. Exterior overhangs

Knight

Green Jobs Training Center

Quiz 2: Insulation

Name: _______________________________ Date: _______________

Choose the best answer for each question:

1. Adding insulation does which of the following?
   a. Increases energy bills
   b. Reduces heat transmission through roof, walls and floors
   c. Increases indoor space temperature
   d. Increases air sealing value

2. R-value is a measure of what?
   a. Reduced losses of conditioned air
   b. Air flow through a substance
   c. Reducing toxic air
   d. Thermal resistance

3. Fiberglass batt insulation has an R-value of what per inch?
   a. R-2.0
   b. R-3.0
   c. R-5.5
   d. R-7.5

6. Cellulose dense pack insulation has an R-value of what per inch?
   a. R-2.4
   b. R-3.2
   c. R-5.0
   d. R-7.5

7. Vapor barriers should be installed where in cold climates?
   a. On the inside of the house
   b. Facing the area warmer in winter
   c. On the outside of the house
   d. On the inside and outside exterior walls.

8. Fire barriers are made to do what?
    a. Prevent the spread of fire between areas
    b. To control smoke between areas
    c. Slow the spread of fire an hour or more
    d. Not burn

NOTES

ENERGY COORDINATING AGENCY

KNIGHT GREEN JOBS TRAINING CENTER

Manual Four

Weatherization Installation: Technical Applications

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Energy Coordinating Agency
Philadelphia, PA

Weatherization and Retrofit Course

MANUAL FOUR

Weatherization Installation Technical Applications

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Philadelphia, PA

MANUAL FOUR

Weatherization Installation Technical Applications

Manual Four: Weatherization Installation: Technical Applications

Energy Coordinating Agency

Manual Four: Weatherization Installation Technical Applications

Overview

This course is the capstone course in the Retrofit Installer Technician training sequence. It is designed to provide training in intermediate- to advanced weatherization measures, including roof repair, roof vent installation, drywall repair, stair building, door installation and window installation. The course is designed for individuals who wish to enter the retrofit installer technician field and have some experience with weatherization and basic carpentry and tool operation, as well as incumbent workers who wish to brush up on the competencies covered in the course.

The Manual will proceed as follows:

- Discuss safe use of hand and power tools
- Discuss different uses of hand and power tools
- Describe and discuss roofing structure and materials
- Describe and discuss roof venting systems
- Install mushroom, gable and slope roof vents
- Perform minor roof repairs, including replacing shingles, fixing small holes and fixing air bubbles
- Identify and remove roof drainage blockages and repair drainage systems
- Discuss the importance of a sealed and insulated attic hatch
- Discuss and apply weather-stripping to an attic hatch
- Build a site-built and pre-fabricated attic hatch
- Discuss stair components, safety issues and repairs
- Assist in the building and repair of stairs
- Discuss and install drywall (cutting, hanging, and finishing)
- Discuss the function and components of doors

- Install a pre-hung door and perform minor door repairs (sticky door, door shaving, tightening components)
- Discuss benefits and drawbacks of different types of windows
- Cut and install single-pane window glass
- Assist in the installation of a window

Learning Objectives

At the conclusion of this manual, the student will have the following competencies:

- Demonstrate advanced hand- and power tool use
- Identify roofing materials and basic roof structure
- Describe the importance of the integrity of a roof drainage system
- Indicate when a gable, slope roof or mushroom vent should be installed
- Perform basic roof repair
- Install gable vents, mushroom vents and slope roof vents
- Ensure proper roof drainage
- Build a site-built attic hatch and install a pre-fabricated attic hatch
- Identify components of stairs
- Assist the building of basement steps
- Perform minor stair repairs
- Explain benefits of using drywall for walls and ceilings
- Install and patch drywall
- Identify door components
- Explain leakage problems associated with doors and windows
- Install pre-hung doors
- Perform minor door repair (shaving, tightening, loosening)
- Weather-strip a door
- Cut window glass
- Install new window glass in a frame
- Assist in window installation while maintaining moisture barrier
- Demonstrate proper use of Personal Protective Equipment
- Handle tools and materials according to manufacturer specifications
- Analyze a work scope and explain how it is used before and on a job site
- Address deviations from work scope if needed
- Gather materials and supplies for a weatherization application
- Set up tools and materials

- Clean up and organize work area as work is in progress
- Pick up tools and materials, and clean up and close out a job site

Key Terms

- Attic hatch
- Baluster or spindle
- Bore
- Cleat
- Circular saw
- Door jamb
- Door leaf
- Drywall
- Drywall knife
- Expanded polystyrene (EPS)
- Fastener
- Flashing
- Flat roof
- Garage door roller
- Garage door track
- Glazing
- Gypsum wall board
- Header
- Landing
- Latch
- Low slope roof
- Mortise
- Mushroom vent
- Newel post
- Pitch
- Pitched roof
- Plumb
- Pull-down stairs
- Bry bar
- R-factor
- Rabbet
- Rail
- Riser
- Rise
- Safety cable
- Sash
- Sidelights
- Sill
- Slope roof
- Slope roof vent
- Solar heat gain coefficient
- Stile
- Stringer
- Sweep
- Tape measure
- Tempered glass
- Tool belt
- Torsion spring
- Tread or run
- U-factor
- Utility knife
- Weather-stripping
- Work scope

Manual Four: Weatherization Installation Technical Applications

Topic 1: Hand and Power Tools

Overview:
Tools are the means by which nearly every task is performed. As an installer, you will be working with a variety of tools on a daily basis, and the ones most frequently used in weatherization and basic carpentry are included here. Tool maintenance, including sharpening, lubrication, and replacement of worn or damaged parts (or entire tools) is critical to productivity. Also, it has been estimated that carpenters spend up to a third of their time looking for tools. This means that keeping tools well organized and accessible can greatly increase productivity.

Organization of tools depends on the person and/or company. Tools in a truck or a shop can be grouped according to function or as needed for specific tasks. It is helpful to have more than one of a given tool so that frequent tasks can each have a dedicated set of tools. What is important is not the organizing system but that it is understandable and that all crew members or users agree and use it consistently.

Power tools can be either corded (with an electric cord and plug) or cordless. Corded tools have the advantage of greater consistent power but cords limit mobility and cause tripping or shock hazards. Cordless tools have greater mobility but the disadvantage of needing batteries or a recharge. Batteries add weight and must be replaced at least a few times during the life of the tool, adding extra cost. Usually, but not always, corded tools are used in a shop while cordless tools are better in the field. Tools requiring a large amount of power are nearly always corded; however this is gradually changing with improvements in battery technology.

Safety
Most tools have sharp edges and in the case of power tools, powerful motors that can cause injury or damage if not used properly. There are basic rules but these are not a substitute for following instructions, constant attention to the task at hand and the use of common sense.

- **Appropriate personal protective equipment (PPE) should always be worn when using tools**. This includes goggles for eye protection and ear plugs (or earmuffs) for hearing protection. Common tools like power saws can cause permanent hearing loss if hearing protection is not worn. Gloves are also important to protect the hands from splinters and sharp edges or toxic materials. Wear enough clothing to protect the skin from flying chips and pieces but avoid loose-fitting clothing, dangling jewelry, loose or long hair to prevent getting caught in the tools.
- **Always disconnect the electricity to a power tool before changing a blade or bit**. This means unplugging the power cord or removing the battery. Don’t just check to see that the

switch is off, a switch could get bumped or malfunction. Many workers have lost fingers or suffered more serious injuries by forgetting this simple but very important rule.
- **A dull tool is a dangerous tool**. If a blade or bit is not as sharp as it should be, the tool and the worker both have to work harder to complete the task. In such cases, the worker has less control and the tool is more likely to kick back, bog down, slip or bind. In addition to the hazards, this can stress the tool and shorten its life and is likely to produce an inferior job result.
- **Check for any metal such as nails, screws or staples prior to drilling or nailing**. Remove any obstacles in the path of a cut or hole before beginning. Cords, furniture or other obstructions should all be well out of the way.

Always work against the cutter/tool. Power tools are designed so that the direction of the material and the tool move in opposite directions. This is to avoid the tool pulling the material out of control, resulting in serious injury or damage.

Hand Tools

Tool Belt
The tool belt is the primary tool organizer and how a worker can keep the basic tools handy and within reach. It has loops, holders and pockets for tools and fasteners and is worn around the waist. It should fit comfortably and not be loaded too heavily with things that are not in use so as to be wearable through the work day.

Hammer
The hammer is the most primary and basic tool and perhaps the oldest in human history. It is used to drive nails and other fasteners and to pound stubborn pieces and items into place. In demolition, the hammer is used to break apart material or remove fasteners. The hammer consists of two parts, the handle and the head. The handle is made of wood, fiberglass or metal with a rubber or plastic grip and is typically 12” to 16” long. The head is always of drop forged machined steel and has a face for striking nails or other objects and a claw for pulling nails or prying materials apart.

Toolbelt and Hammer. (Photo ©)

Most hammers have either a curved claw or a “straight” claw. Between the face and the claw is the eye where the handle is inserted into the head and secured in place. Correct use of the hammer for striking an object is to hold the handle close to the end for maximum leverage and with the thumb on top, swing from the wrist with only limited motion of the forearm and almost no motion of the upper arm.

Flat Pry Bar

The flat pry bar is used when a hammer is inadequate for prying or for pulling out fasteners. It has a gentle curve at one end and a hooked curve at the other to be used for different situations. Both the hammer claw and both ends of the pry bar have a slit for grabbing fastener heads. It can also be used to lift heavy things for a short distance.

Prybar. (Photo ©)

Tape Measure

The tape measure is a necessary tool for both planning a project and for making accurate cuts and placement of pieces during construction. It is made in various lengths with the most commonly used being 25'. A hook at the end of the tape allows for one person to measure long distances alone. Reading the tape is important to making accurate measurements and should be done carefully.

Although made of very thin metal that allows the tape to wind around the spool, the tape is has a curve across it's width that provides stiffness when the tape is extended. Care of the tape includes keeping it dry and avoiding making kinks caused by severe bending. A pencil is used for marking the material being measured. The tape and pencil are generally used together and the ability to handle them with one in each hand is an important skill that contributes to efficiency and speed. The pencil needs to be kept sharp which is usually done with the utility knife.

Square

Squares are used along with the tape measure to accurately mark, measure and cut material. The speed square is most frequently used for marking wood for a square (orthogonal) or diagonal cut. It has a flange that is held against the edge of the material while the square lies flat on the material. The mark from measuring can then be extended by using a pencil on the long edge of the square.

For longer cuts, a framing square is used. Both speed square and the framing square can be used to check 90 degree corners and angles. Both squares have numeric measurements printed on them that are useful for small measurements. A drywall t-square has a four-foot long blade and can also be used to mark sheets of plywood or other material as well as for cutting rigid insulation board.

Chalk line

A chalk line is a metal or plastic case that encloses a reel of string and filled with powdered colored chalk. The chalk-laden string is drawn out from a hole in the case, pulled tight between two marks and then snapped against a flat plane to produce a straight line on the material for cutting or fastening.

Chalk line and refill chalk Photo ©)

Utility Knife

A utility knife consists of a hand-held metal or plastic handle with a retractable blade (similar to a razor blade) with sharply angled ends. The blade can be reversed when it becomes dull and the handle can also hold spare blades. Some utility knives are made without retractable blades and are considered unsafe. The utility knife is versatile, and thus is a valuable tool. It can be uses for sharpening pencils, cutting drywall and rigid insulation, marking for precise cuts, whittling or shaving wood and other simple tasks.

Utility Knives (Photo ©)

Chisels

Chisels are another wood cutting tool used for removing more wood than a utility knife can but where using a saw is impractical. Typically made in widths of ¼” to 1-½”, a chisel consists of a straight handle with a thick stiff metal blade that is beveled at the end to a very sharp edge. Regular sharpening keeps the chisel in condition for making accurate and clean cuts. The chisel is held in one hand and tapped gently with a hammer or with the heel of the other hand to make accurate small cuts. With acquired skill and attention to the grain of the wood, a sharp chisel can make mortises nearly as neat as a machine router.

Assorted chisels. (Photo ©)

Plane

A plane is basically a small chisel mounted in a steel or iron housing that controls the depth of the cut and allows thin layers of wood to be removed to achieve a smooth surface. Shaped more or less like a shoe, it was once called a “shoe plane.” The plane has a flat bottom or “sole” through which the blade protrudes and can be adjusted for different depths.

Planes are made in a wide variety of sizes, the smallest held between the thumb and forefinger and the largest as long as two feet or larger. All but the smallest planes are held with both hands and used in long steady strokes. Even more than with a chisel, blade sharpness is critical to the effectiveness of this tool.

Sharpening Stone/Grinding Wheel

Sharpening stones and grinding wheels are used to sharpen chisels and planes. Holding the bevel edge flat against the stone surface, move it evenly back and forth parallel to the blade edge to grind the surface of the bevel. A blade that is very dull will take a long time to sharpen in this manner and so a grinding wheel in this case is more efficient.

In using the grinding wheel, the blade is steadied on a rest and held against the outside of the wheel with the blade edge parallel to the wheel axis and the bevel surface tangent to the wheel.

Blades

Some blades are typically not kept sharp, such as putty knives, scrapers and drywall joint knives. All of these have a straight handle and a flat blade. These blades have different widths and stiffness levels, based on the type of job they are meant for.

The putty knife is typically 1 to 1 ¼ inch wide and is designed for applying glazing compound to a window. It can also be used for small amounts of scraping, freeing stuck windows or doors and other miscellaneous tasks.

The scraper is typically three inches wide and has a stiff blade with an edge that has limited sharpness but can be sharpened. This very versatile tool can be used for scraping, prying trim or other materials loose, protecting wood surfaces when using another tool to pry or pull fasteners and other tasks.

Drywall joint knives are typically 6”, 10”, 12”, or 14” wide. Drywall joint knives are used to spread out drywall compound (“mud”) to create a smooth surface over cracks and holes.

From left to right: putty knife, scraper, 6” drywall joint knife, and 14” drywall joint knife. (Photos ©)

Screwdriver

Screwdrivers can either be hand or power driven, Phillips head (“x” shaped head) or flat. Most screws are driven with a power screwdriver/drill and are of the Phillips type. The standard size is #2, but #1 (smaller) and #3 (larger) are sometimes seen. A hand-held Phillips screwdriver is usually only used when access does not allow a power tool or one is not available.

“Single slot” screws are rarely used today, but are frequently encountered in older buildings, in which case a flat screwdriver is needed. A worn or abused flat screwdriver can be sharpened or “dressed” using a sharpening stone or grinding wheel. When a worn single slot screw must be reused, the slot can be improved by running it a few times down the blade of a hacksaw. Sharpening a worn Phillips bit or reconditioning a Phillips screw head is difficult and not practical.

Hand Saw/Hacksaw

Most saw cutting is done with a power circular saw or reciprocating saw (see below), but there are still times when hand sawing is more practical. There are three common types of hand saws: the wood cutting type commonly called a hand saw is a wide blade with teeth on one edge and a “D” type wood or plastic handle. The size and number of teeth is designated in points per inch and the most commonly used is “8 point.”

Hacksaw. (Photo ©)

The hacksaw is used for metal cutting and has a narrow blade with very small teeth held in tension on a metal frame with a pistol grip or “D” type handle. Utility knives are used for cutting drywall by scoring and breaking the drywall along a straight line. For other than straight cuts, the drywall saw is used. This is a narrow blade about eight inches long with a straight handle and fairly large teeth. Drywall and rigid insulation are soft products and therefore are easily sawn with this tool. Cutting drywall is covered in the drywall module.

Power Tools

Screwdriver/drill

The combination screwdriver and drill is the primary fastening and boring tool used by carpenters. Most drivers/drills used on the job site are cordless, so keeping batteries charged is essential to continued operation. Using a Phillips #2 bit, a wide variety of screws can be driven or removed with this tool. By replacing the screwdriver bit with a drill bit, it becomes a drill. Whether corded or cordless, the main safety issue with this tool is twisting of the wrist or arm from getting caught in the work and not releasing the trigger. When drilling, it is important to grasp the tool firmly and steadily and keep body parts clear of the whole location. Fingers can easily stray to the exit point and be suddenly and unexpectedly injured.

Drilling a straight hole at a (near) perfect right angle to the work can be a challenge. A good way to approach this is to look at the angle of the bit from two directions when starting the hole. Check the angle of the approach again while the hole is still shallow, making any adjustment as needed. If this task is difficult, a guide that holds the drill at the correct angle or a drill press should be used.

When drilling completely through a material that is finished on both sides such as a door, stop drilling when the point of the bit is just visible on the other side to prevent damaging the finish. Then start from that side drilling in the opposite direction. This way the roughness that occurs at an exit hole is avoided. A different drill bit is used for every size hole. For holes up to ½" diameter, a twist bit is used. Holes ½" to 1 ½" can be bored with a spade bit, and for larger holes a hole saw which is a saw blade in a circle with teeth parallel to the axis is needed.

Cordless drill with battery and charger. (Photo ©)

Hand-Held Circular Saw

A circular saw is a very powerful cutting tool and operates by the motor spinning a circular saw blade at high speed. In addition to the basic PPE, hearing protection should be worn when using these tools. There are several types of circular saws.

Circular Saw. (Photo ©)

The most commonly used circular saw is the hand-held circular saw that moves over the work on a flat metal plate called the sole or sole plate. The sole can be adjusted for depth of cut and it is advisable to adjust the sole so that the blade is only slightly deeper than the thickness of the material. A blade guard is provided which is spring loaded and in the closed position covers the portion of the blade that protrudes below the sole. In addition to the obvious safety precaution of keeping body parts away from the blade, care must be taken not to back up the saw or the blade can catch the work. This will cause "kickback," which damages the work and is potentially dangerous.

The principle for using a circular saw is that the force of the blade against the work should always be toward the sole plate so that the tool is providing its own resistance rather than exerting force against the operator. The saw should always be running before beginning the cut and the cut is normally started at the edge of the work which pushes the guard is out of the way as the saw is advanced. A plunge cut can be done with this tool but should only be attempted after considerable experience in basic use. To make a plunge cut, the "toe" or leading edge of the sole is placed on the work and the saw is moved forward so that the blade guard is rolled back allowing the blade to gradually penetrate the work.

Table Saw
A table saw is an enlarged stationary version of the hand-held circular saw which is upside down. The saw is mounted to a table with the blade sticking up and the table acting as the sole plate. The saw remains stationary while the work moves on top of the table. The table saw is typically used for cutting larger pieces of material with greater accuracy and straightness of cut. The work is guided past the blade by a vertical piece called the fence, which can be adjusted for the needed width to be cut.

Miter Saw
A motorized miter saw, commonly called a chop saw, is mounted to a narrow table with a stationary fence that is perpendicular to the blade to chop wood or cut the wood perpendicularly. The blade and motor called the head are on an arm that has a horizontal axis and can be swung down for the cut in a chopping motion. The arm can be swung side to side on its vertical pivot and tightened in place for diagonal cuts called miters. Some models have a third pivot that is horizontal but at a right angle to the fence to tilt the head sideways for compound miters.

Miter Saw. (Photo ©)

Reciprocating Saw
A reciprocating saw is used for cuts not possible with a circular saw (such as curved cuts or cuts close to corners) or squaring circular cuts. The blade moves back and forth and like the hand held circular saw, it has a sole plate, or foot that rests firmly against the work. The saw should always be running before engaging with the work.

Reciprocating Saw. (Photo ©)

Extension Cord
Extension cords are needed whenever a corded power tool is used farther from an electric receptacle than the tool's cord can reach (which seems to be most of the time!). The most

useful lengths are 25’and 50’. Longer cords are available, but are not recommended because of their tendency to become tangled and to become tripping hazards. Shorter cords can be strung together for longer distances but more than 100’ is not recommended because the resultant voltage drop can damage electric motors.

The cord must have a rated capacity that is equal to or greater than the tool (measured in amps) and be free of damaged or frayed insulation. The male and female ends must both include a third prong connected to the grounding wire. Cords can cause tripping hazards and therefore should not be run across traffic areas. Coiling a cord for storage is best done by holding the end in one hand and making loops with the other of equal length. The resulting skein can be tied or held together by wrapping the two ends around the middle a few times and plugging them to each other.

Tool Organization
The well organized shop or truck has a designated place for every tool and includes an adequate number and variety of tools for the work performed. Time is wasted when two crew members need a certain tool and only one is on hand or when a needed tool is difficult to find. Different sizes or types of the same tool should be kept near each other, such as various blades for the reciprocating saw or sizes of drywall finishing knives. It can also be useful to group tools according to function, such as measuring and marking tools, cutting tools, fastening tools etc. For frequently performed tasks, having the entire set of tools needed in one kit eliminates the step of gathering them each time the task is performed.

On the job site, loss of tools is a major contributor to unnecessary added time and expense. The discipline of returning tools to their proper place at the end of the work day is an effective way of reducing or eliminating tool loss.

When you are working with a weatherization crew, it is important to use the organizational system that the rest of the crew uses. If you are certain that putting a tool in a different location will help the team out, discuss it with the crew and your superiors before you reorganize anything. Looking for tools wastes time, which is bad in and of itself. More importantly, speeding up the work to make up for this lost time can cause shoddy work, and even accidents.

Topic 2: Roofing Materials and Surfaces

SAFETY MATTERS

The roof is the primary moisture barrier, designed to keep water out of a house. Moisture that does manage to enter a house (through the roof, exterior walls or other parts of the building) can cause serious health problems by allowing the growth of mold and other organisms. It can also cause gradual degradation to the house and serious damage to the structure. It is therefore essential to maintain a watertight roof and adequate drainage away from the home.

A leaking roof can severely reduce the benefits of a weatherization job. Wet insulation and building degradation (rotting wood, etc.) are only two of the consequences of moisture penetration. If a roof is in need of replacement, weatherization should be delayed until the roof repair work is done. However, minimal roof damage can often be corrected as part of the weatherization process because experienced workers can fix minor problems relatively cheaply and easily. Whether or not repairs are done depends on the policies of the company/organization and the decision of the crew chief.

Roof Pitch

The **pitch** of a roof is the roof's angle, expressed in a fraction. It is calculated by measuring how high a roof rises from the low point (usually the eave) and how far across this slope is (the horizontal distance from the eave to the peak). The pitch is how high the "rise" is for every 12 feet (or inches) of "run". For example, if a roof slope goes up 4 feet and across (from eave to peak) 12 feet, the pitch is 4/12 (it rises 4 feet for every 12 feet of run). Note that this is the same thing as saying the roof rises 4 inches for every 12 inches of run.

There are three categories of roof pitches you will likely see on the job. **Flat roofs** have a pitch of less than 2/12, **low slope** roofs have a pitch between 2/12 and 4/12, and **conventional slope** roofs have a pitch greater than 4/12. Roofs that are absolutely "dead" flat are uncommon but do exist and maintaining adequate drainage is often an issue for them.

Roofs with greater than a 6/12 pitch are dangerous or impossible to walk on without the worker losing their balance. Working on these roofs requires special staging and safety equipment because of how steep the roofs are.

Pitch: the angle of a roof above the horizontal. It is expressed as a fraction of 12, e.g. 4/12, 3/12, 2.5/12, etc.

Flat roof: roofs with a pitch less than 2/12.

Low slope roof: roof with a pitch between 2/12 and 4/12.

Conventional slope roof: roof with a pitch greater than 4/12.

