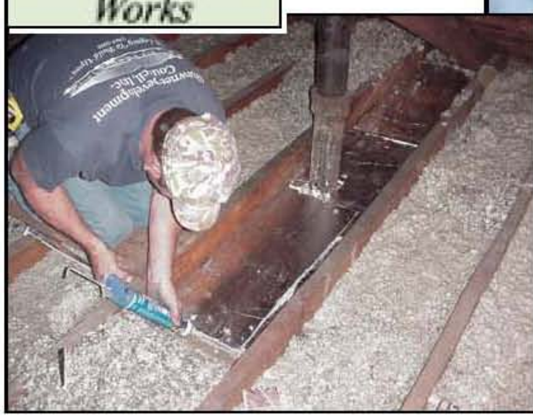
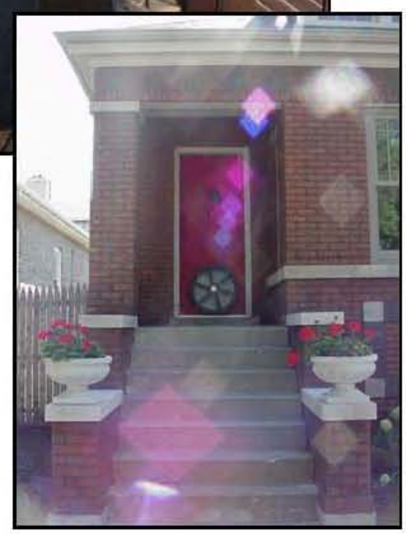
Midwest Weatherization Best Practices Field Guide

Weatherization Works





for the
US Department of Energy
Weatherization Assistance Program

May 2007

We help people enjoy a more comfortable home, a home that costs less to live in, a home that is safer and a home that is healthier. We help people – that is what the Weatherization Assistance Program is all about. Saving people money, improving the environment, saving energy and helping the economy are the results of our efforts.

The Midwest is the center of Weatherization activity in the nation. One-third of the U.S. Department of Energy's program is operated in the eight states that comprise the Midwest Region. These eight states provide some of the highest quality service and innovative approaches available to addressing the energy needs of the low-income community.

Since the 1970's, when the Weatherization Program began, our efforts were often not as effective as they are today. We would put storm doors and windows on most homes, blow some insulation in the attic and caulk any crack we could find. Those early efforts were well meaning, but we always believed we could do better.

Today, the Weatherization crews throughout the Midwest are setting the standard for effective energy efficiency investments in the housing sector. They are also leading the housing sector overall in testing and implementing efficiency measures that are the result of more than 25 years of regional cooperation. Many of the techniques developed by Weatherization programs in our region are now standard practice in all building efficiency work. They are a foundation for affordable housing and building science applications.

This field guide is another step in that evolution. It provides a single source for the best of what we do and how to do it, not only for our eight states, but for others around the country who are striving to implement high quality programs. It is the result of the strong partnerships and cooperation that our eight states share on a regular basis as we work throughout the region.

We applaud all of the men and women of the Weatherization program who not only helped develop this guide, but who spend a good portion of every day striving to provide quality services to our clients, our neighbors and our communities. We encourage you to use the Guide, to apply it to your work and to share it with others who are working to make our homes and communities as energy efficient as possible. Your efforts are improving the lives of millions of Americans and laying a strong foundation for a healthy, energy efficient future.

Peter Dreyfuss
Midwest Regional Office Director

Michael Peterson
Midwest Regional Weatherization Project Manager

Midwest Weatherization Best Practices Field Guide

The Weatherization Assistance Program (WAP) of today bears little resemblance to the one that began in 1976. Those who have some history in WAP would hardly recognize that early Program from today's systematic approach. The early practioners became skilled at installing storm doors and plastic storm windows while weatherstripping everything that moved and caulking everything that didn't. Weatherization was focused toward saving energy for those who could least afford to pay for it and doing it with the "best available information" at the time.

The focus has remained the same, but the "best available information" has not. Who would have thought that those early weatherization measures would evolve into blower door guided air-sealing, zone pressure diagnostics and dense-packing building cavities, just to mention a few of the many weatherization practices now commonly employed throughout the country. And who would have thought that the mission of saving energy would expand to encompass occupant health and safety and building durability?

The intent of the *Midwest Weatherization Best Practices Field Guide* is to capture the currant "best available information" and transform it into recommended best practices for the midwest weatherization programs. It is a voluntary standard that individual state weatherization programs can use and adopt as their programs continue to evolve to provide better and more effective services to their clientele.

This document was produced under Weatherization *Plus* as part of the "advanced technology capability" effort and represents the combined efforts of the eight states in the region. Representatives from each of the states and the Midwest Regional Office formed a working group to guide and provide input to the document. The standards of all of the states in the region were reviewed (as were state standards from outside the region). Strengths, weakness and "holes" were identified. This information was combined with the thoughts and ideas of the working group members and the authors to determine where weatherization practices currently are and in what direction they should be moving.

This *Best Practices Field Guide* is by no means cast in stone; it is an evolving document, changing as our understanding evolves about the dynamics of building systems and the occupants interaction with those systems. Mold, for example, is merely one example that falls in a long line of issues such as asbestos, knob-and-tube wiring, and lead-based paint that have affected the course of the Weatherization Program. Mold was just a "blip" on the weatherization radar screen when work on this document began in late 2002. What will the next "mold" be for weatherization in the coming years and how will it affect the focus of the Weatherization Assistance Program?

The *Best Practices Field Guide* represents a snap-shot in time. Users of this document are encouraged to submit their comments and ideas to the Midwest Regional Office or to the authors. Just as today's weatherization practioners might get a chuckle if they were to review a “Best Practices Field Guide” produced in 1980, weatherization practioners reviewing this document 25 years from now may also get a chuckle – but it is our hope it will be just a slight one.

“So what’s the Best Practice?”

Acknowledgements

Producing the *Midwest Weatherization Best Practices Field Guide* has been a long and arduous journey, and a journey not to be taken alone. When first approached about developing this document, I knew that Don Michael Jones would be the perfect traveling companion. His technical expertise was nationally recognized and he was a key player in the evolution of the Weatherization Program. Don single-handedly brought many weatherization practioners (some kicking and screaming) into the blower door age of weatherization. But Don's personality and easy-going teaching ability made this change palpable to even the most suspicious of weatherization staff. Don was a rare individual who knew both the technical side and the practical art of weatherization. Don's loss was not only a tremendous loss for those who knew him, but for the entire weatherization program as well.

Rick Karg was asked to step-in to help fill the void left by Don. He brought renewed energy to the project at a very difficult time. His background and experience in weatherization proved invaluable. Rick also has that unique gift of transforming difficult technical subjects into easy-to-understand language that was needed in producing this document. Working with Rick has been truly a wonderful and enlightening experience. I'm glad he said "Yes" when asked to work on this project.

John Krigger, Saturn Resource Management, deserves credit for his work in developing weatherization field guides over the past number of years. These field guides particularly those developed for some of the states in the Midwest Region, served as a resource on which this document was able to build.

The project was managed by Eddy Haber with the Office of Energy Assistance at the Illinois Department of Health Care and Family Services. The document was originally scheduled to be completed in March 2004. His patience and understanding through difficult times was remarkable, particularly in dealing with bureaucratic paperwork for contract extensions. He has been the strongest supporter of this document and provided encouragement on almost a weekly basis.

Rob deKieffer with Boulder Design Alliance provided a review of the document from a national perspective. Rob brings a unique, energetic and refreshing approach to weatherization. He asks the right questions that also happen to be the difficult ones. It is that kind of thinking that keeps weatherization true to its spirit.

Finally, I would like to thank all of the members of the Best Practices Working Group. Their comments, insights and support kept things in perspective.

- Paul Knight

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Midwest Weatherization Best Practices Recommendations

111 Blower Door Tests

- State weatherization programs should examine the implications of adopting ASHRAE Standard 62.2-2004, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings,* in place of using Building Tightness Limits (BTL).
- Depressurization Tightness Limits (DTL) should be estimated for homes where BTL or BTLa is used. The greater of the two should be used as the minimum ventilation rate.
- In homes that are tighter than the minimum ventilation rate as determined by BTL, BTLa or DTL, air sealing work should be limited to sealing attic bypasses and where air sealing work is necessary to correct a health and safety condition.

112 Zone Pressure Diagnostics

- Zone pressure diagnostics (ZPD) are not recommended for every home. The use of ZPD is recommended when additional information is needed regarding the relative and absolute leakage of pressure boundaries when the following conditions are found;
    - Indoor air quality concerns (tuck-under garages, crawl spaces or other zones are present that may have an adverse effect on indoor air quality),
    - Moisture problems in attics, and
    - Air leakage remains high after air sealing.
- Both pressure and flow readings should be determined when using ZPD in primary zones.

113 Duct Leakage Tests

- Pressure-pan testing is recommended:
    - On ducts located in unconditioned spaces (attics, behind knee walls, tuck-under garages, for example),
    - When basement return ducts are suspected of creating a hazardous venting condition, or
    - When basement return ducts may be contributing to indoor air quality problems, such as elevated interior moisture levels associated with wet basements.
- Measuring duct leakage to the outside with a Duct Blaster™ fan is recommended when:
    - The ducts are substantially outside the building envelope, and
    - The ducts are accessible and can be repaired.
- Pressure pan tests should always be conducted on mobile home ducts.

114 Duct-Induced Room Pressures

- Provide pressure relief when pressures are + or -3.0 Pa between a room and the main body of the house with the air handler operating.

121 Furnaces and Boilers

- A combustion efficiency test should be performed for an adequate appraisal of the operation and efficiency of the heating system.
- The following tests should also be conducted to help assess existing condition of heating system.
    - CO test,
    - Draft test under worst-case draft conditions,
    - Gas leak test (gas-fired systems),
    - Temperature rise (forced-air furnaces), and
    - Clocking the meter (gas-fired systems).

122 Water Heaters

- The following tests should be conducted to help assess existing condition of water heaters.
    - Draft test under worst-case draft conditions,
    - CO test, and
    - Gas leak test (gas-fired systems).

123 Worst-Case Draft Testing

- A worst-case draft test should be performed near the end of each work day in appropriate dwellings.
- The worst-case draft test should include:
    - Determination of the worst-case condition in the dwelling.
    - Testing each vented combustion appliance for spillage under worst-case conditions.
    - Testing each vented combustion appliance for adequate draft under worst-case conditions.
- Any appliance that fails the worst-case test before or after all weatherization work is completed should be made non-operational until the hazardous condition is corrected.

124 Gas Range Testing

- The following should be completed in dwellings with gas ranges.
    - Inspect the gas range top burners and oven burners for proper maintenance and operation.
    - Measure the range top burners for CO emission levels (as-measured).
    - Measure the oven bake burner for CO emission levels (air-free).
    - Educate the client about gas range use and maintenance.

130 Health & Safety

- Existing smoke alarms should be inspected for proper location and operation and replaced or relocated if necessary.
- Existing CO alarms should be inspected for proper location and operation.

- All homes should received exterior and interior inspections for previous or existing moisture problems. Weatherization staff should understand the mechanics of moisture movement, the impact that excess moisture has on occupant health and building durability and the impact that weatherization may have on solving or creating moisture problems in homes.
- Existing bathroom and kitchen exhaust fan systems should be examined for actual flow rates, vent condition, exterior termination and controls.
- Dryer vents should be examined for proper vent material, exterior termination and connections.
- Recommended weatherization activities must be done within the context of lead-safe work practices.
- It is the State's responsibility to ensure insulation installed around knob-and-tube wiring be in conformance with applicable codes in the jurisdiction where the work is being performed.

211 Air Sealing

- The primary objective of air sealing is to establish an effective air barrier at the thermal boundary of the home.
- The benefits of air sealing must be balanced with maintaining acceptable indoor air quality and ensuring proper draft of combustion appliances.
- Blower door tests should be performed during air sealing activities to help guide those tasks.

212 Attic Insulation

- Attics should be thoroughly inspected for safety and moisture related issues. Such issues should be addressed prior to installing attic insulation.
- Effective R-value of existing attic insulation should be determined taking into account age, settling, gaps and voids and uniformity of coverage.
- Unfinished Attics
    - Blown insulation is recommended for unfinished attics cavities and should be installed to a uniform depth according to manufacturers' specifications for proper coverage.
- Cathedral ceilings should be dense-packed with insulation.
- Finished Attics
    - Collar beams and outer ceiling joists should be insulated as per unfinished attics.
    - Sloped ceiling should be dense-packed with insulation.
    - Knee walls should be insulated to the maximum R-value as allowed by stud cavity depth. A vapor permeable air barrier should be used to enclose the back-side of the knee wall cavity.
- Attic ventilation should be part of an overall strategy for controlling attic air temperatures and should be considered an optional measure.

213 Sidewall Insulation

- Dense-packing sidewalls utilizing the one-hole method and tubes is recommended.

214 Foundation Insulation

- Basements should generally be considered part of the conditioned space of a home.
- Foundation walls of crawl spaces containing mechanicals should generally be considered the thermal boundary.
- Foundation wall insulation should be a minimum R10.
- Floor joist cavity insulation should be the maximum R-value structurally allowable or highest SIR value in cases where the floor above the crawl space is the thermal boundary.
- Properly installed ground covers are recommended for crawl spaces, regardless of the thermal boundary location.
- Crawl space vents should be sealed where the foundation walls form the thermal boundary.
- Band joists should be both air sealed and insulated.

215 Window Measures

- Window measures should be governed by cost effectiveness or the individual home's need for window repair. Window measures to solve minor comfort complaints should be avoided.
- Window measures should be accomplished using lead-safe weatherization practices.
- Replacement windows should be ENERGY STAR® rated.

216 Door Measures

- Door measures should be governed by cost effectiveness. Door related security and durability issues should be addressed within the overall budget context. Door measures to solve minor comfort complaints should be avoided.

221 Clean & Tune - Gas & Oil Fired Furnaces & Boilers

- Heating systems should be cleaned and tuned to ensure that they are operating in a safe and efficient manner.
- Shell retrofits should not be done until health and safety issues, such as gas leaks, high CO readings or venting problems are corrected.
- Comprehensive testing protocols should be adopted to ensure proper operation, venting and combustion air supply for gas- and oil-fired space heating appliances.

222 Heating System Retrofits

- The following heating system retrofits are recommended for the Midwest Region;
    - Automatic setback thermostat,
    - Intermittent ignition device and vent damper,
    - Boiler pipe insulation, and
    - Flame retention head burner.
- Heating system retrofits should be considered based on cost effectiveness, condition and life expectancy of heating system and client being served.

223 Heating System Replacement

- Every effort to repair and retrofit heating appliances should be made prior to replacement. Heating appliances that are non-operational or non-repairable should be replaced.
- Replacement heating systems must be sized according to accepted calculations such as the *Residential Load Calculation* (Manual J) or approved computerized load calculation software. Sizing should account for lower heating loads resulting from insulation and air sealing work. Sizing calculations must be included as a permanent part of the client file.
- Replacement heating appliances should meet the guidelines and efficiency ratings as shown in the table below or be ENERGY STAR® rated unless shown not to be cost-effective or if existing conditions are not appropriate for their installation.

Natural Gas/LP Furnaces	90%, direct vent sealed combustion
Oil Furnaces	83%
Gas and Oil Boilers	85%

- Weatherization work shall not be done in any home with an unvented space heater where client does not permit its removal.

224 Water Heater

- Water heaters should be cleaned and tuned to ensure that they are operating in a safe and efficient manner.
- The following water heater measures are recommended for the Midwest Region;
  - Water heater temperature setting,
  - Tank insulation,
  - Pipe insulation, and
  - Replacement
- Mechanically vented, direct vent and tankless water heaters should be considered as replacement units based on cost-effective and appropriateness of existing conditions.

225 Masonry-Chimney Liners

- A flue may be left unlined if the appliance is not to be replaced and the flue and chimney appear to be in good condition.
- Rebuilding a chimney, lining or relining should be considered for unlined chimneys, when existing liners are in poor condition or if the cross-sectional area of the chimney is oversized for the appliance(s).
- It is recommended flues be properly lined for solid-fuel appliances that are used as a primary or frequent secondary space heating source.

226 Heat Pumps and Air Conditioners

- All air-source heat pumps with electric auxiliary must be served by a control system – thermostat(s) – to minimize the operation of the electric heaters.

- Clients should be informed about routine maintenance and operation of heat pumps and air conditioners.
- When a heat pump requires more than simple maintenance, a professional service technician should be hired to check coil air flow, inspect for refrigerant leaks and charge, inspect and adjust controls, and perform other specialized testing and adjustment.
- Replacement heat pumps and air conditioners should be sized properly and ENERGY STAR® rated.

227 Duct Improvements

- Ducts located in unconditioned areas must be sealed and insulated.
- Duct system airflow should be checked and corrected if necessary in response to client comfort complaints.

230 Baseload

- Fluorescent lamps used for replacement should be ENERGY STAR® rated.
- Low-flow showerheads should be included as part of weatherization services.
- Measuring kWh or referring to http://www.waptac.org/sp.asp?id=68 should be used to determine electrical consumption for refrigerators being considered for replacement.
- Replacement refrigerators should be ENERGY STAR® rated.

240 Health & Safety

- At least one smoke alarm should be installed in each weatherized home.
- Fire extinguishers should be given to each weatherization client if they do not already have one.
- At least one CO alarm should be installed in each weatherized home having combustion appliances, when the home has an attached or tuck-under garage or when assessors believe that there are other health and safety situations related to CO.
- CO alarms should also be installed when weatherization services must be deferred due to unsafe combustion appliances.
- Whole house ventilation should be added to homes that are below the BTL or BTLa ventilation rates.
- Consideration should be given to providing whole house ventilation in all homes according to ASHRAE Standard 62.2-2004, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*.
- Exhaust fan ducts should be sized according to ASHRAE 62.2-2004.
- Disconnected or improperly vented clothes dryers should be corrected as part of weatherization.
- Missing or damaged gutter systems should be repaired or replaced if causing an indoor moisture problem.
- Weatherization staff should be knowledgeable of mold remediation procedures and outside funding sources available to remediate moldy surfaces in clients' homes.

300 Mobile Homes

- Air sealing should be limited to sealing ductwork and large holes needed to hold insulation in place until all insulation measures have been completed and a blower door test has been conducted.
- Cost effectiveness of insulating floors, sidewalls and roof cavities should be examined by State Weatherization Programs. If cost effective, actions should be taken to increase local agency capacities to include these measures as part of production.
- Replacement windows should be double-glazed.
- Pressure-pan testing should be done in all mobile homes.
- Replacement water heaters should be done with HUD approved units.

