SATURN ENERGY AUDITOR FIELD GUIDE

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Saturn
Energy Auditor
Field Guide

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The *Saturn Energy Auditor Field Guide* describes the procedures used to analyze the performance of existing homes.

The companion volumes *Saturn HVAC Systems Field Guide* and *Saturn Hydronic Systems Field Guide* include procedures for inspecting, servicing, and improving the efficiency and safety of residential heating and cooling systems.

The companion volume *Saturn Building Shell Field Guide* outlines procedures for improving the effectiveness of insulation, doors, windows, and air-sealing details.

In compiling this publication, the authors have benefited from the experience of many individuals who have reviewed our documents, related their experiences, or published information from which we've gained insight. Though we can't name everyone to whom we're indebted, we acknowledge the specific contributions of the following people: Martha Benewicz, Michael Blasnik, Anthony Cox, Bob Davis, Jim Davis, R.W. Davis, Rob de Kieffer, Rick Karg, Rudy Leatherman, Dave Like, Bruce Manclark, David Miller, Rich Moore, Gary Nelson, Russ Rudy, Russ Shaber, Cal Steiner, Ken Tohinaka, John Tooley, Bill Van Der Meer, and Doug Walter. We take full responsibility, however, for the content and use of this publication.

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Foreword

The *Saturn Energy Auditor Field Guide* outlines a set of best practices for home performance organizations. This guide looks at residential structures through the eyes of the auditor who focuses on energy auditing, sales, and quality control.

Chapter 1 describes a methodical audit procedure that helps assure consistent data collection. It includes simple recommendations the auditor can make to help improve the efficiency of their customer's home right away.

Chapter 2 focuses on inspection of the home's insulation and the associated parts of the building shell. It includes tips on assessing hidden areas.

Chapter 3 describes the diagnostic procedures used to evaluate air leakage through the building shell. These procedures help the auditor determine which air-sealing measures will be most beneficial.

Chapter 4 covers the analysis of heating and cooling systems. These procedures are used to specify maintenance, assess the cost effectiveness of system upgrades, and protect the health and safety of the occupants.

Chapter 5 describes the analysis of baseload consumption, including water heating, refrigeration, and lighting. These simple procedures often identify the best energy-saving procedures of all.

Chapter 6 identifies the best ways to improve doors and windows. Though the energy savings from window and replacement are often minimal, these upgrades remain among the most popular home improvements.

Chapter 7 focuses on the well being of both auditors and customers. Health and safety remains paramount to our work in the building trades, and we hope you take to heart the advice contained here.

Chapter 8 includes inspection procedures for mobile homes. Some of these measures can pay off handsomely, especially for the owners of older homes.

The *Saturn Field Guides* have benefited greatly over the years from the generous feedback of our readers. Please help continue this process by sending us your comments and suggestions.

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CHAPTER 1: ENERGY AUDITS AND CUSTOMER RELATIONS

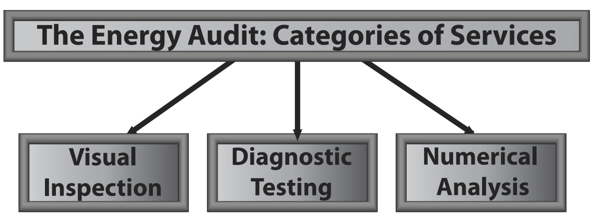
This chapter outlines the services delivered during an energy audit. It also discusses ethics, customer relations, and customer education.

1.1 WHAT IS AN ENERGY AUDIT?

An energy audit is a package of services that delivers these benefits to customers.

Help customers make decisions about how to conserve energy and save money.

- Help customers increase the comfort, health, safety, and durability of their homes.
- Protect the environment by reducing waste and pollution.



1.1.1 Purposes of an Energy Audit

An energy audit includes some or all of the following tasks, depending on the level of the audit.

- ✔ Encourage behavioral changes that reduce energy waste.
- ✔ Inspect the building and its mechanical systems to gather the information necessary for decision-making.
- ✔ Evaluate the current energy consumption and current condition of the building.

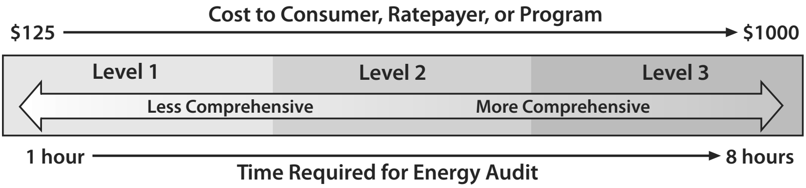
- ✔ Diagnose areas of energy waste, health and safety, or durability problems related to energy conservation.
- ✔ Recommend energy conservation retrofits.
- ✔ Project savings expected from energy retrofits.
- ✔ Estimate labor and materials costs for energy retrofits.
- ✔ Note current and potential health and safety problems and how they may be affected by proposed changes.
- ✔ Educating the homeowner about energy usage and conservation options.
- ✔ Provide a written record of the energy audit and the recommendations offered.

Why We Care about Health, Safety, and Durability

The health and safety of customers must never be compromised by energy auditing or energy conservation measures. Harm caused by our efforts would hurt both our customers and our profession. Energy conservation work can alter the operation of heating and cooling systems, alter the moisture balance within the home, and reduce a home's natural ventilation rate. Energy auditors and technicians must take all possible precautions to avoid harm and instead deliver enhanced safety, indoor air quality, and home durability.