Shingled Roofs

Shingles are materials that are attached to the roof in an overlapping manner, and are used to prevent water from getting into the home through the roof. There are many types of shingle materials, including slate, wood, terra cotta (molded clay) and asphalt. (All of these types other than asphalt require specialized skills to do anything but minor repairs.) The most common shingle used on pitched roofs is asphalt shingles. These are actually pieces of fiberglass covered with asphalt, and are nailed to the roof's wood sheathing. Most roofing manufacturers specify a minimum roof pitch of 3/12 in order for the shingles to effectively shed water. Asphalt shingle roofs with less than a 3/12 pitch are prone to water leakage, especially under severe weather conditions such as wind driven rain, ice and snow due to their flatness.

Shingle: material attached to roof in a overlapping manner, used to drain water away from the roof structure.

Asphalt shingles on a conventional slope roof. Note the black slits perpendicular to the bottom edges, which give the impression that there are many more individual shingles than there actually are. (Photo ©).

Most fiberglass asphalt shingles measure 36" x 12" and are manufactured in two basic types: three-tab and architectural. Three-tab shingles lie flat on the roof's sheathing while architectural shingles have extra layers for a more appealing rustic or historical look. Most shingles, no matter what type, have slits or cuts at right angles to the bottom edge that give them the desired appearance of having been made in smaller sections. In some regions of the country, these cuts are often eliminated, resulting in a one tab shingle that is a bit more weather resistant.

Grany mineral material of various colors is applied to the surface of asphalt shingle. This provides aesthetic appeal (makes them "look good"), and makes them more durable by preventing sunlight from shining directly on the asphalt. White/light grey is the most advantageous color for shingles for both product life and energy savings. Lighter colors reflect more sunlight than darker colors, and so are good at preventing solar degradation and heat gain. To reduce wind lifting of the shingle's loose tabs, an adhesive strip activated by the sun's heat is placed under the bottom edge of the tab. This helps the shingle "stick" to the roof below.

Depending on the quality of the shingles, life expectancy of fiberglass asphalt shingles is 18 to 45 years. As shingles age, the shingle shrinks and curls. Curling is an obvious signal to replace the shingles. Crumbling of the shingles is also a sign of advanced age and the need to replace them. It is best to be proactive with shingles. In other words, you should replace shingles *before* water starts leaking into the building. Once roof/framing elements are waterlogged and/or rotted, repairs become difficult and costly. The best way to prevent this is to repair damaged shingles as needed, which is much cheaper and easier.

Low Sloped or Flat Roofs

Very low sloped roofs or flat roofs cannot be shingled since water will get "up" and under the shingle tabs. Flat roofs require a continuous waterproof membrane. The most commonly used roofing for these houses is hot asphalt that is applied in two or three layers ("plies"). There are also some single-ply roofing materials that have been developed recently including modified bitumen, EPDM (ethylene propylene diene monomer), and TPO (thermoplastic polyolefin). Hot asphalt and modified bitumen roofing systems can be repaired using roof cement ("roof mastic" or "tar") very easily and cheaply. Emergency temporary repairs to EPDM and TPO roofing systems require the expertise of a professional roofer due to their more complicated installation and makeup.

The standard low slope roofing material is called hot asphalt which usually consists of two or three sheets ("plies") of roofing felt (or tar paper) mopped in with liquid hot asphalt onto the roof surface. Manufacturer's standards and some local building codes require no more than one layer of new roofing material applied on top of an existing older layer. However this practice is widely ignored. Some roofs have been found with as many as seven or eight layers, some containing a great deal of trapped rain water in between layers. This water and all the layers of roofing add a great deal of extra weight to the roof deck. This often results in excessive sagging and/or deformation of the roof's structure.

Raised vertical portions of the **party walls** (common walls that are between two housing units) that extend above the top of the roof are called curbs and also need to be covered in roofing. Hot asphalt does not adhere to vertical surfaces and therefore roll roofing is used. Roll roofing is an asphalt material similar to shingles that comes in a continuous 36" wide sheet. Unfortunately, roll roofing is not as long lasting as shingles or hot asphalt and should be properly maintained. As an improvement, modified bitumen roofing is now used for these vertical wall transitions and curbings.

Party wall: common wall shared between two housing units. This is common in row homes and townhouses.

"Alligatoring," or cracking of the surface of the roofing, is caused by shrinkage of the top layer of asphalt. It is usually the result of the asphalt being excessively thick, but it is generally not considered a concern because the cracks do not extend deeper than the top felt layer.

Maintenance and White Roof Coating
For asphalt and modified bitumen roofs, applying a cold coating to the roof surface every two to three years is recommended to extend the life of the material. Any repairs or maintenance to the roof or flashings, chimney, skylight, etc. should be done before recoating. The material is supplied in five gallon buckets and is applied using a brush with a long handle that resembles a small push broom. Sometimes a paint roller is used but a brush is still needed to work the material into any alligator cracks or other irregularities. A good roof coating job completely covers all of the surfaces, including alligator cracks, curbs and tar flashings.

White roof coatings create a moisture barrier and reflect much more solar radiation than a darker roof. It helps keep a house dry and cool. (Photo courtesy of Louis Febus)

Often asphalt roof coating is aluminized (a layer of aluminum-based liquid is added and hardened), which creates a silver surface that is somewhat less heat absorbent than the black asphalt. The visual difference with the dark layer underneath also makes it easier to achieve complete coverage. However the more highly recommended material is white elastomeric roof coating, an acrylic based material that is considerably more heat reflective.

Roof Diagnosis and Repairs
Unless you are working in a commercial or industrial setting, you will most often encounter asphalt roof shingle. In shingle roofs, tears, breaks and missing tabs are the most common

roofing defects. As noted above, fixing problems is important, and should be done prior to weatherization. To replace a damaged shingle, carefully lift the overlying tabs using a flat blade such as a putty knife or trowel to break the seal at the tab bottom. Remove the nails using a flat pry bar. Any adjoining shingles damaged in this process will also have to be removed. Place the new shingle in the proper position and nail in place taking care not to locate nails in the original holes. A small amount of roof cement can be used to glue down the tabs.

Another common defect is nails that penetrate the overlying tab after having worked their way out of the sheathing underlayment from wood shrinkage or placement in a joint of the sheathing. These can be easily fixed by removing the nail carefully so as not to do further damage and putting a dab of roof cement in the hole. If the nail has risen but not penetrated the tab, carefully lift the tab, remove the nail and place a dab of roof cement in the hole. Do not attempt to drive another nail in either of these cases.

It is important that the roof drain all water away from the home. Underlayments like the one in this picture (the plastic sheet upslope from the workers) helps maintain a continuous drainage plane. These workers are installing slate shingles on a historic roof. (Photo courtesy of US National Park Service)

Minor repairs to slate, tile or cedar shingle roofs can often be done with sheet aluminum that is slid carefully up the slope between the roofing material layers under the damaged area. Wedged in tightly, the aluminum should stay in place and with a carefully-placed dabs of roof cement even in severe weather conditions or temperature changes. More extensive repairs should be done by a qualified roofer who has expertise with the particular material.

Finding and Repairing Leaks

By the time a roof leak becomes evident, it may have been active for a long time. Repair of a roof leak should always be accompanied by investigation for sheathing or structural damage. Finding a leak can sometimes be difficult. Once the leak has penetrated the roof, water can travel along rafters and other structural members before it enters the building's interior. In other words, a roof leak can cause damage far from where the leak is located. When searching for a roof leak based on leakage inside the building, start at the spot directly above the visible water penetration. Then look for damage and/or openings working up the slope in the roof above. It is easiest to find leaks *while they are occurring*, because you should be able to detect dripping or seeps in the roof decking.

Check the attic for moisture damage/leakage. Make repairs to any possible leak sites but do not stop at the first spot as the site of the major roof leak may be farther up the roof slope. Repairs to sheathing or framing may involve removing a larger amount of roofing as well. Before opening up a roof, be sure that adequate materials and time are available to finish the same day. This is especially important if bad weather is expected.

As low slope roofing systems ages and weaken, cracks and other openings can occur in the roofing material as at the flashing. Where aluminum flashing meets the asphalt, cracks often occur due to the different expansion rate of the two materials (asphalt expands faster than aluminum). Minor cracks can be repaired using roof cement with four inches of asphalt-impregnated fabric. First, make sure there is no moisture in the crack. Apply a layer of cement using a trowel, then embed the fabric into the cement and add another layer of cement. No fabric should be visible on the finished job.

A common problem with hot asphalt roofing is air pockets (blisters) caused by air and/or moisture trapped between the plies of roofing material. As these pockets are heated, they expand and can cause cracking and blistering. Minor air pockets rarely cause leaks, however a roof showing numerous or very large blisters is a sign of a poor installation. This can possibly be a result of the roof’s installation being performed in wet weather, or with lack of attention to properly sealed components.

Repairs to blisters should always be done on a warm, dry day if possible. Using a sharp knife, cut across the blister at its longest dimension, then three more diagonal cuts that intersect in the center. Pull the flaps back and thoroughly dry out any moisture. Apply roof coating to the exposed surface and replace the flaps, making sure they stick to the coating and no air is trapped. The cuts can then be sealed using four inch asphalt impregnated fabric and roof cement.

Flashing

Flashing includes any thin sheet materials used to join roofing to walls, penetrations, edges and other roofing types or where slopes meet. The term originated when all flashing was copper or sheet metal which was shiny when new. Most flashings today are aluminum, copper or tar, though copper is becoming rarer as price increases. Sheet metal flashings are still in use but have a tendency to rust. This is a problem because rust will eventually put holes in the material and thus leakage will occur. Plumbing vents in pitched roofs are usually flashed using a rubber (neoprene) collar that forms a tight seal at the pipe base and is mounted on top of a rigid “boot.” The flat portion (“flange”) of the boot is installed under the roof shingles or membrane.

Metal flashing is very commonly used to prevent water from penetrating the chimney chase. The image to the left is of “stepped flashing,” which is often used on masonry chimneys (brick and stone). (Images courtesy of US National Park Service)

Flashing that has rusted through needs to be replaced and is usually done with sheet aluminum. Removing the old flashing may cause further damage and is usually not necessary. Cut and shape the replacement aluminum to match the original and slide it into place over the deteriorated piece. Nailing is typically not practical; a small amount of roof cement or tar can be used to hold the new piece in place and further reduce the risk of leakage. Tar flashings tend to dry out and crack over time. Any open tar flashings should be repaired.

Flashing: thin, continuous layer of waterproof material (often sheet metal) that keeps water out of and/or away from a given area. For example, chimneys have flashing around the base to prevent water from leaking into the building where the chimney penetrates the roof.

The neoprene rubber collars at the plumbing vents can deteriorate over time, allowing water to run down the outside of the pipe into the house. This may first become evident in lower levels of the house including the basement. If the deterioration is not too severe, the collar can be resealed using silicone caulk. In most cases of extensive deterioration, the roof is also in need of repair or replacement and the entire boot should be replaced with the shingles. If the roofing is still good and the collar cannot be resealed with silicone, a new collar can be placed over the old one.

Copper flashings are long lasting, but expensive. It is typically only used on “high end” houses when cost is not a concern. Copper forms a desirable green “patina” or oxide coating when exposed to weather over a period of time. Exposure to the elements can eventually deteriorate the copper. As it deteriorates, it becomes very thin and the green patina disappears and the copper returns to its bright shiny appearance. Copper flashing that has worn through can be temporarily repaired with tar and/or aluminum, however, proper replacement of copper flashings should be done by a qualified roofer. Aluminum in continuous contact with copper will corrode both materials by the process called electrolysis. Fasteners for these metals need to match the materials or be specially coated.

Vent Styles. Gable vent (above) and slope roof vent (below). Note that the upslope side of the slope roof vent is closed to prevent infiltration. (Photo ©)

Roof Vents

Roof vents are used to vent air from inside the attic to reduce moisture problems and to remove excess heat buildup during hot days. The ones most commonly encountered are one of three types: mushroom vent, slope roof vent, and gable vents. Gable vents are applied at the gable end of attics, and are relatively easy to install. They are usually built into each end of a roof (both gables) to facilitate air flow. Slope roof vents and mushroom vents are built through the roof decking and roofing materials. Slope roof vents are closed on one side (the upslope side) to prevent water from going into them. These can be used on any roof with a pitch greater than 2/12, i.e. low slope roofs and above. Mushroom vents are used on flat roofs, and are open on all sides.

Installing Vents

As a retrofit installer technician, you may be required to install roof vents. This is especially important if the house is well-sealed and well-insulated. Tightly sealed and insulated houses need ways for water vapor to leave the building shell, and for excessive unconditioned attic heat to leave the attic. The basic procedure is as follows:

A typical roof vent is made of aluminum with a flange at the bottom to attach it to the roof. The first step for a roof vent installation is to measure the vent's bottom opening and mark its proposed location on the roof. On a shingled roof, the vent should be placed so that the upper edge of the vent flange is located slightly downhill from a row of roofing nails. Mark the opening of the vent on the roof with chalk or crayon the same size as the vent opening. If the location of the roof rafters is known, place the vent opening between them.

Roof vents are often made of aluminum, like this mushroom vent. All roof top vents have flanges (the flat metal at the bottom of the vent), which are fastened to the roof. (Photo ©)

Drill a one inch diameter hole on the circumference of the opening's outline. If the rafter locations are not known, bend a stiff wire such as a coat hanger to a right angle inside the roof at least as far from the end as the diameter of the planned opening. With the bent section in the hole, turn the wire to make sure no rafter is in the way. If necessary, relocate the opening to avoid the rafter, keeping the hole within the vent's circumference. Starting in the hole, use a reciprocating saw to cut the opening in the roof sheathing and roofing material.

On a shingle-side of the roof, slip the flange of the vent into place with the upper edge of the flange under the shingle tabs upslope of the opening. With roofing nails, fasten the flange to the roof, one at each corner and one or two additional nails along the sides and top. Carefully lift the shingle tabs to drive the nails that will be under the tabs. Do not drive nails into the lower edge of the vent flange. Seal each nail head with roof cement and use a few dabs of cement to refasten the shingle tabs so that wind does not lift them.

This slope roof vent is made of black plastic. It is closed on the up slope side to prevent water from draining in. The flanges are tucked under the shingles and fastened. (Photo ©)

On a low slope roof, apply a continuous bead of roof cement to the roof at the perimeter of the flange so that the flange will seal to the roofing. Then put the vent in place and fasten the flange to the roof with roofing nails, one at each corner and one or two additional nails along each edge. Apply a thin layer of cement to the perimeter of the flange and the adjoining roofing wide enough to embed asphalt-impregnated roofing fabric, then apply additional cement to cover the fabric. Keep the cement as low as possible, especially on the downhill edge, so that excessive water will not pond on the flange.

Topic 3: Attic Hatches

Attic access is needed to install and maintain wiring and insulation, to diagnose ventilation and moisture issues, and possibly for storage. Weatherization installer technicians often need to work in attic spaces directly above the thermal envelope. Access is usually provided by a hatch or an opening in the ceiling large enough to crawl through.

The maximum width of the opening is typically determined by the spacing of the ceiling joists. Hopefully the length of the opening is at least 24” so that an average person can get into the attic without too much difficulty. In some homes, there is no attic access. If this is the case, a new opening for the hatch will have to be cut into the ceiling in order to gain access. The building code requires a minimum 22” x 30” opening for new or updated residential construction. Weatherization installers often find access hatches that are fit between existing ceiling joists that are spaced 16” or 24” o.c.

The hatch needs to be air sealed with weather-stripping and insulated so that the thermal and air barriers are not compromised. A manufactured system made of expanded polystyrene (EPS) that meets these criteria can be used as part of the weatherization process. Attic storage is not generally recommended but is commonly found in larger attics. Access to these larger storage attics is often provided by a pull-down stairway. Pull-down stairs take up space in the attic when not in use and present a greater insulation and air sealing challenge.

Making a Hatch Opening

Where no attic access exists a hatch will be needed. First, select the appropriate location. For a row house with a low slope roof and a “crawl space” type attic, the highest end of the roof is best, which is typically toward the front of the house. For aesthetic reasons, the ceiling of a closet is usually the best location for the hatch. In a conventional attic, the opening should be closer to the middle of the house because the peak (the highest point) is above the middle of the home. If possible, a hallway ceiling location is usually chosen to allow for easier access.

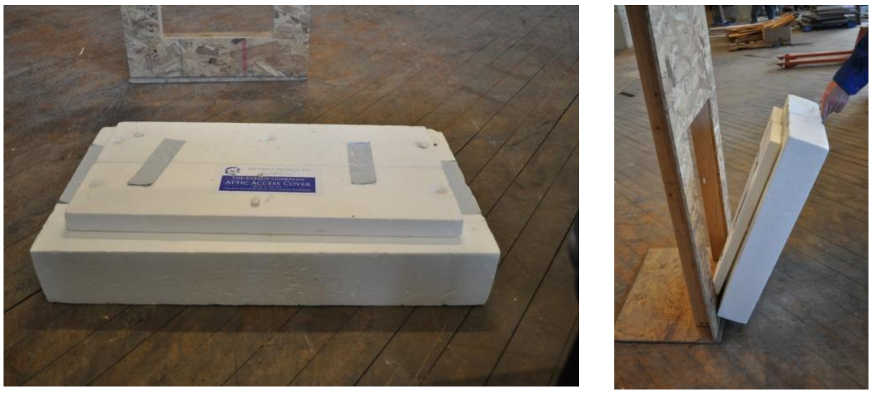
It is best to fit the opening between joists – cutting joists is a last resort. The hatch should be as wide as the joist bay. For newer construction with 24” O.C. ceiling framing, there is enough space for the code-required 22” x 30” opening. Keep in mind that the initial opening does not have to be the same size and shape as the hatch; it just has to be big enough to provide access. In fact, it is better to start with a smaller opening and enlarge it as needed than to risk making an opening that is too large.

When cutting the opening, there are a few things to keep in mind:

- If the ceiling is plaster, take care to avoid damaging the plaster beyond the limits of the opening. Plaster, unlike drywall, is difficult to patch up.
- If the joists are located in such a way that making an opening between them is impractical, the opening may cross a joist. This requires installing headers and additional structural framing.
- Make sure that the opening will have joists on at least two sides.

Installing a Manufactured EPS (Expanded Polystyrene) Hatch

Place four 2” x 2” pieces of rigid foam on the top of the ceiling joists to form the outside of the hatch opening. Make sure that they form a rectangle with square corners. Glue these pieces in place using the adhesive supplied with the hatch. The glue should be applied to one of the surfaces (joists or 2” x 2” foam) to be joined in a continuous bead ½” from the edge and with a diagonal bead to form an “x” on the ends of each piece. After placing the pieces, move them back and forth slightly to spread the adhesive. Cut the side pieces of EPS for a tight fit in the joist bays to close the openings between the joists and glue them in place with the adhesive. If there is not enough EPS to fill all of the gaps, use additional pieces of drywall, foam board or plywood to make up the difference. Caulk all joints and any remaining openings with the adhesive.



An EPS hatch is a quick and inexpensive way to insulate and seal an attic access.. (Photos ©).

The installation is finished by fastening the two pieces of EPS together to form the hatch cover. Use adhesive to glue the large pieces together, and caulk the joint between the main body of the cover and the inset piece. Install the handle across the joint in the bottom of the cover with the two plastic pins. Allow the adhesive to set and put the cover in place.

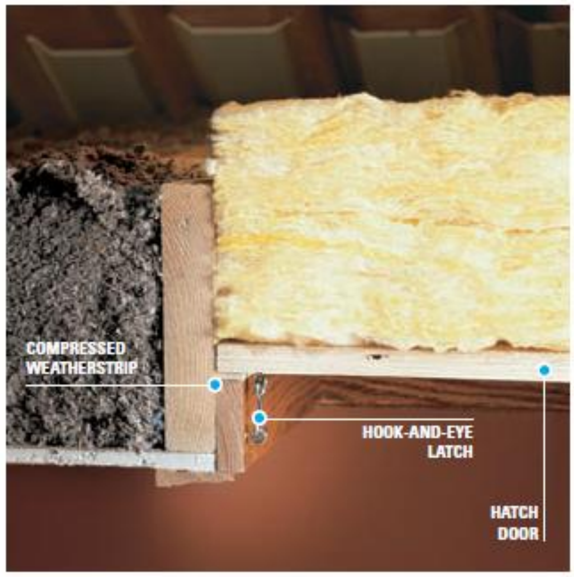
Site Built Hatch

A hatch can also be built on-site using standard weatherization materials. This is called an attic hatch or “scuttle hole.” It is a fully removable structure that is pushed or pulled out of the way

Attic Hatch with Trim. This hatch will be attached with screws to the underside of the ceiling. (Photos ©).

when attic access is needed. There are a number of ways to build these. One way is to build and insulate a 1/2" to 3/4" thick plywood door that is 3" larger than the opening in both directions, and fasten it with hooks and eyes to the joists and headers surrounding the opening. The joists and headers must be flush (form an even surface surrounding the hole). Make sure you apply weather-stripping between the plywood and joists/headers, and apply enough insulation to match the R-value of the attic. This hatch opens into the attic. Another method is to create a well-insulated hatch with trim that is screwed through the ceiling into the joists. Access can be more difficult through these because the screws must first be removed to remove the hatch.

For all existing hatches, be certain that they are weather-stripped, tightly sealed, well-insulated, and fit snugly in the hatch hole (see images below).

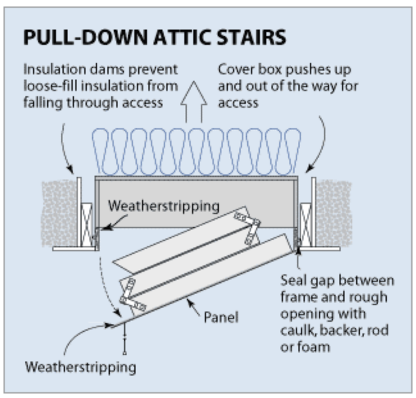


Weather-Stripping and Insulating an Attic Hatch. For this hatch, 1 x 3 boards were cut and installed to the joists, then weather-stripping applied. The hatch door is insulated to the same R-value as the attic. (Images courtesy of US EPA)

Pull-down Attic Stair Cover

For pull-down attic stairs, an insulated and sealed box that is big enough for the folded steps to fit up into should be built. The box should rest on wood stops attached to the joists and headers bordering the hole.

A pull-down attic stair opening is typically surrounded by plywood flooring. Make sure the flooring is securely fastened to the ceiling joists and is continuous where it meets the opening. Close any gaps with additional plywood of the same thickness.



Air Sealing and Insulating Pull-Down Attic Stairs. It is important that a continuous air barrier and insulation is maintained. (Image courtesy of US DOE).

Again, weather-stripping should be applied where the box meets the border. Hook and eye fasteners should be used to ensure a tight seal. Caulk all joints to create a continuous air barrier.

Topic 4: Stair Repair & Construction

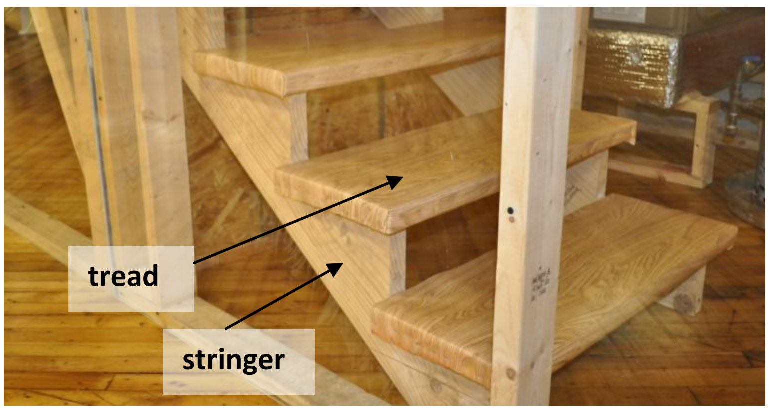
Any house built on more than one level has at least one staircase. There are many different kinds of staircases that differ in terms of their materials, construction methods, general shape, design as well as a number of other features. In most situations, a staircase is an integral part of the home's design and style. Stairs may be steep or gradual, narrow or wide, purely functional, or grand and showy. Some are built in place by woodworkers, finish carpenters, or stair makers, while others are factory manufactured, shipped to a building site and installed by carpenters.