400 Final Inspection Tests

- Blower door tests should be done when all weatherization work has been completed to evaluate effectiveness of air sealing work. If this test was not done, it must be completed during the final inspection.
- Homes should be visually inspected for evidence of effective air sealing work. Zone pressure diagnostics may be helpful to evaluate air sealing activities when "hidden" air sealing has occurred (bypass sealing under attic insulation, for example).
- Visual inspection and duct testing should be done during the final inspection to verify work results when duct repair and sealing has been specified.
- If a worst-case draft test was not done after weatherization work was completed, it must be completed during the final inspection.
- If a steady-state combustion efficiency test for gas- and oil-fired appliances was not done and thoroughly documented following completion of heating system work, it must be completed during the final inspection.
- If gas range inspection and testing was not done and thoroughly documented during the weatherization work, it must be inspected and tested during the final inspection.

111 Blower Door Test

Best Practice Recommendations:

- State weatherization programs should examine the implications of adopting ASHRAE Standard 62.2-2004, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings,* in place of using Building Tightness Limits (BTL).
- Depressurization Tightness Limits (DTL) should be estimated for homes where BTL or BTLa is used. The greater of the two should be used as the minimum ventilation rate.
- In homes that are tighter than the minimum ventilation rate as determined by BTL, BTLa or DTL, air sealing work should be limited to sealing attic bypasses and where air sealing work is necessary to correct a health and safety condition.

A blower door measures total leakage rate of a home, indicates the potential for air leakage reduction in a home, provides an estimate of the natural infiltration for a home and assists in finding air leakage locations.

The blower door measures air flow at a pressure difference of 50 Pascals (Pa) between the house and outside, producing a number (CFM_{50}) that is used to compare the leakiness of homes. The blower door also creates pressure differences between rooms in the house and buffer zones like attics and crawl spaces that can give clues about the location and size of a home's air leaks.

Only air sealing work that significantly reduces air leakage or mitigates indoor air quality hazards should be performed. Air sealing should be directed by blower door diagnostics at every opportunity. The primary goals of air sealing are to:

- Reduce heat loss resulting from air leakage,
- Avoid moisture migration into building cavities,
- Save energy by protecting insulation's thermal resistance, and
- Increase thermal comfort.

All weatherization workers should understand how to perform a blower door test properly.

1111 Preparation

A walk-through of the house should be done prior to conducting a blower door test. Items listed in sections 11111 through 11116 should be reviewed prior to conducting a blower door test.

Setting up the blower door for a depressurization test

11111 Depressurization Test

A depressurization test is recommended as it is the standard test in the low-income weatherization program because it is easier to perform than a pressurization test. If there are concerns about doing a depressurization test, perform a pressurization test or gradually depressurize the house to 50 Pa while checking the condition of the suspect areas.

11112 Pressurization Test

A pressurization test should be done, rather than a depressurization test, if one of the following conditions is present in the home:

- Drip-pot heating appliance operating,
- Wood or coal fired heating appliance operating,
- Animal or bird feces is found in the attic that may be a health hazard,
- Interior wall or ceiling finishes might be pulled in or down by a depressurization test,
- An open sump in basement,
- Open sewer line in the home,
- Harmful pollutants could be introduced into the home by the operation of the blower door, or
- Friable asbestos is found in the basement or in another area within the thermal boundaries of the dwelling.

11113 Blower Door Test Cannot Be Done

There may be instances when a depressurization or pressurization test cannot be performed. If so, reasons for not doing a blower door test must be documented and included in the client's file. When blower door testing cannot be performed, air sealing work is limited to:

- Attic bypass and key juncture sealing.
- Glass replacement, and
- Up to one work hour of comfort sealing[1].

11114 Blower Door Set-Up

Follow set-up procedures in blower door manufacturer's instruction manual for depressurization and pressurization tests.

11115 House Set-Up

Preparing the house for a blower door test involves putting the house in its heating or cooling operating condition with all conditioned zones open to the blower door. See Section 11116, "Basements", for guidance as to whether the basement should be considered conditioned space.

- Identify location of the thermal boundaries and house zones that are conditioned.
- Deactivate all vented combustion appliances by turning the thermostat down or the appliance off.

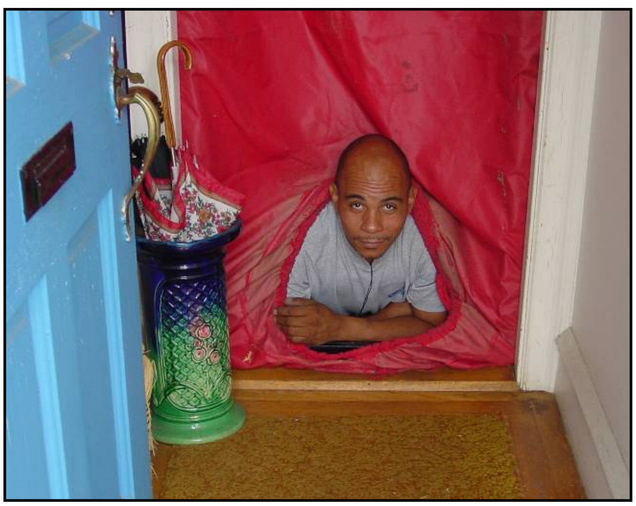
[1] Comfort sealing is air sealing work that targets drafts, directed primarily by the occupant and is limited to 1 labor hour.

- Prevent ashes of wood/coal burning units from entering the living space by closing/sealing doors and dampers or by cleaning out ashes.
- Inspect house for loose or missing hatchways, paneling, ceiling tiles or glazing panes. Secure any items that may become dislocated during the test and seal any missing hatchways.
- Remove one ceiling tile on suspended ceilings to relieve pressure, if necessary.
- Close all primary windows, self-storing storm windows, exterior doors and latch them as they normally would be found during the winter.
- Open interior doors so that all indoor areas within the thermal boundary are connected to the blower door.
- Temporarily seal appropriate intentional fresh air openings (air ducted from the outdoors to the furnace, for example). Do not seal intentional exhaust air openings, such as combustion appliance flues, dryer vents or exhaust fans.
- Ensure children, pets, manometer hoses, and power cords are at a safe distance from fan blades.

11116 Basements

Basements may be used as living space. Furnaces and boilers and their respective distribution systems, water heaters and washers/dryers are often located in the basement. Heat from these items as well as heat from the space above helps condition basements during the winter. Therefore, basements are usually considered conditioned space and basement doors should be open during the blower door test unless of one the following conditions are present (even if the basement door is generally closed during the winter):

- None of the above mentioned appliances are located in the basement,
- It is clear that the occupants do not use the basement on a regular basis; for example, access to the basement is through an exterior door or hatch, or
- Moisture problems in the basement that weatherization work cannot solve.



Has anyone seen my blower?

1112 Existing Leakage Rate

The following procedure is based on The Energy Conservatory's Minneapolis Blower Door, Model 3.

Perform a one-point blower door test at 50 Pa or the highest achievable house pressure if unable to reach 50 Pa. If wind seems to be affecting the test results, take several one-point tests and average the results.

Record existing CFM_{50} leakage rate and determine cost effective air sealing standard (see section 1115, "Air Sealing Guidelines").

11121 Air Density Correction Factors

The CFM_{50} rate can be adjusted for greater accuracy based on differences in air density caused by air temperatures.

Air Density Correction Values
Table 110-1

Outdoor Temp	CFM_{50}
90°F	4360
70°F	4280
20°F	4073
-10°F	3944

The CFM_{50} rate read at the blower door is measuring the air flow from the house out through the blower door (depressurization test). It is generally assumed that this flow rate is equal to that coming into the home through air leaks. However, when the inside and outside temperatures are different, the air flow through the fan is actually different from the air flow back into the building due to differences in air density. In some case, the differences in air flow can be as much as 10%. This may be especially important when climatic conditions have changed between the initial air leakage test taken during the assessment and the air leakage test taken during the final inspection.

Table 110-1 demonstrates the variation in CFM_{50} numbers based on different outdoor air temperatures and an indoor temperature of 70°F.

Refer to tables in the blower door manual for the appropriate correction factors. Note that separate tables are used for depressurization and pressurization tests.

11122 "Can't Reach 50" Multipliers

If the blower door cannot achieve -50 Pa house pressure, re-inspect the home to assure that all windows and doors are closed.

Can't Reach 50 Factors
Table 110-2

House Pressure	CRF
45	1.1
40	1.2
35	1.3
30	1.4
25	1.6
20	1.8
15	2.2
10	2.8

If the blower door still cannot depressurize the house to -50 Pa, get the house pressure to the highest multiple of five (25, 30, 35, 40, or 45 Pa). Multiply the flow rate (CFM) by the "Can't-reach-fifty (CRF)" multiplier listed in Table 110-2.

For example, a house can only be depressurized to -25 Pa. The CFM reading is 4600. Converting to -50 Pa, the house leakage is 7360 CFM_{50} (4600 CFM_{25} x 1.6 = 7360 CFM_{50}).

11123 Fan Rings

The blower door is generally operated with the fan open (no rings). Ring A or ring B may be added to the fan for tight or small dwellings. If the measured fan pressure is less than 25 Pa, install a ring to increase accuracy. Note that this is fan pressure, not house pressure.

For example, a house pressure of -50 Pa has been achieved with the fan open. The fan pressure is 20 Pa. Ring A should be installed since the fan pressure is less than 25 Pa. The manometer must be reset to indicate the presence of ring A. Another indication that a ring may be required is when the fan doesn't sound like it's working very hard with a house pressure of -50 Pa.

11124 Approximate Leakage Area

The CFM_{50} measurement may be converted into square inches of total leakage area to help visualize total leakage area in the home. The simplest way to convert CFM_{50} into an approximate leakage area (ALA) is to divide CFM_{50} by 10. This approximation may be used with the fan open or if rings were used on the fan.

$$ALA = CFM_{50} \div 10$$

11125 Existing Leakage Rate Greater than the Building Tightness Limit (BTL)

The Building Tightness Limit (BTL) is discussed in section 1113. If the existing leakage rate is above the home's BTL, see section 1115, "Air Sealing Guidelines" to determine the extent of cost-effective air sealing work.

11126 Existing Leakage Rate Less than the BTL

If a home's existing leakage rate is below its BTL, air sealing work might still be appropriate. Conductive heat loss measures, heating system work, duct sealing and balancing, along with ventilation assessment and corrective actions should still be accomplished (see section 123, "Worst-Case Draft Test").

Air sealing work should be limited to sealing attic bypasses and circumstances where air sealing work is necessary to correct a health and safety condition. A home may be tightened beyond its BTL if continuously operating mechanical ventilation is provided.

Bathroom and kitchen exhaust fans should be checked for proper operation with an Exhaust Fan Flow Meter®, if possible. If these fans are non-operational or not present, they should be repaired or new fans installed. Exhaust fans vented into attics or crawl spaces should be ducted to the outside.

Don't do this! Four small holes in the fan flow sensor ring must be unobstructed and regularly cleared of dust accumulation

11127 When Air Sealing Should be Deferred

Air sealing should be done in all homes; however, air sealing work should be deferred until the following conditions are corrected.

- Presence of unvented space heaters (whether used for primary or secondary heating),
- Depressurization tightness limit exceeded (see section 1114, "Depressurization Tightness Limits"),
- Measured drafts of combustion appliances do not meet standards under worst-case conditions,
- Carbon monoxide levels exceed suggested action levels,

- Evidence of serious mold issues (an area of mold greater than 10 ft^2), or
- The building CFM_{50} tightness level is lower than the Building Tightness Limit (see section 1113, "Building Tightness Limit") and mechanical ventilation cannot be provided.

11128 Post-Blower Door Test

The following items should be checked prior to leaving the home following a blower door test.

- Inspect all pilot lights of combustion appliances to ensure that blower door testing did not extinguish them.
- Reset thermostats of heaters and water heaters that were turned down or off for testing.

1113 Building Tightness Limits (BTL)

Establishing a building tightness limit (BTL) is intended to prevent the creation of an indoor air quality problem (IAQ). A building tightness limit must be determined for every home and may be established by one of three methods as specified by the state;

- BTL, Basic Calculation based on ASHRAE Standard 62-2001.
- BTLa, Advanced Calculation based on ASHRAE Standards 62-2001, 119-1988, and 136-1993.
- 62.2, based on ASHRAE Standard 62.2-2004.

In addition, a Depressurization Tightness Limit (DTL) should also be determined for each home (see section 1114, "Depressurization Tightness Limits"). The DTL is used to develop a tightening limit for safe combustion appliance venting and is not related to other IAQ issues.
The DTL becomes the minimum tightness level if it is greater than the BTL.

11131 Building Tightness Limit (BTL method), Basic Calculation

This method is based on ASHRAE 62-2001. Both of the requirements of this Standard – fresh air at the rate of 15 CFM/person and 0.35 air changes per hour – must be satisfied. These numbers form the basis for determining BTL in units of CFM_{50}.

BTL should be calculated using for both occupancy and house volume. The method that yields the greatest CFM_{50} is the BTL for the house. See Appendix A for information on how BTL is calculated based on occupancy and house volume.

11132 Building Tightness Limit (BTLa method), Advanced Calculation[2]

This method for determining acceptable indoor air quality is based on ASHRAE 62-2001 with the fresh air requirements of 15 CFM/person and 0.35 air changes per hour. It also

[2] A survey conducted in 2001 for the Chicago Regional Diagnostic Working Group, *Survey of Tightness Limits for Residential Buildings*, concluded that the BTLa method was more accurate than the BTL method. This conclusion was based on the opinions of the surveyed experts. See www.karg.com/btlsurvey.htm.

utilizes two other ASHRAE standards for the calculation procedure, making it more accurate than the basic BTL method.[3]

The complexity of this calculation requires the use of a computer or programmed calculator. For the advanced BTLa method, these values must be entered into the computer or programmed calculator. See Appendix A for additional information about the BTLa method.

11133 ASHRAE Standard 62.2-2004 (62.2 method)

ASHRAE Standard 62.2-2004 – *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings* – is significantly different from ASHRAE Standard 62-2001 and, as its title makes clear, is for residential buildings only. The next time Standard 62-2001 is revised (probably in 2005), all requirements for residential buildings will be removed and it will address only commercial buildings. When this happens, any weatherization program using the current BTL or BTLa methods, will be basing their procedures for ensuring acceptable indoor air quality on an obsolete standard.

Some significant differences between ASHRAE 62-2001 and 62.2-2004 include:

- Ventilation fans – whole building ventilation – are required in more houses under 62.2-2004.
- The required CFM of whole building ventilation under 62.2-2004 is usually less than that required by 62-2001. This is primarily because 62.2-2004 allows an “infiltration credit”, but 62-2001 does not.
- Local mechanical exhaust in bathrooms and kitchens is required by 62.2-2004, but not by 62-2001.
- The 62.2-2004 Standard recognizes the potential hazards of air leakage paths between living areas and garages.

DG-700 digital manometer from The Energy Conservatory

The ZipTest Pro[2] software for the Texas Instruments TI-86 programmable calculator calculates whole building ventilation needs required by ASHRAE 62.2-2004. For information, see www.karg.com/software.htm. The Energy Conservatory software TECTITE 3.1 will also calculate the whole building ventilation needs based on this standard. For information, see www.energyconservatory.com.

[3] The BTLa method is based on ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality;* Standard 119-1988, *Air Leakage Performance for Detached Single-Family Residential Buildings*; Standard 136-1993, A *Method of Determining Air Change Rates in Detached Dwellings*.

1114 Depressurization Tightness Limit (DTL)

Weatherization agencies currently use BTL, BTLa or ASHRAE 62.2-2004 for determining ventilation guidelines in homes. Depressurization tightness limits should also be checked as a screening process to identify potential backdrafting problems. If the depressurization tightness limit is greater than the BTL or BTLa, then the depressurization tightness limit should be used as the ventilation guideline.

Worst-case draft testing (Section 123) should always be done regardless of the method used to determine the ventilation guidelines.

The depressurization tightness limit (DTL) is the CFM_{50} value (leakage rate) at which the appliances in the house that exhaust air are likely to cause vented combustion appliances to backdraft. Appliances that exhaust air include bathroom and kitchen exhaust fans, vented dryers, and furnace air handlers. The more air sealing done in a house, the greater the negative pressure each of these exhaust appliances produces.

The DTL method is based on estimating the exhaust potential of all devices located in the home. These devices are defined as mechanical equipment or combustion appliances that exhaust through a vent connected to the outside of the envelope and that draw air from the living space. This method allows the inspector to determine when the minimum CFM_{50} at which backdrafting may occur.

Locate and record all devices located in the building. Use Table 110-3 to record the effective flow of the devices. If possible, it is always best to measure actual exhaust flow rates. Sum the effective flows for the home.

ESTIMATED EXHAUST RATES
Table 110-3

Device	Approximate Duct/Flue Size (inches)	Typical Nominal Flow CFM	Average Actual Flow CFM
Bathroom and Range Hood Fans	3	85	53
	3¼x 10	85	53
	4	106	64
	7	212	127
	8	318	223
Exterior Mounted Kitchen Fans	10	424	297
	10	636	445
Clothes Dryer	4	85-127	106
Central Vacuum			117
Jenn- Air or similar Range or counter Top/ext.vent	5	800	300
	6	800	500
	3¼ x 10	800	600
Wood Burning Fireplace			300
Open Wood Stove			65
Airtight Wood Stove			50
Atmospheric gas oil or Propane Appliances (Water heaters, Boilers, Furnaces)	3		21
	4		38
	5		47
	6		72

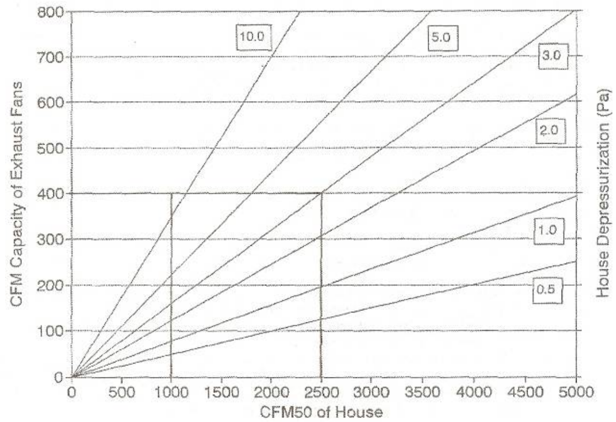
Select the appropriate building depressurization limit from Table 110-4. If more than one appliance is located in a combustion appliance zone (CAZ), use the appliance Pa limit most likely to backdraft. For example, an appliance with a rating of -2 Pa is more likely to backdraft than an appliance rated at -5 Pa.