1.2 The Energy Auditing Process

Visual inspection, diagnostic testing, and numerical analysis are the three broad types of services that compose energy audits. Screening is also an important energy-audit function, which gathers preliminary information that helps to target further energy auditing. The number of energy-auditing services and their complexity depends on the customer's commitment, the auditor's capabilities, and the requirements of energy programs among other factors. Here, we classify energy audits as Levels 1, 2, and 3, although energy auditing is actually more of a continuum as shown in the chart here.



Energy Audits: The cost of an energy audit depends on the time it requires and the complexity of the services offered. The customer's commitment to energy conservation and the energy auditor's capabilities determine the level of the energy audit and which services are rendered as part of the audit.

The Level 1 energy audit can be as simple as a paper form or internet survey. Or it may be a limited home visit to collect information and perform simple customer education. Level 2 energy audit usually includes a blower door test and may include computer modeling. Level 3 audits focus on diagnosing specific serious problems and prescribing solutions. The training level of the auditor determines what level of audit he or she is qualified to perform.

1.2.1 Screening and Surveys

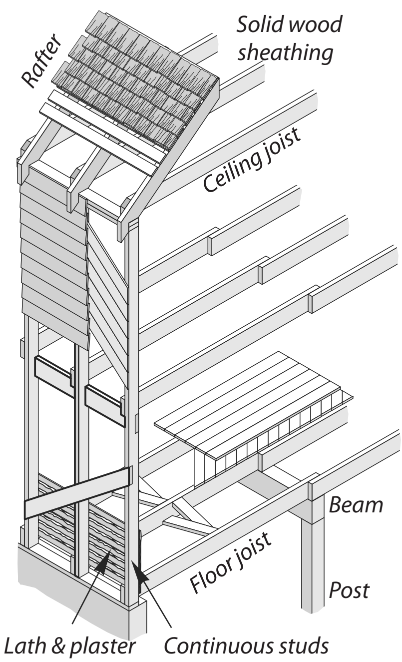
Many energy conservation programs include screening, which is a preliminary evaluation of customer needs that requires less effort than more comprehensive audits. Screening methods include the internet-based energy audits that are completed by customers and customer phone calls that are processed for further analysis.

The goal of screening is to gather information by a less expensive method than sending a highly trained individual to do a comprehensive energy audit. Screening results in requests for further information, leads for energy contractors, and requests for additional energy-auditing services.

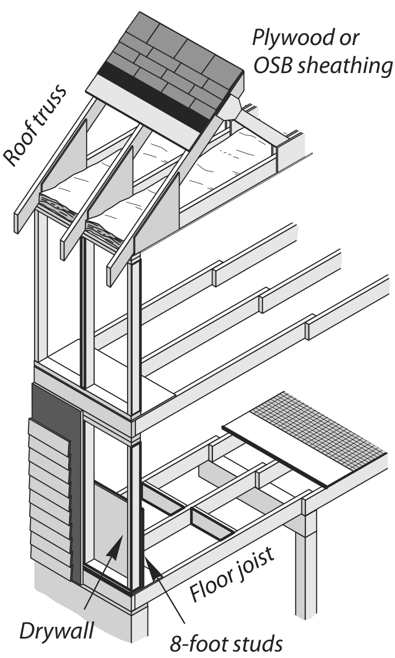
CHAPTER 2: EVALUATING INSULATION

Determining insulation levels, and estimating labor and materials for retrofit insulation, are among the energy auditor's most important tasks. The auditor should also determine how the crew will access the attic, crawl spaces, and other difficult locations, and, if necessary, obtain customer approval for this access.

This chapter focuses on the thermal resistance provided by insulation. It also addresses the construction details of building components which are commonly retrofitted with insulation.



Balloon Framing: Balloon framing is characteristic of some older homes. The wall cavities of balloon-framed houses are often open to both the basement and the attic.



Platform Framing: Modern homes on the other hand feature pre-built roof trusses, platform framing, and 4' x 8'-sheets of plywood or OSB sheathing material for walls, floors and ceilings.

2.1 Infrared Scanning

Use an infrared scanner, in conjunction with a blower door when possible, to view the wall from the interior or exterior of the home using the following general recommendations.

Infrared Scanner: Allows the user to see temperature differences which reveal the effectiveness of insulation and air-sealing details in building cavities.

Try to scan on very hot or very cold days. The quality of definition and contrast of the view depends on the temperature difference between indoors and outdoors. Well-insulated walls have a sharp definition between the studs and insulated cavities. Uninsulated walls have a poorly defined difference between studs and cavity.

View from indoors when possible because there are fewer solar effects such as warm spots in direct sun. However, viewing from outdoors can be effective at night during cloudy or very cold weather.

Evaluating IR-scanner images from outdoors requires experience with how different weather conditions and solar orientation affects the exterior temperatures of the building.

2.2 Evaluating Attic or Roof Insulation

Most attics and roof cavities have access hatches from inside the house. If there is no interior access, remove a roof vent, gable vent, or piece of soffit to look in the attic or roof cavity. If you choose to create a new interior hatch, cut in a closet at least 14 by 20 inches or as conditions permit. Get permission from the customer first.