Stair design is heavily affected by function. An entry stairway that handles a lot of foot traffic and is in a highly visible location is bound to be more interesting than, say, a stairway to a basement, where function is much more important than appearance.

Retrofit installer technicians are sometimes asked to build or fix stairs in order to gain access to the basement.

Components

All stairs have two main parts: the **treads** are the "planks" that are stepped on; the **stringers** (or carriage or horses) support the treads at their ends. The simplest stairs consist of treads and stringers. The treads usually rest on the horizontal cut portion of the stringers, but sometimes cleats are used. A cleat is a small board or other material that is attached to the inside of the stringer. The treads are then attached to this protrusion. This simple type of stairway is called a "cleat" stairway because of the cleat attached to the stringers to support the treads. A cleat stairway is usually a temporary stair and is considered substandard for permanent use. It has the advantage of being easy to construct with limited skills and uses a minimum of basic materials. When the stair is no longer needed, the materials can be re-used for another stair or a different purpose.



The two essential components of stairs are the tread and stringer. (Photos ©).

A more finished and durable type of stairway has the treads mounted on two or more saw tooth-edged stringers. These are made from solid pieces of lumber, usually 2" x 12". Cuts are made for the treads and risers to be attached. Risers are the vertical pieces of wood that connect the back of one tread to the front of the next one above. Straight stairs may not be practical where space is limited, so other layouts with landings and turns may be used. Landings also have the advantages of reducing the chance of a fall on long straight stairways, and they also give the climber a place to rest while ascending.

Safety is Important

Because of its vertical nature, a stair may be the area of the house where the most accidents occur. For this reason, particular attention must be paid to details that affect safety of the stairs under normal use. Basic standards require a rise of no more than eight inches and a tread depth, or run, of no less than nine inches. For greater safety, if space permits, the standard is a maximum seven inch rise and a minimum ten inch run. In any straight run of stairs, all treads and risers must be of equal size to be considered safe.

Tread: the (horizontal) part of stairs that are stepped on. These are commonly referred to as “steps.”

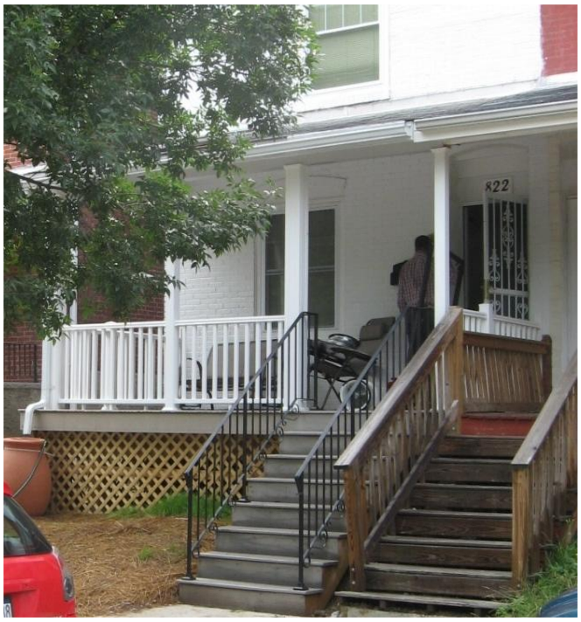
Stringer: the (vertical) portion of stairs that support the treads.

Secure railings are also essential to protect against fall. The optimum railing height is 34” to 38” above the tread, and the railing should run continuously for the full length of the flight of steps, from the top riser to the bottom riser. Handrails fastened to the wall should allow at least 1-1/2 inch clearance between the wall and the handrail. Also, the rail should be small enough in diameter or thickness to be easily grasped. Any break or interruption in the rail run should have a “return” or a knob to prevent the hand from slipping off the end of the railing unexpectedly. (A railing return is simply a right angle in the rail so that the end is against the wall.)

Loose railings (typically as a result from inadequate fastening) are a common safety issue and should be fixed immediately. Note that all the dimensional and design information listed here must be verified with local building codes, which are regularly updated. In terms of materials, manufactured wood rails are best but they can also be of 1-½” round stock or 2” x 3” lumber. The railings should be smooth and free of splinters.

All open sides of the stairs should be addressed per local building code. Where the stairway is open between the rail and the treads, the opening must include fall protection primarily for child safety. Balusters, sometimes also called spindles, should be installed. These are vertical components that connect the treads to the railing on every step. The balusters need to be close enough to each other that nothing larger than a four inch diameter ball can pass through. This standard can also be met by installing boards or dimension lumber parallel to the rail and the slope of the stair.

Headroom, or the distance between the tread nosing and the ceiling, should be a minimum of 6'-8". This is impossible to achieve where the ceiling height in a basement is less than this dimension or where the stair opening is too short. Where adequate headroom is not possible, a clearly visible warning sign must be posted and a cushion of soft material placed where head injury might occur.



Secure railings are also important. The railing is part of the balustrade, which also includes the balusters (the vertical spindles) and the newel posts (Photos © eca).

All landings should be at least as long as the stairway is wide but should not exceed four feet in length if there is no change in direction of the stairway. A landing should be used to break any stairway that rises twelve feet or more. Landings are placed half way between the top and bottom of the staircase when possible. Note that all dimensional and design information listed here must be verified with local building codes which are regularly updated.

Basement Stairs

Where a door opens toward the steps at the top of a stairway as in a basement, a landing is recommended at the top of the stairs long enough so that when the door is fully open it does not extend over the first step. This top-of-stair landing is not provided in most older houses because of space considerations. In this case the door should swing away from the stair.

Many older basement stairs have open risers (no risers). This is no longer acceptable as the space between treads must be 4" or less. Fastening the stringers to a concrete basement floor is usually not necessary, but a 2x4 should be fastened between the stringers for stability. A closed riser may be appropriate here to strengthen the stair construction. For the treads, nominal 5/4" material is typically used (this tread materials is 1" (one inch) in actual thickness). Dimensional 2 x lumber can also be used.

Comfort and Convenience

Stair treads too deep or shallow feel awkward and clumsy to the climber. There is a height of rise and depth of tread that is most comfortable to the majority of adults. Two simple rules should be followed: First, the rise should be between 6" and 8". Second, the "rule of 17 ½" should be used. The riser height added to the tread depth should equal (close to) 17-1/2" for a comfortable stair design. For example, a riser of 7" should have a tread of 10 ½". Following these two rules will make most any combination of rise and run will have a comfortable "feel" to most adults.

Most stairs are built with a "nosing" or a protruding edge on the front leading edge of each tread. The projection forward of one tread over the tread below is usually about 1-1/4” and is designed to give the climber a wider base of support on each stair. The nosing is ignored when calculating the run (horizontal distance) of each tread but must be considered when considering stair construction materials.

Stair Construction and Design

Calculating New Stair Dimensions
A stair in an existing building must be designed to fit the stairwell opening in the floor. Measure the length and width of the opening, the height from floor to floor and the ceiling height at the bottom end of the opening (where the bottom of the stairs will be). Divide the floor to floor height (in inches) by seven and round down to a full number to get the number of risers required. Then divide the floor to floor height by the number of risers to obtain the height of each riser.

Example**:**

- Existing floor to floor height: 8’ = 96”. 96”/7” = 13.17. Therefore, the stair will have 13 risers.
- Next, 96”/13 risers = 7.38”. 7.38” = 7-3/8”, therefore each riser will be 7-3/8”. Note that the conversion from decimals to fractions of an inch is not exact, so compensation will be needed in the layout. In this case, 3/8” is slightly less than .38”.

The number of treads is always one less than the number of risers because the top and bottom risers each meet a floor and a floor is not considered a stair tread.

Because of existing opening and height limits, occasionally minimum standards cannot be achieved especially in older houses. In such cases, the designer’s goal should be to come as close as possible to the rise and run minimums and compromise headroom as little as possible. Warnings should be posted on the stairs and protection can be provided as mentioned above. Check with building officials if necessary.

Stair Repairs
The most common stair problem is inadequate railings. These include loose or missing rails or fasteners, rails too low or too high and insufficient balusters. Broken or damaged treads are also a hazard and replacement material should be of the same size and thickness as the original construction. Simply fastening a piece of plywood over the damaged tread is not acceptable because it makes the risers above and below the tread are now at different heights and therefore a tripping hazard. If the correct thickness is not available, thicker material must be notched, or mortised to fit the stringers and achieve the correct tread height.

Topic 5: Drywall Installation and Repair

Drywall, also called gypsum wall board (GWB), is far and away the most-used material for wall and ceiling coverings currently. GWB consists of a noncombustible core with paper surfaces on the face, back, and along the edges. Commonly used generic names for these products are drywall, wallboard, plasterboard, or Sheetrock™, the latter being a brand name that has come into common use.

The material is so prevalent because it is very versatile and can be installed using relatively few basic tools. It provides a large surface area that can be made smooth when its joints (seams) and fastener (screw) heads are covered with joint compound. When properly finished, the surface is comparable to plaster but is much less expensive. Gypsum board was introduced in the 1930s in 16” x 48” sheets as a less-expensive, labor-saving alternative to the wood lathe and plaster system. Manufactured in 4’ x 8’ sheets, it rapidly replaced plaster during the 1950s and is nearly universally used today.

Drywall is given a smooth finish by applying special tape and drywall compound (“mud”) over seams, and mud over fasteners. In the image above, the small splotches of mud are covering fasteners. (Public domain image available through Wikipedia)

The most significant drawback of GWB is that it has very little moisture resistance. While some specialized types of drywall are more moisture-resistant, these come at a higher cost and can never be considered truly moisture-proof. Additionally, gypsum wall board is less impact-resistant than plaster, but is also more easily repaired.

Drywall is finished using joint compound, commonly called “mud,” which seals the joints, seams and fasteners. For joints, seams, and corners, paper or fiberglass mesh tape is embedded in the “mud” to reduce cracking. Basic finishing can be done with minimal skills using easily learned techniques; however, expert finishing is a skilled trade that is mastered only with extensive practice.

Composition

Gypsum wall board is comprised mostly of a mineral known as calcium sulfate dehydrate. Calcium sulfate is found in gypsum. Gypsum rock is mined or quarried, crushed then ground into a fine powder and heated. It is used as the base for gypsum plaster, gypsum board and other gypsum products. To produce gypsum wallboard, the calcium sulfate (mined or produced synthetically) is wetted to a slurry and compressed between

Drywall (gypsum wall board) typically comes in 4’ x 8’ sheets. It is filled with a gypsum-based material and covered with paper on the outside. (Photo © eca)

paper layers. The paper surface or wrapping becomes chemically and mechanically bonded to the core as moisture is removed through drying. Once dehydrated, the gypsum reverts to its original rock state. This explains why one of the most commonly known brand names for the product, “Sheetrock™,” has become semi-generic.

Types and Sizes

There are several types of drywall products with most common type being a standard off-white paper-wrapped 4’ x 8’ sheet product. This is meant for use in general building construction. There are fire-resistant types, which are clearly marked on the paper covering at the edges. Soundproof drywall differs in that it provides a sound barrier comparable to eight layers of standard drywall. Another type has a water-resistant wrapping for use in bathrooms and where there is high humidity. The water-resistant product is often called "greenboard" because the paper is green for identification. Exterior gypsum soffit board is also moisture resistant and designed for use on the underside of eaves, canopies, carports, soffits and other horizontal exterior surfaces that are indirectly exposed to the weather.

Identified by their technically correct names, various gypsum board products are as follows:

- **Gypsum wallboard** is produced primarily for use as an interior surfacing for buildings. It is the most commonly used gypsum board. Gypsum wallboard has a manila or off-white colored face paper and is manufactured in various thicknesses as both a regular and a fire-resistant core material.

- **Gypsum ceiling board** is an interior surfacing material with the same appearance as gypsum wallboard. Gypsum ceiling board is manufactured as a ½-inch thick material and is designed for application on interior ceilings (primarily those intended to receive a water-based texture finish). It has a sag resistance equal to 5/8” thick gypsum wallboard.

- **Water-resistant gypsum board**, commonly referred to as “green board,” is readily identified by its green-tinted face paper. It is designed for use on walls primarily as a base for the application of ceramic or plastic tile. It has a water-resistant core and a water-repellent face and back paper, and is generally installed in bath, kitchen, and laundry areas. Products like USG’s Mold Tough are particularly resistant to mold. Moisture-resistant drywall is not *waterproof* and like all drywall products, it should be properly finished and painted to provide the best performance. Basically, it works well on walls where it will not be in direct contact with water. It should never be used instead of waterproof cement board for backing beneath tile work and shower enclosures or on floors or ceilings.

- **Exterior gypsum soffit board** is designed for use on the underside of eaves, canopies, carports, soffits and other horizontal exterior surfaces that are indirectly exposed to the weather. It has water-repellent face and back paper and is more sag-resistant than regular wallboard and typically has a light brown face paper.

- **Gypsum sheathing board** is used as a backing under exterior siding or cladding. It has a water-repellent face and back paper and can be manufactured with a water-resistant core. Depending on the thickness of the board, gypsum sheathing board is manufactured with either a square or a tongue-and-groove edge and a fire-resistive core. It generally has a brown or light black face paper.

- **Gypsum base for veneer plaster** has a distinctive blue-tinted face paper that is treated to help thin coats of hard, high strength gypsum veneer plaster stick to it. Commonly called "blue board," it is produced in sheets that are the same width as gypsum wallboard and can be manufactured with a fire-resistive core

- **Fire-resistant drywall** is often recommended and sometimes required in garages, rooms with combustion appliances and in multifamily buildings. Fire-resistant drywall is not fireproof but can withstand higher temperatures than standard drywall before burning. All gypsum-based drywall is fire resistant. The thicker the gypsum layer, the more fireproof the material is.

- **Type X firewall** has fiberglass added that increases the fire rating of the sheet by helping to maintain the structural integrity of the firewall when exposed to high temperatures.

- **Type C firewall** has other additives for still better fire protection than type X firewall.

- **Abuse-resistant drywall** is most often used in commercial construction. These 5/8" thick panels are treated to better resist impact and penetration. It is definitely worth considering for use in a garage or other room that will be used regularly as a workshop or play room. One example is 528 abuse-resistant, a mold-resistant paperless sound resistant drywall that costs about three times more than other products.

- "**Soundproof" drywall**, like abuse-resistant drywall, differs from regular drywall in that it provides a sound barrier comparable to eight layers of standard drywall. Instead of a solid gypsum core, both of these products have a combination of viscoelastic polymers, ceramics, and gypsum layered to produce their exceptional qualities. Just as completing the vapor and air barriers is needed for air and vapor sealing, complete sealing is required to avoid sound transmission through wall penetrations or gaps. A building's structure can spread sound wherever it permits air leakage.

- **EPS (expanded polystyrene) laminated drywall panels** have expanded polystyrene insulation bonded to the gypsum board to create many benefits for exterior wall applications. This insulation provides a thermal break from the exterior wall by bringing the thermal boundary inside the framing. It also has sound deadening characteristics. It is installed using the same method as regular drywall except that the fastening screws need to be matched in material to any type structural framing materials to prevent electrolysis and have extended depth shafts. When making a corner, the insulation needs a special adhesive such as Dow EnerBond SF for a complete bond.

Drywall thickness ranges from ¼” to ⅝” in the types detailed above with the standard thickness being ½ inch. The sheets are four feet wide and the common length is eight foot but available in ten foot lengths. Drywall is also made in six to fourteen foot lengths, and some stores may have precut pieces in smaller sizes. A full range of sizes may not be readily available at all local home stores.

Tools and Methods

Hanging

Fastening drywall to ceilings and walls is called “hanging drywall.” Drywall is most often hung using screws, but nails can be used as well (screws are easier to use and faster). Drywall is fastened to framing elements, usually studs in walls and joists in ceilings. The fasteners must be firmly attached to the framing, otherwise the drywall is prone to sag over time. This can cause air gaps in the wall, reducing home efficiency and offering a place for pests to infiltrate. The fasteners should go into the framing member at least 1”, and should create a dent in the paper, but never break it.

Adhesive is also sometimes applied to the framing, using a “gun” or tube applicator. If hanging drywall throughout a room, it is best to a) start with the ceiling and work your way down to the floor and b) hang the sheets with the long side (usually 8’) horizontally. In standard 16 O.C. framing, fasteners should be 12” apart on walls and 8” apart on ceilings. For wider stud bays (e.g. 24 O.C.), more fasteners should be used (8” – 10” for walls, 6” for ceilings), and for thinner study bays less can be used.

With the exception of experienced professional, drywall hanging should be done by at least two people (Photo ©)

For hanging drywall on a ceiling a mechanical lift can be rented, or if enough workers are present, the board can be held in place by hand. A t-brace, or “dead man,” can also be made of 2x4s or other scrap lumber to hold up the board against the joists until it can be fastened. For fastening to wall framing, a flat plate or piece of wood on a roller is used for lifting and holding a piece of drywall off the floor and tight against the piece above it.

Cutting

For most drywall cuts, a utility knife, a drywall t-square and a drywall saw are all the tools that are needed. The utility knife is useful for straight cuts. A supply of new blades should be on hand to keep the utility knife sharp at all times and to produce clean cuts. The drywall saw is used to make curved or unusual cuts and holes and has a point that enables it to be punched through the board using the heel of the hand. A measuring tape is useful for accurate

Drywall is traced, scored and snapped. (Photo ©)

measurements although where practical, simply holding the piece of drywall up to its desired location and marking the cut is the most accurate way to fit the drywall to the purpose at hand.

To cut a straight line, the most important thing to do is cut the paper on one side to the shape you want. This is called “scoring.” After this, the drywall can be snapped by hand, then the paper on the other side cut with the knife. As indicated above, drywall saws should be used for curved cuts. You must cut through both layers of paper (and of course the sheet rock) to do this. Drywall does not usually cut cleanly (it can be quite ragged), so always cut a little longer than you need. A rasp can be used to shave it to the proper size, and it can always be cut smaller if need be. For clean corners, a “corner bead” is used. This is a metal, plastic or plastic and paper strip with a rigid outside corner.

Finishing

Drywall finishing is done with flat trowels called joint knives. The standard size is 6”, with 10”, 12” or even wider (16”) blades for final “feathering.” A three inch or four inch blade is useful for narrow spaces. A corner trowel, consisting of two blades at a right angle to each other, can sometimes be handy, but is not absolutely necessary.

The most important finishing material is joint compound, often called “mud.” To cover up and seal seams, mud is applied wider than the seam, then drywall tape is added, then more mud applied and smoothed over. The tape should be wetted with water before it’s applied, and there should be no air pockets. After this fully dries, it is sanded smooth, then another layer of mud applied. This dries, then is sanded. The process continues until the seams are not noticeable. Smaller blades should be used for each step – the wider the blade, the thinner the mud layer can be made. This helps create the smooth surface. Fasteners are covered with mud and sanded as well.

A standard method for sanding drywall is a type of mesh that looks like a very gritty screen allowing a large amount of dust to exit through the holes. The mesh is mounted on a soft rubber pad to avoid gouging the surface of the wallboard. A better method to minimize dust and maintain good air quality for worker and occupant health is to use sponges and work “wet” so no dust is created. For ease of movement, the finishing tool is often attached to a painter’s pole. Vacuum systems are used in larger operations to collect sanding dust.

Drywall Patching and Repair
Oftentimes, drywall will only need to be patched. Shave or cut the edges of the hole so they are smooth and straight. This will make patching easier. For holes around 2” or smaller, simply cutting a piece to fit and using tape and joint compound is enough. For bigger holes up to around 7”, a single board (1 x 4 is best) should be cut long enough to extend a few inches beyond the hole on each side. Slip the board through the hole, pull out and hold it firmly against the wall board. Fasten it using drywall screws, then attach the patch to the board. If the hole is bigger than 7”, use two boards along each long edge of the hole, with only half of the width of the board showing. For both of these, avoid fastening the board too tightly against the wall. This can cause damage. Finish the seams in the usual manner.

Safety Equipment
Standard Personal Protection Equipment (PPE) should be used when working with drywall. Goggles and breathing protection are particularly important because of the dust generated. Gloves and hard hat are also strongly recommended especially when working on ceilings. Hearing protection is needed when working with power machinery, including high speed screwdrivers, cutting tools and vacuuming equipment.

Topic 6: Doors in Weatherization

A door is the cover on an opening by which people enter or leave a building or go from room to room. The primary functions of a door are for privacy, protection from intrusion and weather, and to exclude noise or pollutants. Weather-tight doors are an important part of any building envelope. Because it is in constant use, a door can easily become degraded and require maintenance, repair or replacement.

Doors, especially front doors, are prominent features of homes. It may seem that exterior doors are very important in terms of having an energy efficient home because a very leaky door can cause major heat loss or gain. However, doors are a very small portion of the building shell and they are expensive to replace. Replacing doors is usually a high cost/low reward endeavor in energy terms. (The SIR is usually below 1.0, unless the doors are very leaky.) Because they are such prominent features, though, occupants frequently request doors replacement, especially if they have an older home. When working in WAP, doors are rarely replaced because of the low SIR. If anything, it is usually best to make basic repairs and add door weather-stripping. In market-rate work, it is up to the discretion of the homeowner and auditor or crew chief. Either way, the occupants should be informed of the low return on investment.

Door Components
In addition to the door itself (also called the leaf), the components of a complete door assembly include the frame and hardware. The frame is the assembly that surrounds the door leaf and from which the door is hung. The frame consists of vertical and horizontal pieces and includes:

- the hinge jamb which holds the door in place (or hung) by the hinges

- the latch jamb which has a strike plate or strike that engages the latch to hold the door shut
- the head jamb or head at the top, and
- the threshold at the bottom.

The three jamb pieces together are also collectively referred to as the jambset or the jamb.

Stops are provided on the inside of the jambs to keep the door from moving past its closing position. The stops are usually separate pieces nailed in place for interior doors and are integral parts of the jambs for exterior doors. The frame also includes the casing (or decorative trim), that covers the gap between the jamb and the wall surface. In an energy-efficient building, this gap on an exterior door is filled with insulation or foam before the casing is installed.

The door is connected to the frame by hinges. Before attaching hinges, the frame should be notched with a chisel or other tool to form mortises the same size as the hinges. This will allow the door to close tightly, and thus help prevent air leakage. Hinges come in a variety of sizes and styles. The door is held shut by the lockset, which consists of the door knob and the latching system. The latch protrudes beyond the edge of the door, and sticks into the latch side jamb (frame) through the strike plate. The metal strike plate sits in a mortise and covers the latch hole which allows the door to be securely shut and locked.

Mortises are depressions carved into door frames so components like hinges and strike plate (pictured) can become flush and allow the door to close tightly. (Photo ©)

Some exterior door frames include sidelights which are fixed glass panels next to the door (outside the frame). These allow additional light inside. Today's standards require that all glass in doors, including sidelights, be tempered glass which is more resistant to breakage. Tempered glass also breaks into small pieces rather than large ones with sharp edges.