Building Depressurization Limits for Various Appliance Types
(Used to calculate the Depressurization Tightness Limit)
Table 110-4

Appliance Type	***Building Depressurization Limit, Pascals***
Atmospheric water heater only (separately vented from furnace)	-2
Atmospheric water heater and atmospheric furnace common vent	-3
Furnace or boiler, gas atmospheric or fan assist., Category I[4]	-5
Oil or gas unit with power burner	-5
Induced draft appliance (fan at point of exit at wall)	-5
Direct-vent, sealed combustion appliances	-25

[4] Category I appliances are defined as "An appliance which operates with a non-positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent". For additional information, see NFPA54-2002, "Vented Appliance Categories" under Definitions.

Locate the effective flow on the Y-axis on the House Depressurization Chart (Figure 110-1). Locate the appropriate building depressurization diagonal line in Figure 110-1. Read down to the X-axis at the intersection of the effective flow and building depressurization limit to find the minimum CFM_{50} value.



House Depressurization Chart

Figure 110-1

Since the DTL is an estimate of exhaust potential and could overestimate the exhaust, there is some flexibility in this method. When the DTL is approached while air sealing, a worst case draft test should be performed (see section 123). If no problems exist, further air sealing is possible.

If the DTL is greater than the BTL, the DTL should be used rather the BTL as the weatherization tightness limit for the home. Otherwise, the BTL remains as the weatherization tightness limit.

1115 Air Sealing Guidelines

Guidelines for cost-effective air sealing work should be established. The guidelines may take the form of cost limit per 100 CFM_{50} reduction or may be based on the existing CFM_{50} leakage rate.

A cost-effective guideline per 100 CFM_{50} reduction should be established based on climate, fuel costs, material and labor costs for air sealing and heating system efficiency. CFM_{50} needs to be measured on a periodic basis as the air sealing is done. The cost of the CFM_{50} reduction achieved is compared to the cost-effectiveness of achieving it. If actual air sealing costs are less than the cost-effective guideline per 100 CFM_{50}, additional air sealing may continue. If actual air sealing costs exceed the guideline, air sealing work should cease. See Appendix A for additional information regarding cost-effective air sealing guidelines.

If a cost-effective guideline per 100 CFM_{50} is not established, target CFM_{50} levels based on a range of existing leakage rates may be used. Target CFM_{50} levels relate existing CFM_{50} leakage rates to expected post-weatherization leakage rates. The premise is that homes with high leakage rates have a potential for a larger cost-effective leakage reductions than tighter dwellings. Example target CFM_{50} levels are shown in Table 110-5.

Target CFM_{50} Levels
Table 110-5

Existing CFM_{50}	**Target CFM_{50} Levels**	**Example**
less than BTL	see 11146, “Existing Leakage Rate Less than the MVR”	
BTL to 1560	CFM_{50} not to drop below BTL	
1560 to 2750	80% of existing CFM_{50}	Existing CFM_{50} = 2600 .80 x 2600 = 2080 Target CFM_{50} = 2080
2750 to 4250	70% of existing CFM_{50}	Existing CFM_{50} = 3600 .70 x 3600 = 2520 Target CFM_{50} = 2520
4250 to 5500	60% of existing CFM_{50}	Existing CFM_{50} = 5000 .60 x 5000 = 3000 Target CFM_{50} = 3000
5500 to 7500	55% of existing CFM_{50}	Existing CFM_{50} = 6800 .55 x 6800 = 3740 Target CFM_{50} = 3740
> 7500	50% of existing CFM_{50}	Existing CFM_{50} = 8100 .50 x 8100 = 4050 Target CFM_{50} = 4050

The most cost-effective air sealing involves addressing the largest leakage paths first and sealing leaks in the top part of the home. Confirm effectiveness of air sealing strategies by performing interim blower door tests.

Air seal a home until further tightening is no longer cost-effective or to achieve the target CFM_{50} level. Air sealing may be done beyond the target if air sealing work remains cost effective and the building has not been sealed below its BTL.

11151 Air Sealing Exceptions

Because of structural conditions or other factors, some homes may not reach the target CFM_{50} level. Exceptions for not reaching the target are:

- The weatherization installers made every reasonable attempt to reach the target, or
- Further air sealing is not cost effective, or
- The home is at or below the BTL.

A reasonable attempt to reach the target CFM_{50} level should be made in every home. Note that conditions may prevent air sealing levels from being achieved. In all cases the client’s file must provide clear and adequate documentation of the installer’s efforts to reach the target, and the reason(s) the standard could not be achieved.

1116 Mobile Homes

Mobile homes should be treated similarly to single-family homes when determining the Building Tightness Limit and air sealing level. See section 310, “Air Leakage”, in chapter 300, “Mobile Homes”.

1117 Recording

All homes must have a blower door test performed during the audit and again at the final inspection. The BTL, the DTL and the initial and final blower door tests must be listed on the audit input form. Reasons for not performing a blower door test must be listed in the client file.

1118 Post-Weatherization Blower Door Test

If post-weatherization CFM_{50} is less than the BTL, remedial action should be considered that could include client education, mechanical ventilation or combustion air supply. See section 411, “Blower Door”, for Post-Weatherization blower door testing procedures.

112 Zone Pressure Diagnostics

Best Practice Recommendations:

- Zone pressure diagnostics (ZPD) are not recommended for every home. The use of ZPD is recommended when additional information is needed regarding the relative and absolute leakage of pressure boundaries when the following conditions are found;
  - Indoor air quality concerns (tuck-under garages, crawl spaces or other zones are present that may have an adverse effect on indoor air quality),
  - Moisture problems in attics, and
  - Air leakage remains high after air sealing.
- Both pressure and flow readings should be determined when using ZPD in primary zones.

The blower door can be an effective tool at finding direct leaks by depressurizing the house and looking or feeling for airflow through leaks. However, leaking air often takes a path through two surfaces that have a space, or zone, between them. These zones can include attics, basements, garages, knee-wall areas, or attached porch roofs. These leakage sites may be difficult to find because they are in unconditioned spaces or hidden within the framing systems of a house. Once found, these leaks may be the largest and easiest leaks to seal.

A blower door is required for zone pressure diagnostics

Zone pressure diagnostics can be used to measure the size of the leakage paths to various house zones and the extent to which those holes are leaking. Measurements may be taken that indicate the amount of air leakage between the house and zone and zone and outside, both in terms of CFM_{50} flow and square inches of leakage area. Following weatherization work, zone pressure diagnostics can quantify the effectiveness of air sealing efforts.

1121 Zones

A "zone" is an enclosed space that separates a heated space from the outdoors. Typical zones include attics, crawl spaces and attached garages. The inner boundaries of these zones are building components such as walls, ceilings, or floors that separate these zones from the conditioned space. The outer boundaries of these zones are the walls, roofs, and foundation walls that separate a zone from the outdoors.

The building component that separates the conditioned space from the outdoors should be the primary pressure boundary. The pressure boundary is often thought of as being the building's air barrier and is where air sealing should be done during weatherization. The thermal boundary is defined by the placement of insulation. In order to maximize the effectiveness of the thermal boundary, the pressure boundary must be aligned with it. In other words, it's very important that the pressure boundary be part of the thermal boundary. If the insulation and the air barrier are not aligned; that is, located in different building components, air is allowed to pass around or through the thermal boundary, making the insulation less effective.

Measuring zone pressures during a blower door test indicates whether the thermal and pressure boundaries are aligned. The pressure measured across either the inner boundary of a zone – house with reference to (wrt) the zone – or the outer boundary of a zone (zone wrt outside) can indicate the relative leakiness of each of the boundaries.

Depending on zone pressure measurements alone can be misleading, however. For example, a house-to-attic pressure measurement of -45 Pa (-5 Pa wrt outside) indicates that the ceiling is tighter than the roof. However, it does not indicate how much air is flowing through the roof and the ceiling or how many square inches of holes are in each. For example, the attic floor structure could have 40 or 400 square inches of leakage area.

11211 Primary Zones

Primary zones are spaces that can be physically accessed and inspected. Typical primary zones include attics, crawl spaces, basements, and attached garages. Because temporary openings can be created to the house and/or to the outdoors from these primary zones, an air leakage rate (CFM_{50}) between the house-to-zone and zone-to-outside can be determined. These flows can be converted to leakage areas simply by dividing them by 10. This information provides the assessor and air sealing team with information regarding the extent of air sealing work required and a method for evaluating the effectiveness of air sealing work.

11212 Secondary Zones

Secondary zones are spaces that cannot be physically accessed. Secondary zones include:

- Dropped soffits and other ceiling height changes,
- Open joist cavities (beneath knee walls in finished attics),
- Cantilevered floor joists,
- Floor joists over tuck under garages, and
- Porch ceilings or living space floor cavities along the porch ceiling.

Temporary openings usually cannot be made between the house and secondary zones or between the zone and the outdoors. Consequently, flow rates and leakage areas cannot be measured. However, pressure readings can be taken if a pressure probe can be inserted into the secondary zone. This pressure reading is used to determine how well connected (or disconnected) the secondary zone is from the house.

1122 Zone Pressure Diagnostics – Recommendations

Zone pressure diagnostics are recommended when additional information is needed regarding the relative and absolute leakage of pressure boundaries. Specifically, zone pressure diagnostics is recommended when the following situations are encountered.

1. Indoor Air Quality concerns - Zone pressure diagnostics should always be done in houses with attached or tuck-under garages, crawl spaces and other spaces where pollutants, moisture and soil gases can enter a home through air leaks.
2. Moisture-related problems in attic - this might be the case if:
    a. The attic has obvious moisture problems,
    b. There is evidence of high relative humidity in the home during winter, or
    c. Ice dams are a concern.
3. Air leakage/energy loss concerns - If the leakage rate of the house remains high after initial tightening of large leaks, zone pressure diagnostics can help identify less obvious air leakage sites in the attic floor, house walls, or basement and crawl space walls.

Zone pressure test to basement with blower door depressurizing house to -50 Pascals

Zone pressure diagnostics is most valuable on homes of moderate air leakage, rather than on homes with very high or very low air leakage rates. There are probably very obvious air leakage sites in homes where a pressure difference of -50 Pa cannot be achieved with the blower door. Sealing these obvious leaks is likely the most cost-effective measure that can be done in these homes. Likewise, identifying and sealing leaks between unconditioned zones and the living space in tight homes (less than 150% of the BTL) is probably not cost-effective. However, zone pressure diagnostics in tight homes is recommended when conditions as discussed above in items 1 and 2 are found.

1123 Zone Pressure Diagnostics - Preparation

Identify primary and secondary zones that will be tested.

Install a pressure probe or tube into the zones to be measured. Avoid pinching the tube. The tube/probe should be well above any insulation and not in any direct airflow.

Set-up the house and blower door for a typical air leakage test. The tube used to measure the pressure difference between the house and outside for the blower door test can also be used to measure the zone-to-outside pressure. Ensure that this hose will not be affected by the blower door airflow.

1124 Measuring Zone Pressures

11241 Zone-to-Inside/Outside Pressures

Depressurize the house to -50 Pa. If the house cannot be depressurized to -50 Pa see section 11242, "Zone Pressures when the House Cannot be Depressurized to -50 Pa". Note that flow rates and leakage areas cannot be determined unless the house can be depressurized to -50 Pa unless software for advanced zone pressure diagnostics is being used (see section 11251, "Software Calculations").

Connect the hose coming from the zone to the "input" tap on the manometer. This will be the zone with reference to inside pressure. Record the pressure.

With the zone hose still connected to the "input" tap, connect the hose from the outside to the "reference" tap. This will be the zone-with-reference-to-outside-pressure. Record the pressure.

The two pressures should add up to the house wrt outside pressure of -50 Pa. For example, if the zone-to-outside pressure is -5 Pa, the zone-to-house pressure should be 45 Pa if the blower door is at -50 Pa.

11242 Zone Pressures when the House Cannot be Depressurized to -50 Pa

If the house cannot be depressurized to -50 Pa, zone pressures can still be measured. However, measuring a CFM_{50} flow and air leakage area between the zone and house cannot be done unless the house can be depressurized to -50 Pa.

Depressurize the house to the highest multiple of 5. Measure the zone pressure and use the adjustment value found in Table 112-1 to determine the corresponding CFM_{50} Pa pressure reading.

For example, the house can only be depressurized to -35 Pa. The attic-to-outside pressure reading is -7 Pa. The corresponding CFM_{50} pressure reading is -9.8 Pa or (-7 Pa x 1.4 = -9.8 Pa).

Zone Pressure Adjustment Factors

Table 112-1

House Pressure	-10 Pa	-15 Pa	-20 Pa	-25 Pa	-30 Pa	-35 Pa	-40 Pa	-45 Pa
Zone/House	2.9	2.2	1.8	1.6	1.4	1.3	1.2	1.1
Zone/Outside	5	3.3	2.5	2	1.6	1.4	1.2	1.1

11243 Interpreting Zone-to-Inside/Outside Pressures

Pressure readings between the zone and the inside/outside indicate whether the pressure boundary is aligned with the thermal boundary. In all cases, both the pressure boundary and thermal boundary should be in the same construction assembly.

Generally, the thermal boundary should be between the conditioned space and an unconditioned space or outdoors. The thermal boundary must always be between the conditioned space and a tuck-under or attached garage.

For an attic, zone-to-outside readings of 0 Pa to -24 Pa (or zone-to-inside readings of 50 Pa to 26 Pa) indicate that the pressure boundary between the living space and attic is tighter than the boundary between the attic and outside (for example, the ceiling is tighter than the roof of an unfinished attic). Pressure numbers closer to 0-wrt-outside (or 50-wrt-inside) generally indicate that the pressure boundary is aligned with the thermal boundary. However, flow readings should be taken to determine the amount of CFM_{50} leakage between the house and zone and to determine the amount of air-sealing needed.

Zone-to-outside readings of -26 Pa to -50 Pa (or zone-to-inside readings of 0 Pa to 24 Pa) indicate that the pressure boundary between the zone and outside is tighter than the pressure boundary between the living space and zone. For example, the crawl space foundation walls are tighter than the floor between the crawl space and conditioned area. If it is determined that the crawl space foundation walls should be the thermal boundary, holes in the foundation wall should be sealed. Flow readings between the house and crawl space can be helpful in determining the amount of air sealing needed.

House-to-zone pressures in secondary zones such as framing cavities within the living space should be relatively low since they are supposed to be within the pressure boundary of the house. If the pressures are elevated, this normally means that one end or the other of that framing component is connected to a source of air leakage to the outdoors.

Zone-to-outside readings of -25 (zone-to-inside readings of 25 Pa) indicate that the air barrier between the zone and conditioned space and the air barrier between the zone and outside are equally leaky. This can make the tasks of defining conditioned space and where to do air sealing more difficult. Determining CFM_{50} flow readings can be an important tool for making such a decision.

Pressure readings between primary zones and living spaces indicate the location of the best air barrier and its relative leakiness. However, it is often important to have an estimate of the leakage area for purposes of air sealing. Using either calculator/computer based programs or the tables explained below can help accomplish this estimate.

1125 Measuring Flows and Leakage Areas

Air leakage flow in units of CFM_{50} between the zone and the living space and between the zone and the outside can be calculated with the methods described below. An opening, or hole, is added to the zone, either between the zone and house or zone and outdoors. Pressures are read before and after the temporary opening is created. The size of the hole is measured. Flow rates and leakage areas between the house and zone and zone and outside can then be determined. Additionally, the total path flow can be calculated. This represents the combined flow or Total Path, in units of CFM_{50}, taking into account the resistance of *both* of the pressure boundaries.

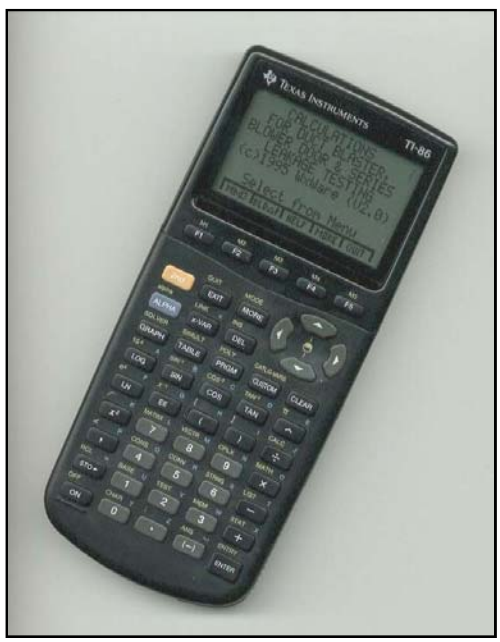
An operable hatch or door to the zone, or from the zone to the outside, is required to determine these flow values. Therefore, flow rates and leakage areas can only be measured for primary zones.

Flow rates and leakage areas between zones and the house can be calculated with software or manually with the use of tables. See the software users' manual for their recommended procedures. Additional information about flow values is provided in section 1126, "Manually Calculating Flow Rates (CFM_{50})".

11251 Software Calculations

Using software calculations to calculate flow rates and leakage areas is easier and more accurate that manually using tables. Software calculations should be used whenever possible.

The Energy Conservatory (www.energyconservatory.com/) offers a free zone pressure diagnostic (ZPD) utility program that calculates both flows and leakage areas. A Windows-based computer is required to run this program. This program utilizes advanced ZPD calculations.



Texas Instruments TI-86 calculator loaded with ZipTest Pro^2 building diagnostics software

Pressure readings between the zone and outside (or zone and inside) are taken with the house depressurized to -50 Pa. An opening is made between the house and zone (or zone and outside). Pressure readings are adjusted and the area of the opening is measured. The ZPD program then calculates the estimated flow and bypass area between the house and zone.

The Zip Test Pro™ (basic ZPD calculations) and Zip Test Pro2™ (basic and advanced ZPD calculations) software utilizes a hand held Texas

Instruments TI-86 calculator that calculates flows. This tool is used in the field and will provide immediate answers. Information about this software may be found at www.karg.com/software.htm.

Measuring pressures and determining flow rates either manually or using basic ZPD calculations can only be done if the house can be depressurized to -50 Pa. However advanced ZPD calculations allow use of pressures of less than 50 Pascal difference between the house and outdoors.

1126 Manually Calculating Flow Rates (CFM_{50})

Flow rates and leakage areas may be calculated manually with the use of tables. These procedures are described in Appendix 112.