- ✔ Try using a digital camera or a borescope held into a hole or cavity to aid your view of the insulation.

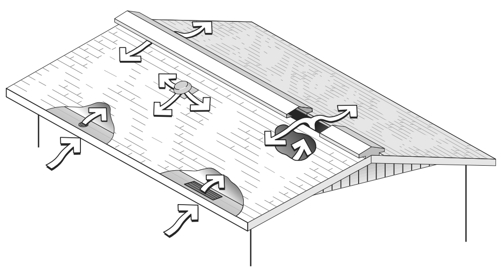
✔ Try using an IR scanner to find voids and irregularities in existing insulation.

If access to the attic isn't possible, estimate the attic insulation based on any information available, for example customer interview and insulation levels in similar building components. Be sure to note in your paperwork that this is an estimate only.

2.2.1 Attic Ventilation

Attic ventilation is intended to remove moisture from the attic during the heating season and/or to remove solar heat from the attic during the cooling season. It is often ineffective, however, and adding attic ventilation during insulation work is seldom necessary.

Many building codes require a minimum ratio of one square foot of net free area to 150 square feet of attic area. With a vapor barrier or with distributed ventilation (high and low), only one square foot per 300 square feet of attic area is required.



Low and High Attic Ventilation: Distributed ventilation — high and low — is more effective than vents that aren't distributed.

Adding attic ventilation won't cure a moisture problem caused by airborne moisture migrating up from the living space. Instead, preventing moisture from entering the attic is the best way to keep attic insulation dry. Ceilings should be thoroughly air-sealed to prevent moist indoor air from leaking through the ceiling.

Excess attic ventilation can drive ceiling air leakage through the stack effect, which can transport moisture from the house to the attic. Nighttime cooling of the roof deck can also cause water vapor that enters on ventilation air to condense on attic surfaces.

Chapter 3: Diagnosing Shell and Duct Air Leakage

This chapter discusses how to diagnose air leakage through the building shell and through ducts. Buildings and their ducts vary widely in air-tightness, making testing and diagnosis an important part of modern energy auditing. Air leakage provides ventilation and combustion air in most homes and this makes diagnosis doubly important to ensure that good indoor air quality and safe combustion are a priority of weatherization and home performance work.

3.1 Air-Leakage Problems and Solutions

The testing described here will help you analyze the existing air barriers and decide if air sealing is needed.

Ideally, an air barrier and insulation forms the thermal boundary, which completely surrounds a building. Leaks in the air barrier can cause the following deficiencies. Excessive air leakage is one of the typical home's biggest energy wasters.

- Air leakage can significantly reduce insulation R-value.
- Air leakage moves moisture and other pollutants into and out of the house.
- Air leakage can cause house pressures that can interfere with the venting of combustion appliances.

3.1.1 Driving Forces for Air Leakage

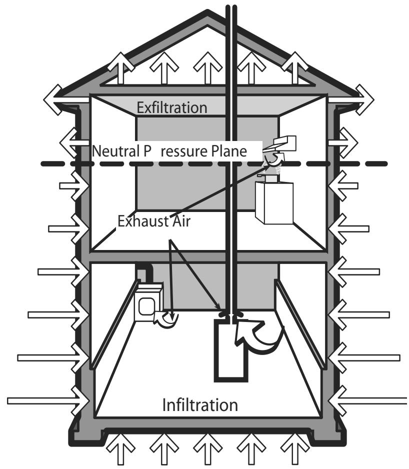
Building height and location, weather, and mechanical equipment all effect air leakage in a building.

Wind

Strong winds may create a positive pressure on one side of a building, and a negative pressure on another side.

Stack Effect

Air moves through a building as if it were a chimney. Depending on the outside temperature, air enters low or high in the building (infiltration) and exits at the top or bottom of the building (exfiltration). This is called the stack effect. The area between the air coming in at the bottom (infiltration) and the air leaving the building at the top (exfiltration) is called the neutral pressure plane.



Air Leakage Concepts: When performing air sealing, it helps to understand the effects of exhaust appliances, the stack effect, and wind effect.

Not much air leakage comes in or goes out near the neutral pressure plane. As the building is tightened at the bottom, the neutral pressure plane moves up. As the building is tightened at the top the neutral pressure plane moves down. For the best results, specify air-sealing at both the top and bottom of the building.

Duct Leakage Effects

Ideally, airtight return ducts gather air from the home, feed it to the air handler for heating or cooling, and airtight supply ducts supply the same air back to the home. Duct leaks are responsible for the following deficiencies.

- Duct leakage pressurizes the building, resulting in increased shell air leakage whenever the air handler is operating.

- Duct pressures can bring pollutants into the home and interfere with combustion-appliance venting.
- Unbalanced airflow between supply ducts and return ducts can pressurize and depressurize zones within the home. Recommend that operable supply vents be left open, or be replaced with non-operable grilles.

Exhaust Effects of Chimneys and Exhaust Fans

Chimneys and exhaust fans create negative pressure inside a home because they exhaust air from the home.