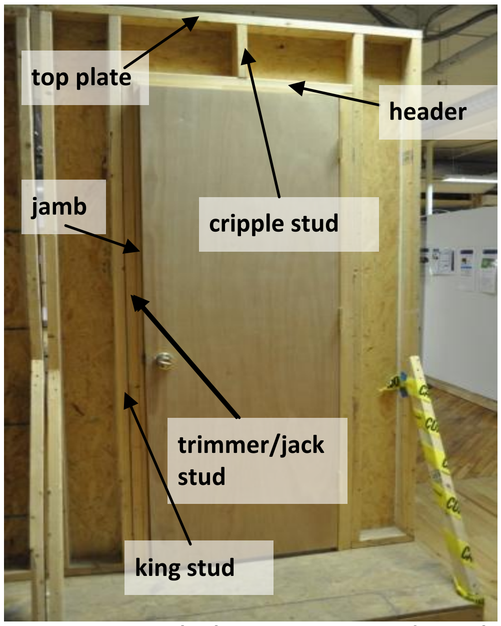
Door Framing

Door framing is similar to window framing. Essentially, a door opening is a large window opening, with the exception that there is no horizontal framing in the bottom section of the opening.

On either side of the door are the trimmer studs, also called jack studs, which support the header. The hinge and latch jambs attach to these studs. As in window framing, the trimmer studs are attached to king studs which go from floor to ceiling (i.e. they are the same height as the wall studs). These attach to the top plate and bottom plate. The header is the horizontal framing above the door opening. It runs between the king studs and supports the cripple studs. The head jamb attaches to this member. The cripple studs (the same as window framing) run from the header to the top plate.

Door Types

There are a number of door types commonly used today. Solid wood doors are the most common type used in residential buildings. Solid-core doors are made of solid wood (usually high-quality lumber or particle board) covered in a thin wood veneer. Wood panel doors are more decorative and have recessed areas that give the door detail. Solid-core wood doors usually have an R-value around 2.5, and wood panel doors an R-value of around 1.75.



Door Framing. The king, trimmer, and cripple studs, and header can clearly be seen. The jamb is harder to see – it is what the hinges and strike plate attach to (Photo ©)

Another type of door commonly used has an outer layer (skin) made of steel, fiberglass or wood and filled with polyurethane foam. This type of door is lightweight and has a relatively high R-value. Steel- and fiberglass-glad doors have R-values ranging from 5 to 7, though windows in the doors do reduce the effective R-value. According to the U.S. Department of Energy, a 1 ½" foam-core door has five times the insulating value of a solid-core door of equal thickness[1].

Glass doors, unless they are very expensive, top-of-the-line doors, are very poor insulators. Not only is glass a poor insulator, but the metal frames that these doors often are in are heat conductors. Many modern glass doors have a thermal break made of clear plastic sandwiched in-between the glass panes, but still do not provide very good levels of insulation. Storm doors are usually a combination of metal and glass. They are installed on the outside of the main door, with an air gap between the two. They can increase the effective R-value by around R-1, depending on the type of door. They also help prevent air leakage and can facilitate ventilation in the summer if they have a removable screen.

The "handedness" of a door is defined by which way it swings on its hinges. With the door opening away from you, if the hinges are on the right, the door is right handed. Conversely, the door is left handed if the hinges are on the left.

Pre-Hung Doors

A properly functioning door consistently latches and swings effortlessly on its hinges. There are several fine tolerances needed to achieve good performance all of which are rarely met on the first attempt of installation. In the past, the jamb would be assembled and set, the hinge mortises hand-cut, and then the door hung, all separately. Today, most doors are "pre-hung" in

[1] From the Energy Efficiency and Renewable Energy Program: http://www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13620

the factory, with the jambs, hinges, the bored-out door leaf, and sometimes a threshold, all in one unit. This greatly simplifies installation, but still these doors and jambs must still be carefully adjusted to fit into for imperfect rough openings.

The basic steps in installing a pre-hung door are as follows:

- **Checking and Adjusting the Rough Opening.** If a pre-hung door is to properly fit the rough framing, the opening must be square. You may first want to measure diagonally from the top right to bottom left of the opening, then top left to bottom right. If these lengths do not match up, the doorway is not square. If accessible, insert and nail shims behind the door framing to make it square, or at minimum try to plumb the hinge side. Sometimes shims are added to the inside of the opening. Shims are small, pre-cut wedges of wood. Shims are often installed behind the jambset once it is installed in the rough opening. Once they are adjusted to final fit, they are cut off flush with the wall surface with a hand saw, or scored with a utility knife and snapped off.
- **Installing the Jamb.** Remove the door from the jamb and insert the jambset into the rough opening. Make sure it the hinge side is plumb (vertical) and the head jab is level (horizontal). It fits tightly and all corners are square. Add shims as needed to square and level the door frame. For the sides, shims should be placed at the top and bottom, behind each hinge, and behind the latch and deadlock area. Install the door on the hinge jamb and make sure it swings readily. Once adjusted, the side jambs should be attached firmly to the rough frame, but do not put screws through the header. Install the casings to complete the installation.
- **Attaching the Split Jamb.** Some pre-hung doors are made with a split jamb, allowing installation with casing on both sides. After the main jamb has been installed, the smaller section of the jamb can be placed.
- **Mounting the Latch and Lock Hardware.** Make sure the latch bolt and strike plate fit snugly into the mortises. If the mortises are too small, use a chisel to make it the proper size. Attach both firmly with screws, then install the knobset.

Replacing a Door in an Existing Jamb
Replacing an existing door with a new one means that the new door must be fitted to the existing opening. New hinges, locksets and any other miscellaneous door hardware must be installed. In most cases, the existing door can be used as a template to cut the new door to size, but care must be taken to make the cuts without damaging the surface of the new door. Also, because the existing door may not fit properly and/or have other defects that should not be copied to the new one, careful attention is needed for the process of marking and cutting the new door. All existing hardware must be either replaced or removed from the old door and installed on the new one. Remember to follow LSW, Lead Safe Work, practices when working on old painted woodwork. A few pointers when installing new doors on existing jambs:

- Use the old doors as a template, but only if it swung freely and fit properly. There should be a gap of 1/8” at the sides and top and approximately 5/8” at the bottom. If the gaps are significantly different from this, mark the door to indicate how the new one should be installed differently.
- Inspect the hinges, lockset, mail slot and any other hardware to determine if their condition is good enough for reuse. Damaged or excessively worn hardware needs to be replaced.
- The centerline of the lockset is usually set at 36” above the threshold. If there is a deadbolt it is mounted at 42” to 48” above the bottom of the door.
- Standard hinge locations are 7” from the top of the jamb to the top of the top hinge and 11” from the threshold to the bottom of the bottom hinge, with the middle hinge centered between the other two. If reusing hinges, leave the hinges on the old door until you are ready to put them on the new door. Hinge position is critical to a properly functioning door.
- If reusing the locks, observe how they come apart, and put the parts aside in the order that they came off the door. Be careful not to lose any small screws or other parts.
- Remove the pins from the hinges starting from the bottom hinge and working your way up. Gently tapping up from the bottom of the pin may be helpful, as is prying the top up with a flathead screwdriver.
- Remove the old door, clamp it to the new door, and then trace the cut lines.
- After cutting the new door, install the hinges and then the door. If the door does not close easily, mark the location where the problem is occurring and shave wood off with a hand plane.
- If new mortises need to be made, mark the outline carefully with a sharp utility knife, then use a chisel to remove wood a little bit at a time. Check the hinges for a tight fit, careful not to chisel too much away. It’s always better to start small and expand the mortise than try it the other way around.
- If the mortise is too deep, a thin cardboard shim can be added underneath.

Threshold Defects

A door threshold should be high enough to make a seal with the door bottom shoe or sweep and allow the door to swing without hitting the floor, but low enough to keep the tripping hazard to a minimum. In many cases, the threshold can be adjusted or repaired but a severely damaged or missing one must be replaced.   To replace a damaged threshold, first remove all fasteners. Check the floor for level and straightness and use shims or other material to build up the surface and correct any deficiency. Cut the new threshold to fit snugly but not tightly between the jambs. Apply caulking, such as polyurethane sealant to the floor and buildup to prevent any leakage between the threshold and the floor. Older wood flooring may require caulking in each joint. Put the new threshold in place and fasten with screws. Apply caulk to all joints.

Fixing a Sticking Door
Sticking or binding of wood doors can have a variety of causes. All wood shrinks and swells according to temperature and humidity conditions. A door that operates correctly in winter may fit too tightly in the door opening in hot humid weather. Multiple coats of paint can also result in a slight enlargement of the door size. Hinges can become loose from binding or abuse, causing the door to sag. Loose or poorly adjusted latching or locking hardware can be the culprit. Careful observation can usually determine the cause of the problem.

Sometimes simply tightening the hardware (latch, strike plate, etc.) will fix the problem. Check all hardware, and tighten as needed. While you are doing this, check to see if the latch plate and strike plate are flush with the door. If they are not, adjust the mortise size until they are. The door may need to be shaved if there is inadequate space between it and the jamb. The gap should be between 1/8" and 3/16", or about the thickness of a quarter. Fixing this may be as simple as scraping off some paint, or slightly more difficult by shaving or cutting the door itself. Remember to follow Lead Safe Work, practices when working on old painted woodwork.

Weather-stripping
Adequate weather-stripping on an exterior door is critical to reducing air leakage. The door sweep or bottom shoe, when properly installed and adjusted, forms a seal with the threshold by means of a vinyl rubber strip. This strip has one or more flanges that come in contact with the threshold. Because the strip wears out from repeated contact and release, it needs to be replaced periodically. The vertical and head jambs are sealed using a soft compressible gasket combined with a harder nailing flange. This is usually fastened to the stops with nails or screws with the softer gasket material against the door. Metal doors will often have magnetically-attached weather-stripping.

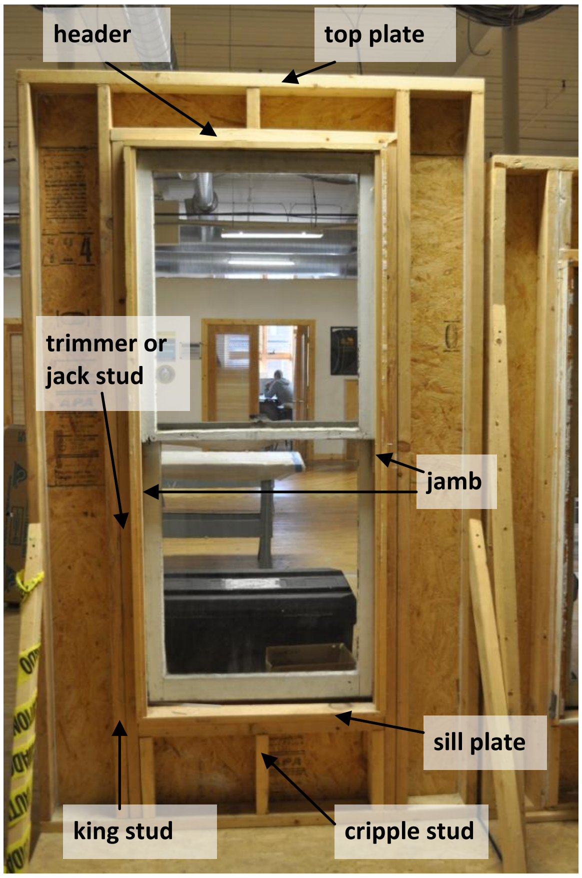
Care must be taken when installing weather-stripping not to compress the soft portion of the strip too much or the door will be too difficult to close. Air tightness must be balanced with ease of use. The properly weather-stripped door should put up some resistance when being closed and latched, but not too much resistance. In addition to being difficult to use, excessive tightness can cause premature wear on door hardware. After final adjustments are made, caulking the weather-stripping and the stops is a good idea.

Topic 7: Windows in Weatherization

Windows are a critical component of the building envelope and maintaining their functionality is essential to health and safety, building durability, comfort and energy efficiency. Difficulty of operation and severe air leakage are the two most common window problems. Cracked or broken glass, or damage from deterioration, misuse or advanced age can also occur. Diagnosis, determination of the need for repair or replacement, and execution of needed measures are important to any complete weatherization program.

Glazing: the glass portion of a window.

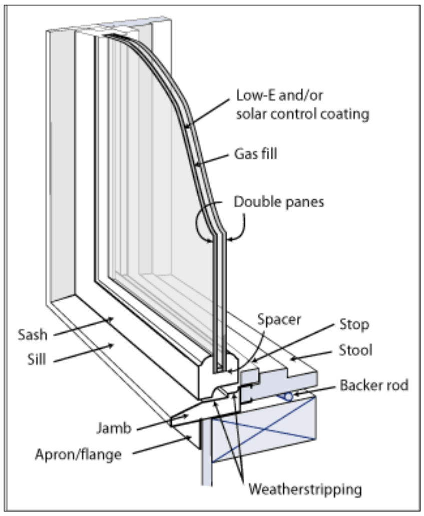
Window replacement is a low priority in weatherization retrofit programs such as WAP, because the cost of replacement windows is high compared to the improvement in the house's insulation value. On the other hand, windows, like doors, are often a top priority for occupants. Market-rate retrofit installer technicians will likely see many more window installations than WAP technicians. For the WAP program, if the cost-benefit is good enough, windows will be replaced. Though most weatherization crews will have carpenters on the team (or at least individuals specializing in carpentry) to install windows, it is good for all installer to have experience installing windows. If for no other reason, you may be asked to help with an installation.



Basic Window Parts. (Image ©eca)

Thermal Characteristics:

Windows are thermally rated by U-Factor. The U-factor measures the rate at which the window transmits non-solar heat: the lower the number, the lower the heat loss. U-factor is the reciprocal of R-value, meaning that 1/R=U and 1/U=R. Therefore, a window with a U-factor of 0.5 would have an R-value of 2. In the current market, high efficiency windows with a U-factor of 0.20 (R-5) or lower are becoming available. The National Fenestration Rating Council is the accepted authority on U-factor and other window characteristics in the U.S.



All of the components listed in this diagram affect the thermal characteristics of windows. (Image courtesy of US DOE)

The solar heat gain coefficient indicates the amount of solar radiation that is transmitting through the window through direct radiation (being clear, glass tends to let sunlight right in) or through absorption and re-radiation. Lower SHGC numbers indicate less solar gain, and more shading. A higher SHGC is better in a heating climate (allow more solar gain in the winter) and a lower SHGC is better in a cooling climate (reduces solar gain in the summer). An *ideal* cold-climate window is one with a high SHGC and a low U-factor, and vice-versa in a heating climate.

Low emissivity, or "low-e," windows have a thin coating of metallic material either applied to or embedded in the glass that reflect or absorb radiation. This coating is nearly invisible to the naked eye, but can reduce energy loss by as much as 30% - 50%. This coating lowers the U-value by reducing transmission of infrared radiation (heat) from warm panes to cooler panes. Low-e windows cost more than the same style without the coating, but are often worth the investment. In heating climates, low-e coating should be on the inside of the window, and on the outside in cooling climates.

Another way to improve U-factor and get higher R-values is through the use of multiple panes of glass. The gap between two panes reduces heat transmission. Inside this gap, the less air the better, because a vacuum only lets radiant heat through. Vacuums are difficult to maintain, so newer multi-pane windows are filled with gases like Argon or Krypton, which have relatively high resistances to heat flow.

Compare the U-factors in the chart on the right to the value of one inch of fiberglass or cellulose (U-.33 to U-.28) or one inch of foam insulation (U-.28 to U-.14). Low-e windows seem like they might be a good investment because their U-factor is comparable to insulation. There are important things to remember, though. First, windows, unlike insulation, cannot easily be built-up layer upon layer to achieve high R-values. Consider that these low-e windows have an R-value of about 3, while the minimal recommended wall insulation in much of the U.S. is R-19. Windows are a weak spot in the thermal envelope, even high efficiency ones.

Glazing Assembly	U-factor
Single Glass	1
Standard Insulating Glass	0.50
Low-e Glass	0.30
Fiberglass Batt	0.33 - 0.28
Spray Foam	0.28 – 0.14

Typical U-Factors of Different Housing Components. Note that despite similar U-factors, high efficiency windows are much more expensive than insulation, and thus have a low SIR.

Second, based on net cost-effectiveness, the cost per square foot of installing insulation is 60-80% less than installing new windows. Some heat gain can be realized through solar radiation, but the low gain in insulating value of a replacement window, combined with the relatively high cost per square foot makes for a very low savings to investment ratio (SIR).

Calculating Heat Loss

The heat loss of a window in BTUs per hour (BTUh) is calculated by multiplying the U-factor by the area of the window in square feet by the difference in temperature in degrees Fahrenheit: U x A x ΔT. If a window rated at U-.30 has an area of 15 square feet and the inside to outside temperature difference is 20 degrees, the heat loss is 90 BTUh: .30 x 15 x 20 = 90. If this window replaced an older U-1 window (with a heat loss at ΔT 20 degrees of 300 BTUh), the heat loss reduction would be 210 BTUh: 300 – 90 = 210.

Other Efficiency Measures
Retrofit installer technicians do more than just replace windows – there are some simple measures that can be taken to increase efficiency. First and foremost, proper weather-stripping is essential to reducing air leakage around windows. Weather-stripping should be applied to the top and bottom sashes of all double-hung windows. Temporary seasonal rope caulk can be used to prevent air leakage between double-hung windows. Rope caulk is convenient because it can be molded and is reusable. Another important repair is to replace any broken or missing glass panes.

U-factor: the rate at which a window, door, or skylight assembly conducts heat. It is usually expressed in units of BTU/hr*ft^2. U-factor is the reciprocal of R-value; lower U-values indicate more efficient windows and doors.

Solar heat gain coefficient: the percentage of solar radiation a window, door, or skylight allows

Sometimes storm windows are installed. They can be expensive, but greatly increase the efficiency of older windows. Before installing storm windows, it is worth investigating the cost-benefit of installing high efficiency windows to replace the old windows. It may be worth the time and money. Finally, a very inexpensive means of improving R-value is to add plastic coverings over the inside or outside of windows. This decreases air leakage, creates an air gap, and lowers the U-factor.

Weatherization and Retrofit

Energy Coordinating Agency

APPENDIX G

Manual Four Lab Exercises

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Lab 1: Roof Repair

Roofing repairs are an important aspect of maintaining a home. For the weatherization installer, it is critical that the roof be watertight. Attic areas must be kept dry to protect new insulation materials, stop the formation of mold, and prevent further damage to the building. With a few tools and materials, the skilled installer can make effective roof repairs. Roof repairs are very cost effective, especially compared to delaying work until full roof replacement and structural repairs are required.
It is important for a retrofit installer technician to know the installation standards for different slope roofs, and the types of materials to be used for different roofing applications.

After this lab is completed, you will be able to make roof repairs to shingle and low-slope roofs as well as repair roof flashings. You will know the installation standards for different slope roofs, and the types of materials to be used for different roofing applications.

Tools
Tape measure & pencil
Hammer
Flat pry bar
Utility knife
Reciprocating saw
Small trowel
Level
(Ladders)
Broom
Trash barrel
5-gallon bucket
Tarp

Consumables
Plastic roof cement
Roof fabric mesh
#15 asphalt roof paper
Aluminum flashing
Asphalt shingles
Roofing nails
Roof vents
Rags
Mineral spirits; hand cleaner
Trash bag

Safety Equipment
Eye protection
Respirator
Gloves
Hardhat
(Fall protection)
Caution tape/cones

Approximate time needed to complete this lab: 2 hours

Procedure

Debris Control
Preparation for removing roofing materials often includes debris control measures like posting notices and taping off a drop zone; draping tarps over the house to protect it; and covering

bushes, landscaping, and other outdoor items. Care must be taken to get all debris collected and swept up. Pay special attention to collecting all removed and dropped nails from yards, sidewalks, driveways, and streets.

Drainage Plane

The roof, wall, and foundation are parts of the building envelope or shell. They all work together to provide drainage down and away from the house. This important continuous layer which keeps water out of the house is called the drainage plane. For the roof the drainage plane includes the roofing coverage materials, the underlayment, and the flashings. Each piece should be placed so its high end is under the next piece above; each piece's low end will then be on top of the piece below. As gravity (the force which pull things toward the ground or earth) pulls water down the roof there is always roofing material to prevent the water from getting behind or under the roof. Along with the roof slope, this shingling effect provides drainage down the roof.

An installer always needs to ensure that a roof and the connected gutters, flashings, and wall structures have "positive drainage"; that is that the water runs down the roof and eventually away from the building as intended. If pooling water or evidence such as water stains are observed, these need to be reported. Contact you crew leader for further direction.

For any repair work, confirm positive drainage with a level (a small round object like a marble can serve a quick check in small areas). If positive drainage is not there, stop work and contact your crew leader for further direction. Sometimes the roof slope changes over different areas. For low-slope roofs, sometimes called "flat roofs", there may be a positive drainage near the top and bottom, but because of sagging rafters or excess loading, the middle section has a low or negative slope. Sometimes there are blockages or material build-ups that need to be removed to eliminate problems and promote drainage.

Plastic underlayment was applied to maintain the drainage plain here. (Photo courtesy of US National Park Service)

Remove all organic materials like sticks & leaves from gutters and drains, and moss from roof shingles. Remove inorganic materials like stones, fallen brick or mortar, old building materials and equipment parts, and built-up, excess roofing cement and materials. All of these measures will work to keep water flowing down and away from the building.

Roof Structure

The typical roof is a wood frame structure made of structural rafters covered by a layer of wood sheathing. The rafters rest on and are supported by the outside walls of the building. Sometimes they have additional support inside the building. The rafters and sheathing must be strong enough to support several loads . First there is the "dead load", which is the weight of the rafters and sheathing itself plus the added weight of the roof materials. Second there is the "live load", which is the temporary added weight of workers and equipment. Third there is the "environmental load" which includes the added weight of snow loads plus other factors like wind, water, and ice. Buildings must be built strong enough to carry all these loads. To design buildings that are strong enough calculations are made by engineers, architects, and builders using structural information about the different materials and loads. Some of this data is included in tables in the building code.

Code note: When working on the roof remember to keep combustible materials away from chimneys and flue pipes. There are required "clearances," which are minimum spaces that an installer must know to keep rigid foam and other combustibles out of around heat-producing items. The typical clearance space for masonry chimneys is 2". Check with your crew leader.

Typical Roof Structure. This is a pitched-roof mockup with 2x6 rafters, roof sheathing (OSB). The rafters are attached to joists at the base. (Photo ©)

Roof Calculations

Installers need to know how to calculate the amount of materials needed for roofing work. In roofing, the "square" is the unit used for buying material. 1 square of roofing = 100 s.f. (square feet).

1. If a roof measures 16' x 45' calculate the number of squares of roofing you would need to cover it. Multiply 16' x 45'; then divide the answer by 100'/square to get the number of squares of roofing. Remember to round up to the next whole square.

   Note: After getting the squares of coverage, roofers multiply by different factors (like 5%; 10% 15%) to account for extra needed material because of special roofing, waste from cutting, fitting against or around objects, and odd shaped roofs which require extra cuts and materials.

Shingle Roof

Remove the damaged shingle

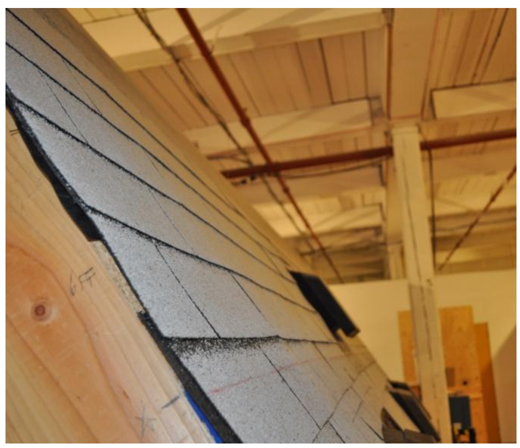
1. Carefully lift the overlying tabs using a flat pry bar or trowel to break the seal at the tab bottom.
2. Remove the nails using a flat pry bar. Use extreme care in removing nails from a shingle that will not be replaced. Any shingles damaged in this process will also have to be removed and replaced.