113 Duct Leakage

Best Practice Recommendations:

- Pressure-pan testing is recommended:
  - On ducts located in unconditioned spaces (attics, behind knee walls, tuck-under garages, for example),
  - When basement return ducts are suspected of creating a hazardous venting condition, or
  - When basement return ducts may be contributing to indoor air quality problems, such as elevated interior moisture levels associated with wet basements.
- Measuring duct leakage to the outside with a Duct Blaster™ fan is recommended when:
  - The ducts are substantially outside the building envelope, and
  - The ducts are accessible and can be repaired.
- Pressure pan tests should always be conducted on mobile home ducts.

Duct leaks can lead to many problems in a dwelling, the most common one being wasted energy. Other problems can include hazardous combustion venting, thermal discomfort and substandard indoor air quality.

Ductwork leakage can take place within the confines of the conditioned envelope of the building or to and from the outdoors.

Duct leakage to or from the outdoors may waste more energy than leakage within the confines of the thermal envelope. Mobile home ducts and site-built homes with ductwork in crawl spaces or attics are susceptible to leakage to and from the outdoors.

Although duct leakage within the conditioned envelope usually does not have a significant energy impact, it might cause comfort problems or may impose a hazard to occupant health by causing poor indoor air quality or backdrafting of combustion appliances.

Two types of duct leakage tests are discussed in this section; pressure-pan and duct blower.

1131 Pressure-Pan Test Description

The pressure-pan test is a duct leakage diagnostic tool that is used with the blower door and digital pressure gauge to identify duct leakage to the outdoors. A gasketed pan is placed over each register or grille with the air handler fan off and the blower door depressurizing the house to -50 Pa. A pressure measurement between a duct and the room where the duct register or grille is located provides an indication of whether duct leakage to the outdoors exists.

Pressure-pan testing is recommended when ducts are found in:

- Unconditioned spaces (attics, behind knee walls, tuck-under garages, for example), or
- Basements when return leaks are suspected of creating a hazardous venting condition.

Pressure pan and digital monometer, both from The Energy Conservatory

Pressure pan tests should always be conducted on mobile home ducts (see section 34042, “Duct Leakage Standards”).

Pressure-pan testing may also be done on basement ducts when the ductwork is suspected of causing a thermal comfort or indoor air quality problem.

1132 Duct Blower Test

A duct blower test measures the air tightness of forced air duct systems. Duct leakage to the outdoors of a home can be measured or total duct leakage to both the interior and exterior of a home can be measured. This section addresses only the measurement of duct leakage to the outdoors. A duct blower and blower door are required for this test. The duct blower used in the following description is The Energy Conservatory Duct Blaster™.

The Duct Blaster™ fan is connected directly to the duct system at a central return or at the air handler cabinet. With all the registers and grilles temporarily sealed, the duct system is either pressurized or depressurized. When the Duct Blaster™ is used with the blower door, duct leakage to the outside can be measured. Total duct leakage to the outside should be measured when the ducts are substantially located outside the building envelope.

Duct blower (Duct Blaster) from The Energy Conservatory

1133 Importance of Duct Location

11331 Ducts Located in Conditioned Spaces

Perform a house-to-zone pressure and flow test to determine if the space in question is conditioned in terms of its pressure boundaries (see section 112, “Zone Pressure Tests”). The house-to-zone pressure should be 20 Pascals or less (or zone-to-outside pressure 30 Pascals or greater).

Visually inspect the conditioned space to ensure that the shell is properly insulated and air sealed. If it is determined that weatherization work should be done to the shell of the conditioned space that houses the ducts, perform a house-to-zone pressure and flow test before and after the work to quantify the effectiveness of the air sealing work.

Always repair disconnected ducts. Sealing the shell of the space rather than sealing the duct joints will maximize energy savings. Sealing the duct joints may correct a combustion venting problem, increase thermal comfort or improve an indoor air quality problem, but will do little to save energy.

11332 Ducts Located in Unconditioned Spaces

If possible, permanently convert the unconditioned space where the ducts are located to a conditioned space, making sure the air and thermal barriers are installed effectively. Demonstrate the effectiveness of this weatherization work by performing a house-to-zone pressure and flow test before and after converting the unconditioned space to a conditioned space (see section 112, "Zone Pressure Diagnostics").

Always repair disconnected ducts in unconditioned spaces. If the unconditioned space is impossible or impractical to convert to a conditioned space:

- Make all necessary ductwork repairs, seal all ductwork joints with mastic, and
- Add R8 insulation to uninsulated ducts.

Examples of unconditioned spaces that may be impractical to convert to conditioned space include some crawl spaces, unconditioned basements, attics, attached or tuck-under garages, and exterior walls.

1134 Duct Leakage Standards (Site-Built Homes)

11341 Pressure-Pan Testing for Ducts in Conditioned Spaces

Pressure-pan testing is not recommended for ducts located within conditioned spaces. Rather, air sealing leaks to the outdoors in the space in which the ducts are located is recommended.

11342 Pressure-Pan Testing for Ducts in Unconditioned Spaces

Pressure-pan testing is recommended for ducts located within unconditioned spaces in site-built homes. Pressure-pan tests are also recommended for mobile home ducts (see section 34042, "Duct Leakage Standards").

If the ducts themselves or the space in which they are located is perfectly sealed to the outdoors, no pressure difference will be read during a pressure-pan test. The higher the pressure reading in ducts, the more connected the ducts are to the outside. This connection means leaks and leaks lead to wasted fuel.

- Following weatherization work, no more than three registers shall have pressure-pan readings greater than 2.0 Pa. No readings shall be greater than 4.0 Pa.
- If all readings are under 1.5 Pa, no duct sealing is needed.
- Pressure pan readings in excess of 4.0 Pa indicate a serious breach in the duct system. Locate and seal holes in duct.

Inspect the boot connections behind registers measuring more than 4 Pa. Re-attach or seal boots if necessary.

11343 Standards for Duct Blower-Measured Leakage to the Outdoors

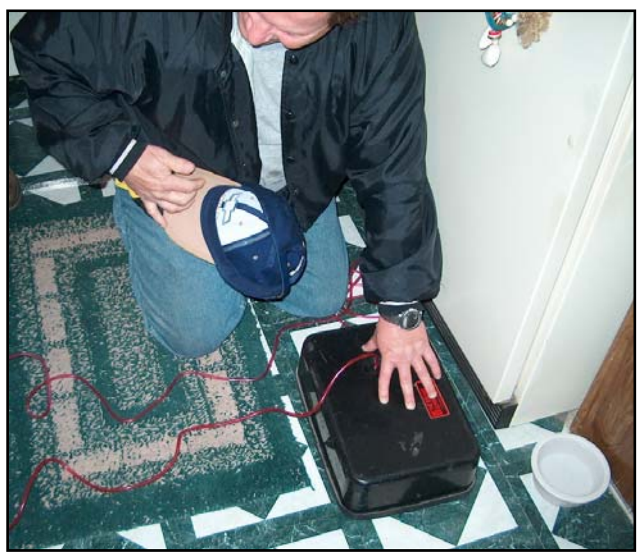
Total duct leakage to the outside should be measured when the ducts are substantially located outside the building envelope. Duct leakage to the outdoors, as measured with the Duct Blaster™ fan[5] and blower door, should be no more than 5 percent of conditioned floor area. For example, if the conditioned floor is 1,300 ft^2, duct leakage to the outside should be no more than 65 CFM.

1135 Pressure-Pan Test

11351 Duct Leakage to the Outdoors

Pressure-pan duct testing can help identify leaky or disconnected ducts that are leaking to or from the outdoors. Testing before and after duct sealing gives an indication of the effectiveness of sealing efforts. Pressure-pans do not read duct leakage directly; they infer leakage to the outdoors by reading the pressure at individual registers.

Pressure-pan readings are taken at each supply and return register served by ducts running through unconditioned spaces with the house depressurized by the blower door to -50 Pa. Pressure-pan readings close to 0 Pa indicate no leakage to the outside. Pressure-pan readings greater than -4 Pa indicate a significant leak to the outside.



Pressure pan test (operating blower door not pictured)

Duct boot connections should be inspected at registers measuring more than 4 Pa. Boots that have dropped-down or have holes in

[5] At 25 Pa; see section 1136, "Duct Leakage to the Outside".

the corners should be re-attached and sealed. Another pressure-pan reading should then be taken. Inspect the duct if the pressure-pan reading remains elevated.

Special attention should also be given to registers attached to stud cavities or panned joists used as return ducts. These wood framed ducts are often very leaky to the inside and outside of a dwelling.

11352 Duct Leakage to Conditioned Spaces (Basements/Crawl Spaces)

Basements are most often considered part of the conditioned space of a home. Therefore, it is recommended that the door between the basement and living space be **closed** during pressure-pan testing. If pressure-pan readings are taken on ducts located in basements with basement doors open, the pressure readings are likely to be very small, despite the fact that large holes in the basement ducts may be present and visible.

When pressure-pan tests are taken with the basement door open, low pressure readings indicate little duct leakage to the outside, although there may be significant duct leakage to the basement. Basement leaks may cause discomfort, indoor air quality and combustion venting problems. Leaks in the return system may become apparent during the worse case draft test. However, location of these leaks with a pressure pan may become quite apparent when the basement is connected to the outdoors by opening basement windows.

To check for leakage to the basement from basement ducts with the pressure-pan, place the basement outside the conditioned space. Close the basement door between the house and basement. Open basement windows and/or the basement door to the outside. Seal supply and return registers in the basement. Seal filter slot as well. Measure the pressure pan readings in the main floor ducts.

Air sealing the foundation walls will likely reduce pressure-pan readings for ducts located in conditioned basements and crawl spaces. Unless duct leakage is causing a hazardous combustion venting problem, creating a comfort problem or causing an indoor air quality problem in the main body of the house, it is always preferable to air seal the foundation walls before duct sealing (see section 11331, "Ducts Located in Conditioned Spaces").

11353 Pressure-Pan Test Procedures[6]

Identify ducts that are in unconditioned zones of the house. It is not necessary to take pressure-pan readings on ducts located in conditioned spaces unless ducts located in basements are suspected as causing a thermal comfort or indoor air quality problem (see section 11352, "Duct Leakage to Conditioned Spaces").

Install the blower door and set-up the house for winter conditions. Open all interior doors, including door to basement.

[6] Pressure-pan standards for mobile homes are located in section 34042, "Duct Leakage Standards".

Make sure the furnace burner and air handler are off and will not start during the testing. Remove the furnace filter. Ensure that all grilles, registers, and dampers are fully open in the conditioned space of the house[7].

Temporarily seal any outside fresh-air intakes to the duct system. These are usually ducted to the return side of the ductwork. If supply ducts are located in a garage or other unconditioned space, seal these registers so that the register opening does not show up as a duct leak.

Open zones that contain the ducts as possible to the outside. These zones include attics, crawl spaces and garages.

Connect the hose between the pressure pan and the input tap on the digital manometer. The reference tap to the house should be open.

Depressurize the house to -50 Pa. Place the pressure pan completely over a grille or register to form a tight seal. Record the reading. Note that only one register is sealed with the pressure-pan at a time.

A blower door is needed for the duct blower test to determine leakage to the outdoors

If unconditioned spaces in which ducts are located are not well connected to the outdoors or have very large connections to the house, then the unconditioned space will be at a pressure between the outside and inside house pressure during the blower door test. In this case, the pressure-pan reading will show an artificially low number. To correct this misleading number:

- With the house at -50 Pascals, measure the pressure difference between the house and the unconditioned space. (For example, the house-to-zone pressure is 10 Pascals and the pressure pan reading is 2.0 Pascals).

- Multiply the pressure pan reading by the multiplier in Table 113-1 to get the adjusted reading. (For example, multiply the pressure pan reading of 2.0 Pascals by 5, resulting in a pressure pan reading of 10 Pascals).

If you are testing a house with a very leaky building shell and are not able to create a 50 Pa pressure difference with the blower door, perform pressure-pan

[7] Before fully opening or changing the position of balancing dampers, mark their position so that they can be returned to that position after the pressure pan testing.

tests with the house at the highest achievable pressure. Interpret pressure-pan readings carefully. Compare the measured pressure-pan reading with the maximum possible reading.

Pressure Pan Multipliers
Table 113-1

se/Zone Pressure	***Pressure Pan Multiplier***
50	1.0
45	1.1
40	1.25
35	1.42
30	1.66
25	2.0
20	2.5
15	3.5
10	5.0
5	10.0

Repeat the test for each register and grille on ducts located in unconditioned spaces in a systematic fashion.

If a grille is too large or supply register is difficult to access (under a kitchen cabinet, for example), seal the entire grille or register with duct-mask tape. Insert a pressure probe through the duct-mask tape and record reading. This is more time consuming than using the pressure-pan, but it gives an accurate reading.

When two registers or grilles are closely connected to the same duct run (for example, two registers on opposite sides of the same partition wall), seal one and use the pressure-pan on the other unsealed register or grille.

1136 Duct Leakage to the Outside

In some cases, especially where the ducts are substantially outside the building envelope, it can be useful to quantify the amount of air leakage that is occurring through the ducts to the outside. This test can provide a clear picture of the amount of leakage between the ducts and unconditioned zones and should only be done if the ducts are accessible and can be repaired.

A Duct Blaster™ fan is used in combination with the blower door to measure air leaks to the outside in the duct system. The blower door neutralizes duct leakage to the indoors. Only CFM leakage to the outdoors not neutralized by the blower door is measured.

11361 Duct Leakage to the Outside Procedures

Put the house into a winter condition with all interior doors open. The basement door is to remain open if the basement is conditioned.

Cover all supply and all returns with an air impermeable material (plastic bags work well as do magnetic panels and 3 inch masking tape). Make sure all major openings to the inside of the house are covered (i.e., basement, toe kick, closet registers and the front and back of any open filter slots). Remove the furnace filter prior to sealing the filter slot.

Locate a large unobstructed opening into the return side of the distribution system. This may be a large return register (remove the grill covering before installing the Duct Blaster™ fan), but is usually the access panel to the fan compartment of the furnace. Cover/tape the opening of the return access with a sheet of rigid material (cardboard, rigid insulation, etc) with an opening cut in it sized to fit the Duct Blaster™ fan. Attach the fan to the rigid covering with the intake side of the fan (flow reducer side) facing the house. Place a restriction plate on the fan opening (Ring 2; 48 to 340 CFM is the best to start with). Install the fan and covering in a way that minimizes the amount of fan opening restriction by the circuit board present in newer furnaces.

On the digital manometer, install one hose into the supply side of the distribution system (in other words, the opposite side of the heat exchanger from the fan) and attach it to the reference tap of the pressure gauge's Channel A. Install a second hose to the pressure tap located on the fan housing and attach it to the input tap of Channel B. Since this is a pressurization test the flow conditioner is not required.

Select a level of pressure to measure the duct leakage. The most common pressure used for this test is 25 Pa. Switch the blower door fan to the pressurization mode and pressurize the house to the desired duct measurement level. Be sure the pressure gauge is out of the fan flow since air will be drawn in through the fan at a significant rate. There is no need to determine the CFM_{50} of the house; just pressurize the house to 25 Pa.

Note the pressure across the ducts produced by the duct leaks in the system. Slowly increase the Duct Blaster™ fan speed until the duct system pressure is decreased to a 0 (neutral) Pascal pressure. Check the fan pressure/flow. If the fan pressure is too low (<10 Pa) the flow restriction plate should be replaced with a smaller plate (Ring 3; 20-140 CFM). If the pressure across the ducts cannot be neutralized, a larger sized restriction plate should be installed or use the open fan (Ring 1; 124 to 878 CFM or Open Fan; 330 to 1696 CFM).

When the leakage is neutralized and a measurable fan pressure is attained, check the house pressure produced by the blower door to make sure it is still at 25 Pa and make any needed adjustments to the blower door and/or Duct Blaster™ fan speed. Using either a conversion chart or the fan flow calculation mode on the pressure gauge, find the CFM_{25} fan flow needed to neutralize the duct leaks in the system at 25 Pa

The previous procedure details a test where both the house and duct system are pressurized. Duct leakage to the outside may also be done by depressurizing both the house and duct system. One advantage of depressurizing is not having to switch the blower door to the pressurization mode. Also, it may be difficult to keep the tape or plastic on the registers during a pressurization test. Depressurizing the ducts tends to make the covering over the registers tighter. Check the Duct Blaster™ fan manual for additional information on depressurizing the ducts.

114 Duct-Induced Pressures

Best Practice Recommendation:

- Provide pressure relief when pressures are + or -3.0 Pa between a room and the main body of the house with the air handler operating.

An improperly balanced air-handling system can cause comfort, impact building durability, and contribute to indoor air quality problems. An imbalance between the supply and return sides of the distribution can be caused by duct leakage to the outside, restricted/inadequate returns, the restriction of supply flow back to the main living spaces of the house and/or pressure driven exfiltration.

1141 Whole House Dominant Duct Leakage

This test identifies the side of the distribution system that has the strongest connection to the unconditioned spaces of the dwelling or to the outdoors.

1. Set-up the house for winter conditions. Close all windows and exterior doors. Turn off all exhaust fans.

2. Open all interior doors, including the door to basement if it is a conditioned space.

3. On the manometer, place a hose from "reference" tap to the outside.

4. Measure the house pressure with reference to the outside. This is the baseline pressure created by natural pressure forces (stack-effect air leakage).

5. Turn on the air handler (high speed, if two-speed fan).

6. Measure the house pressure with reference to the outside.

Note the difference between the baseline pressure and the duct-induced pressure. If the house pressure with reference to (wrt) the outside is negative, it indicates that the dominant duct leakage to the outdoors is on the supply side of the distribution system. If it is positive, the dominant duct leakage to the outdoors is on the return side.

1142 Duct-Induced Room Pressures

This test identifies the restriction of supply flow to the main living space by measuring pressure differences between the main body of the house and each room, including the combustion appliance zone (usually the basement).

1. Set-up the house for winter conditions. Close all windows and exterior doors. Turn off all exhaust fans.

2. Close all interior doors, including the door to basement.

3. Turn on the air handler (high speed, if two-speed fan).

4. On the manometer, place a hose from “input” tap under the door of the room being tested. Leave “reference” tap open to main body of house.

5. Read and record measurement for each room, including the basement.

6. With the doors still closed and the air handler operating place the hose outside and measure the pressure between the main body of the house and the outside. This will identify if door closure is producing a negative pressure across the main body of the house and how strong that pressure is.