3.1.2 Safety Considerations for Air Sealing

Most homes depend on air leakage to provide outdoor air for ventilation. When air leakage provides ventilation, we evaluate the minimum ventilation requirement (MVR), which is the minimum amount of blower-door-measured air leakage that provides sufficient ventilation by air leakage. *"Evaluating Home Ventilation" on page 251*

Air sealing or duct sealing may affect combustion-appliance venting by changing house pressures or reducing the available supply of combustion air. After all weatherization measures have been performed, technicians must conduct worst-case testing of all combustion appliances. *See "Worst-Case Testing for Atmospheric Venting Systems" on page 129.*

3.1.3 Goals of Air-Leakage Testing

The first goal of air-leakage and pressure testing is to decide how much time and effort is required to achieve cost-effective air-leakage and duct-leakage rates, while safeguarding indoor air quality.

The second goal of leak testing is to decide where to locate the thermal boundary with its air barrier and insulation adjacent to one another. An intermediate zone like an attic or crawl space gives you two choices for completing the thermal boundary. The

CHAPTER 4: EVALUATING HEATING AND COOLING SYSTEMS

This chapter specifies energy efficiency improvements to heating and cooling systems.

The most important visual-inspection tasks are covered in this chapter. All heating systems should also be tested for combustion safety and steady state efficiency (SSE) as part of a comprehensive energy audit. Heating systems should be adjusted, repaired, or replaced, based on inspection and testing.

Cooling systems should be tested during service work for correct airflow and refrigerant charge. Decisions about air conditioning service or system replacement also depend on testing and visual inspection.

Duct leakage should be evaluated for both heating and cooling systems.

The inspection and testing procedures in this chapter may go beyond the auditor's training and daily practice. The reason they're included is that installation and service problems are common, and it makes sense for the auditor to be able to specify procedures for HVAC technicians. The better your quality control, the better energy savings, comfort, and customer satisfaction you can deliver. Consider the advanced procedures something to learn about as needed.

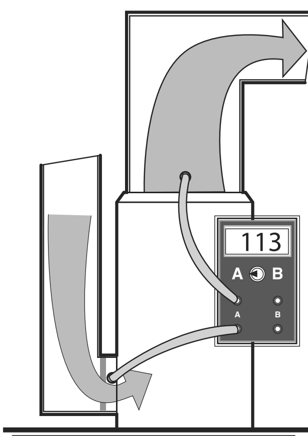
4.1 HEATING SYSTEM REPLACEMENT

Here, we discuss replacing furnaces and boilers. Water heaters are also discussed in this first section. Then we examine the fuel issues for both oil and natural gas.

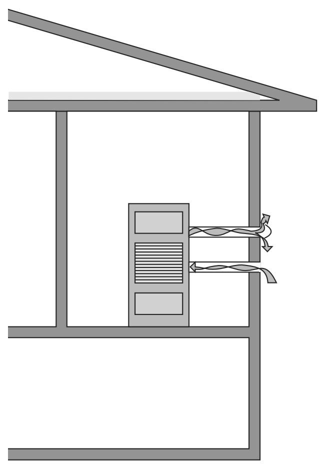
4.1.1 Combustion Furnace Replacement

This section is for the air handlers of combustion furnaces. Successful furnace replacement requires selection of the right furnace and testing to verify that the new furnace is operating correctly.

- ✔ Make sure that the furnace is sized correctly, using an accurate methodology such as Manual J.
- ✔ Select a 90+ AFUE furnace and specify its installation as a sealed-combustion (direct vent) unit.
- ✔ Specify a programmable thermostat, if customers' schedule and behavior allows.
- ✔ Verify that all accessible ducts were sealed as part of installation, from the air handler and plenums to the branch connections.



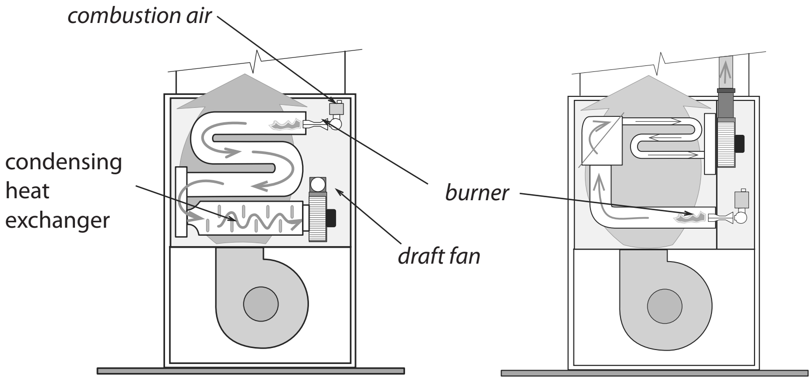
Static Pressure and Temperature rise: Testing static pressure and temperature rise across the new furnace should verify that the duct system isn't restricted. The correct airflow, specified by the manufacturer, is necessary for high efficiency.



Sealed Combustion Heaters: Sealed combustion furnaces and boilers prevent the air pollution and house depressurization caused by some open-combustion heating units.

✔ If flue-gas temperature or supply air temperature are unusually high, check static pressure and fuel input. *See "Ducted Air Distribution" on page 150.*

✔ Filters should be held firmly in place and provide complete coverage of blower intake or return register. Filters should not permit air to bypass the filter when installed in the return plenum. Filters should be easy to replace.



90+ Gas Furnace: A 90+ furnace has a condensing heat exchanger and a stronger draft fan for pulling combustion gases through its more restrictive heat-exchange system and establishing a strong positive draft.