Check the roofing underlayment

1. With all damaged shingles removed, check the roofing underlayment (usually asphalt felt paper) and the sheathing beneath it. This is particularly important if leakage has occurred.
2. If the underlayment paper is damaged, add a new piece. Pay attention to how water drains: place the high end under existing layer of paper; place the low end over the existing layer of paper.

Install new shingle

1. Place the new shingle in the proper position and nail in place starting with the lowest.
    a. Take care not to locate nails in the original holes. Typically shingles have an adhesive strip just above the tab slits to hold down the tabs of the shingle above.
    b. Nails should be placed just below the adhesive strip, with one nail located above each tab slit. A standard 36" shingle has 4 nails. 1 at each end about 1" in, and 1 above each of the 2 tab slots. Note that these nails will also go through the upper edge of the next shingle down.
    c. A small amount of roof cement can be used to glue down the tabs to older shingles where the adhesive is compromised. Roof cement is also called cement, tar, mastic, or muck.
2. Using a level, confirm positive drainage, and report any problems to crew leader.

Shingles should overlap as shown on this sloped roof. Note the tar paper underneath. (Photo ©)

Fixing nail problems

Another common defect is nails that have worked their way out of the sheathing and lifted to penetrate the overlying tab. This is caused by wood shrinkage or the nail being located in a joint between sheathing boards.

1. These can be easily fixed by carefully lifting the tab and carefully removing the nail, so as not to do further damage.
2. Put a dab of roof cement in the hole and on the tab if it has been penetrated. Do not attempt to drive another nail in this case if a large number of nails near each other have lifted.
3. Using a level, confirm positive drainage, and report any problems to crew leader.
4. If possible, check the underside of the roof sheathing from inside the attic for defects.

Minor repairs to slate, tile, or cedar shingle roofs

These repairs can often be done with sheet aluminum slid carefully up the slope between the layers to go cover the damaged area. Wedged in tightly, the aluminum should stay in place for a time and a carefully placed dab or two of roof cement can help hold it in place and minimize loosening by weather conditions or temperature changes. More extensive repairs should be done by a qualified roofer who has expertise with the particular material.

Low Slope Roof

On low-slope roofs (less than 4/12 pitch), cracks and other openings occur in the roofing itself as it ages and weathers. In addition, cracks also develop where aluminum flashings meet asphalt roofing because the materials have different expansion rates.

Minor cracks

Minor cracks can be repaired using roof cement with four inch asphalt impregnated fabric.

1. Make sure there is no moisture in the crack. Fill the crack with cement as much as possible to avoid trapping air.
2. Apply a layer of cement using a trowel, then embed the fabric into the cement and add another layer of cement. No fabric should be visible in the finished job and the surface should be smooth and even. Spread out the cement at least 1" past the fabric mesh in all directions. Slope the cement so that water will drain away from the area.
3. Using a level, confirm positive drainage, and report any problems to crew leader.

Air pockets/blisters

Air pockets are blisters caused by air and/or moisture trapped between the plies of roofing and expanded by the sun's heat. Repair should be done on a warm, dry day.

1. Using a sharp utility knife, cut across the blister at its longest dimension, then cut three diagonal cuts that intersect in the center, like cuts in a pie.
2. Pull the flaps back and thoroughly dry out any moisture. Remove any materials like moss or leaves.
3. Apply roof coating to the exposed surface and replace the flaps, making sure they adhere to the coating and no air is trapped. Press down with the trowel.

4. The cuts can then be sealed using four inches of asphalt impregnated fabric and roof cement as described above. Spread out the cement at least 1" past the fabric mesh in all directions. Slope the cement so that water will drain away from the area.
5. Using a level, confirm positive drainage, and report any problems to crew leader.

Flashings

Metal flashing replacement

Flashings that have rusted through can sometimes be repaired with aluminum. Removing the old flashing may not be necessary.

1. Remove old materials such as moss or excess caulking or cement build-up.
2. Cut and shape the replacement aluminum to match the original and slide it into place over the deteriorated piece.
3. Nailing is typically not practical and a small amount of roof cement or tar can be used to hold the new piece in place and further reduce the risk of leakage.
4. Where the flashing adjoins masonry, cutting the mortar with a diamond saw or chipping it out with a chisel is usually needed and these operations should be done by a qualified roofer or mason. The mortar joint is opened to allow the top edge of the flashing to be inserted. Then masonry caulk is used to seal the joint.

Small pieces of aluminum can sometimes be used to fix roof flashing. Flashing is usually used to prevent water from entering the building through the chimney chase. Only a qualified roofer or mason should cut grooves in the chimney (left image). (Photos courtesy of US National Park Service)

Asphalt "Tar" flashings and Pipe Collars

Asphalt "tar" flashings tend to dry out and crack over time. Any open tar flashings should be repaired using roof cement and fabric mesh as described above. In addition, the neoprene rubber collars, called vent boots, at plumbing vent pipes in shingle roofs can deteriorate allowing water to run down the outside of the pipe. This may first become evident in lower levels of the house even the basement. If the deterioration is not too severe, the collar can be resealed using silicone caulk. If the collar cannot be repaired, a new collar can be installed over, and sealed to, the old one.

Clean-up work area and store tools and materials

1. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used as these are usually flammable and could contains VOC's (volatile organic compounds).

2. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.
3. Return any items or personal belongings that may have been moved or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
4. Complete a final check and clean your work area and the work site.

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Lab 2: Roof Drainage

When working properly, gutters and downspouts direct rain water away from the building shell releasing it into a drain or onto a permeable surface (usually the lawn). Several things cause gutters and downspouts to malfunction - improper slope, blockages, loose connections, unsecured sections, and more.

As every house is a system, these malfunctions that began at the roof can cause moisture issues as far away as the foundation. This lab will help you identify how this happens and how to resolve the problems.

After this lab is completed you will be able to identify grading issues, moisture symptoms & problems, and proper roof slope. You also will be able to make minor repairs to resolve drainage issues.

Tools	Consumables	Safety Equipment
Ladder	Roofing Cement (tube)	Gloves
Drill	Sheet metal screws	Fall protection
6 in 1 driver	Flashing	
Level	Roofing nails	
Metal shears		

Approximate time needed to complete this lab: 4 Hours

Procedure

Visual inspection precedes each action within this lab exercise. Improper drainage leaves visual signs of deterioration (rust, peeling paint, etc). Being able to identify these signs is the most important aspect of inspection.

Safety Concerns

1. Ladder safety
2. Tool safety

Inspection of work area

1. Identify signs of moisture problems
   - Rust
   - Discoloration / Stains on building materials (brick, drywall, stucco, etc.)

- Peeling paint
2. Identify various moisture sources
   - Roof leaks
   - Pipe leaks
   - Air Leakage
   - Improper slope
3. Identify issues with flashing
   - Missing / Loose sections
   - Bent sections
   - Flashing cement failure
4. Identify improper slope
   - Measure slope using bubble level
5. Locate blockages (use drainage verification test if necessary)
   - Visual inspection of obvious blockages
   - Verify drainage using garden hose or buckets of water. Apply water to highest zone of roof and allow natural drainage. Testing the entire roof zone by zone verify that water runs to drain or gutter system.

Replacement and repair

1. Remove organic/inorganic blockages
   - Leaves
   - Gutter moss
   - Trash
   - Toys/Balls
2. Repair loose connections
   - One sheet metal screw should be drilled into each accessible side of the downspout. When this can't be achieved refer to manufacturer specifications.
3. Repair flashing (replace missing sections, seal joints, & seams)
   - Measure missing section and add a inch to measurement, this extra inch will allow the adjoining ends to overlap.
   - Cut flashing to specified length using metal shears.
   - Using roofing nails drive one nail every 4-6" or if piece is smaller in length drive nail at both ends only.
   - Apply roofing cement to all seams, joints, and nail penetrations.
4. Verify drainage (using garden hose or buckets of water)

All obstructions should be removed from the roof drainage systems, including the gutters (top image), and splash blocks (bottom image). (Photos courtesy of Dan Kasper)

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Lab 3: Roof Vents and Vent Chutes

Roof vents are often necessary to ventilate an attic space. The vent is typically placed as high on the roof slope as possible and central to the area being vented. Careful consideration of the location is important, taking into account the roof structure and the dynamics of air movement within the building envelope. In some cases more than one vent may be needed. The primary function of roof ventilation is to prevent moisture problems and excess heat build-up in the attic areas under the roof sheathing.

Another part of roof ventilation is a soffit vent chute installed under the roof deck or sheathing. This is a thin plastic or foam channel that is fastened under the roof deck between the rafters to provide an air path for roof ventilation. Insulation can then be installed under the roof above a sloped ceiling.

When this lab is completed, you will know how to install slope roof vents, mushroom vents, and gable wall vents. You will also be able to install a soffit vent chute and insulate under the roof deck.

Tools
Power drill
1 ¼" spade drill bit
Utility knife
Tape measure
Hammer
Reciprocating saw
Caulk gun
Small framing square
Flat Pry Bar
(Ladders)
(Tie-offs; Warning Lines)
Stapler
Tarp
5-gal. Bucket

Consumables
Pencil
Nails (common 3")
Nails (roofing ¾")
Silicone caulk
Roof Cement (Use Drywall Joint compound for Lab)
Mineral spirits
Rags
Fiberglass Batt; faced
1" x 3" furring strip; 8'
Staples
Soffit Vent Chute
Trash bag

Safety Equipment
Eye protection
Breathing equipment
Gloves
Hard hat
(Tie-offs; Fall Protection)
Caution Tape

Approximate time needed to complete this lab: 5 hours

Procedure

Important Note on Code

When working on the roof remember to keep combustible materials away from chimneys and flue pipes. There are required "clearances," which are minimum spaces that an installer must know to keep rigid foam and other combustibles away from heat-producing items. The typical clearance space for masonry chimneys is 2". Check with your crew leader.

Debris Control

Preparation for removing roofing materials often includes debris control measures like posting notices and taping off a drop zone; draping tarps over the house to protect it; and covering bushes, landscaping, and other outdoor items. Care must be taken to get all debris collected and swept up. Pay special attention to collecting all removed and dropped nails from yards, sidewalks, driveways, and streets.

Drainage Plane

The roof, wall, and foundation are parts of the building envelope or shell. They all work together to provide drainage down and away from the house. This important continuous layer which keeps water out of the house is called the drainage plane. For the roof the drainage plane includes the roofing coverage materials, the underlayment, and the flashings. Each piece should be placed so its high end is under the next piece above; each piece's low end will then be on top of the piece below. As gravity (the force which pull things toward the ground or earth) pulls water down the roof there is always roofing material to prevent the water from getting behind or under the roof. Along with the roof slope, this shingling effect provides drainage down the roof.

A retrofit installer technician always needs to ensure that a roof and the connected gutters, flashings, and wall structures have "positive drainage"; that is that the water runs down the roof and eventually away from the building as intended. If pooling water or evidence such as water stains are observed, these need to be reported. Contact you crew leader for further direction. For any repair work, confirm positive drainage with a level (a small round object like a marble can serve a quick check in small areas). If positive drainage is not there, stop work and contact your crew leader for further direction.

Sometimes the roof slope changes over different areas. For low-slope roofs, sometimes called "flat roofs", there may be a positive drainage near the top and bottom, but because of sagging rafters or excess loading, the middle section has a low or negative slope. Sometimes there are blockages or material build-ups that need to be removed to eliminate problems and promote drainage. Remove all organic materials like sticks & leaves from gutters and drains, and moss from roof shingles. Remove inorganic materials like stones, fallen brick or mortar, old building materials and equipment parts, and built-up, excess roofing cement and materials. All of these measures will work to keep water flowing down and away from the building.

Roof Structure

The typical roof is a wood frame structure made of structural rafters covered by a layer of wood sheathing. The rafters rest on and are supported by the outside walls of the building. Sometimes they have additional support inside the building. The rafters and sheathing must be strong enough to support several loads . First there is the "dead load", which is the weight of the rafters and sheathing itself plus the added weight of the roof materials. Second there is the "live load", which is the temporary added weight of workers and equipment. Third there is the "environmental load" which includes the added weight of snow loads plus other factors like wind, water, and ice. Buildings must be built strong enough to carry all these loads. To design buildings that are strong enough calculations are made by engineers, architects, and builders using structural information about the different materials and loads. Some of this data is included in tables in the building code.

Typical Roof Structure. This is a pitched-roof mockup with 2x6 rafters, roof sheathing (OSB). The rafters are attached to joists at the base. (Photo ©)

Slope Roof Vent

Slope roof vents are used on roofs with slopes of 3/12 or greater (3" rise/vertical for every 12" run/horizontal). To install slope roof vents, it is best to install them on the back of the house not visible from the street. They should be placed evenly apart and about 1-2 feet down from the roof ridge. Do an inspection in the attic if possible. Make sure there are no electrical wires or other obstructions located where the roof vents are to be placed.

Cut the hole for the vent

1. Hammer a long nail in the center of the area where the roof vent is to be installed. THE VENT MUST NOT CUT ACROSS RAFTERS – make sure you will not cut any rafters when cutting the vent hole.
2. Go back outside and set up your equipment on the roof. Mark the area for the vent using

the nail as a reference point for the center of the vent hole. Mark the cut out ½" to 1" larger than the vent opening.

3. Carefully loosen the shingles just above and to the side of the cutout area. Remove any shingle nails around the vent hole. You will cut these shingles so that they will overlap the flange by 1"-2" on the top and sides. (Later when installing the vent, you will slide the vent up under the loosened side and top shingles; if not, you will have to remove them, cut them to fit, and reinstall them after the vent is in place). Do not loosen or remove the shingles below the vent cutout because they will be covered by the flange.
4. Drill a 1"-1 ½ " hole using a paddle bit in opposite corners of where the vent hole will be cut. Use these holes to start your cut with the reciprocating saw.
5. Cut the vent hole with the reciprocating saw.
6. Carefully remove all roofing materials and the roof deck sheathing from the vent hole area. Warn other workers about this debris and carefully place it in a container like a bucket to be lowered or drop it in a designated tarped area.

Installed Slope Roof Vent. The image to the right shows the hole to be cut, and the finished product. Note that the extra hole in the roof (bottom right of image to the right) must be fixed before the vent is installed. Also note that the flanges are tucked under the shingles. (Photos ©)

Install the vent

1. Gently lift up the shingles at the top and sides of the hole without bending, breaking, or removing them. Apply roofing cement to the underside of the flange on the vent, and slide it under the shingles. Make sure the top and side shingles are covering the roof vent flange.
2. Nail the flange to the roof deck on the top and sides UNDER THE SHINGLES and at the bottom with galvanized roofing nails.
3. Cover the nail holes with a good caulk or roofing cement and use it under the shingles that you loosened, leaving the bottom edge exposed.
4. Using a level, confirm positive drainage, and report any problems to crew leader.

Mushroom Vent

A mushroom vent is used on roofs with a slope less than 3/12 (3” rise/vertical for every 12” run/horizontal). This is common in urban rowhomes. Roofs of this low angle are considered “flat” roofs. The mushroom vent is often located about 5’ to 10’ from high/top end of the roof. This allows for more headroom if weatherization workers are using the hole for attic access. It also keeps the vent above the low end where water can pool.

Cutting the hole for the vent

1. If you cannot mark the vent hole from inside the attic, you must first check for rafters from on top of the roof. Try tapping with a hammer to locate rafters, drilling a 1” – 1 ½” hole and using a 7” wire to feel for rafters in a circular motion. If available, you can also use a fiber optic camera set. Find an area that will allow you to install the vent without cutting rafters.
2. Measure a hole between 13”-14” wide. Mark the hole with chalk or a pencil.
3. Using a 1”- 1 ½” paddle bit drill 2 holes in opposite corners on the inside of the markings.
4. Using a reciprocating saw cut out the vent hole along the markings.

Install the vent

1. Apply the 1st layer of roof or flashing cement. Place cement either on the underside of the flange or on the roof around the hole.
2. Make marks around the outside so you know where to place the vent and place it centered over the hole.
3. Screw down or nail down the vent flange – start at any point, then go around the perimeter of the flange and nail or screw it down as you go around. Take care to keep the metal flange flat to the roof so there are no bulges in it.

Apply roofing fabric

1. Apply another layer of roof or flashing cement. Place cement on the entire flange and to a distance 3” on to the roof.
2. If using a 4” mesh, place the first layer 3” over the flange and 1” over the roof. Then more cement.
3. Place the second layer 1” on the flange and 3” on the roof. The total width of the fabric should total 6” wide.
4. If using 6” mesh, place only one layer - ½ on the flange and ½ on the roof.
5. Embed the fabric into the cement. Pinch down one end of the fabric to hold it while you press and slide the trowel across the fabric until the cement comes through the holes in the mesh.

Finish sealing the vent

1. Bevel the cement from the raised part of the vent to the outside edge of the fabric so that it has a slope moving away from the center of the vent. Also make sure that the cement is smooth to prevent pooling water around the vent.
2. Using a level, confirm positive drainage, and report any problems to crew leader.

Installed Mushroom Vent. This mushroom vent has been installed on the flat roof of a rowhome. (Photo courtesy of David Dennis)

Gable Vent

Gable vents are installed on roof gable walls, which are the vertical triangular-shaped walls at each end of the house that are located below and between the roof slopes. To install gable vents, it is best to install two vents, one at each end of the house as high on the gable as possible without any obstructions to the vent.

Cutting the hole for the vent

If you can't mark from the inside of the attic:

1. The vent should be centered high on the gable wall below the ridge. Remove the siding from the area you think the vent should be installed.
1. Mark your vent hole and drill the sheathing at the bottom of your marking with a 1"- ½" paddle bit. Use this hole to check for obstructions and adjust the vent hole markings as needed. Mark the sheathing by using the square to create a rectangle outline.
2. Remember to oversize your cutout about 1/4" for easy installation.
3. Using a reciprocating or jig saw, cut out the vent rough opening.

If you can mark from the inside of the attic:

2. From the attic, measure and mark for a hole using a level and square. Remember to oversize your cutout about 1/4" for easy installation.
3. From the inside corners of your frame, drill a 1/4" or 3/8" hole through to the outside.
4. Go outside on a ladder and mark straight lines to connect the holes.
5. Remove the siding in the area determined for the cut out and re-mark the sheathing by using the square to connect the holes.

6. Using a reciprocating or jig saw, cut out the vent rough opening.

Install the vent

1. Add wood supports if there is no wall sheathing, or if it is weak or deteriorated. Use 1” x 4”s or 2” x 4”s to frame out the vent opening on the inside. This will provide the vent flange with a solid base for the nails or screws.
2. Before installing the vent, caulk the back side of the vent flange.
3. Place the vent over the rough opening, adjust it for level and square, and then secure it with screws.
4. Mark the siding that coincides with your flange. Cut it to fit around the vent and re-install the siding.
5. Install flange cover.


Installed gable vent. The images to the left and right show an interior and exterior view, respectively. (Photos ©)

Soffit Vent Chute and Roof Deck Insulation

Installing the vent chute

A soffit vent chute provides a path for roof ventilation air to travel under the roof sheathing or roof deck up to the roof vents above.

1. Get a vent chute which is the correct width to fit between the rafters. Standard sizes are for 16” and 24” o.c. rafters. These are very lightweight plastic, foam, or coated cardboard. They can be attached by stapling directly to the roof deck. ½” staples should not penetrate through the deck and cause any problems above. Staple each stapling flange every 12” from top to bottom.
2. If the spacing is different than the vent chute, cut the chute with the utility knife to fit. This does not have to be a tight fit; it does not have to be sealed. Remember, its purpose is to provide a path under the roof deck for ventilation air to rise up to vents higher up the roof like ridge, slope, or gable vents.

3. (If you are starting the vent chute directly above a roof soffit, you also want to block from the vent chute to the ceiling or top of wall. This is called a baffle. Baffles stop “wind washing” which is outside air from the soffit vent blowing under the chute and through the ceiling insulation. They also keep loose fill insulation from falling into the soffit area. Some vent chutes have baffles attached which can be bent down and stapled to the top of a wall plate and to the sides of the rafters. Another option is to make a baffle by installing a fiberglass backing and covering it with spray foam. A third baffling technique is to cut pieces of rigid foam to fit from the vent chute down to the top of wall of ceiling below. Then seal it in place with spray foam all around the edges).
4. Once the vent chute is in place, you will insulate the roof deck. Use faced fiberglass insulation that is the correct depth to fit against the vent chute.
5. Measure the space between the rafters to determine the spacing. Usually for a roof the rafters will be 24” apart (24” o.c on-center). The fiberglass batt will be available for installation between 16” or 24”o.c. framing.
6. For installation for a sloped ceiling under a roof deck, you need to hold the insulation up and secure it against the rafters. If the batt has a facing, you will need to place the facing toward you into the house, because you want the vapor barrier to face the warm, moist inside conditioned air. You can then use flange on the facing to staple the batt to the rafters.

These soffit vent chutes have been sealed with 2-part foam (perhaps excessively so). (Photo ©)

Insulating the roof deck

Roof insulation can be installed in a number of ways. In this lab you will attach fiberglass batt installed directly between roof rafters. Another method is to use rigid foam boards that are cut and fit between rafters. If a vent chute is needed, the foam is set about 1” off the roof deck with wood spacers. Rigid foam can also be installed across the rafters, minimizing thermal bridging through the wood. A final different roofing and insulation method involves attaching rigid foam over the roof deck sheathing and applying roofing materials over that.

1. To attach the insulation you need to start at the top of the slopped ceiling to be insulated and work your way evenly down the rafters stapling the facing flange along the rafter at about every 12”. The insulation should be smooth, even with the face of the rafter (not pushed in), and against the full length of the rafter (no gaps). When you use more than one piece in a rafter bay make sure they fit snugly against each other (no gap between them). Remember the quality of the installation is critical to getting good insulating R-value.
2. If the rafter bay is not a standard width, you will have to cut the insulation. Lay it on a smooth solid surface with the fiberglass up / the facing down. Get a 1” x 3” furring strip and press down the insulation along the line you want to cut. Using the furring strip as a guide, use your utility knife to cut the insulation. Holding the blade at about a 45 degree angle, cut all the way through the insulation while running the knife along the wood.
3. If you encounter electrical boxes, pipes or other fixtures, you must notch the insulation around them. Do not compress or crush the insulation. Fit the insulation so it is tight and even along the rafters. You should have insulation behind the fixture and tight around it. Above, below, and to the sides of an electrical box, the insulation should be full depth coming right out to the front of the rafter.

Insulation has been added between the vent chute and roof rafters. This is a view looking down over top of the vent chute (Photo ©eca)

Clean-up work area and store tools and materials

5. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used as these are usually flammable and could contains VOC's (volatile organic compounds).
6. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.
7. Return any items or personal belongings that may have been moved or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
8. Complete a final check and clean your work area and the work site.

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Lab 4: Work Scope

A Work Scope (or work order) is a document created by the Energy Auditor that lists all weatherization measures which will be applied to the corresponding work site. The work scope is used by the retrofit installer as a guide to apply the appropriate measures and as a checklist to determine whether all work has been completed.