The blower door is NOT used for this testing

11421 Interpreting Duct-Induced Room Pressures

If the pressure difference is more than + or -3.0 Pa with the air handler operating, pressure relief is necessary. To estimate the amount opening for adequate pressure relief, slowly open the door until pressure difference drops between +3.0 Pa and -3.0 Pa. Measure and calculate the area of the door opening. This is the area required to provide pressure relief by undercutting the door or installing a door grille.

Alternately, transfer grilles may be mounted in a partition wall (one high on the wall and one low on the opposite side), a jumper duct may be installed across the ceiling between the room and the hallway, a door louver may be installed or the door may be undercut.

Correcting most significant pressure differences will require a larger opening than a door undercut can provide and the door louver sacrifices a certain amount of privacy. The wall and ceiling mount relief strategies are usually the most effective. It is also important to remember that the door opening measured is a gross opening and so the size of the transfer grilles must be adjusted for the restriction of those grilles.

Additional information about calculating the area required for pressure relief may be found in Appendix 114.

Adding return air ducts (or enlarging existing return air ducts) may also correct pressure balance problems.

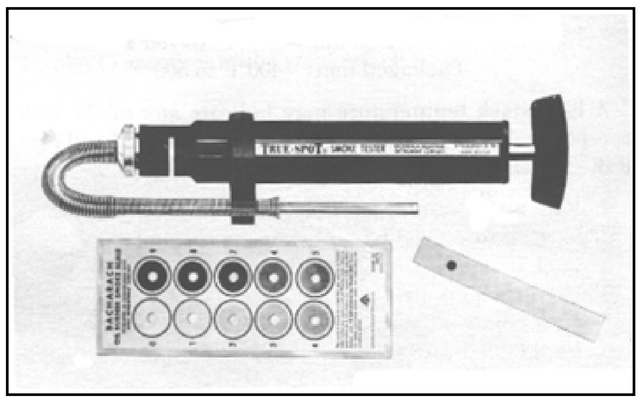
121 Furnaces and Boilers

Best Practices Recommendations:

- A combustion efficiency test should be performed for an adequate appraisal of the operation and efficiency of the heating system.
- The following tests should also be conducted to help assess existing condition of heating system.
    - CO test,
    - Draft test under worst-case draft conditions,
    - Gas leak test (gas-fired systems),
    - Temperature rise (forced-air furnaces), and
    - Clocking the meter (gas-fired systems).

1211 Smoke Testing

A combustion smoke test should be performed on all oil-fired heating systems *before* a steady-state efficiency test is done. This smoke test is not required on natural gas- or propane-fired systems.



Bacharach True Spot® Smoke Test kit used for oil-fired systems only

If the measured smoke reading of the combustion emissions is 2 or less, the steady-state efficiency test may be performed. If the smoke test shows a reading higher than 2, the system must be cleaned and tuned before a steady-state efficiency test is performed.

This standardized smoke test measures the amount of carbon in the flue gases by pulling a measured amount of these combustion gases through a special filter paper. The smoke dot on the filter paper is then matched with one of ten smoke density samples numbered from 0 to 9 on a sample card.

The most common device for measuring smoke on an oil-fired system is the Bacharach True-Spot® Smoke Test Kit. This is a pump-type device with a slot for filter paper. While the burner is operating and when the system has reached steady-state (stable flue gas temperature), insert the probe for the calibrated pump into a hole in the breech of the vent connector and then manually operate the pump according to the instructions to pull combustion gases through the filter paper. Match the smoke spot on the filter paper with one of the ten choices on the sample smoke card.

1212 Combustion Efficiency Testing

A combustion efficiency test should be performed by the assessor or a heating system specialist for an adequate appraisal of the operation and efficiency of the heating system. This test must always be performed during steady-state conditions. This means that the burner must be operating and the flue gas in the vent connector must reach a stable temperature. If the burner stops firing during a steady-state efficiency test, the test must be aborted and started again.

12121 Information Needed for Test

To determine the steady-state efficiency of a heating system, the net stack temperature and the amount of excess air in the flue gas must be measured.

The net stack temperature is the temperature of the combustion supply air (room temperature) subtracted from the temperature of the combustion gases in the vent connector. Older combustion analyzers measure the gross stack temperature. The combustion supply air, which is usually the room air temperature of the space in which the heating appliance is located, must be subtracted from the gross stack temperature to find the net stack temperature.

The Testo 325 combustion analyzer measures steady-state efficiency and carbon monoxide emissions

Newer digital combustion analyzers automatically subtract room air temperature from stack temperature for their calculation of efficiency. Make sure that the room temperature is recorded by the analyzer so that it calculates the efficiency correctly. The lower the net stack temperature, the higher the efficiency of the heating system.

In order to determine the amount of excess air is in the combustion gases, the oxygen (O_2) or carbon dioxide (CO_2) percentage in the combustion gas is measured. Digital combustion analyzers always read O_2 with an oxygen sensing cell. These newer digital units are sometimes referred to as dry-type analyzers. The older wet-type analyzers determine the percentage of CO_2 in the flue gas by pumping the combustion gases through a special liquid (potassium hydroxide) that absorbs CO_2. As the CO_2 is absorbed the volume of the liquid increases.

12122 Where to Test

The temperature and O_2 or CO_2 must always be measured before any room air is allowed to dilute the combustion gases. For a gas boiler, the measurements must be taken before the draft hood or draft diverter. For some older gas-fired boilers, room dilution air enters through an opening in the underside of the vent connector at the point it connects to the heating unit. For these older systems, the temperature and O_2 or CO_2 readings are taken by inserting the instrument probe into the vent connector opening (drilling a hole is not necessary) and holding the probe in a position that will not be affected by room dilution air.

For an atmospheric gas furnace, the readings must be taken just before the emissions are diluted by room air at the draft diverter.

For oil-fired units, the readings must be taken at the breech before the barometric damper.

12123 Conducting the Test

With the heating unit operating, insert the sampling probe of a combustion analyzer into the appropriate location of the vent system. Measure the temperature of the flue gases to determine when steady-state condition is reached. This will be when the flue gas temperature stabilizes (steady-state condition).

The Bacharach Fyrite Pro combustion analyzer measures steady-state efficiency and carbon monoxide emissions

Measure and record the net stack temperature (room temperature subtracted from steady-state stack temperature) and O_2 or CO_2. Determine whether the readings are within the acceptable limits listed in Table 121-1, "Acceptable Combustion Test Analysis Values".

If the burner shuts down while conducting the test, start the test again. Turning up the thermostat so that the burner runs longer may be helpful. Other temporary adjustments will ensure that the burner runs for longer periods, but it is important to follow state program recommendations when making such adjustments.

Return the thermostat(s) and other modified controls to their original settings when the test is complete.

Always be aware of health and safety during combustion testing. If any of the following conditions are present during an efficiency test, shut down the heating system and take remedial action:

- If significant draft reversal occurs, filling the combustion appliance zone with combustion gases.
- If ambient carbon monoxide levels reach 10 ppm.
- Flame rollout.

- Hazardous heat exchanger defects.
- Obvious electrical or system control problems.
- Any other hazardous malfunction of the heating unit or distribution system.

Acceptable Combustion Test Analysis Values
Table 121-1

Heating Unit Type	***Oxygen (O_2)***	***Carbon Dioxide (CO_2)***	***Net Stack Temp.***	***Smoke Test***
Gas				
Atmospheric	4 - 9%	Natural 9.6 - 6.8% LPG 11.2 - 7.8%	300-600º F	NA
Fan-assisted	4 - 9%	Natural 9.6 - 6.8% LPG 11.2 - 7.8%	300-480º F	NA
Condensing	See man. Info.	See man. Info.	See man. Info.	NA
Standard Power Burner	4 - 9%	Natural 9.6 - 6.8% LPG 11.2 - 7.8%	300-650º F	NA
Oil (No. 1 & 2)				
Oil gun burner	4 - 9%	12.5 - 8.8%	325-600º F	2 or less
Flame Retention Burner	4 - 7%	12.5 - 10.3%	325-600º F	2 or less

1213 Carbon Monoxide Test

With the heating unit operating and in steady-state condition, insert the sampling probe into the appropriate spot in the vent system (before any room dilution air has entered the vent system). The CO test is always done in the same vent system location as the steady-state efficiency test.

Measure and record the amount of carbon monoxide in the flue gas, either as-measured or air-free. The measured CO emissions level must be equal to or less than that listed in Table 121-2. If cleaning and tuning does not adequately lower the CO emissions, consider replacement of the heating unit (see Section 223, “Heating System Replacement”, for other criteria related to replacing existing heating appliances).

The best time to measure for CO emissions is during worst-case conditions. Please refer to Section 123 for more information.

Carbon Monoxide (CO) Action Levels and Allowable Levels
Table 121 -2

Appliance	***Allowable CO Level***	***Comments***
Gas Furnace / Boiler	100 ppm / 200 ppm	as-measured / air-free
Oil Furnace / Boiler	100 ppm	as-measured

1214 Draft Testing

All heating system units should be tested for draft at the time of the efficiency test, during a cleaning and tuning, and under worst-case conditions (see Section 123, "Worst-Case Draft Testing"). Exceptions to this requirement include:

- Condensing furnaces and boilers.
- Direct-vent, sealed combustion appliances.
- Heating units with vent connectors under positive pressure.

Under all conditions, including worst-case, heating units must demonstrate a minimum draft strength corresponding to the values in Tables 121-3 and 121-4. Notice that typical oil-fired units have two draft values – overfire and breech. In addition, notice that draft readings for oil-fired units are not dependent on outdoor temperature – as atmospheric gas-fired units are – because the barometric damper on oil units automatically adjusts for differences in temperature.

Draft readings are often taken at a different location in the vent connector than combustion efficiency or carbon monoxide readings. Make sure that the draft reading is always taken at the proper location.

Atmospheric Gas Appliances Only
Acceptable Draft Test Readings for Various Outdoor Temperature Ranges
Table 121-3

ºF	<20	20-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column inches	-.02	-.016	-.012	-.008	-.004

Power Oil Burners
Acceptable Draft Readings Overfire and at Breech
Table 121-4

Draft Reading Location	**Acceptable Draft**
Overfire Draft	-0.01 to -0.02 inches or -2.5 to -5 Pascals
Vent Connector or Breech	-0.04 to -0.06 inches or -10 to -15 Pascals

1215 Gas Leak Testing

Gas leak testing should be done for all natural gas and propane appliance lines and connections. Because propane is heavier than air and natural gas is lighter than air, hold the combustible gas detector probe just below a propane gas line and just above a natural gas line. All identified gas leaks should be referred to appropriate persons for repair or replacement.

1216 Temperature Rise

The temperature rise of a furnace distribution system should be measured before and then after any significant heating unit or distribution system repairs or modifications.

The measured temperature rise should be between 40^{o} and 70^{o}F or within the manufacturer's specified range. The specified temperature rise is almost always included on a nameplate on the furnace.

If the temperature rise is too high, it could be due to:

- Low air handler fan speed or broken fan belt.
- Obstruction in the return or supply ductwork, including a dirty filter.
- Inadequate or restricted return ductwork.
- Overfired burner.
- Dirty or defective blower.

If the temperature rise is too low, it could be due to:

- Air handler fan speed is too high.
- Excessive duct leakage.
- Underfired burner.

With the heating unit and blower operating, measure the temperature in a duct within 12 inches of the supply and return plenums. In a mobile home, measure the supply temperature at the supply register closest to the furnace.

If the temperature rise is out of range, take action to correct the cause.

1217 Clocking the Gas Meter

Clock the gas meter to measure gas input. Ensure that other gas appliances (water heater, dryer, range) do not fire when clocking the meter. Refer to table 121-5 for input rates based on clocking the gas meter. Use the following formula if the gas meter does not have a ½ ft^3 or 1 ft^3 dial:

1,000 Btuh = (dial type * 3600)/time for revolution

For example, a there is a 2 ft^3 dial on the gas meter and it takes 50 seconds to make one revolution. The metered gas input is 144,000 Btuh.

1,000 Btuh = (2 x 3600)/50 seconds = 144

Clocking the Gas Meter

Table 121-5

Using a watch, measure the number of seconds for either the ½ ft^3 or the 1 ft^3 to make one complete revolution. Read the corresponding input rate in 1,000 of Btus/ft^3.

Seconds for One Revolution on the Dial	½ ft^3	1 ft^3	Seconds for One Revolution on the Dial	½ ft^3	1 ft^3
10	180	360	40	45	90
11	164	327	41	44	88
12	150	300	42	43	84
13	138	277	43	42	84
14	129	257	44	41	82
15	120	240	45	40	80
16	112	225	46	39	78
17	106	212	47	38	77
18	100	200	48	37	75
19	95	189	49	37	73
20	90	180	50	36	72
21	86	171	51	35	71
22	82	164	52	35	69
23	78	157	53	34	68
24	75	150	54	33	67
25	72	144	55	33	65
26	69	138	56	32	64
27	67	133	57	32	63
28	64	129	58	31	62
29	62	124	59	30	61
30	60	120	60	30	60
31	58	116	62	29	58
32	56	113	64	29	56
33	55	109	66	29	54
34	53	106	68	28	53
35	51	100	70	26	51
36	50	100	72	25	50
37	49	97	74	24	48
38	47	95	76	24	47
39	46	92	78	23	46

122 Water Heaters

Best Practice Recommendations:

- The following tests should be conducted to help assess existing condition of water heaters.
    - Draft test under worst-case draft conditions,
    - CO test, and
    - Gas leak test (gas-fired systems).

1221 Draft Test

The draft test on a gas- or oil-fired water heater must be measured through a hole drilled in the vent connector. For an atmospheric gas-fired unit, drill a hole between the draft hood and the chimney, and in a straight vertical section, if possible. For an oil-fired water heater, drill the appropriately sized hole before the barometric damper and at least six inches away from the water heater unit.

After the water heater has been operating for at least two minutes, insert the probe of the draft device into the hole to the center of the vent connector. Under all conditions, including worst-case, water heaters must demonstrate a minimum draft strength corresponding to the values in Tables 122-1 and 122-2. Notice that draft readings for oil-fired units are not dependent on outdoor temperature – as atmospheric gas-fired units are – because the barometric damper on oil units automatically adjusts for differences in temperature.

Atmospheric Gas Appliances Only
Acceptable Draft Test Readings for Various Outdoor Temperature Ranges
Table 122-1

ºF	<20	21-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column inches	-.02	-.016	-.012	-.008	-.004

Power Oil Burner Water Heaters
Acceptable Draft Readings at Breech
Table 122-2

Draft Reading Location	**Acceptable Draft**
Vent Connector	-0.04 to -0.06 inches or -10 to -15 Pascals

1222 Carbon Monoxide Test

With the water heating unit operating for at least two minutes, insert the sampling probe into the appropriate spot in the vent system (before any room dilution air has entered the vent system). For an atmospheric gas-fired unit, the probe must be inserted into the opening in the draft hood to sample the combustion gases before they are diluted by room air. Readings need to be taken on each side of the vent baffle that divides the integral vent into two sections.

On an oil-fired water heater, check for CO levels at the same hole used to check the draft.

Measure and record the amount of carbon monoxide in the flue gas, either as-measured or air-free. The measured CO level must be equal to or less than that listed in Table 122-3. If cleaning and tuning does not adequately lower the CO emissions, consider replacement of the water heating appliance. See section 2243 for other criteria relating to water heater replacement.

The best time to measure for CO emissions is during worst-case conditions. Please refer to Section 123 for more information.

Carbon Monoxide (CO) Action Levels and Allowable Levels
Table 122-3

Appliance	***Allowable CO Level***	***Comments***
Gas Water Heater	100 ppm / 200 ppm	as-measured / air-free
Oil Water Heater	100 ppm	as-measured

1223 Gas Leak Testing

Gas leak testing should be done for all natural gas and propane appliance lines and connections. Because propane is heavier than air and natural gas is lighter than air, hold the combustible gas detector probe just below a propane gas line and just above a natural gas line. All identified gas leaks should be referred to appropriate persons for repair or replacement.

Bacharach Leakator® – 10 combustible gas detector

123 Worst-Case Draft Testing

Best Practice Recommendations:

- A worst-case draft test should be performed near the end of each work day in appropriate dwellings.
- The worst-case draft test should include:
  - Determination of the worst-case condition in the dwelling.
  - Testing each vented combustion appliance for spillage under worst-case conditions.
  - Testing each vented combustion appliance for adequate draft under worst-case conditions.
- Any appliance that fails the worst-case test before or after all weatherization work is completed should be made non-operational until the hazardous condition is corrected.

1231 Introduction

The purpose of worst-case draft testing is to ensure the proper venting of vented combustion devices in a dwelling. Additionally, carbon monoxide (CO) emissions are measured to ensure they are within acceptable levels.

There are two parts to this important test. For the first part, the assessor establishes the worst-case condition for the Combustion Appliance Zone (CAZ), in other words, finds the greatest magnitude of negative pressure in the CAZ under which the combustion appliances might have to operate. For the second part, the assessor checks for spillage, measures the draft, and determines the level of CO emissions while the dwelling is in worst-case condition.

Obvious evidence of drafting failure

If a house contains more than one CAZ, a worst-case draft test must be performed for each area. Additionally, if more than one vented combustion appliance is located in a CAZ, each must be tested for safe operation under worst-case conditions.

At the end of each weatherization work day and after the completion of ALL weatherization work, a worst-case draft test must be performed by an assessor or crew foreman. The results must be documented in the job file.

If any vented combustion appliance fails the test under worst-case conditions, actions must be taken to correct the cause (see section 12355, “Solutions to Draft Failure or High

CO under Worst-Case Conditions”). After correction, another worst-case draft test must be performed.

1232 Appliances and Dwellings Requiring Worst-Case Draft Testing

Worst-case draft testing should be performed on the following appliance types as specified:[8]

- All Category I gas appliances, both natural draft and fan-assisted, should be tested for spillage, draft, and carbon monoxide emissions.
- All vented oil-fired appliances should be tested for spillage, draft, and carbon monoxide emissions.
- All Category III and IV, sidewall-vented but **NOT** direct-vent/sealed combustion should be tested for CO, but not for spillage or draft. It is recommended that the test for CO emissions be done at the outdoor vent termination.
- All mobile home furnaces should be tested for CO, but not for spillage or draft. It is recommended that the test for CO emissions be done at the outdoor vent termination.

Table 123-1 lists the worst-case conditions testing recommended for various appliance types.