80+ Gas Furnace: An 80+ furnace has a restrictive heat exchanger, a draft fan, and has no draft diverter or standing pilot.

4.1.2 Combustion Boiler Replacement

Boilers are replaced as an energy conservation measure or for health and safety reasons. Boiler seasonal efficiency is more sensitive to proper sizing than is furnace efficiency.

CHAPTER 5: BASELOAD MEASURES

Baseload energy consumption—water heating, refrigeration, lighting, clothes drying, and plug loads—accounts for a large part of the energy use in most homes. In mild climates, baseload consumption may be larger than heating and cooling combined. Water heating, refrigerators, and lighting are discussed in this chapter.

5.1 WATER-HEATING ENERGY SAVINGS

The most important tasks in evaluating hot water energy savings are determining the water heater's insulation level, measuring the shower's flow rate, and measuring the hot-water's temperature.

5.1.1 Determining the Water Heater's Insulation Level

Common storage water heaters consist of a tank, insulation surrounding the tank, and an outer shell. There is typically either 1 or 2 inches of insulation surrounding the tank. The insulation is either fiberglass, if the water heater was manufactured before 1991, or polyisocyanurate if it was manufactured after 1991.

Follow this procedure to determine the water heater's insulation level.

- ✔ Look for a listing of R-value on a label on the water heater.
- ✔ Find a hole in the outer shell where the flue pipes emerges or where plumbing connects. Look around the hole for either fiberglass or polyisocyanurate insulation.
- ✔ If the hole isn't large enough, on an electric water heater, try the access panel for the heating element after disconnecting power from the unit.

- ✔ You may just be able to see the gap between the tank and outer shell. If you can't see this gap, use a ruler or probe to push through the insulation along side of a pipe connecting to the tank until the probe hits the steel tank to determine thickness. Make sure that the probe is against the tank and not against a nut welded to the tank.
- ✔ If the existing water heater has less than R-10 insulation, specify a water-heater blanket for the unit.

Identifying Tank Insulation

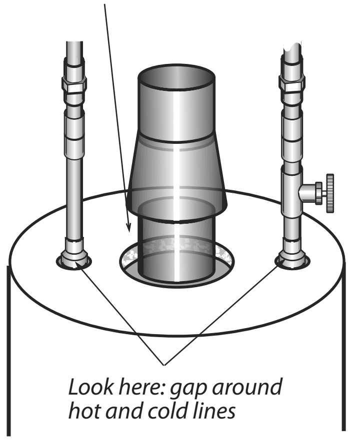


Table 5-1: Insulation R-Values

Insulation/thickness	R
Fiberglass 1 inch	3
Fiberglass 2 inches	6
Isocyanurate 1 inch	6.5
Isocyanurate 2 inches	13
Isocyanurate 3 inches	19.5

5.1.2 Water Heater Blankets

Install an insulation blanket on all heaters that are outside the heated space, unless the manufacturer's label prohibits it. Follow these guidelines to avoid fire hazards and to simplify future service.

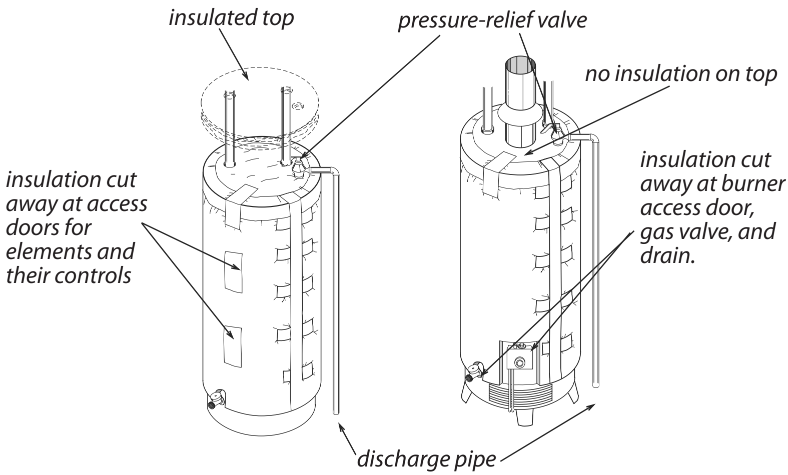
Gas Water Heaters

- ✔ Keep insulation at least 2 inches away from the gas valve and the burner access panel. Do not install insulation below the burner access panel.
- ✔ Don't cover the pressure relief valve.

- ✔ Don't insulate the tops of gas- or oil-fired water heaters to avoid obstructing the draft diverter.

Electric Water Heaters

- ✔ Cut the blanket around the thermostat and heating element access plates, or cover the plates and mark their location on the insulation facing.
- ✔ Don't cover the pressure relief valve.
- ✔ Cover the top of the water heater with insulation if it doesn't obstruct the pressure relief valve.



Water Heater Insulation: Insulation should be installed carefully so it doesn't interfere with the burner, elements, draft diverter, or pressure relief valve.

5.1.3 Measuring and Adjusting Hot Water Temperature

- ✔ Measure the water heater's water temperature at the nearest faucet to the water heater, and reduce the temperature to 120˚ F with the customer's permission.