Also, it will be important for an installer to become familiar with the “tool list”, which list all the tools and materials which are loaded onto the truck. Depending of your agency’s policy tools may loaded each day per the necessities of that days’ work order or there may be a master list which list all the tools & materials that could be used on any work scope. It is imperative that an installer knows what he has on his truck in order to report missing or deficient tools & material.

After this lab is completed, you will be able to analyze a work scope to identify work site areas, pull the proper tools & materials for weatherization measures, and determine the completion of work scope measures. This lab can be done in conjunction with any of the labs in the retrofit installer technician manual – it is not a standalone lab.

Tools	**Consumables**	**Safety Equipment**
Varied	Varied	Varied

Approximate time needed to complete this lab: additional 30 minutes to associated lab

Procedure

The work scope is reviewed by the crew prior to reaching the work site. The crew chief will sanction individual task to each installer. Upon reaching the work site the crew chief will use the work scope to introduce the home owner to the work areas of the home. During this time the installers pull their task designated tools and materials from the truck. The installer then waits for “start-work” verification from the crew chief. After work is complete the installer will return all tools and unused materials to truck to be inventoried and organized.

Safety concerns

1. Proper care of tools and materials
    - Power tools are somewhat delicate and need to be moved appropriately
    - Hand tools should be carried by the grip or handle

- Materials have manufacture specifications about proper storage (ex. One part foam shouldn't be stored in temperatures above 120^{o} to maintain material integrity and ensure safety)
- Materials and tools also have manufacturer limitations. When these limitations are exceeded it becomes a safety hazard (ex. A chisel is designed to shear wood with its sharp edge, though the sharp edge is flat it should not be used as a flathead screw driver because of the risk of injury)

2. **ALWAYS WEAR THE PROPER PPE!**

3. Work Area Hazards
   - Low head clearances
   - Rodents/rodent waste, aggressive animals/waste
   - High ambient CO, loose, friable asbestos
   - Illegal activity, aggressive client
   - Obstructions (e.g. client belongings)

Analyze Work Scope

1. Per Crew Chief instruction identify your task and locate it on work scope form
2. Cross check other installer measures
   - Ensure there will not be a conflict in work area space
   - Ensure there are no measures which may need to proceed your task
   - Report any issue to crew chief for further instruction

Pull Tools and Materials

1. Unload tools from truck
   - Find a place to compile your task appropriate tools & materials. This area shouldn't be on adjacent properties or in the path of passersby.
   - Compile your task appropriate tools & materials. Lay the tools out so they are all visible, never one on top of the other.
2. Confirm start-work order and enter work area
   - Confirm start-work order per crew chief
   - Carry tools and materials into work area (Safety First! Never carry more than what feels comfortable. Generally 2 hands = 2 tools.)
   - After all tools & materials are within specified work area apply weatherization measure.

Install Measures

During installation, issues may come up that are not in the work scope. For example, a safety hazard (e.g. broken step) may arise or an additional efficiency problem may occur between the tie the work order was created and given to you. If you feel the work scope needs to be deviated from *no matter how slightly*:

1. Clearly identify the deviation – where it is, why it is a problem, and that it is not in the work scope
2. Report the deviation to the crew chief or supervisor

   a. Unless specifically authorized to do so from the crew chief, do not deviate from the work scope
3. Request direction for modified work scope
4. Implement the modified work scope

Clean Work Area

1. Remove all materials & tools from work area into an adjacent area of the work site. This selected area should not restrict movement throughout the work site.
2. Remove and clean work area of material debris, dust, and dirt.

Load Truck

1. Carry tools to truck, placing each in its designated place. Again a safe carrying method is 2 hands = 2 tools. (prior to organizing tools in truck inventory each tool on tool list)
2. Locate appropriate facilities (per Crew Chief instruction) for dumping of trash, recyclables, and lead hazardous materials.
3. Place materials in appropriate facility or separate and compile materials for site removal.

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Lab 5: Attic Hatch or Access Door

While attic space is typically outside the thermal envelope, access to the attic is usually needed to install and maintain wiring and insulation among purposes. Access is usually provided by a hatch or an opening in the ceiling large enough to crawl through. The access door or hatch needs to be air sealed and insulated so that the thermal boundary or envelope is not compromised.

When this lab is completed, you will know how to build and install an attic access hatch door in a ceiling with standard framing of 16" or 24" o.c. (on-center) spacing.

Tools
Measuring tape & pencil
Speed square or framing square
Drill with #2 Philips bit
Driver sleeve
Reciprocating saw
Utility knife
T-square
Tape measure
Rasp
Hammer
Keyhole saw
Miter saw
Circular Saw
Small framing square
Caulk Gun
Staple gun

Consumables
Screws (sheet rock 1 ⅝")
Nails (finish, 1 ½")
¼" or 3/16" plywood &/or ½" drywall
Weather stripping
Construction adhesive
Caulk (latex)
4" Rigid insulation
Hooks and eyes
Wood – 2" x 2"
Wood - 2" x 4" and/or 2" x 6" or 2" x 8"
Staples
Batt (fiberglass, R-38, unfaced)
EPS hatch

Safety Equipment
Eye protection
Respirator
Hard hat

Approximate time needed to complete the lab: 2.5 hours

Work Scope:
Provide an attic access hatch door that is fully operable, air sealed, and insulated. Following the work specification, construct the hatch from the materials listed above using the tools indicated. Locate the hatch between existing joist ceiling joists. Secure the hatch and trim and seal it. Minimize material waste and demonstrate proper safe tool use. Plan for project, prepare, construct, install, test, clean-up, and put equipment and materials away.

Work Specification:
Access hatch door to be installed in prepared ceiling opening (approx 16” x 24”) between ceiling joists. Attic access hatch door to be constructed on 1” x 3”wood frame with ½” drywall panel to fit prepared ceiling opening. Mitered casing trim to be attached through drywall into frame with 1 ½” finishing nails. Hatch to be securely attached to ceiling joists with screws through pre-drilled holes in casing flush to ceiling. Door to be insulated to achieve R-38 level. Door to be airsealed using weather-stripping gasket

Introduction
For this exercise, you will be building an access hatch that fits between joists that are either 16” O.C. or 24” O.C. These are the standard construction framing spacings. Actual field conditions will vary and you need to make measurements and adjustments. (Note that for new construction, the IRC code now requires a min. 22” x 30” opening in attics over 30” in height. Check with local code officials for your area. Also as a weatherization worker you should know about working safely in confined spaces. OSHA has guidelines for you and your company to follow if you are working in a permit-required confined space).

On the job, an access opening may require cutting through joists and installing headers. In this case, a skilled carpenter must do this structural repair. Installing headers involves providing temporary supports and adding the required structural lumber and hardware such as joist hangers.

There are also premade insulating cover kits available in several sizes for access doors, sidewall/kneewall doors, and pull-down stairways. These kits are made of rigid foam pieces that are easy to cut and fabricate on the job.

Procedure

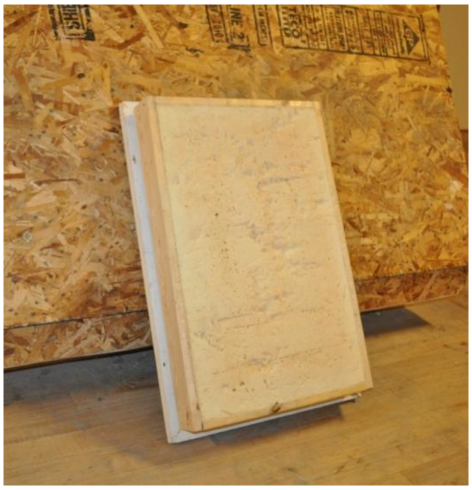
Build the Attic Hatch

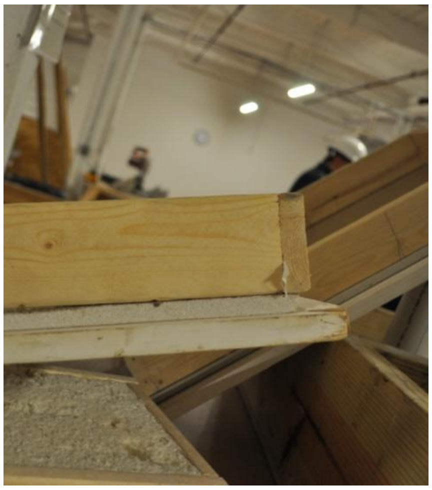
1. Start by measuring the access hole. Be sure to measure in 3 locations, both ends and the middle, the same as you would a door or window. Cut a piece of drywall to fit the smallest dimensions.
2. Cut 1” x 3” furring strips to fit the dimensions of the drywall and nail the frame together using 1 ½” finish nails.
3. Fasten the drywall to the frame using 1 ½” finish nails, or 1 ¼” drywall screws.
4. Use a framing square to create an inside boarder line approximately 1 1/4” in from the edges of the drywall. Check to make sure the lines are square.
5. Measure the lines forming the inside square and use these measurements to mark the trim pieces at a 45 degree angle using a speed square. Remember the inside edge of the casing trim is the thin side.

6. Cut the trim using a miter saw or circular saw and place all pieces on the lines for a dry fit before attaching.
7. Firmly attach the trim by nailing through the trim, drywall and into the wood frame with the above mentioned finish nails (2-3 per side).
8. Caulk all corners of the trim, the seam between the trim and the drywall, and the inside of the wood frame where wood meets wood and where wood meets drywall.
9. Pre-drill holes in the trim for the mounting screws
10. Attach weather stripping to the underside of the trim to form an air tight seal against the existing ceiling.
11. Add insulation by gluing and fastening rigid foam pieces with screws, or stapling batt insulation facing, to the top of the panel to achieve the desired R-value. The goal is to match the R-value of the attic insulation.
12. Install the door by using 1 5/8" screws through the pre-drilled holes.

Clean-up work area and store tools and materials

1. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used, such as paint thinner, as these are usually flammable and could contains VOC's (volatile organic compounds).
2. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.
3. Return any items or personal belongings that may have been moved or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
4. Complete a final check and clean your work area and the work site





Finished attic hatch front view (left) and view from behind (center). The cavity is filled with a 4" thick piece of rigid foam board. The image to the right shows the frame, drywall, and 1 x 4 cavity frame. (Photos ©ECA)

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Lab 6: Stair Repair and Construction

Stairs do not impact weatherization in and of themselves, but they are necessary to gain access to areas of the home that require weatherization. They are an especially important consideration because the two most important areas in terms of air sealing and insulation are the attic and basement, both of which generally require the use of stairs to gain access to them. If the steps are not functioning properly on a work site, retrofit installer technicians may be required to repair them. This decision is ultimately up to the crew chief and/or auditor.

After this lab is complete, you will know how to build a set of steps and repair damaged steps.

Tools
Tape Measure & Pencil
Framing Square
Small clamps
Circular Saw
Hand Saw
Hammer
Screwdriver
Driver/Drill
Level
Pry bar
Reciprocating saw

Consumables
2” x 12” (for stringers)
5/4” x 12” (stair treads)
1” x 6” risers
2” x 4” blocks; ledgers
1” x 3”
Common nails; 6d; 8d; 12d
Finish nails; 6d; 8d
Wood Screws; 2; 2 ½”; 3”

Safety Equipment
Eye Protection
Hearing Protection
Dust Mask
Gloves

Approximate time needed to complete this lab: 4 hours

Procedure

Components

All stairs have two main parts: the treads people step on and the stringers, carriage or horses which support the treads. The treads are mounted on two or more stringers cut out of solid pieces of lumber (usually 2" x 12").

Dimension	Minimum Standard	Optimal Standard	Acceptable Range
Rise	≤ 7 ¾” (IRC) ≤ 8 1/4” (some states)	≤ 7”	6” to 7 3/4” (IRC) 6” to 8 1/4” (some states)
Tread (run)	≥ 10” (IRC) ≥ 9” (some states)	≥ 10”	10” to 11-1/2” (IRC) 9” to 11-1/2” (some states)
Rise plus Run	---	17-1/2”	Rise 6” to 8” Rise + Run: 17” to 18”
Total Rise	< 12’	---	Single Run
Slope	≤ 41°	33° to 37°	27° to 41°
Headroom	≥ 6’- 8” (80”)	7’ (84”)	≥ 6’- 8” (80”)
Rail Height	34”	36”	34” to 38”
Rail Diameter	≤ 2”	≤ 1 5/8”	1-1/4” to 2”
Baluster Opening	≤ 4”	---	
Wall to Handrail	≥ 1-1/2”	---	

Important Safety and Other Considerations

- In any straight run of stairs, all treads must be equal and all risers must be equal.
- The handrail should extend from over the top tread to over the bottom tread.
- Any break in the handrail, except at the end of a run, should have a return, or a knob, to prevent the hand from slipping off the end unexpectedly.
- Landings must be at least as long as the stairway is wide but should not exceed 4 feet in length if there is no change in direction of the stairway.
- Where adequate headroom is not possible, a clearly visible warning sign must be posted and a cushion of soft material should be placed where head injury might occur.

Stair Design and Construction

To build new steps, you first need to determine the number and height of risers.

1. Measure the height from lower floor to upper floor.
2. Divide the height (in inches) by seven and round down to get the number of risers.
3. Divide the floor to floor height in inches by the number of risers to get the height of each riser.
4. Subtract 1 from the number of risers to get the number of treads.

5. To find the tread depth. Take the total horizontal run dimension and divide by the number of treads. If there is no stairwell or headroom issue, you can figure a 10” tread. Multiply 10” by the number of treads to get the total horizontal run for the stairs.

Stair Calculations Example

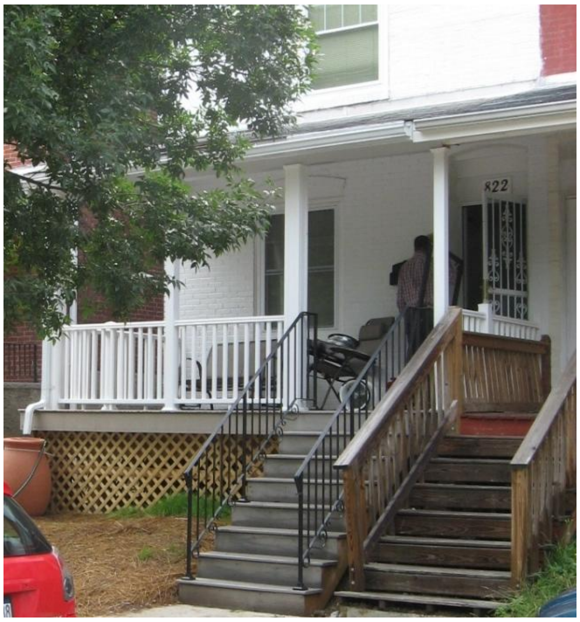
1. Floor to floor height: 8’ = 96”   96/7 = 13.17, therefore the stair will have 13 risers.
2. Then 96/13 = 7.38 which is about 7 3/8” therefore each riser will be 7 3/8”.
3. The number of treads is always one less than the number of risers, so there will be 12 treads.
4. If the ceiling height is less than 6’-8” plus one riser height, the total run must equal or be less than the well opening minus one tread.
5. Divide the length of the opening in inches by the number of tread depths that will be within the opening (13 in this case) to get the tread depth.
6. Opening length: 10’ = 120”   Tread depth: 120/13 = 9.23 = 9 ¼”
7. Total run: 9.23 x 12 = 110.76 = 9’-2 ¾”

Build a Set of Stairs

Measure the floor to floor height. The floor to floor height is ____________”.
Divide the floor-to-floor height by 7”: ____________ / 7” = ______________.
Round down to get the number of risers: Number of risers: _______________.
Subtract 1 from the number of risers to get the number of treads:
Number of risers: ____ - 1 = Number of treads ________

For this lab you will construct a set of stairs with 4 risers and 3 treads.
You will use a riser height of 7” and a tread depth of 10”

1. Measure diagonally between the locations of the bottom and top risers to get the length of the stringers.
2. For stair stringers two 2x12s are typically used. (2x10s can be used for steeper stairs but intermediate support and/or reinforcing of the stringer may be needed. If 2x12 or 2x10 lumber is not available, two layers of ¾” plywood can be used by cutting 11” wide strips from a 4x8 sheet and fasten together).
3. “Crown” the stringers by sighting along the edges to find the curve. You will layout and cut along the edge that is curved up.
4. Lay out the tread and riser cuts using a framing square. For a uniform layout, a straight piece of wood can be clamped to



Two relatively simple sets of stairs can be seen in this picture. Stringers, treads, risers and ballustrades (one wood, one metal) can be seen. (Photo courtesy of Paul Ricker)

the square at the rise and run dimensions. A sharp pencil and attention to accuracy are important.

5. Some needed adjustments to your stringer layout:
    a. If the risers sit over the treads, subtract the nosing overhang and the riser thickness from the tread cuts. For a 11 ¼” tread you will cut the stringers 9 ¼” for each step: 11 ¼” – 1 ¼” nosing – ¾” riser. (If the treads are set against the risers, or ¾” out from the riser cut, you would only have to subtract the nosing 1 ¼” nosing and cut the stringers 10” for each step).
    b. The thickness of the tread should be subtracted from the bottom riser. (A 7” riser – 1” tread thickness = 6” riser cut for the bottom riser. You will also need to use a narrower bottom riser.
    c. If the top riser will not be installed against the joist or header, subtract the riser thickness from the top plumb cut (the end that sets against the upper floor joist or header). You will also need to use a narrower top tread: cut the top tread to reduce the width from 11¼” to 10 ½”.
6. Marking the stringer ends, if they need to be cut to fit the framing of the stairwell at the head, can also be done at this time.
7. Using a circular saw at full depth, carefully cut the stringers as marked. Do not overshoot the corners.
8. Use the cut stringer as a pattern for marking the other stringers. Clamp them to make sure the ends are kept even and the edges flush while marking.
9. Separate the stringers and finish the cuts on the second stringer.
10. Use a hand saw or reciprocating saw to complete the cuts where they meet at the corners.
11. To place the stringers, typically a 2x4 “ledger” on which the stringers will rest, is fastened securely to the joist at the head of the stair opening. The stringers can be notched underneath to rest on the ledger. Remember to drop the top of the stringers to allow for the top tread. (Add the tread thickness to the riser height for the distance below the floor at the head).
12. . A 2” x 4” should be fastened between the stringers at the foot for uniform width and stability, and this can be fastened to the floor if desired. Fasten the treads in place making sure that the distance between the stringers is equal throughout the run
13. You will now install the risers. Many older basement stairs have open risers, but building codes now only allow 4” max. openings, so wood needs to be installed across the riser opening. Add the 1” x 6” riser material to build a closed stair. Hold them tight up and under the nosing of the next tread above, and secure with 6d finish nails. There will be a small gap at the bottom along the tread.

A very simple set of basement stairs can be built with relative ease in a pinch. Note that these steps have only treads and stringers. A proper set of stairs should have risers and a handrail or balustrade. (Photo ©)

Repair a set of stairs

A common stair repair an installer technician may encounter is a broken or missing tread. The important things to remember are that the final stair rise and run dimensions should match, and the new pieces should be securely installed with no protruding nails or screws.

1. Using a pry bar, remove the broken tread.
2. Measure the tread and find an equal sized replacement. If the material you have is different you will have to set it so the stairs have equal rise and run dimensions.
3. If needed, add 1" x 3" cleats along the stringer to raise the tread. (This may be needed to raise the new tread if it is thinner. Note that thinner treads will also need additional 2x4 support running between the stringers. Cut and install 2x4 blocks between the stringers to provide this additional support).
4. If needed, use a reciprocating saw or hand saw to cut the stringer tread cuts down. (This may be needed to lower the new tread if it is thicker).
5. Install the replacement tread, onto the stringers are secure with 8d finish nails that are set below the surface.

Clean-up work area and store tools and materials

1. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used as these are usually flammable and could contains VOC's (volatile organic compounds).
2. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.
3. Return any items or personal belongings that may have been moved or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
4. Complete a final check and clean your work area and the work site.

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Lab 7: Drywall Installation and Repair

Drywall is by far the most common material used to cover the inside of house framing. It can be used for both ceilings and walls. It is sometimes known as gypsum wall board (GWB) or sheet rock. This is because drywall is actually made of gypsum (a type of rock) plaster sandwiched between two sheets of thick paper.

Though drywall is commonly used because it is relatively easy and cheap to work with, it is also an important aspect of energy efficient homes. Though not a good insulator, drywall with two coats of paint on it is an excellent air barrier. Energy losses and moisture problems result if there are cracks or holes in drywall that allow air movement.

When this lab is complete, you will know how to install new drywall (called "hanging" drywall) and patch drywall that has already been installed.

Tools
Tape measure & Pencil
Drywall 48" T-square
Chalk line
Utility knife
Drywall Rasp
Drywall saw
Power driver/drill
#2 Philips screw bit with
Driver guide sleeve
Hole saw: 2 ½"
Hammer
Mud pan
6" taping knife
Dust Pan & Broom

Consumables
½" Drywall sheets
GWB Joint compound
GWB Joint tape (paper)
GWB Screws (1 ¼" coarse-thread
for wood)
Twine
Shims (7")
Utility Knife blades
Pencil
Trash Bags

Safety Equipment
Eye protection
Breathing protection
Hard hat
Hearing Protection

Approximate time needed to complete this lab: 3.5 Hours

Procedure

Cutting the drywall

Using a tape measure, measure the size of the piece you need to install. If you need to continue with additional pieces, remember to only go half way onto the stud so that the next piece will have something to attach to.

1. Mark and cut the drywall using a pencil, a T-square and a utility knife. Mark the finish side of the drywall with the measurements using the pencil. Use the T-square to get a straight line from a factory edge.
2. Use the utility knife to score the finish side of the drywall. (you do not have to cut all the way through the material.)
3. Fold the sheet back at the score line, to a 90 degree angle, causing it to snap. Cut the back side of the sheet while the sheet is folded at the angle.

Marking, Cutting, and Snapping the Drywall (from Left to Right). (Photos ©)

Installing or "hanging" drywall

1. Fasteners (screws) should be placed approximately 12" apart on walls and eight inches apart on ceilings.
2. If the framing is 24" on center, fasteners should be 8"-10" apart on walls and six inches apart on ceilings.
3. The head of the fastener should be just below the surface of the board to allow for finishing, but not so deep as to break the paper.
4. Construction adhesive can be placed on the framing to supplement the nails or screws.
5. Start with the ceiling *then* cover the walls from the *top down* for the fewest gaps or open joints in the field and corners, leaving any extra space at the floor where it is typically covered by baseboard.
6. Fasten drywall sheets to wall studs using the guide above. Place the drywall against the studs and attach with the proper thread and length of screw. Be careful to drive the screw in just far enough that it causes a dent, but does not break the paper. Adjust the driver/drill until you reach the right setting for installing the screws.

Finishing the drywall using joint compound

1. On the seam between 2 pieces of drywall, apply a thin layer of joint compound approximately 4 inches wide using a 4" or 6" taping knife.
2. Place a piece of joint tape over the seam and press it into the compound using the taping knife. Pinch one end of the tape, and with the knife at a 45 degree angle to the tape, pull the knife across the tape to the other end.
3. Install a coat of joint compound over the tape making sure the edges of the tape are completely covered.
4. Allow to dry thoroughly, then sand smooth

5. Add a wider finish layer of compound, let dry, and sand smooth. (If available, use a wide 10" or 12" trowel for this).
6. Remember, thick gaps and holes are better filled in layers, so if you must do a third coat, do so.