Worst-Case Conditions Testing for Various Vented Combustion Appliances
Table 123-1

Combustion Appliance Type	*Tests Under Worst-Case Conditions*		
	Spillage Test (at 2 minutes)	*Draft Test* (at 5 minutes)	*CO Emissions Test* As-measured CO $\leq$ 100 ppm (at 5 minutes)
Gas-fired, Category I, natural draft and fan-assisted	yes	yes	yes
Oil-fired with typical power burner	yes	yes	yes
Gas-fired, Category III & IV, side wall vented, but not direct-vent/sealed combustion	no	no	yes
Mobile home furnaces	no	no	yes

Worst-case draft testing must be done in all dwellings. The following are *exceptions* to this requirement:

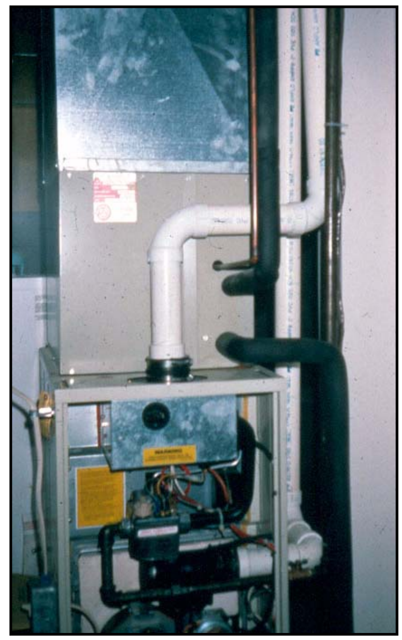
- If the house or mobile home is all-electric with no vented combustion appliances, woodstoves or fireplaces.
- If the dwelling has a boiler and/or an atmospheric water heater ***and*** has no exhaust equipment, including clothes dryers, vented bath and kitchen fans, vented central vacuum systems, fireplaces, woodstoves, etc.

[8] For a definition of vent categories, please refer to the *National Fuel Gas Code* (NFPA 54), Chapter 3, “Definitions”, “Vented appliance, Category I, II, III, and IV”.

- If the only vented appliances in the dwelling are direct-vent/sealed combustion appliances.
- If the CAZ is located outside of the thermal boundary, such as in a mobile home water heater closet or a garage
- In multi-family buildings with no combustion appliances.

1233 Testing Before Job Completion

In order to ensure that clients are not exposed to the hazards of venting problems between the beginning and completion of the weatherization work, a worst-case draft test should be performed at the end of each work day.



This direct-vent, sealed combustion gas furnace does not require worst-case draft testing

If any combustion appliances fail the worst-case draft test, remedial action must be taken before the work crew leaves the job site for the day. This action might include:

- Correcting the cause of the draft failure or high CO emissions.
- Shutting down the appliance(s) failing the test. This might not always be an option, for example, turning off a heating system during the winter months. Some weatherization programs loan portable electric heaters to clients if heating systems must be temporarily shut down for safety reasons.
- Inform the client of the draft hazard and tell them not to use the appliance until the problem is eliminated by the weatherization organization.

All test results from each day must be documented in the job file.

Caution: Never use the DTL nor the worst-case test threshold values as a substitute for the final worst-case draft test.

1234 Testing After Job Completion

All other diagnostic testing and weatherization work must be completed before the final worst-case draft test is performed. It is particularly important to perform the Duct-Induced Room Pressures Test and correct related problems. Refer to Section 1142 for instructions.

1235 Test Procedure

"Worst-case" is defined as the configuration of the house that results in the greatest negative pressure in the combustion appliance zone (CAZ). Consideration must be given to:

- The types and locations of the heating systems.

- The location and CFM rating of all exhausting equipment (bath fans, dryers, kitchen exhaust devices, etc.).
- The location of wood stoves, fireplaces, and water heaters.
- The volume of the area where the combustion devices are located.
- The location of forced-air system supply registers and return grilles.

12351 Procedure Setup

1. For the final worst-case draft test, duct-induced room pressure testing and adjusting should have been completed Refer to Section 1142 for this test.
2. Place the building in the wintertime condition with all windows and exterior doors closed. If the blower door is set-up, make sure the fan is closed off.
3. Measure and record the outdoor temperature.
4. Deactivate all combustion appliances by turning them off or setting the control to “pilot.” Try to test the appliances with a cool vent system, if possible.
5. Close all operable vents (for example, a fireplace damper).
6. If there is a furnace, replace or clean the filter if it is dirty.
7. Check and clean the lint filter in the dryer.
8. If there are any supply registers in the CAZ, close them.
9. Set up the digital manometer and pressure hoses so that the pressure differential of the CAZ with reference to the outdoors can be easily measured. If the CAZ is in a basement, run a pressure hose to the outdoors through a window or door, and then close the window or door as tightly as possible without totally closing off airflow through the hose. Use masking tape to seal the opening and the meeting rail. Brake lining tubing is also works well as it resists “pinching”.
10. With the interior doors in the conditioned area open, the CAZ door open, and all combustion appliances and exhaust devices off, record the baseline pressure in the CAZ. This is the pressure in the CAZ resulting from stack-effect air leakage. Generally, the colder the outdoor temperature the greater the magnitude of this baseline value. Record the baseline pressure (**P1**).

12352 Determining Worst-Case Conditions

1. Turn on all exhaust devices (except a whole-house exhaust fan). Close all interior doors except those for rooms that contain an exhaust fan, but no supply register. If you are not sure whether to close a door or leave it open, close the door and use smoke to determine which way the air is flowing under the door. If smoke is sucked into the room, leave the door open. If smoke blows out of the room, leave the door closed. Record the pressure in the CAZ (**P2**). The pressure created in the CAZ from the operation of these exhaust devices is the difference between P1 and the baseline pressure, or P2 - P1.

Note: If there is a whole-house exhaust fan, it is important to inform the client that operating this fan with the house closed up could be very hazardous.

2. If the house contains a furnace, activate the blower. Record the pressure reading in the CAZ with reference to the outdoors (**P3**). The CAZ pressure resulting from the operation of the exhaust devices *and* the air handler is the difference between P3 and the baseline pressure, or P3 - P1.

Caution: If the only way to activate the blower is to fire the furnace, extreme caution must be used due to the potential for combustion backdrafting or flame rollout. Try to activate the furnace blower without firing the furnace burner. If this is not possible, measure ambient carbon monoxide levels in the CAZ during the test. If ambient CO levels exceed 10 ppm, abort the worst-case draft test and take corrective action.

3. Close the door to the CAZ (this is usually the basement door). If closing this door results in greater depressurization in the CAZ with reference to the outdoors (for example, closing the door changes the pressure from -2 to -4), leave this door closed and record the pressure (**P4**). Leave door open if closing it decreases the depressurization (for example, closing the door changes the pressure from -4 to -3). If the CAZ door is left open, this pressure should be the same as **P3**.

Stand-alone gas water heaters are the most likely appliance to suffer draft reversal

4. Review the results of the testing and determine the dwelling configuration resulting in the greatest negative pressure in the CAZ with reference to the outdoors. Record the worst-case depressurization and its corresponding mechanical systems/doors configuration. This is the configuration – worst-case – to use when checking for adequate draft and CO emissions from each combustion appliance.
5. If there are other Combustion Appliance Zones in the dwelling, find the worst-case configuration for each. Record all data in the job file.

12353 Multiple Combustion Appliance Zones, One with Fireplace

In some cases, it is best to simulate the draft from a fireplace in a dwelling that has multiple combustion appliance zones and one of the zones includes a fireplace used by the client.

Use the blower door to simulate 300 CFM drawn by a typical working fireplace. To do so, place the “B” ring in the Minneapolis Blower Door, Model 3, and increase the fan pressure to 26 Pascals. **Note that this is fan pressure, not house pressure.** Alter the above procedure – Section 12352 – by turning on the blower door (the fireplace simulator) just after activating all the exhaust appliances, but just before activation a furnace air handler, if there is one. Otherwise, proceed with the sequence of the test as instructed in Section 12352.

12354 Verifying Proper Appliance Operation under Worst-Case Conditions

1. For personal safety, measure CO in the ambient air while appliances are being tested for proper venting.
2. Under these worst-case conditions in each CAZ, fire the combustion appliance with the lowest Btu input first to determine if the appliance is drafting properly.
   a. There should be no spillage of flue gases after two minutes of combustion. If there is spillage after two minutes, the appliance fails the test.
   b. After five minutes of combustion, the draft should meet or exceed the values in Table 123-2 or Table 123-3. If the values in the appropriate table are not met, the appliance fails the test.
   c. After five minutes of combustion, measure CO emissions in the vent. Make certain the emissions are measured *before* dilution air enters the vent. As-measured CO should be 100 ppm or less. If CO emissions are higher, the appliance fails the test.
3. Fire all remaining appliances, one at a time, in order of input rating (smaller to larger), testing each one for spillage at two minutes and draft and CO emissions after five minutes or more.
   a. If the appliances vent into the same chimney flue or vent connector, test each one individually.
   b. If the appliances vent into different chimney flues or vents, test with each successive unit running, that is, when firing up the next appliance, allow the previous one to operate. In the case of a water heater, retest the water heater with the other larger Btu input appliances operating.
4. If the dwelling has other combustion appliance zones, repeat the sequence of activating exhaust equipment, door closure, furnace blower activation, recording pressure readings, etc.
5. When all worst-case draft testing has been completed, turn off all exhaust equipment and return doors and combustion appliances to their previous operational settings.

Category I Appliances, Natural and Fan-Assisted
Acceptable Draft Test Readings for Various Outdoor Temperature Ranges
Table 123-2

ºF	<20	20-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column inches	-.02	-.016	-.012	-.008	-.004

Power Oil Burners
Acceptable Draft Readings at Breech
Table 123-3

Draft Reading Location	***Acceptable Draft***
Vent Connector or Breech	-0.04 to -0.06 or -10 to -15 Pascals

12355 Solutions to Draft Failure or High CO under Worst-Case Conditions

If spillage is a problem or if a draft measurement is unacceptable, correct the problem by one of the following methods:

a. Check for blockage in the vent system and, if found, correct the problem;
b. Check vent system for leaks, including missing or loose cleanout doors or open or cracked mortar joints. Seal vent system as appropriate. Lining a chimney may solve this problem (refer to Section 225).
c. Properly seal return duct leakage in the CAZ.
d. Increase the CAZ air volume by connecting the CAZ to other areas within the conditioned volume of the dwelling (see NFPA 54, NFPA 31);
e. Increase the CAZ air volume by connecting the CAZ to the outdoors (see NFPA 54, NFPA 31, or NFPA 211).
f. Install a manufacturers' outdoor air kit for the failed appliances. This is an option with a number of oil-fired furnaces, boilers, and water heaters.
g. Install fan to supply air to pressurize the CAZ. It is best to link the controls of such a make-up air fan to the operation of the combustion appliance(s) in the CAZ.
h. For high CO emissions, clean and tune the appliance and test for CO emissions again. Replace appliance if high CO emissions are not correctable.

124 Gas Range Testing

Best Practices Recommendations:

- The following should be completed in dwellings with gas ranges.
    - Inspect the gas range top burners and oven burners for proper maintenance and operation.
    - Measure the range top burners for CO emission levels (as-measured).
    - Measure the oven bake burner for CO emission levels (air-free).
    - Educate the client about gas range use and maintenance.

1241 Introduction

Gas ranges pose a difficult problem for the assessor and the weatherization agency. First, of all the combustion appliances in the field, gas ranges present the greatest challenge for the accurate measurement of carbon monoxide emissions. No other combustion appliance in a dwelling is interacted with as much by clients, making it very difficult to accurately simulate client use during field measurement of CO emissions. In addition, unlike any other combustion appliance in the house, the oven bake burner turns on and off during CO emissions testing, forcing the assessor to be very aware of the cycle during CO emissions testing.

Kitchen range, four top burners, one oven bake burner

Second, the preferred method of measuring CO emissions from gas oven bake burners requires equipment that measures air-free carbon monoxide. This electronic equipment must be able to measure carbon monoxide ppm and oxygen percentage.[9] In addition, it is important that the assessor understands that CO is measured in two different ways, “air-free” and “as-measured”.[10]

Third, if gas range problems are discovered by an assessor, it might be difficult or impossible to find a qualified technician to repair the appliance.

Use this list to help establish program priorities for protecting clients from any hazard caused by a gas range. The list starts with the most important and ends with the least important.

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[9] *Two major manufacturers of the equipment that measures air-free CO are TESTO and Bacharach.*

[10] Please refer to *Air-Free Carbon Monoxide Emissions from Gas Ranges: Analysis and Suggested Field Procedure,* R. Karg, 1998 for an explanation of as-measured and air-free measurement of carbon monoxide. This document is available at www.karg.com/PDF files/COairfree.PDF.

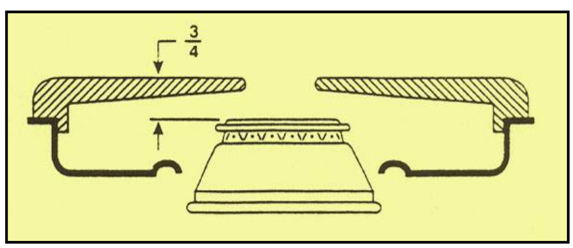
- Install at least one CO alarm in a house that has a working gas range (see section 243, “Carbon Monoxide Alarms”). Make sure this alarm is not closer than five feet to the range.
- Inspect the range as instructed below.
- Educate the client about gas range use. See Section 1244, “Client Education”.
- Ensure that your CO test equipment is operating properly and has been calibrated according to the manufacturer’s recommendations.
- Test the oven for CO emissions. Field research has demonstrated that ovens are more likely to be high emitters of CO than range top burners.
- Test range top burners.

1242 Inspection

12421 General

- Inspect gas range installation for compliance with NFPA 54, the National Fuel Gas Code.
- Check for a flexible gas line connector. If the flexible gas connector can be inspected without moving the range, or if the range is moved out for replacement, make sure the flexible connector is not brass, is not a two-piece connector, and has no pre-1973 rings (in some cases, the date can be found on the flare nuts rather than the date rings). Do not move the range for the sole purpose of inspecting the flexible connector; this movement might crack or otherwise damage it.
- Check for gas leaks at the range top burner area, oven area, and any accessible gas lines with an appropriate combustible gas detector. Check for propane leaks below connections (propane settles) and for natural gas leaks above connections (natural gas rises). If any gas leaks are found, specify repair. Shut off the gas to the appliance and do not proceed with testing until the leak is repaired.
- Check the unit for a pressure regulator. If no regulator is present, check the nameplate for the suggested gas pressure. Measure the gas pressure that is being delivered when the oven is operating. Adjust the gas pressure if necessary.

12422 Range Top Inspection



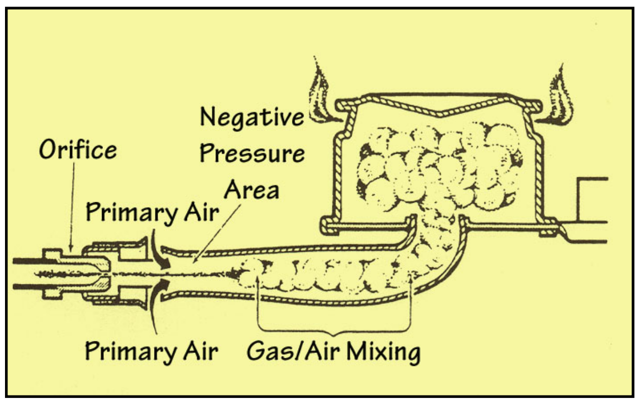
Top of burner should be at least ¾ inch below top of grate

- Inspect the burners for proper alignment and seating.
- All cooking vessel support grates should be in place, fit properly, and be in one piece.
- If any of the grates are missing or in unsatisfactory condition, the client should not use the affected range burner(s) until the substandard or missing grate is replaced.

- If the range top burners are ignited with a standing pilot light, verify that the pilot flame is present, is about 5/16 in length, and is soft blue in color (not yellow).
- Ignite each burner for at least 30 seconds to inspect its flame for color and noise.
  - The flames should have sharp blue edges with orange specks rising through the flames (dust particles). Make sure there is no significant yellow at the upper tips of the flames.
  - You should be able to hear the gas/flame flow in a quiet kitchen. The sound should not be loud or irregular.

12423 Oven Area Inspection

- Check the oven for blockage of the oven-bottom vents. These vent holes must not be blocked by anything in the oven, such as aluminum foil. The vent openings must never be obstructed because they are an important part of the oven combustion venting system.
- Check for air blockage at the bottom of the range and drawer and/or broiler compartment under the oven. Dust, lint, pet hair, rugs, or any other obstruction blocking free airflow to the oven bake burner must be removed.
- Check the oven bake-burner spreader plate (burner baffle). Most bake burners (the one at the bottom of the oven compartment) have a flame spreader plate just under the oven compartment bottom and above the bake burner flame (typically, this plate is attached to the oven bottom). Warped or detached spreader plates can result in flame impingement and quenching (cooling) of the gas flame, causing increased production of carbon monoxide. Many spreader plates are intentionally bent into curved or angular shapes, or dimpled, to add strength. Inspect carefully with a flashlight and inspection mirror to determine if the spreader plate has distorted from its original shape or has detached from the oven bottom. Ignite the bake burner to inspect the flame. The flame should not extend beyond the edge of the spreader plate. Also, inspect for carbon buildup on the spreader plate and the oven bottom. Any carbon buildup can be an indication of incomplete combustion caused by flame quenching or a fuel-rich gas mixture.



Typical range burner operation

- If the range also has a broil burner at the top of the oven compartment, check its flame for proper size and color.
- If the oven burner(s) is ignited with a standing pilot light, verify that the pilot flame is present, is about 5/16 in length, and is soft blue in color (not yellow). When properly adjusted, a standing pilot uses about 75 Btuh.

1243 Measurement of Emissions

12431 Safety During Testing

While testing, if indoor air CO concentrations rise above 20 ppm, shut down the burner(s), discontinue testing and open windows and/or doors.

12432 Range Top Burner Emissions Testing[11]

Test the range top burners after all other appliances have been tested for CO emissions, but before the oven is tested. Test the range top burners as-measured, that is, without adjustment for oxygen content. To test the range top burners:

- Remove all pots and foil from the burners.
- Turn all burners on high and allow them to warm up for at least four minutes.
- Measure the emissions 6 inches above each burner with an open flame.
- Take action based on the table 124-1.