Chapter 6: Windows, Doors, and Exterior Insulation

This chapter discusses these topics that relate to energy and repair measures.

- Window shading for low-cost cooling.
- Storm windows.
- Doubling of primary windows.
- Weatherstripping and repair of windows and doors.
- Window replacement.
- Window and door replacement with exterior insulation.

If windows and doors are in poor condition, their repair is often essential for a building's survival even if it's not an energy-saving measure. All tasks relating to window and door repair should be accomplished using lead-safe repair methods.

6.1 Window Shading

Much of the solar energy that strikes a home's windows passes through the glass and enters the living space. This solar heat accounts for up to 40% of summer overheating in many homes. It's better to block solar heat before it enters the home than to cool the home after the sun overheats it.

Window shading increases comfort and reduces the cost of cooling. Window shading is one of the most cost-effective weatherization measures in hot climates. Not all windows cause overheating, so you should direct your suggestions and specifications towards windows where the most solar heat enters.

- Windows that face east or west
- Windows that face south and have no effective roof overhang.

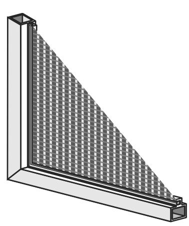
- Large windows.
- Skylights or other sloping glass.

6.1.1 Exterior Window Shading Treatments

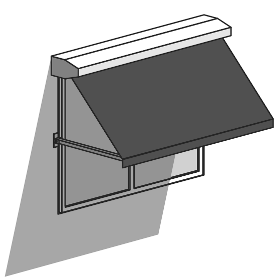
Sun screens, made of mesh fabric, which is stretched over an aluminum frame, are one of the most effective window-shading options. They absorb or reflect a large portion of the solar energy that strikes them, while allowing a view through the window.

Sun screens are installed on the outside of the window, and work well on fixed, double-hung, or sliding windows. For casement and awning windows, the sun screen should be mounted on the movable window sash rather than on the window frame.

Awnings, exterior venetian blinds, and exterior rolling shades and shutters are also very effective but are more expensive than sun screens.



Sun Screen



Adjustable Awning

Exterior Venetian Blind

Exterior Shading: Installed on the window's exterior, these devices absorb or reflect solar heat before it enters the home. This strategy is superior to interior window treatments, which reflect heat back after it has entered.

6.1.2 Interior Window Shading Treatments

Interior shades or curtains are not as effective as exterior shades because they allow solar energy to enter the home. A significant portion of this heat remains inside the home.

Venetian blinds or opaque roller shades with bright white or metallic surfaces facing the exterior can block considerable solar heat.

Avoid translucent or light-admitting shades and blinds because they allow more heat to enter the home. Purchase window shades in the standard sizes that fit most windows since custom-sized shades are considerably more expensive.

Good management of window shades improves their effectiveness. Discuss these principles with the customers.

- ✔ Close window shades in the morning before the home begins to heat up. Also close the windows.
- ✔ Open shades in the evening to help cool the home. Also open the windows.
- ✔ Open south-facing shades all day during winter to allow solar heat to enter the home.

Metalized window films are applied to the inside of existing single- and double-pane windows. Non-metalized window films aren't appropriate for effective window shading. Highly reflective window films have shading coefficients as low as 0.30.

6.1.3 Landscaping for Shade

Trees and bushes can provide shade for windows, walls, and roofs. They also cool the air around the home with shade and moisture evaporating from their leaves. Well-planned landscaping can reduce an un-shaded home's air-conditioning costs by up to 50% while adding value to the home and neighborhood.

The best plan for cool landscaping includes tall deciduous trees on the south side of the home to block high mid-day sun. Shorter trees or bushes on the east and west block morning and afternoon sun.

Suggest planting deciduous trees that loose their leaves in the autumn to admit winter sun. Choose types that are quick-growing and easy to care for in your region. Advise customers to

Chapter 7: Health and Safety

This chapter introduces some of the most pressing hazards that customers face in their homes. Major hazards and potentially life-threatening conditions should be corrected before installers begin work in the dwelling unless the installers are making the corrections as part of their work. Among the most important pollutants are air pollutants. Source control is the best strategy for reducing indoor air pollution. In airtight homes, whole house ventilation systems are necessary to assure good indoor air quality.

7.1 Pollutant Source Control

The control of pollutants such as moisture and volatile organic compounds becomes more important as homes become more airtight.

Controlling pollutants at the source is always the best solution, especially in tighter homes. Mechanical ventilation can help remove and dilute pollutants, but ventilation isn't the first choice for pollutant control.

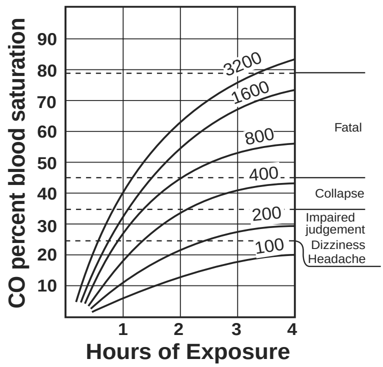
Auditors should survey the home for pollutants before weatherization or home performance work and to specify the following measures if needed.

- ✔ Repair roofs and plumbing leaks.
- ✔ Install a ground-moisture barrier over any bare soil in crawl spaces or basements.
- ✔ Vent clothes dryers and exhaust fans directly to the outdoors and not to attics or crawl spaces.
- ✔ Confirm that combustion-appliance vent systems operate properly.
- ✔ Replace unvented space heaters with vented appliances.