Hanging and Finishing the Drywall. To finish, compound is applied, drywall tape is embedded in the compound, then more compound is smoothed over top. (Photos ©)

Matching a drywall patch to the size of the hole

1. It is best if a drywall patch crosses at least two studs. If it is a small hole, one stud is sufficient.
2. Measure the drywall hole. If it is irregularly shaped, you may cut it to a regular shape (square or rectangle) by using a keyhole or drywall saw.
3. Draw the shape with the exact same measurements on a piece of drywall.
4. You may also use cardboard and string to trace an irregularly shaped drywall hole.
    a. Cut the cardboard so it is an inch or so bigger than the hole
    b. Cut a hole in the center, then insert the string and tie a knot so you can pull on the string and it will not come through the hole.
    c. Fold or bend the cardboard until it can fit through the hole, holding the string in the other hand.
    d. Pull the cardboard tight against the hole (the cardboard should be on the *inside* of the drywall).
    e. Trace the outline of the hole.
    f. Pull the cardboard out, cut it along the line you traced, and trace around the edges of the cardboard shape on a piece of drywall.

Cutting the drywall patch

1. Draw the line with a pencil and a t-square if regular, or with the cardboard shape if irregular. Mark the *finish* side of the drywall (the side that will be visible inside the home) with the measurements using the pencil. Use the T-square to get a straight line from a factory edge.
2. Use the utility knife to score the *finish* side of the drywall.
    a. If the cut is straight and goes all the way across the board, you do not have to cut all the way through the back of the drywall.

   b. Fold the sheet back at the score line, to a 90 degree angle, causing it to snap. Cut the back side of the sheet while the sheet is folded at the angle.
   c. If the piece is an irregular shape, cut all the way through the back of the drywall.
3. Use the drywall rasp to smooth the edges of the drywall,
4. Put into place and fasten to studs.
5. If the drywall is too big, use the drywall rasp to grind it to the right size.

Finishing
Follow directions above: "**Finish the drywall using joint compound.**"

Alternate drywall patch method
Using a hole saw the same way you would cut for dense packing, cut a hole and save the piece for the patch.

1. Start by preparing a shim or scrap piece of, "1 by" approximately 7" long by 2" wide. Loop a piece of twine, wrap it around the wood, and pull the ends through the loop.
2. Slide the wood into the hole while keeping the twine tightly wrapped around one finger and tight around the wood.
3. Use the twine to keep the wood firmly against the cavity side of the drywall and running across the center of the hole.
4. Use a drill/driver to screw through the drywall and into the wood, pulling the wood tight to the drywall creating a support for the patch on the inside of the wall cavity.
5. Insert the drilled out drywall plug into the hole and insert a screw in the center pilot hole. Use this screw to attach the plug to the wood support.
6. Using joint compound or spackle with a 6" taping knife, spread the compound over the patch, filling in the indentations from the screws and any gaps around the plug.
7. Allow to dry thoroughly, sand smooth, and add a finish layer of compound.

Remember, thick gaps and holes are better filled in layers, so if you must do a third coat, do so.

Drywall Patch. A small piece of wood may be fastened behind the drywall, then a plug fastened to the support. This would be finished with compound. (Photos ©)

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Lab 8: Installing a Pre-Hung Door

Replacing doors is not usually high on the priority list, because it is relatively expensive to do (doors themselves are expensive) and often does not save much money. However, in some situations, replacing a door is a very effective way to make the home more comfortable and reduce energy bills. A pre-hung door unit comes with the hinges in place and the door installed in a frame, also called the jambs or jamb set. The finish trim casing usually comes pre-installed on one side of the jambs. The door and latch-side jamb are pre-bored with holes to accept a standard lockset and strike plate. Pre-hung doors are available in standard size widths typically ranging from 24” to 36”. The door height is usually 6’-8” (80”). Exterior doors are usually 2/8 x 6/8, meaning 2’-8” (32”wide) by 6’-8” (80” high); or 3/0 x 6/8 meaning 3’-0” (36”wide) by 6’-8” (80” high).

After this lab is complete, you will know how to properly install a pre-hung door. There are also other door activities where you learn about adjusting existing doors and installing weather-stripping.

Tools
Tape Measure & Pencil
Hammer
Flat Pry Bar
Levels (2’ & 6’)
Utility Knife
Chisel
Hand Saw
Circular Saw
Drill
Screwdrivers
Wood Plane

Consumables
Pre-hung Door Unit
Nails; Screws
Lockset
Wood Shims
Caulking
Door Sweep
Weather-stripping
1” x 4”, or 2” x 4” (approx. 36”)

Safety Equipment
Eye protection
(Gloves)
Breathing equipment, if needed for LSW
Other PPE, if needed for

Approximate time needed to complete this lab: 5 Hours

Procedure

Check and Adjust the Rough Opening
Using a level, check the floor at the door opening, and door rough opening. Pay close attention to then hinge side stud for level, plumb, and square.
If possible and needed, adjust and shim the stud on the latch side of the opening to make the rough opening ½" to ¾" wider than the door frame's width. This allows a space around the door jambs for adjusting and shimming them.

Install the Door Frame or Jamb set

1. If the wall is out of plumb in different amounts on the two sides of the opening, the jambs will have to be installed with the difference split between the two sides and checked for plumb as it is fastened to avoid twisting.
2. Remove the door from the jamb, placing the pins in the door hinge knuckles to avoid losing them. Place the jamb into the opening. Use a 1"x 4" or 2"x4"spreader cut to the width of the door. Locate it at the bottom of the frame temporarily tacked between the jambs.
3. Check all sides for plumb and shim as needed. Space all the shim locations as evenly as possible. For the hinge side: top/bottom/ and behind each hinge. For the latch side top/bottom/ and behind latch area. A shim may be needed under one side to level the head jamb. No shims are need above the head jamb, although you can use them to help hold the door in place for fitting. Note that if the wall is out of plumb, the door will tend to either swing closed or swing open and hit the floor.
4. Make sure all corners are square, with no twist in the jamb and the jamb edges are as flush with the wall surface as possible, evenly taking any difference from both sides. Additional shims may be needed.
5. Drive nails or screws through the jambs into the trimmer studs at the top and bottom on each side where they will not interfere with the door just far enough to hold the jamb in place.
6. Replace the door on the hinges and put the pins in place but do not drive them all the way down.
7. Operate the door to make sure it closes properly against the stops and that all the gaps between the door and the jamb are equal. Adjustments can be made by pulling out certain nails, adjusting shims, and renailing as needed.
8. Nail or screw the jamb to the to the trimmer studs starting at the top of the hinge jamb and alternating sides checking frequently to make sure it doesn't drift out of place. Do not drive fasteners home until it is certain that all adjustments are correct. Removal of one or more fasteners to make an adjustment may be needed. Do not nail or screw the header. Use at least one long screw in the top hinge to minimize sagging. (If the screw head is too large for the countersunk hole in the hinge leaf, remove the leaf and locate the screw under it making sure it is flush with the bottom of the mortise). If possible adjust the door stop for a

tight continuous fit. If the stop is integral to the jamb, any remaining gaps can be taken care of with weather-stripping.

Mount the latch and lock hardware

1. Slip the latch bolt into its bore and the lockset into its bore to engage the bolt.
2. Fasten the latch plate into the mortise on the door's edge and the strike plate to the mortise in the latch jamb with the screws provided. If a mortise is too tight, outline it with a utility knife and cut to the outline with the knife or a chisel.
3. Fit the knobs to both sides of the mechanism bolt then insert and tighten the connecting screws that hold the knobs together.
4. Close the door and listen for the latch sliding into its strike. If the door rattles or the latch doesn't catch, bend the prong away from the stop or move the strike plate as needed. Tighten all the screws.

Fix a Sticking Door

Note: An installer technician needs to be accurate with door work. A 1/16" accuracy is needed, as this is often the difference between a door operating smoothly or sticking.

1. Before beginning, correct all loose hardware first.
    a. Tighten loose latch or strike plate if needed.
    b. To tighten a loose hinge, remove the door by taking out the pins and remove the screws from the loose hinge leaf. Whittle slightly tapered slivers of wood scraps to make plugs slightly larger than the screw holes and apply wood glue to them and into the holes. Tap the plugs into the holes and snap off flush with the surface.
2. Immediately reinstall the screws tightly to fasten the hinge leaf. This method can also be used for other screws that do not tighten by simply turning.

Shaving a Door

Note: An installer technician needs to be accurate with door work. A 1/16" accuracy is needed, as this is often the difference between a door operating smoothly or sticking.

1. The gap between the door and jamb should be 1/8 to 3/16 inch wide or about the thickness of a quarter. Never remove wood from the jamb to relieve binding but only from the door.
2. Scrape all paint off the door and excess paint from the jamb in the binding location. REMEMBER: Use Lead Safe Work (LSW) practices when working on old painted surfaces like doors, windows and trim.
3. If it still binds, mark the binding area with a pencil, remove the door from the opening, and shave down the wood with a hand or power plane. If working on the top or bottom, cut away from the corner of the door toward the middle.
4. If more than a small amount of wood must be taken off the door edge, it must be removed from the hinge edge of the door.
5. Take the door from the jamb. Make sure the hinge leaf edges are clearly marked, and then unscrew them from the door.
6. Mark the hinge edge for the amount to be shaved off. Using a chisel, deepen the hinge mortises by the same amount.

7. Use a straight-edge like the 6' level as a guide fence for the circular saw. Cut wood off the door edge, checking frequently to keep it square, and round the finished corners slightly with sandpaper to better accept paint.
8. Reinstall the hinge leaves, and re-hang the door.

Weather-Stripping

The door sweep or bottom shoe and the soft compressible strip of the side and head jambs wear out and need to be replaced periodically. Installing these requires attention to the balance between tightness and ease of operation. Caulking the weather-stripping and stops unless they are integral with the jamb is also advisable to eliminate leakage as much as possible.

A Fully Installed Door. Note the snug fit and framing components in the left picture. The weatherstripping (white stripe along the inside of the door frame) can clearly be seen in the picture to the right. (Photos ©)

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Lab 9: Window Glass: Cutting and Replacement

Window replacement is not a priority in weatherization work because it is generally not cost effective: there is a long payback period, or low SIR (savings-to-investment ratio). A new window unit plus installation is expensive, and the energy savings are not substantial. However, problems like broken window panes can be addressed in a cost-effective manner. The weatherization worker may have to cut and install a new glass pane to repair an otherwise sound window. This can eliminate a major air leak and water entry point as well add to security. Remember that old painted surfaces typically require Lead Safe Work (LSW) practices.

When this lab is complete, you will know how to properly and safely cut window glass and replace the glass pane in a window.

Tools
Tape Measure
Framing square
Glass cutter
Felt pen
Putty chaser
Screwdriver
Putty knife
Dust pan & brush

Consumables
Sandpaper: 80-100 grit
Glazing points
Glazing compound
Masking Tape
Container for glass pieces

Safety Equipment
Eye protection
Gloves
(PPE for Lead Safety)
(Hard hat)

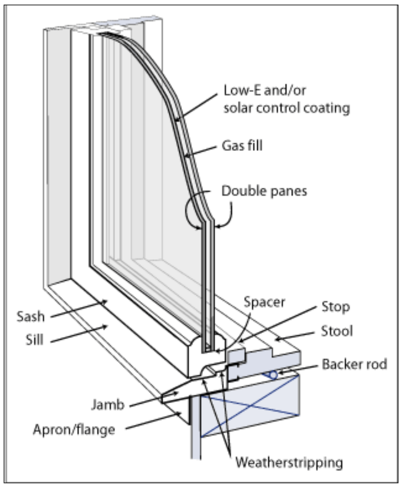
Approximate time needed to complete this lab: 4 Hours

Window Types and Components by Name

Originally made of wood, many of today's windows are also made of aluminum, vinyl, or combinations of the three materials, such as vinyl or aluminum clad wood, vinyl reinforced with aluminum, or aluminum with vinyl as a thermal break. Most of today's windows have two layers of glass that reduce their conductive heat loss, and some have coatings to reduce heat loss by radiation. In some older windows, the glass in each sash has multiple smaller panes, divided by smaller members called "muntins." Some newer windows have decorative muntins placed against one large glass pane to give them an older appearance.

Windows can open in two basic ways. The movable part is called the sash, and a window can have one or more sashes. Most sashes either swing out of the frame on hinges or pivots, or slide within the frame to another position. The channels in which a sash slides, on a double hung or horizontal sliding window, are called tracks.

The most common window is the "double hung," where two sashes slide vertically past each other. A "single hung" window has a bottom sash that can be lifted but the top one is fixed permanently in place.



Basic Window Components. (Image courtesy of US DOE).

Procedure

Note of Caution when Repairing Older Windows

PPE for this work includes gloves, goggles and breathing protection. Older windows should be assumed to have lead-based paint unless testing indicates otherwise, or the unit is known to have been made after 1978. Wet scraping technique should be used when removing any paint, to minimize dust. Possible flying chips of paint, wood or glass, and sharp edges also make gloves and goggles necessary.

When diagnosing difficult operation in a wood window, the first thing to check is excessive paint in multiple layers. Paint in the channel, or track, on the stops, or on the sash where it contacts the stops, should be scraped off. If the house was built in 1978 or earlier, be sure to use lead paint protocols (LSW). The window zipper is a useful tool to cut through the paint layers, and saves a lot of time, but it does chip the finish in the process. It may also be necessary to remove the stops, especially for the upper sash, which are often more in need of attention because they are opened less frequently.

Measure the opening for the glass. The objective is to cut a piece of glass that is about 1/8" shorter in both directions than the measurement. This should accommodate most unevenness in the glass edges. A smooth, level working surface is needed ideally covered with a firm but resilient material such as a rubber sheet.

Cutting Glass

Prepare for the cut

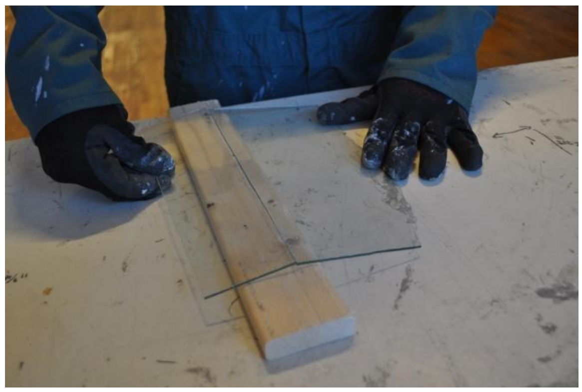
1. Clean any dust and dirt from both sides of the glass where it is to be cut. If re-using old glass, remove all paint, putty, glazing compound, etc. prior.
2. Carefully make a small mark on the glass with a felt pen or crayon at the location of the cut. Remember to make the cut 1/8"-1/4" short of the desired length.

Score the glass

1. Using the blade of the framing square as a straightedge, hold a framing square on the glass so that the cut will be at a 90 degree angle to the existing edge (the larger leg of the framing square is called the blade and the smaller leg is the tongue). Holding the tongue of the square against the edge of the glass is helpful in holding the straightedge in place.
2. Place the upper part of the glass cutting tool between the first and second fingers with the forefinger and thumb gripping the flat part. The wheel should point down and the side of the tool should be against the straightedge.
3. After making sure the straightedge is correctly in place, start with the tool at the farthest point away, make sure to start the cut right on the edge, and draw it toward you applying firm and even pressure all along the line. The sound should be similar to paper tearing or duct tape being pulled off a roll.

Complete the cut

1. Place the glass with the score line up and directly over the edge of the bench. With one hand holding the glass firmly flat on the bench, apply downward pressure with the other on the part that hangs over, starting at one end of the score and the glass should beak cleanly along the line.
2. Any small pieces remaining can be broken off by using the notches on the glass cutting tool.
3. Lightly sandpaper the corners of the edge to reduce sharpness.

Scoring and Completing the Cut. (Photos ©).

Glass Replacement

The following points are important to remember while installing glass:

- Care must be taken not to damage the wood. Avoid motions that result in slipping, and potential injury.
- Downward pressure on the tool works best but sideways pressure can also be useful.
- Place the blade edge where the putty or glazing compound meets the wood.
- Take advantage of any cracks or openings in the compound or between the compound and the wood.

- Using the tool as a lever, apply concentrated shearing force to separate the two materials.
- Moving the handle of the tool back and forth to work it into a joint or crack is an effective variation on this technique.
- Light taps with a hammer can help but may increase the risk of damaging the wood.
- Waste from this operation must be disposed of properly. This is especially important because it may contain sharp pieces of glass and lead based paint.

1. Remove the sash from the frame, lay it on a bench or work table, and clean all of the old glazing compound, putty and glass from the sash. Glass that remains in the sash usually becomes loosened by removal of putty, however stubborn bits of glass may remain and care must be taken to avoid injury from pieces that may fly off as material continues to be removed. The work of cleaning old compound from a sash is normally done using a putty knife with a stiff blade. A chisel is not recommended because the edge could become severely dulled and nicked.

A tool made by Prozi[SM] especially for removing old putty from a sash is called the "putty chaser." It attaches to a drill and has a flat blade similar to a blunt screwdriver. As it spins, it knocks away the old material. While this tool can save time in the hands of a skilled operator, it can also be very dangerous or damaging, and is recommended for use only by someone thoroughly familiar with the properties of the tool and materials. It can also generate a significant amount of toxic dust.

Photo ©

2. This should leave a "rabbet" or L-shaped groove in the inside edge of the sash stiles and rails, on the exterior face of the sash. Apply primer to the bare wood and allow it to dry.
3. Cut a piece of glass that is 1/8" to 1/4" shorter in both directions than the inside dimension of the rabbet, and check to make sure it fits in the opening.
4. With a putty knife, lay a bed of glazing compound on the horizontal leg of the rabbet, about 1/16" thick. Lay the glass on the bed, and gently work it into place, until the glass is completely in contact with the glazing compound. Be careful not to exert excessive or uneven pressure, which could break the glass.
5. Install glazing points by placing them on the glass surface, at least one per edge but no more than 16" apart or 8" from a corner, and push the points into the wood using a screwdriver or putty knife.
6. Lift the sash and scrape off all excess compound that squeezed out of the bed.
7. Lay the sash back down, and fill the remaining space in the rabbet with a bead of compound that is angled from the top edge to a line on the glass even with the bottom edge. The putty knife can be used to compress the compound and achieve a smooth surface. The compound can be primed and painted after about 24 hours.

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Lab 10: Window Replacement

Window replacement is not a priority in weatherization work because it is generally not cost effective: there is a long payback period, or low SIR (savings-to-investment ratio). Removal of an old window plus the cost and installation of the new unit is expensive, and the energy savings are typically not substantial. However, sometimes deteriorated and leaky windows call for new replacement units to be installed. A weatherization installer may have to know how to remove an old window; prepare, insulate, and flash the opening; level, shim and secure the new replacement; and install and seal all trim. A new window unit can eliminate a major air leak and water entry point, increase insulation, and add to the security of the occupant. Remember that old painted surfaces typically require Lead Safe Work (LSW) practices.

After this lab is completed, you will be able to assist in the installation of replacement window units.

Tools
Tape measure & pencil
Level
Flat pry bar
Utility knife
Hammer
Screwdriver
Hand saw
Miter saw
Staple gun
Dust pan and broom

Consumables
Window
Shims
Screws; nails
Low-density foam
Caulk
Housewrap
Staples
Housewrap tape
Drip cap flashing
Flexible tape flashing
Casing
Rags
(LSW materials: poly sheeting, tape; trash bags)

Safety Equipment
Eye protection
Gloves
Breathing protection
(PPE for LSW)

Approximate time needed to complete this lab: 4 Hours

Procedure

The Drainage Plane and Flashings

The roof, walls, and foundation are parts of the building envelope or shell. They all work together to provide drainage down and away from the house. This important continuous layer which keeps water out of the house is called the drainage plane. For the roof the drainage plane includes the roofing coverage materials, the underlayment, and the flashings. For the walls, the drainage plane is the layer of housewrap, building paper, or sealed rigid foam covering the wall sheathing and located under the siding. This layer also serves as an outside air barrier to minimize the wind effect. Together with the flashings around openings, this drainage plane is critical to keeping moisture out of the building (Most siding does not keep out all the water. For example, wind-driven rain is often pushed up and around siding; wood shingles breathe; and cement-based stuccos absorb).

Like with roofing, each piece of housewrap or flashing should be placed so its high end is under the next piece above; each piece's low end will then be on top of the piece below. As gravity (the force which pull things toward the ground or earth) pulls water down the walls there is always drainage material to prevent the water from getting behind and onto the wood sheathing. As walls are vertical and the water is being pulled down by gravity, this shingling effect provides drainage down the wall. At the base of the wall the yard should be sloped away from the house to keep the water from building up and entering. There is often a grading issue that needs to be addressed where the yard outside slopes back toward the house. This causes water to always drain against the building and run along the foundation and enter the basement or crawl space.

Window Replacement

There are two basic approaches to window replacement:

1. Full replacement, where the entire frame is removed and the new window is installed in the rough opening, and
2. Partial replacement, where only the sashes and tracks are removed and the new window is installed in the existing frame.

In either case, the replacement window is essentially the same except for the size and the procedure of actually installing the window itself is also very similar. The difference is in the flashing, siding, trim and casing. Different building techniques will require different materials and windows. For example, for a masonry building new or replacement windows install inside a new or existing frame and there is no housewrap or siding. For wood frame construction, a replacement can be fit inside an existing frame or a rough opening; or a new construction window could be installed in a rough opening with outside nailing flange that fits against the outside wall. This installation would require housewrap, flashings, and siding work on the exterior around the new window. Always read and check manufacturer's specifications for installation. There will be details about unpacking; preparation and size of rough opening; sealant location and type; fasteners; and installation instructions including shimming and securing.

Carefully measure the opening

1. Measure the opening diagonally in both directions. If there is more than 1/4” difference between the two dimensions, the opening is out of square. Use a level to determine if the verticals, horizontals, or both, are off. This will determine what adjustment to the measurements will be needed as noted below.
2. Measure the depth of the opening. The thickness of the replacement window can be less than this but should not be more.
   a. For a partial replacement, this is the distance between the inner and outer stops.
   b. For a full replacement, this is the thickness of the wall including the inside finish and the outer sheathing but not the siding. It may be necessary to find this dimension in another location in the house. For a conventional wood frame house it is typically 4-½” to 5”.
3. Measure the width of the opening at the top, bottom and middle and record the smallest dimension. Do the same for the height.
   a. For a partial replacement, the height is from the top of the sill just below the stool to the bottom of the head.
   b. For a full replacement, it may be necessary to remove the casing on the inside to accurately find these measurements.
   c. Be sure to deduct ½” to 3/4” from the opening size in both directions for shimming and adjustment to square and allow for flashing at the sill if installing in a rough opening. Some manufacturers automatically make this deduction, so find out whether they do that.
   d. If the diagonal measurements are different, deduct an additional 1/3 of the difference from the measurement between the opening limits that are out of plumb or off level.
4. Depending on the expected turnaround time and weather, it may be necessary to take temporary measures to secure the opening until the replacement window is delivered. (Turnaround time is the time it takes from ordering a window until it is manufactured and made available to be installed, typically 2 to 6 weeks).