Action Levels for Range Top Burners

Table 124-1

As Measured CO PPM	Measuring Time	Action
< 25 PPM	After 4 minutes of operation	Should be cleaned by client to prevent possible CO problems.
25 to 50 PPM	After 4 minutes of operation	Have appliance serviced.
> 50 PPM	After 4 minutes of operation	Appliance should not be used until either repaired or replaced.

12433 Oven Bake Burner Emissions Testing[12]

Test gas ovens after all other appliances have been tested for CO emissions, including the range top burners. If the oven has a broil burner at the oven ceiling, do not test it for emissions. Only test bake burners located under the floor of the oven. Gas oven bake burners must be tested air-free, that is, with adjustment for oxygen content. To test the over bake burner:

- Remove any items stored in the oven or in the drawer or broiler under the oven compartment. Remove any foil or other extraneous material from the oven floor.

[11] This test method is based on the Wisconsin Weatherization test protocol.
[12] This test method is based on the Wisconsin Weatherization test protocol.

- Ensure that self-cleaning features are not activated.
- Insert the instrument probe into the oven vent sleeve so that dilution air will not affect the reading.
- Measure and record a peak reading after at least 15 minutes of oven bake burner operation.
- Take action based on the table 124-2.

Action Levels for Range Ovens

Table 124-2

Air Free CO PPM	Measuring Time	Action
< 800 PPM	After 15 minutes of operation	Should be cleaned by client to prevent possible CO problems.
> 800 PPM, < 1000 PPM	After 15 minutes of operation	Have appliance serviced.
> 1000 PPM	After 15 minutes of operation	Appliance should not be used. Replace appliance.
Note: To protect inspector and customer, continually monitor ambient space around oven during testing.		

1244 Client Education

Clients should be educated regarding the safe operation of their gas or propane stoves and ovens.

Testing gas oven for CO emission level

- The holes in the oven bottom must never be blocked with aluminum foil or anything else. Storing too much in the broiler or drawer area under the bake oven can also block the vent holes. This blockage can result in unacceptable carbon monoxide emissions.
- Do not use the range-top burners or the oven burner(s) as a space heater. Manufacturers recommend against such use; gas ranges are not designed for this.
- If the gas range has a vented range hood above it, the assessor should suggest that the client operate this range hood during oven or range top burner operation.
- If possible, the range should be checked and tuned once every two years by a technician with an instrument capable of measuring carbon monoxide. This checkup and tuning should include:
  - Testing of the range's gas pressure.
  - Making all necessary adjustments for the acceptable operation of all burners. The level of carbon monoxide emissions from a burner can only be

determined with an instrument that measures CO and O_2; it cannot be determined by visual inspection of the flames.

- The oven should be kept clean at all times. There is evidence that dirty ovens emit more CO than clean ovens.
- The flames from gas burners – both natural gas and propane – should burn steadily with a clear, blue flame. The flame normally makes a slight hissing sound, but it should not sound like a blowtorch. If the flames burn yellow and/or burn loudly or irregularly, the gas range should be serviced as soon as possible. Avoid using a bad burner until it is properly adjusted or repaired.

130 Health & Safety

Recommended Best Practices:

- Existing smoke alarms should be inspected for proper location and operation and replaced or relocated if necessary.
- Existing CO alarms should be inspected for proper location and operation.
- All homes should received exterior and interior inspections for previous or existing moisture problems. Weatherization staff should understand the mechanics of moisture movement, the impact that excess moisture has on occupant health and building durability and the impact that weatherization may have on solving or creating moisture problems in homes.
- Existing bathroom and kitchen exhaust fan systems should be examined for actual flow rates, vent condition, exterior termination and controls.
- Dryer vents should be examined for proper vent material, exterior termination and connections.
- Recommended weatherization activities must be done within the context of lead-safe work practices.
- It is the State's responsibility to ensure insulation installed around knob-and-tube wiring be in conformance with applicable codes in the jurisdiction where the work is being performed.

Health and safety issues have become an important part of the Weatherization Assistance Program as knowledge about the hazards within dwellings has increased weatherization measures may make an existing situation worse or create a health and safety problem where none previously existed. The weatherization process presents a unique opportunity to reduce or eliminate existing health and safety issues and ensure that none have been created as a result of weatherization.

It is the policy of the Weatherization Program to address a health or safety hazard when one is discovered. This policy is tempered by recognition that the primary goal of the Program is to conserve energy and that funds must focus on that goal. An important objective is to balance these competing issues by routinely identifying the most important hazards and specifying measures for their abatement.

Health and safety issues should be an integral part of weatherization assessment. The presence, location and operation of smoke and carbon monoxide (CO) alarms should be checked. Health and safety issues related to excess moisture in a home, possible lead hazards and potential electrical problems should also be assessed. Please refer to www.waptac.org for the most recent weatherization health and safety guidance.

131 Smoke Alarms

All weatherized homes should have at least one working smoke alarm. Smoke alarms should be installed as necessary. Test smoke alarm and review testing and maintenance procedures with clients. For additional information on smoke alarm installation, operation, client education and specifications, see section 241.

132 CO Alarms

Carbon monoxide (CO) is a poison. When inhaled it combines with blood hemoglobin, replaces oxygen in the blood and may completely overcome the body. CO poisoning symptoms include headaches, confusion, dizziness, nausea, vomiting, convulsions, sleepiness, stinging eyes, and loss of muscular control. Death from CO poisoning occurs suddenly. A victim inhaling a toxic concentration of the gas may become helpless before realizing that danger exists.

The effects can vary significantly based on age, sex, weight, and overall state of health. Children, the elderly and the infirm may be seriously affected by even low levels of CO, depending on the concentration and the exposure period.

CO alarms should be installed on every weatherization job where fuel burning appliances are present or when the home has an attached or tuck-under garage. In addition, assessors should have discretion to install carbon monoxide alarms for other health and safety situations.

Smoke – and CO – alarms should be tested monthly to ensure proper battery and electronics operation

For additional information on CO alarm placement and specifications, see section 243.

133 Moisture Assessment

All homes should be inspected for previous or existing moisture problems. Refer to Appendix 130, “Health & Safety Assessment Findings”, to assist identifying mold and moisture related problems in homes.

One of the worst indoor air quality problems is too much moisture in a home. Too much moisture can cause wood rot and promote mold growth. The effectiveness of insulation is diminished when it gets wet. Pests, dust mites, bacteria and virus tend to flourish when indoor relative humidity is too high (greater than 60 percent) and can cause adverse health effects to the occupants. High humidity also increases air conditioning costs because the air conditioner must remove the moisture to improve comfort.

However, some moisture is needed in a home. The lack of moisture in winter air can irritate noses, dry skin, and aggravate medical problems, such as asthma. Wood can dry-out and shrink. The ideal indoor relative humidity during the heating season ranges between 30 and 50 percent. Bear in mind that people create moisture simply by breathing, cooking, bathing, and laundering clothes. In tighter homes, humidifiers usually are not necessary because of the moisture created by the occupants. Consider removing humidifiers in these homes with the client's permission.

A description of moisture movement mechanisms may be found in Appendix 130.

1331 Symptoms and Types of Moisture Problems

Identifying and solving the source of the moisture should be the first priority when a moisture problem is found. Existing ventilation systems should be checked to ensure that they are functioning effectively. Installing intermittent or continuous ventilation should also be considered to help solve a moisture problem.

Depending upon natural ventilation to solve a moisture problem is not acceptable. The Building Tightness Limit (BTL) should not be adjusted upwards in the hopes that leaving a leaky house will solve a moisture problem.

The following are symptoms of potential moisture problems:

- Mold growth on walls and ceilings, especially in rooms with high moisture loads, such as bathrooms and kitchens,
- Mold in corners or at the wall/ceiling junction (top plate),
- Signs of persistent condensation problems on windows,
- Evidence of water damage or mold on the underside of roof decking,
- Evidence of crawl space moisture,
- Peeling paint, particularly on bathroom and kitchen walls,
- Rusted metal in basements, crawl spaces, bathrooms and kitchens,
- Efflorescence (white, powdery deposits left by water) on concrete or masonry surfaces,
- Musty smell in basement or crawl space, or
- Water stains on foundation walls.

The following list of problems may contribute to the above symptoms.

- Standing water, open sump pumps or dirt floors,
- Leaking plumbing,
- Lack of insulation over top plates or "wind washing" through insulation over top plates,
- Insufficient, poorly installed or lack of insulation in walls and attics,
- Unvented clothes dryer or clothes hung to dry in basement,
- Improper site drainage that causes water to drain into the crawl space or basement,
- Non-operable exhaust fans or exhaust fans not ducted to the outside, and
- No crawl space ground cover.

134 Bathroom & Kitchen Exhaust Fans; Dryer Vents

Moisture should be vented from the spaces in which moisture is generated – bathroom and kitchens. Bathroom and kitchen exhaust fans should be present, operable and vented to the outside. Fans should have tight fitting backdraft dampers. Non-operable bathroom and kitchen exhaust fans should be replaced. Exhaust fans should be installed in bathrooms and in kitchens that have no fans. Recirculating kitchen fans should be replaced with vented kitchen exhaust fans.

Bathroom and kitchen exhaust fans must be vented to the outside of the building utilizing wall caps, roof jacks or eave mounted termination vents. Fan vents may not terminate in soffits or in attics.

1341 Bathroom Exhaust Fans

Assessors should determine the following:

- Does the fan vent to the outside or into the attic, crawl space or floor cavity?
- What is the type and condition of the exhaust duct?
- How much air (CFM) does the bathroom fan actually exhaust?
- How loud is the fan?
- How is the fan controlled?

13411 Venting

It is common to find bathroom and kitchen exhaust fans that are not vented to the outside of the building. Sometimes these fans are vented into an attic or crawl space. In some cases, the exhaust duct may terminate directly beneath an attic vent. Both of these venting options are unacceptable. In the first instance, moisture is being dumped into an unconditioned space that may result in condensation and building rot. In the second instance, the screen in the attic vent may become clogged with dirt preventing the fan from exhausting properly causing mold growth on the roof sheathing.

13412 Exhaust Duct

Consider replacing exposed flexible plastic exhaust duct with rigid or metal flexible duct. Smooth duct provides less resistance and improved airflow compared with ribbed ductwork. Flex duct should have minimal sag. Turns and bends should be minimized regardless of duct type. Ducts located in unconditioned spaces should be insulated to at least R8. Ducts located in the attic should be insulated or covered with attic insulation.

13413 Measuring Flow

The effectiveness of exhaust fans is based on the power of the exhaust fan, length and type of exhaust duct and cleanliness of the fan grille. When there is excessive resistance in the ductwork, the exhaust fan motor may not be powerful enough to vent sufficient airflow through the duct. The longer the duct length, the greater the static pressure in the duct and the less air flow through the duct.

Just because a fan makes noise doesn't mean that it's functioning properly. It is not uncommon to find noisy fans that are moving no air.

Typical bathroom exhaust fans are generally rated between 50 CFM and 70 CFM.

Actual ventilation rates of bathroom fans can be measured with an Exhaust Fan Flow Meter™. The flow meter consists of a gasketed pan that is placed tightly over an operating exhaust fan. The pan has an adjustable opening and a connection for a digital manometer. The manometer measures the pressure difference between the pan and the house during fan operation. Based on the adjustable opening and the measured pressure difference at the fan, the cubic feet of air per minute (CFM) exhaust by the fan is calculated.

13414 Fan Controls

Replacing controls for bathroom exhaust fans is permitted under weatherization. This may be a desirable measure if high moisture loads are common in the bathroom.

There are many ways to control fans

Bathroom exhaust fans may be controlled by a light switch or a separate on/off switch. A single switch assures that the fan operates when the light is turned-on. However, when the light is turned-off, so is the fan, even though there may be a significant moisture load remaining in the bathroom. A fan delay timer may be used to replace a switch that controls both the light and the fan. When the switch is turned-on, both the light and fan operate. When the switch is turned-off, the light goes off but the fan continues to operate for an extended period from 1 to 60 minutes (the timer is adjusted on a dial located beneath the cover plate).

A 60 minute timer switch is recommended when the bathroom fan has a separate on/off switch.

13415 Noise

Newly installed bathroom exhaust fans should have a sone rating of 1.5 or less (sone is a rating for sound). Occupants are more likely to use a quiet fan than a loud one. Most existing bathroom fans will have sone ratings significantly higher than 1.5.

1342 Kitchen Fans

Kitchen exhaust fans may be installed as part of weatherization where none exists, when an existing exhaust fan is non-operable or when the kitchen fan is a recirculating type. Kitchen recirculating fans do nothing to remove moisture from the kitchen but may filter the air.

Assessors should determine:

- Does the kitchen fan exhaust outside and not into the attic or crawl space?
- What is the type and condition of the exhaust duct?

Refer to “Bathroom Fan Venting” and “Bathroom Exhaust Duct” for information on proper exhaust fan duct types and termination points.

1343 Dryer Vents

Installing or correcting dryer venting is also permitted under the Weatherization Program. The following dryer conditions may be corrected.

- Disconnected dryer vent,
- Termination of the dryer vent to a space other than to the outside of the building,
- Plastic ribbed dryer vent,
- Venting fastened with screws or rivets, and
- Improper dryer vent cap (no screen or wire cap).

See section 245, “Dryer Venting”, for information in proper dryer venting procedures.

135 Site Drainage

Poor site drainage is often the reason for wet foundations (basements, crawl spaces and slabs). Homes that have wet foundations often have mold and moisture problems within the living space. To keep the foundation dry, the soil in contact with it must be kept dry.

It’s recognized that weatherization dollars are limited and correcting a site drainage problem may be outside both the budget and scope of weatherization services. However, the following guidelines are presented to assist assessors in identifying causes of wet foundations and the resulting mold and moisture issues resulting from these conditions. Recommendations are provided to help solve site drainage problems.

Look for areas around the home where rainwater may collect – damage is worse where greater quantities of water are concentrated. A valley on a roof acts like a funnel, with the greatest concentration of water at the base of the valley. Gutters act like funnels that collect water from the edge of the roof and concentrate it in the downspout.

Check for the following items regarding site drainage.

- Do site conditions direct rainwater or snow melt toward the foundation rather than away from it?
- Are there localized depressions adjacent to the foundation?
- Do sidewalks or paved drives direct water toward the foundation rather than away it?
- Are there raised plant beds that collect and hold water?
- Are there site features such as valleys and swales that concentrate the water on the site?

Remember the "ground-roof" rule[13] - the soil surface should be viewed as a low-slope roof surface. The surface should be pitched away from the home – the steeper the pitch, the better the drainage. Imagine all the water moving to the low edge of the site, and imagine how best to get it there is the best way to approach solving a site drainage problem.

Specific site drainage guidelines include:

- The house should be built on a crown, not in a hole. If there is sufficient exposed foundation, site grading at the house can be improved. If the house hugs the ground, improvements at the foundation are more difficult. There should be a minimum of 8 inches of exposed foundation between the ground and the beginning of the siding.
- The soil adjacent to the foundation should be sloped away from the house at a minimum of 5 percent. Six inches of fall in the first 10 feet away from the house provides a 5 percent slope.
- Identify localized dips and holes immediately adjacent to the foundation and fill with dirt. Tamp the fill material to prevent future settling. Provide sufficient fill material such that drainage occurs away from the foundation.
- If the house has no gutters, then the base of the soil around the house has to serve as a gutter itself. It should have a surface that helps prevent splash back onto the siding of the house. It should be designed with pitch so that it effectively moves water away from the house.
- Good tamping or compaction of the backfill is very helpful because it slows water absorption by the subsurface soil.
- Bushes and other plantings may be very helpful, especially if their root balls soak up water. Also they can be planted strategically near downspouts so that the downspout extenders are less likely to be kicked off or removed during lawn mowing.

136 Gutters and Downspouts

Gutters and downspouts can be an important part of solving a site drainage problem. They provide a means of collecting rain water and distributing it away from the foundation.

[13] The "ground-roof" is a concept developed by the Building Research Council at the University of Illinois – Urbana Champaign

Check for the following when evaluating a gutter system.

- Is there a gutter system? Gutters are not standard in all states in this weatherization region because of maintenance issues (gutters get clogged with leaves) or ice dam issues (gutters become damaged). Gutter guard systems are available to help keep gutters clean. Bypass sealing, properly insulating over top plates and a properly insulated attic can help solve ice dam problems.
- Gutters should be pitched to the downspouts. There should be no more than a 40 foot length of gutter without a downspout. Short gutters may be level. In areas where tree leaves might cause clogging, gutters and downspouts should be oversized so that leaves and debris will be flushed more easily. Gutter hangers should be strong enough to keep gutters from sagging.
- Downspouts should be securely fastened to the house. Elbows and straight sections should be fastened together with pop rivets – screws that project into the downspout can lead to clogging.
- At the base of the downspout, the water must be directed away from the foundation of the building by 3 to 5 feet. If water is allowed to dump close to the foundation, it might cause moisture problems in the dwelling. The good way to discharge the water away from the house is with downspout extenders (sections of straight downspout) or splash blocks. Both of zthese are often disturbed when lawns get mowed. A notched section of downspout that is hinged to the elbow at the base of the downspout can solve this problem.

Gutter and downspout

137 Lead

Lead paint is the primary source of lead in a homes built before 1978. After 1940, paint manufacturers voluntarily began to reduce the amount of lead they added to their consumer paints. As a result, painted surfaces in homes built before 1940 are likely to have higher levels of lead than homes built between 1940 and 1978.

Lead paint was not used in the manufacture of mobile homes, but may be found in varnishes and stains in mobile homes remodeled before 1978.

Ingestion or absorption of lead into the blood stream over time is a serious health hazard causing brain damage. This can be a particularly serious with small children who may ingest lead contaminated dust or paint chips. This contamination is more likely to occur when lead paint is disturbed by sanding, chipping, or flaking.

Workers can be contaminated in the same way as children, but are most likely to be exposed by breathing dust created by sanding or planing surfaces that contain lead based paints.

All Weatherization Program activities involving renovation work on pre-1978 dwellings are subject to the provisions of the Federal Environmental Protection Agency (EPA)[14]. This regulation requires that an informational pamphlet that explains the hazards of lead paint chips and dust be given to the occupants of the dwelling. This pamphlet must be given to the owner or occupants of the dwelling prior to starting the work, but not more than 60 days before the work begins. Assessors should review this pamphlet with the occupants at the time of assessment. Assessors should explain to occupants that lead-safe work practices will be used when work is being done on their home.

Please refer to your state weatherization office for more details about lead-safe work practices. For detailed information regarding lead safe weatherization practices, see http://www.waptac.org/sp.asp?mc=techaids_health_lead.