The home's occupants have control over the introduction and spread of many home pollutants. Educate residents about minimizing pollutants in their homes.

7.1.1 Carbon Monoxide (CO)

The EPA's suggested maximum 8-hour exposure is 9 ppm in room air. CO at or above 9 ppm is often linked to malfunctioning combustion appliances within the living space, although cigarette smoking or automobile exhaust are also common CO sources.



Effects of CO: This graph's 6 curves represent different exposure levels in parts per million.

Causes of Carbon Monoxide

CO is often linked to unvented gas space heaters, kerosene space heaters, backdrafting vented space heaters, gas ranges, leaky wood stoves, and motor vehicles idling in attached garages or near the home. Central furnaces and boilers that backdraft may also lead to high levels of CO.

CO is normally tested near the flame or at the exhaust port of the heat exchanger. CO is usually caused by one of the following.

- ✔ Gas appliances that are overfired for their rated input.
- ✔ Backdrafting of combustion gases smothering the flame.
- ✔ Flame interference by an object (a pan over a gas burner on a range top, for example).
- ✔ Inadequate combustion air.
- ✔ Flame interference by rapidly moving air.
- ✔ Misalignment of the burner.

✔ Blockage in the flue or heat exchanger.

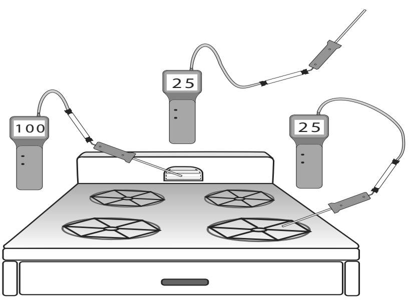
Appliance service technicians should strive to identify and correct these problems.

Testing for Carbon Monoxide

The most common CO-testing instruments are electronic sensors with a digital readout in parts per million (ppm). Follow the manufacturer's recommendations on zeroing the meter – usually by exposing the meter to clean air. CO testing equipment usually needs to be re-calibrated every 6 months or so, using factory-specified procedures.

7.1.2 Gas Range and Oven Safety

Test gas ranges and ovens after all other vented appliances have been tested. Range top burners must be tested as measured (in ambient air without adjustment for oxygen content). Follow this procedure.



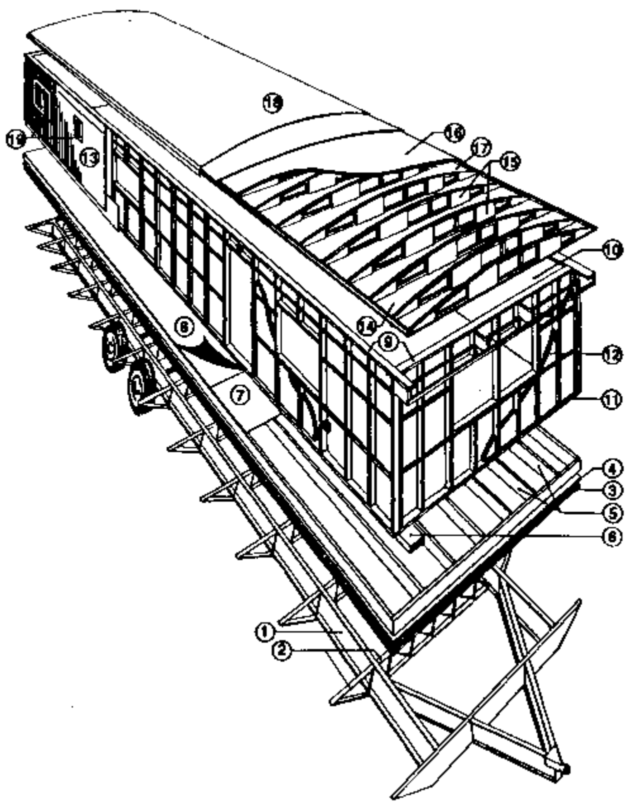
CO from Range and Oven: Measure CO at burners from 6" away. Measure CO at oven in undiluted flue gases.

1. Remove all pots and foil from the burner area.
2. Turn each range top burner on high and allow to warm.
3. Test burner combustion gases 6 inches above the flame.
4. Test the oven with the probe inside the oven vent.

Note: To protect both yourself and the customer, continually monitor ambient space around oven during testing. The ambient air should not exceed 9ppm for any 8-hour period.

Chapter 8: Evaluating Mobile Homes

Mobile homes typically use more energy per square foot than site-built homes, but their consistent construction makes them more straightforward to weatherize. Insulation upgrades save the most energy in mobile homes, though sealing shell and duct air leaks are also excellent energy-saving opportunities. Mobile home heating-system replacement are often cost-effective when a customer's energy usage is high.



Typical Components of a Mobile Home: 1–Steel chassis. 2–Steel outriggers and cross members. 3–Underbelly. 4–Fiberglass insulation. 5–Floor joists. 6–Heating/air conditioning duct. 7–Decking. 8–Floor covering. 9–Top plate. 10–Interior paneling. 11–Bottom plate. 12–Fiberglass insulation. 13–Metal siding. 14–Ceiling board. 15–Bowstring trusses. 16–Fiberglass insulation. 17–Vapor barrier. 18–Galvanized steel one-piece roof. 19–Metal windows.