Replace the window

1. For a partial replacement, prepare the opening by:
   a. Remove the inner stops, sashes, parting beads, pulleys, sash cords and weights.
   b. Fill the weight pockets with insulating materials. Use dense pack cellulose insulation if it is one of the weatherization measures being used in the house. Otherwise, fill them with non-expanding foam, or stuff with fiberglass.
   c. Replace the old weight pocket covers, and caulk them.
2. For a full replacement, remove the entire window frame and casing. Repair framing and sheathing if needed and install flashing. For a full replacement, the opening must be properly flashed and the outside of the replacement is flush with the sheathing.
3. Drainage plane and air barrier housewrap should be installed over any exposed sheathing to ensure proper wall drainage. Start at the bottom of the wall and work your way up, so that the higher/upper pieces always cover the lower piece. Cut the paper with the utility knife, attach with staples, and seal all seams with house wrap tape. For the window opening, first cover right over

the opening; this extra material will be folded back to flash the frame. Then go back and slice the paper in the opening with a capital letter I shape. Fold the lower back piece over the rough sill; wrap the side pieces around the sides of the rough opening; and leave the head piece loose. When installing the window you will slide any drip cap flashing or top nailing flange under this paper.

4. Flashing for the opening is done in stages. The housewrap window flashing is done as above, or can be done with separate pieces after the walls are papered. Remember always work from bottom up, with the piece above covering the piece below. Then the rough sill is flashed with special flexible panning-type tape or pre-made 3-piece rigid sill pan. Measure the opening width and add 4” to 6” to have enough material to flash the corners and up the sides. Then flash the sides with flexible tape. Wait to flash tape the top until after the window is installed.
5. Before installing the window, caulk the inside edges of the outer top and side stops so the window will seal against them. Then install the replacement unit in the opening against the outer stops. Using a level make sure the unit is as plumb as possible side to side and inside to out. (Note: If the window is a new construction type, it will have outside nailing flanges. This type window is installed from the outside: it does not need stops in the rough opening to sit against. The caulking is put on the back of the top and side nailing flanges, and the window is set in the opening from the outside with the flanges against the outside wall).
6. Shim as needed for stability taking care not to stress the frame of the replacement unit. Shim under the bottom of the sill at the sides; shim behind the sides near the top and bottom, behind the screw holes if possible. The head does not usually need to be shimmed.
7. To allow for adjustment, partially drive the top left screw, then the bottom right, top right and bottom left screws, checking regularly for plumb, level and square. Keep the window level to within 1/16”. Gradually tighten the four screws, then check for proper operation. (Note: A new construction window is secured in place by nailing through the outside nailing flange usually with 6d common galvanized nails or similar. Nail near the outer edge of the flange so that flashing tape added later will cover the nail heads. Nail from 3” to 10” from each corner, and regularly spaced around the window. The top flange will go under the house wrap flap above the window to create positive drainage. It can then be taped to the sheathing. If it is on top of the paper, make sure it is sealed well with flashing tape).
8. Fill any openings around the frame with non-expanding foam where possible. (For the new construction window, install flashing tape over the exterior side and then top flanges. Do not tape the bottom flange: if any water gets in this will allow it to drain out onto the housewrap and down the wall. Check all around the window to verify drainage).
9. After securing and filling around the frame, install the head extender piece and all finish trim such as inside stops and casings. Finally caulk all-around the trim to seal in & out. (For the new construction window there is siding work to be completed to fill in around the window).
10. A final visual check is made to verify proper drainage.
11. The blower door can be set up and used with a smoke test to verify air tightness of the window and around the window opening.

Clean-up work area and store tools and materials

5. Clean up and safely dispose of all scrap and debris. Sort materials so that reusable material is organized, saved, and stored. Be careful to properly dispose or store any solvents used as these are usually flammable and could contains VOC’s (volatile organic compounds).
6. Pick up, check condition, count, and put back all tools and equipment. Report any damaged or missing tools to your crew leader or instructor.
7. Return any items or personal belongings that may have been moved or covered during the work process. Make sure that they are handled carefully, reinstalled in their original location, clean, and in sound working condition. (This is a standard work item when working in occupied homes).
8. Complete a final check and clean your work area and the work site.

Installed Window from the Inside Looking Out. The photo to the left clearly shows the framing components around the window, and the photo to the right shows a window fully trimmed within a drywall-covered interior. (Photos ©)

Weatherization and Retrofit

Energy Coordinating Agency

APPENDIX H

Manual Four Quizzes

Quiz 1: Weatherization Installation Technical Applications

Name: _______________________________ Date: _______________

1. A flat roof has a pitch less than what?
   a. 2/12
   b. 1/12
   c. 12/3
   d. 0/12

2. The material attached to a roof in an overlapping manner used to drain rainwater away from the structure is called what?
   a. Vapor barrier
   b. Shingles
   c. Membrane
   d. Asphalt

3. True or False. It is best to install an attic hatch by cutting through ceiling joists.
   a. True
   b. False

4. Fastening drywall to wall studs is commonly called what?
   a. Hanging drywall
   b. Framing drywall
   c. Fastening drywall
   d. Closing drywall

5. When fastening drywall, the fastener (screw) should to at last how many inches into the framing member?
   a. 3”
   b. 5”
   c. 7”
   d. 1”

6. Drywall finishing is done using what?
   a. Hammer and pry bar
   b. Joint knife and corner trowel
   c. Utility knife an plane
   d. Level and t-square

7. What are the horizontal parts of a staircase that are stepped on, commonly called "steps"?
    a. Boards
    b. Treads
    c. Railings
    d. Guards

8. On most staircases, what are the items in question 7 supported by?
    a. Stringer
    b. Spindle
    c. Baluster
    d. Treads

9. Which type of saw is mounted to a narrow table, and is commonly called a "chop saw"?
    a. Reciprocating saw
    b. Table saw
    c. Miter saw
    d. Hack saw

10. Which part of a door assembly is the strike plate and hinges attached to?
    a. Jamb
    b. Jack stud
    c. Header
    d. Top plate

11. What is a simple and inexpensive way to make windows and doors more efficient?
    a. Add low-e glass
    b. Replace them
    c. Add weather-stripping
    d. Paint them

12. True or False. If a roof has shingles, it does not need a water tight layer underneath.
    a. True
    b. False

Weatherization and Retrofit

Energy Coordinating Agency

APPENDIX I

Animations

The following list indicates where each animation icon can be found in the book. Note that many of the concepts may be covered in other areas of the manuals, but the pages below are where the concepts are most thoroughly covered. The CD with the animations is attached to the back cover of this book.

Glossary

Air barrier (air boundary): the parts of the building shell (or exterior wall) that resist air infiltration from the exterior to the interior of a house, or vice-versa.

Air changes per hour (ACH): the number of times that all of the air in a house is replaced by outside air through air leakage and/or forced mechanical ventilation (from a furnace) in one hour.

Air leakage: uncontrolled movement of air through gaps in the house's air/pressure boundary.

Backdraft: combustion gases from household combustion appliances (such as furnaces, hot water heaters and gas-fuelled clothes dryers) that do not exhaust up a house's flue or chimney. Backdrafting is the same as spillage, but lasting a minute or more. Excessive backdrafting can be an extreme health and safety hazard. See spillage.

Balloon framing: a construction method of house building used in the early 20th century that used long wooden studs and beams to construct exterior walls. The first floor's exterior walls were constructed on the building's foundation or sill plate with floor framing then attached to the vertical studs. A cavity was thereby created between the wall studs that permitted air to travel from the basement through the exterior walls up to the attic. This was the lightest and most economical form of construction and has since been replaced by "platform" framing". A safety issue was created by this type of construction due to the lack of fireproofing between the floors (where the long vertical studs bypassed the floor construction at the exterior walls).

Base load: energy used in the home that does not vary much with seasonal changes in weather. Common base load appliances are washing machines, lights, hot water heaters, and household electronics.

Batt: a narrow (usually 15" – 16" wide) blanket of insulation used to fill the spaces between studs in walls, ceilings and floors. Batts most often come in a large roll and are made of fiberglass. They can be "faced" (have paper or foil glued to one or both sides of the blanket) or "unfaced" (fiberglass only).

Blower door: a diagnostic tool used to locate the points of air infiltration and to evaluate the rate of total air leakage in a house's exterior envelope.

British thermal unit (BTU): The quantity of heat required to raise the temperature of one pound of water by one degree (Fahrenheit).

Building cavities: voids or empty spaces inside walls, floors and ceilings and between the interior and exterior wood sheathing of a house's envelope (shell).

Building science: an approach to weatherization that uses modern technology to study building construction, maintenance, safety and durability in an effort to increase energy efficiency.

B-vent: a double-walled flue pipe for gas- or propane-fired combustion appliances.

Bypass: a channel, gap or space in the air and thermal boundaries in a house in which air passes into or out the envelope (shell or exterior wall).

Can't reach 50: a mathematical factor when using an analog blower door instrument used when the pressure difference between the exterior and interior of a house cannot reach of value of 50.

Carbon dioxide (CO_2): a chemical compound (gas) that is one of the two main byproducts of the complete combustion of a hydrocarbon, the other being water vapor.

Carbon monoxide (CO): a gas that is tasteless, odorless, colorless and poisonous that is a by-product of incomplete combustion of fossil fuels. It is usually caused by a lack of air to support combustion or impingement (blocking or clogging) of the flame of a household combustion appliance.

Caulk: A compound commonly supplied in tubes used for filling joints, cracks and gaps in house construction.

Celsius: a temperature measurement scale based on water thermodynamics where water freezes at 0 degrees centigrade (C) and boils at 100 degrees C (see also: *Fahrenheit*).

CFM_{50}: rate of air leakage from a building, in cubic feet per minute, at a 50 Pascal pressure difference between the inside and outside of the home. A blower door must be used to achieve CFM_{50}. A blower door achieves this by forcing air out of the home at a high rate, thus depressurizing it.

$CFM_{natural}$: amount of air leakage in a building, in cubic feet per minute, under natural conditions. $CFM_{natural}$ can be thought of as the "breathing" rate of a building.

Chaseway: vertical cavity or shaft within a house for the purpose of conveying pipes, ducts, etc. through the house and are common sites for significant air leakage.

Cladding: layer of material attached to the outside of sheathing, used for air and moisture control, and aesthetic purposes. Common examples include siding, stucco, and facades.

Combustion air: air that chemically combines with fuel to produce heat. Oxygen is necessary for combustion to occur; combustion air supplies oxygen for this purpose.

Combustion appliance zone: area where combustion household appliances are located, usually in the basement or a closet area of a house.

Compact fluorescent lamps (CFLs): a fluorescent light bulb (lamp) that uses approximately 75% less energy than incandescent bulbs. CFLs are designed to fit into standard incandescent fixtures.

Condensation: the conversion of a gas to a liquid state.

Conditioned air: air that has been heated, cooled, humidified or dehumidified to maintain the desired level of comfort inside a home.

Conditioned space: rooms and spaces in the home that are heated or cooled for the comfort of occupants.

Conduction: the transfer of energy from particle to particle through a material. An example of heat transfer via conduction is when a pot is placed on the burner of an electric stove and heats up.

Convection: the transfer of heat in liquids and gases; the movement of air or liquid that loops as heat rises in a space and cooler air or liquid moves to replace it.

Convection loop: a continuous, closed system where warm air or fluid rises and is replaced by cold air or fluid, causing thermal movement. In an enclosed space, warm air in the center rises, while air in the perimeter flows down due to heat variations in the space.

Conventional slope roof: a roof with a pitch greater than 4/12. See "pitch."

Crawl space: the space beneath the ground floor of a house in lieu of a full basement.

Cubic feet per minute (CFM): a standard measure of air movement used in weatherization. A cubic foot of air is the amount of air that would fill a box that is 1 foot on each side.

Cure: used in reference to spray foam insulation, the process of expanding and hardening of a material.

Delta T (ΔT): difference in temperature. If two areas have a delta T between them and are able to interact, heat will flow from the area of high to low temperature until the temperatures are the same.

Delta P (ΔP): difference in pressure. If two areas have a delta P between them and a pressure barrier is not dividing them, air will flow from the area of high to low pressure until the pressures are the same.

Dense-pack insulation: loose insulation that is blown into building cavities to a specific density or thickness that substantially reduces air leakage and provides a thermal barrier.

Dew point: the temperature air must reach for its water vapor to condense into a liquid. A relative humidity of 100% indicates the dew point has been reached, and the air cannot fit any more water vapor in it.

Direct leakage: occurs where a break in the air barrier of a building allows air to travel in both directions at the same time. Open doors and windows are common examples.

Draft: the movement of exhaust air from a furnace or hot water heater through a chimney flue. A good draft is important to maintain because it gets rid of pollutants. Draft is the result of a number of factors, the most important one being the fact that heated air rises.

Drywall (gypsum wall board, GWB): gypsum wall board that comes in 4 foot by 8 foot sheets with thickness ranging from 1/4" to 5/8" that is applied to vertical wall studs to provide a "finished" wall ready for the application of paint. This product replaces plaster and lath for interior wall finishes.

Eave vent: vent opening located in the soffit under the roof eaves to allow the passage of fresh air into and through the attic.

Elastomeric coating: polymeric material such as acrylic used to resolve roof leaks on any type of roof. This product is used mainly in reference to cool roof coatings and is designed to reduce solar heat gain in the house.

Energy audit: the process of using building measurement tools and methods for identifying energy efficiency opportunities in a house.

Energy efficiency: using less energy to achieve the same goal or function without changing behavior. Weatherization is a process that achieves energy efficiency because the homeowner uses less energy without having to do anything differently. Using a more efficient furnace to heat a home is an example of energy efficiency, because the home is heated just as well with less energy than before.

Energy Efficiency Ratio (EER): an efficiency rating for air conditioning and heat pumps.

Evaporation: when a liquid changes to a gas.

Envelope: the area of a building that separates conditioned space from unconditioned space (inside from outside).

Evaporation: the transformation of a liquid into a gas form.

Excess Air: air in excess of what is required for combustion.

Exfiltration: the movement of conditioned air out of a house, often caused by three driving forces: wind, stack effect and mechanical.

Fahrenheit: a temperature measurement scale based on water thermodynamics where water freezes at 32 degrees F and boils at 212 degrees F. See also: *Celsius*.

Fiberglass: a fiber material of spun molten glass used in common house insulation.

Flashing: thin, continuous layer of waterproof material (often made of sheet metal) that keeps water out of and/or away from a given area. Flashing causes water to run over and away from an area, instead of soaking in it.

Flat roof: a roof with a pitch less than 2/12. See "pitch."

Flue: an exhaust pipe that vents combustion gases out of the home.

Glazing: the glass portion of a window or door which can be single-, double- or triple-paned with different thicknesses, tints and other characteristics.

House as a System: components of a building are connected to each other. For a home to be comfortable and energy efficient, all of the parts must work together.

Humidity: the amount of water in the air. Water in the air is in the form of a gas, and is called water vapor. "Humidity" is often used in place of "water vapor."

Incandescent lamp: a bulb (lamp) that produces light by running electricity across a thin filament producing heat. The original and now outmoded lighting device.

Indirect leakage: occurs when a break in the air barrier of a home is small enough that air can only travel in one direction at a time. Indirect leaks are often difficult to detect without specialized equipment.

Indoor air quality (IAQ): refers to the healthiness (or unhealthiness) of air inside of a building; closely related to indoor air pollution. Common sources of poor IAQ include cleaning products, combustion appliances, mold/mildew, and paints and other home improvement materials.

Infiltration: the movement of outdoor air into a house through cracks and penetrations in the house envelope due to depressurization, exfiltration, wind, stack effect, and/or convective airflow.

Insulation: material with relatively high thermal resistance that is used in house construction, mostly in the house's shell.

Knee wall: wall in a finished attic that reaches from the sloped ceiling to the floor, and is thus shorter than the other attic walls. The small triangular space behind the knee walls usually about three feet high. It is often poorly (or not) insulated, especially in older homes.

Knob-and-tube wiring: an early system of electrical wiring consisting of insulated copper conductors supported by porcelain knobs (along their lengths) and tubes (when passing through framing members) which were widely used from the 1880s until the 1930s. Most states now require replacement of knob and tube wiring before installing any sort of insulation that will come into contact with it.

Light emitting diode (LED): a light bulb that is very small (around ¼" in diameter) that contains a special material that lights up when electricity runs through it. LEDs use about 20% - 25% as much electricity as incandescent bulbs, and last about 25 times longer.

Loose-fill insulation: small pieces of insulation fiber blown into a house's exterior wall using a machine especially effective at filling small and irregularly-shaped spaces within the wall.

Low slope roof: a roof with a pitch between 2/12 and 4/12. See "pitch."

Make up air (replacement air): air that replaces air that was exhausted through a chimney in a house. Make up air enters a house through air leaks in the house's shell or envelope, intentional openings (i.e., doors and windows) or ducts.

Manometer: an electronic device for measuring air pressure differences and air flow. It is used in a blower door test to show how leaky the building is.

Mastic: a thick, pasty substance used to seal seams and cracks in building materials and construction. Mastic is heat resistant, mostly air tight, easy to apply, and non-toxic. It is commonly used to seal ductwork.

Mildew: a coating of whitish fungi found in damp conditions on organic materials such as cloth, paper or leather. Mildew is mold at an earlier stage in its development (see "mold").

Mold: a growth of very small fungi on vegetable or animal matter associated with decay or dampness in a house. Mold needs water, heat and food (organic matter such as wood, paper or food matter) to live.

Natural ventilation: using natural processes (no mechanical or electrical equipment) to remove air from inside to outside a building. Actions such as opening windows and chimney dampers are examples of natural ventilation.

Off-gassing: when chemicals in products (such as household cleaners, paint, and some weatherization materials, such as spray foam) evaporate at room temperature and normal pressure. Off gassing is a major source of *indoor* air pollution, and can cause health problems.This evaporation can sometimes continue for years after the products are used.

One-part foam: an insulation product that comes in spray cans and spray guns that is best suited for filling gaps and holes less that 3/4” in diameter in a house’s construction.

Open combustion furnace: furnace that draws combustion air from inside the home. Open combustion causes depressurization and can lead to infiltration.

Pascal (Pa): metric standard used for pressure. It indicates force per unit area, like pounds per square inch (psi). One psi is equal to 6,895 Pa.

Party wall: common wall shared between two housing units. This is common in rowhomes and townhouses.

Pitch: the angle of a roof above the horizontal. It is expressed as a fraction of 12, e.g. 4/12, 3/12, 2.5/12, etc. A flat roof has a pitch less than 2/12; a low slope roof has a pitch between 2/12 and 4/12; and a conventional slope roof has a pitch greater than 4/12.

Platform framing: a system of framing a house in which the floor joists of each story rests on the perimeter wall top plates of the story below (or on the foundation sill at the first story). This system has replaced balloon framing for new house construction.

Polyethylene: polymer plastic sheeting used for vapor and air barriers, mostly on the exterior envelopes of houses.

Polystyrene insulation: a rigid plastic foam insulation board used in house construction.

Polyurethane foam: a versatile plastic foam insulation that is sprayed or injected into a wall cavity. Use of this product requires certain safety precautions.

Pressure boundary: the surface air barrier that separates inside conditioned space from the surrounding environment outside the house.

R-value: the ability of a material to resist heat transfer. Higher R-value means better thermal resistance.

Radiation: heat energy that travels from a heat source through air to warm a surface.

Radon: a dangerous radioactive gas. Radon is considered a household pollutant that comes from the ground through rocky soil into the basement or crawl space of a house. Measures are required to mitigate radon if it is found.

Relative humidity (RH): a measurement of how much water vapor is in the air compared to how much it could possibly hold. For example, a 50% RH means that the air has half the amount of water vapor that it can hold (it's 50% saturated). Completely saturated air has a 100% relative humidity.

Roof vent: a louver or small dome mounted on a roof (often near the ridge) to allow for the passage of air through the attic to the exterior.

R-value: a measurement of resistance for materials and surfaces (walls, roofs, floors and ceilings) in terms of transfer of heat. The inverse of an R-value is a U-value (1/R).

Savings-to-investment ratio (SIR): a calculation that determines the cost-effectiveness of weatherization measures by dividing the estimated savings over the lifetime (months or years) of the measures installed. SIRs values of greater than "one" are regarded as cost-effective under the U.S. Department of Energy's standards.

Sealed combustion furnace: furnace that draws combustion air from outside the home, avoiding depressurization of the building.

Seasonal load: Energy use that varies depending on the time of year. Space heating and cooling are usually seasonal loads.

Shingle: material attached to roof in a overlapping manner, used to drain water away from the roof structure.

Soffit: the underside of a roof overhand or a lowered part of a room's ceiling (typically above a bathtub, shower or kitchen wall cabinets) framed with wood studs and covered with gypsum wall board which is often not insulated.

Solar heat gain coefficient (SHGC): the percentage of solar radiation a window, door, or skylight allows through. An indicator of solar transmittance.

Solar gain: heat from the sun absorbed by a house's materials and contributing to the heating and cooling requirements of the house.

Spillage: the flow of combustion gases from a household combustion appliance that does not exit through the flue or chimney but rather inside the building. This causes a dangerous situation for the occupants.

Stack effect: warmer air typically rises and is replaced by cooler air at the lower parts of the house, resulting in differences in air pressure in the house.

Stringer: the (vertical) portion of stairs that support the treads. See "treads."

Thermal boundary: combination of the air barrier and insulation of a building's shell.

Thermal break: an element (or piece of house construction commonly found in the exterior wall of a house) of low thermal conductivity placed in an assembly (e.g. metal window or door frame) to reduce or prevent the flow of thermal energy (heat or cold air). .

Thermal bridge: material that allows rapid conductive heat transfer, found within a larger area of higher thermal resistance, e.g. wood framing within an insulated wall.

Tread: the (horizontal) part of stairs that are stepped on. These are commonly referred to as "steps." See "stringer."

Two-part foam: a triple-expanding foam appropriate for larger and more numerous house air leaks and for insulating crawl space walls and other large house areas. Two-part foam comes in portable two-tank kits and truck-mounted rigs.

U.S. Department of Energy (DOE): the federal government agency whose mission is to advance energy technology and to promote energy-related innovations.

U.S. Department of Housing and Urban Development (HUD): the federal government agency charged with rule-making and enforcement of the housing code.

U-factor: the rate at which a window, door, or skylight conducts non-solar heat flow. It is usually expressed in units of BTU/hr*ft^2. U-factor is the reciprocal of R-value.

Vapor barrier: any material that allows zero or almost zero water vapor through. Common examples of vapor barriers in weatherization are plastic, exterior-grade plywood, aluminum foil, and asphalt shingles.

Vapor retarder: any material that slows the diffusion of water vapor through it. Many materials in weatherization are vapor retarders, including plywood, drywall and OSB.

Ventilation: intentional air movement in a house for improving the house's indoor air quality (IAQ) by supplying fresh outside air or removing indoor air that contains pollution, moisture or unwanted heat.

Vermiculite: a heat-expanding mineral once commonly used for house insulation.

Water management: measures to avoid damage to the house's components. Construction strategies include: sloping the ground away from the house's foundation, ensuring properly functioning gutters and downspouts, retention and reuse of rain and grey water and using porous surfaces (paving material that permits water penetration) for sidewalks and driveways to avoid water runoff into the municipality's sewer system.

Weatherization: decreasing energy consumption and increasing comfort in buildings through energy efficiency improvements. This includes a wide variety of measures that impact the building envelope, heating and cooling systems, electrical system, and electricity consuming appliances. Examples include adding insulation, upgrading to more efficient furnaces, and air sealing.

Weatherization Assistance Program (WAP): the United States Department of Energy's program whose mission is to increase the energy efficiency of houses occupied by low-income Americans and to reduce their energy costs while also safeguarding the occupant's health and safety.

Weatherization measure: an action taken that helps to weatherize a building (see Weatherization).

Weather-stripping: flexible materials used in house construction for limiting air leakage, typically around doors.

Worst case CAZ testing: a safety test series performed to assess the probability of combustion appliance back drafting into the house. CAZ stands for the "combustion area zone" of a house.

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NOTES

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