8.1 Mobile Home General Auditing Tasks

Explain to the customer that you need access to all areas of the home including bedrooms, bathrooms, and closets.

Ask customers if they notice problems with the furnace, water heater, or any problems in the building shell.

Advise the customer that inspection holes may need to be drilled in inconspicuous locations in their home for auditing and inspection purposes.

Explain the general procedure of the audit and the weatherization process including the blower door test, health and safety tests, and inspection of insulation levels.

8.1.1 Health and Safety

Consider the following important health and safety issues, which are connected to mobile home weatherization.

- ✔ Check the furnace for cracks in the heat exchanger, gas leaks, carbon monoxide, flex connector, and venting.
- ✔ Check the water heater for carbon monoxide, spillage, venting, gas leaks, and adequate combustion air.
- ✔ Open-combustion furnaces and water heaters located in the living space should be replaced because open-combustion appliances are illegal and unsafe for mobile homes. New furnaces and water heaters must be sealed-combustion units, labeled and approved for mobile or manufactured homes.
- ✔ Check gas range and dryer gas line flex connector.
- ✔ Check dryer (gas or electric) for proper venting to outdoors.
- ✔ Look for rot in the rim joist and bottom of the wall.
- ✔ Look for signs that the home may not be level, such as window and door frames not being square.

- ✔ Check for mold and mildew especially at the bath and kitchen areas.
- ✔ Check for moisture problems that could degrade weatherization measures, such as plumbing leaks and roof leaks.

See "Health and Safety" on page 239.

8.1.2 Repair Work

Repairs are measures necessary for the effective performance or preservation of weatherization installations. Specify cost-effective repairs to the ceiling, sidewall and belly as necessary to prepare for retrofit insulation. Repairs are necessary to seal large air leaks. Repairs may also be necessary to solve health and safety problems. You may specify the following necessary repairs.

- ✔ Roof leaks and repairs.
- ✔ Moisture and drainage repairs.
- ✔ Ceiling panel repair and or replacement.
- ✔ Belly repairs.
- ✔ Plumbing supply leaks. Focus on hot water leaks that also waste fuel.
- ✔ Repair sewage leaks that present a health hazard.
- ✔ Ductwork repairs.
- ✔ Other structural repairs such as repairing rotted floors and walls.
- ✔ Repairing or replacing windows.
- ✔ Home re-leveling

APPENDICES

A–1 REQUIRED DIAGNOSTIC EQUIPMENT

Minimum Equipment For Instrumented Air Sealing

- ✔ Fully instrumented and calibrated blower door, Minneapolis Model 3 or equivalent, capable of measuring CFM_{50} (Cubic feet per minute at 50 Pascals).
- ✔ DG-3 or DG-700 handheld Digital Manometer, or equivalent.
- ✔ Smoke generating equipment.

Minimum Equipment for Heating System Analysis

- ✔ Combustion analyzer.
- ✔ CO testing capacity.
- ✔ Draft gauge or manometer.
- ✔ Heat exchanger leakage testing equipment.
- ✔ Ammeter (sensitive enough to adjust thermostat anticipators).
- ✔ Gas leak detector.

A–2 R-VALUES FOR COMMON MATERIALS

Material	R-value
Fiberglass or rock wool batts and blown 1″	2.8–4.0
Blown cellulose 1″	3.0–4.0
Vermiculite loose fill 1″	2.7
Perlite 1″	2.4
White expanded polystyrene foam (beadboard) 1″	3.9–4.3
Polyurethane/polyisocyanurate foam 1″	6.2–7.0
Extruded polystyrene 1″	5.0
Sprayed 2-part polyurethane foam 1″	5.8–6.6
Icynene foam 1″	3.6
Oriented strand board (OSB) or plywood $^1/_2$″	1.6
Concrete or stucco 1″	0.1
Wood 1″	1.0
Carpet/pad $^1/_2$″	2.0
Wood siding $^3/_8$–$^3/_4$″	0.6–1.0
Concrete block 8″	1.1
Asphalt shingles	0.44
Fired clay bricks 1″	0.1–0.4
Gypsum or plasterboard $^1/_2$″	0.4
Single pane glass $^1/_8$″	0.9
Low-e insulated glass (Varies according to Solar Heat Gain Coefficient (SHGC) rating.)	3.3–4.2
Triple glazed glass with 2 low-e coatings	8.3

A–3 CALCULATING ATTIC INSULATION

Auditors and inspectors also help crews determine how much insulation is needed for ceilings and walls.

Calculating Attic Loose-Fill Insulation

Loose-fill attic insulation should be installed to a uniform depth to attain proper coverage (bags per square foot) so it attains the desired R-value at the settled thickness. Follow the manufacturer's labeling in order to achieve the correct density to meet the required R-value. Attic insulation always settles: cellulose settles between 10% to 20% and fiberglass settles between 3% to 10%. For this reason, it's best to calculate insulation density in square feet per bag rather than installed thickness.

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Energy Audits and Customer Relations

Evaluating Insulation

Diagnosing Shell and Duct Air Leakage

Evaluating Heating and Cooling Systems

Baseload Measures

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