If weatherization work is being done in HUD-assisted housing, HUD's requirements regarding lead safe practices must be followed. These practices are more rigorous than DOE's lead safe practices.

138 Electrical

Electrical safety is an important health and safety concern, especially in older dwellings. Correcting electrical wiring problems is generally an allowable weatherization health and safety expense. Service boxes, fuses/breakers, and wiring should be inspected as part of the house assessment to ensure problems are brought to the attention of the client. If it is determined that a hazardous situation exists with wiring, breakers, or other parts of the electrical system, the client, agency or contractor must correct the problem before weatherization work begins.

- Check for proper sizing of fuses/breakers to wiring size in circuit panel boxes.
- Identify any wiring in the circuit panel box that is aluminum (except for main service connections).
- Inspect circuit panel box for multiple circuits connected to individual breakers or fuses. Inspect for disconnected or loose wiring inside the box.
- #14 copper or #12 aluminum wiring should be protected by a fuse or breaker rated for no more than 15 amps. #12 copper or #10 aluminum should be protected by a fuse or breaker rated at no more than 20 amps.
- Ensure that the circuit panel/fuse box has a secure cover.
- Test all outlets for proper grounding. Identify circuits which contain non-grounding devices. Inspect for ground fault interrupter (GFIC) devices in kitchen,

[14] The lead paint notification requirement is an EPA requirement and is addressed in 40 CFR (Code of Federal Regulations) Part 745, titled, "Lead; Requirements for Hazard Education Before Renovation of Target Housing."

bath, laundry, unfinished basements and pool areas. Test GFIC's for proper operation.

- Inspect for frayed wiring, improper splicing and lack of junction boxes or covers. Wiring splices must be enclosed in approved metal or plastic electrical boxes, fitted with cover plates.
- Record problems found on a building analysis form.
- Identify appliances posing potential electrical shock hazard.

Notify homeowner, in writing, what problems exist and make notation of this in the file.

1381 Knob-and-Tube Wiring

According the National Electrical Code (NEC) 2002:

> *"Concealed knob-and-tube wiring is designed for use in hollow spaces of walls, ceilings, and attics and utilizes the free air in such spaces for heat dissipation. Weatherization of hollow spaces by blown-in, foamed-in, or rolled insulation prevents the dissipation of heat into the free air space. This will result in higher conductor temperature, which could cause insulation breakdown and possible ignition of the insulation."*

Insulating over knob-and-tube wiring would be a violation of the NEC and place weatherization subgrantees at risk for liability where the cause of a fire could be traced to insulation in contact with knob-and-tube wiring.

Knob-and-tube wiring can be hidden under attic floors; don't forget to inspect for it and then treat it accordingly

However, according to a study by the Weatherization Training Center at Pennsylvania College of Technology[15]:

> *Properly installed and unaltered K&T wiring is not an inherent fire hazard. The research shows that insulating over knob and tube wiring, when that wire is free of problems is rarely a fire hazard. However, insulating over wires can be a critical contributing factor to creating a fire hazard when other problems such as loose connections or excessive electrical loads, are present.*

A number of states and local municipalities have amended the NEC to allow for insulating over knob-and-tube wiring, given that certain precautions are first taken. Therefore, the official DOE-WAP policy on installation of thermal

[15] "Retrofitting Knob and Tube Wiring – An Investigation into Codes, Assessment, Wiring Practices and Cost" for the Pennsylvania Department of Community and Economic Development, January 2004

insulation around knob-and-tube wiring is that it is the State's responsibility to ensure that such work is in conformance with the applicable codes in the jurisdiction where the work is being performed.

The following protocol is recommended when knob-and-wiring is found in building cavities where insulation is being planned.

Qualified electrical technicians should assess the condition of the electrical system and its alterations. If knob-and-tube wiring has been deactivated and the dwelling has been rewired with BX, Romex, or other approved electrical cable, insulation may be placed around and in contact with the inactive knob-and-tube wiring.

If the knob-and-tube wiring is active, personnel authorizing work orders or contracts shall arrange for, or conduct a thorough inspection of, the areas to be insulated before approving insulation around live knob-and-tube wiring, and make sure that:

1. All live wiring to be covered is examined and tested to ensure that the voltage drop is 10 percent or less.
2. The electrical system has protective devices matched to the wire sizes and which stop the flow of electrical current if the circuits are overloaded.
    - Number 14 wire shall be fused with 15 amp fuses.
    - Number 12 wire shall be fused with 20 amp fuses.
    - "S" type fuses or breakers must be installed in the electrical panel serving any knob-and-tube wiring.
3. Documentation of items 1 and 2 must be kept in the job file.

If, for any reason, the above items cannot be completed, all insulation must be keep at least 3 inches from the knob-and-tube wiring unless the wiring has been approved or upgraded by a licensed electrician.

Additional information regarding the history of knob-and-tube wiring and the NEC as well the Weatherization Assistance Program's policy may be found in *"Retrofitting Insulation in Cavities with Knob-and-Tube Wiring - An Investigation into Codes, Safety, and Current Practices"*[16].

[16] Jeffrey R. Gordon, Building Research Council at the University of Illinois at Urbana/Champaign, for the Illinois Department of Commerce and Community Affairs, June 2000.

211 Air Sealing

Best Practices Recommendations:

- The primary objective of air sealing is to establish an effective air barrier at the thermal boundary of the home.
- The benefits of air sealing must be balanced with maintaining acceptable indoor air quality and ensuring proper draft of combustion appliances.
- Blower door tests should be performed during air sealing activities to help guide those tasks.

Air leakage reduction is one of weatherization's most important functions, and often the most difficult because of having to balance energy savings against creating indoor air quality problems. Objectives of air leakage reduction are to:

- Protect insulation's thermal resistance to save energy,
- Avoid moisture migration into building cavities, and
- Increase comfort.

Simultaneously, one must ensure that the home is not made too tight. The home must remain healthy and combustion appliances must vent properly.

The ultimate goal of air leakage reduction is to establish an effective air barrier. Establishing an effective air barrier and follow-up blower door and draft testing will meet these objectives.

2111 Air Movement

Air leaks into and out of a home by three main ways:

- Bypasses, which are significant flaws in the home's air barrier,
- Seams between building materials, and
- Leaks in building materials themselves.

Two things are required for air to move into and out of a home – a hole and a pressure difference from one side of the hole to the other. Remove one, and air will not flow. For example, no air will flow through an open window (hole) unless the wind is blowing (caused by a pressure difference). The larger the hole and the greater the pressure difference, the greater the amount of air flowing through the hole.

The first rule of air sealing is: Seal the big holes first. Leaks at the building's high and low points generally see more pressure, so they have a higher priority. Small leaks through door and windows may seem dramatic when depressurizing the home with a blower door because of the high air velocity through these small cracks. However, the less obvious air leaks are usually more important leaks, because they are larger or because they are under a greater pressure by being located in attics and basements or crawl spaces. This type of air movement is called the "stack effect".

Generally, trying to reduce infiltration caused by the stack effect is more important than trying to reduce heat loss caused by the wind. Unlike wind that varies in strength and direction, stack is constant during the heating season. There is a constant temperature difference (hence, pressure difference) between the conditioned space and the attic cavity. Reducing stack has the greatest impact on saving energy (keeping warm air in the house), increasing comfort (less draft near the base of the home), protecting the insulation's thermal resistance (air flow through insulation reduces it's R-value) and keeping moisture out of building cavities (warm air moving out of a house during the heating season carries moisture with it).

2112 Sealing Bypasses

Bypasses are holes and gaps in the air barrier. The effort worth expending to seal a bypass depends primarily on its size and location. In general, the larger the hole near the top or base of a home, the greater the air leakage reduction will be when it's sealed.

Bypasses are found between the conditioned space and attic, conditioned space and crawl space, conditioned space and attached garages and conditioned space and the outside.

Start by sealing the larger bypass openings first to achieve larger air leakage reductions. There will be cases where sealing an important bypass won't necessarily reduce air leakage. For example, a chaseway in a plumbing wall tightly sealed from the house but very leaky to the attic acts as an insulation bypass without actually leaking air between the house and the attic. Even though the house air leakage may not be reduced, the attic insulation performance will improve after this attic bypass is sealed.

A significant air bypass in a closet up into a sloped ceiling through plaster and lath

It is always preferable to use strong air barrier materials like plywood, drywall or rigid foam insulation board to seal bypasses (see section 2114, "Air Sealing Materials"). These materials should be attached with mechanical and/or adhesive bonds. Strong materials with strong bonds are best practice because air barriers must be able to resist large pressure differences. Smaller bypasses may be sealed with expanding foam or caulk. In all cases, air sealing materials used in areas visible to the client should be complementary to the surrounding finish. Air sealing materials should be used in a manner that does not degrade the appearance of the home.

Sometimes bypasses are easily accessible and sometimes not. When they are not easily accessible, dense-packed cellulose insulation may be blown into surrounding cavities. The cellulose will resist airflow and clog cracks between building materials.

The following are some examples of bypasses and how to seal them. A more comprehensive bypass list follows. All bypasses are to be sealed prior to insulating except where they cannot be reached cost effectively.

2113 Bypass Types

- Joist spaces under knee walls in finished attic areas: Connect knee wall air barrier to ceiling air barrier by creating a rigid seal under the knee wall or by blowing short sections of the floor cavity with densely packed cellulose. Blocks of 1 inch rigid foam board insulation may be cut and placed between ceiling joists. Seal perimeter of foam blocks with expanding foam.
- Kitchen or bathroom soffits: Seal the top of the soffit with plywood, gypsum board or foil-faced foam board insulation; fasten and seal to ceiling joists and soffit framing with expanding foam or caulk.

Plumbing stack sealed with foam

- Two-level attics in split-level houses. The wall between the upper and lower levels of the house is often open to the attic of the lower house section: Seal the wall cavity with a rigid material fastened to studs and wall material.
- Tops and bottoms of balloon framed interior partition wall cavities, missing top plates: Seal with ¼ inch plywood, gypsum board or foil-faced foam board insulation and caulked or foamed to surrounding materials.
- Joists between floors: air seal around perimeter of building at bandjoist areas with high density insulation or apply spray foam.
- Chimney passing through attic floor: Seal chimney and fireplace bypasses with sheet metal (minimum 28 gauge thickness) and seal to chimney or flue and ceiling structure with high temperature sealant or chimney cement.
- Soil stacks, plumbing vents, open plumbing walls: Seal joints with expanding foam or caulk. If joint is too large, stuff with fiberglass insulation and foam over the top.
- Housings of exhaust fans and recessed lights: Caulk joints where housing comes in contact with the ceiling (see note below for boxing and air sealing around recessed light – additional information may be found in section 2121 under "Attic Insulation").

- Duct boots and registers: Caulk or foam joint between duct boot or registers and ceiling, wall, or floor finish if ducts are located in attic, crawl space or attached or tuck-under garage.
- Wiring and conduit penetrations: Seal with caulk.
- Duct chases: If chase opening is large, seal with rigid barrier such as plywood, drywall or rigid foam board insulation and seal to ducts and ceiling materials. Smaller openings may be foamed or stuffed and caulked.
- Bathtubs and shower stalls: Seal from crawl space or basement with expanding foam or rigid material for larger openings.
- Attic hatches and stairwell drops: see section 2122, "Preparation" under "Attic Insulation" (section 212).
- Other openings in the air barrier: Seal with rigid material, caulk or expanding foam depending upon size of opening.

Typical attic bypasses include the following.

- plumbing chase
- plumbing soil stack
- furnace flue chase
- missing top plate (interior walls)
- missing top plate (exterior walls)
- wire penetrations
- exhaust fans
- ceiling mounted junction boxes
- recessed lights
- fireplace/chimney chase
- missing fireplace damper or poorly fitting damper
- soffits above interior cabinets
- dropped ceilings
- stairway dropped ceiling
- attic stairway stud spaces
- whole house fan
- joist spaces beneath knee walls
- attic floor level changes (two level attics)
- area above laundry chute
- dumb waiter shaft
- duct plenum
- duct penetrations (wall and ceiling)
- plaster lath voids
- attic hatch
- fold away attic stairway

This blocking allows too much space around this recessed light; insulation must be kept just three inches away

Typical bypasses found at the base, or foundation, of a home include the following.

- plumbing stack
- bathtub trap

- wiring penetrations through floor
- plumbing penetrations through floor
- duct shafts
- duct penetrations
- chimney or flue
- balloon framing wall/ceiling cavity
- basement/crawl space or slab interface
- wiring penetrations
- utility entries
- wiring penetrations to outside
- crawl space vents
- crawl space hatch
- dryer vents
- cores of concrete block exposed at sill plate
- sill plate
- foundation cracks or holes

Bypasses found in the main part of a home are less important as related to the stack effect. However, sealing holes in the middle part of the house will reduce air leakage caused by wind and may improve comfort. Common bypasses found in the middle of the home include:

- drop ceiling (between floors)
- floor trim
- ceiling trim
- outlets/switches
- wall mounted fixtures
- wall mounted exhaust fans
- medicine cabinets
- plumbing penetrations beneath kitchen sink
- plumbing penetrations beneath bathroom sink
- bathtub cutouts
- plumbing access hatch
- vents under fixed windows
- permanent window air conditioners
- cracks or holes in exterior walls
- panned returns, floor cavity
- panned returns, wall cavity
- hollow walls for fish tanks, stereo, etc.

Window and door infiltration reduction measures are found in sections 215 and 216, respectively.

21131 Recessed Lights

Box around recessed light fixtures to prevent overheating and/or fire. Use gypsum board to construct the box. Provide a minimum 3 inch clearance between the box and the sides of the fixture. The box should be constructed to a height that will be

4 inches above the installed insulation. Cover the box with gypsum board and seal to the sides of the box. The box is not to be covered with insulation. If there is insufficient clearance to install a box 4 inches higher than the insulation, do not cover the box and use an appropriate barrier to keep the insulation 3 inches away from the fixture.

Recessed incandescent fixtures may also be replaced with IC rated fluorescent fixtures if cost effective. Replacement fixtures should be ENERGY STAR® rated.

2114 Air Sealing Materials

Materials used to seal air leakage sites must be nearly impermeable to air movement as possible and form a continuous, nonporous surface over the opening being sealed.

Foil faced bubble wrap may NOT be used for sealing chimney chases.

- Caulks/Sealants
  Caulk should be applied according to the manufacturer's instructions. Caulk should be applied to a smooth, clean, dry surface. It should always be applied in a continuous bead and free of voids, with a smooth and neat appearance. Excess caulk should be removed before it cures.

  All openings 3/8 inch to 7/8 inch wide should be filled to within ½ inch of the surface with an appropriate packing material specifically manufactured as a packing material prior to caulking. All packing material should be compatible with the type of caulk used.
    - Latex/Acrylic/Silicone Hybrids – must conform to ASTM C834
    - Acrylic (solvent type), Chlorosulfonated Polyethylene – must conform to F.S. TT-S-00230C
    - Butyl Rubber – must conform to F.S. TT-S-001657

- Packing Materials
  Packing materials used to fill gaps too large for caulks or sealants to seal properly must be flexible closed cell or otherwise nonporous materials that will not absorb moisture and will remain flexible at low temperatures. Packing materials include flexible polyurethane, oakum, butyl rod or similar foam rod stock.

  Fiberglass is not to be used as an air sealing material, but may be used to stuff larger openings as a backer material with spray foam applied over the top of it. Tops of open wall cavities may also be stuffed with fiberglass which will be dense packed with insulation.

- Weatherstripping
  Weatherstripping around doors and windows, including window channel, door sweeps and thresholds must be mechanically fastened in place. Felt and flexible foam weatherstripping need not be mechanically fastened. Flexible foam adhesive-backed weatherstripping may be used to seal ceiling mounted attic accesses.

- General Air Barriers
  The following air barrier materials shall be used for the following conditions.

  - Polyethylene
    Should have a minimum thickness of 6 mil and be used as an interior barrier material when moisture must be kept out of the conditioned space.

  - Spun olefin (*Tyvek*, *Typar*, etc)
    Spun olefin membrane air infiltration barrier should be used when moisture must escape from the conditioned space. These materials are not recommended for use in a location where they remain cool for most of the year, such as the floor above the crawl space or basement ceiling. Water vapor will not move through these materials if they are at or below the dew point temperature.

  - Wood or wood composites
    Wood or wood composites should be used where flame retardant characteristics are not important. When exposed to moisture or weather, all raw exposed wood must be an exterior grade material and primed on all sides.

  - Gypsum board
    Gypsum board should be used in interior applications where excessive moisture is not a problem and where flame retardant abilities are important.

  - Rigid foam board insulation
    Air sealing materials such as rigid foam board must be sealed in place with caulk or non-expanding foam to make it air tight. Polystyrene shall conform to ASTM C576. Polyurethane and polyisocyanurate with foil facing shall conform to F.S. HH-1.

  - Metal flashing

Metal flashing should be used when high temperature or high moisture is a factor.

- Special air barriers

Specialty air barrier materials include such items as electrical outlet gaskets and plugs, window pulley gaskets and interior wall patching materials.

212 Attic Insulation

Best Practice Recommendations:

- Attics should be thoroughly inspected for safety and moisture related issues. Such issues should be addressed prior to installing attic insulation.
- Effective R-value of existing attic insulation should be determined taking into account age, settling, gaps and voids and uniformity of coverage.
- Unfinished Attics
    - Blown insulation is recommended for unfinished attics cavities and should be installed to a uniform depth according to manufacturers' specifications for proper coverage.
- Cathedral ceilings should be dense-packed with insulation.
- Finished Attics
    - Collar beams and outer ceiling joists should be insulated as per unfinished attics.
    - Sloped ceiling should be dense-packed with insulation.
    - Knee walls should be insulated to the maximum R-value as allowed by stud cavity depth. A vapor permeable air barrier should be used to enclose the back-side of the knee wall cavity.
- Attic ventilation should be part of an overall strategy for controlling attic air temperatures and should be considered an optional measure.

Attic insulation in older homes is often both insufficient and ineffective. Even if insulation levels look sufficient, the insulation may be ineffective due to poor installation (particularly batt insulation). Blown insulation may have settled. Sections of the ceiling may be uninsulated due to work related activity or wind-washing through vents. Rooms added to an attic may have uninsulated knee walls or collar beams. Gaps may exist in the attic insulation between the house and room additions. Furthermore, attic bypasses and their effect on insulation performance were unknown when many of these attics were originally insulated.

Installing attic insulation provides a number of benefits to the client besides energy savings. Comfort may be increased while decreasing moisture problems, including ice dams. But attic insulation must be installed in a proper and safe fashion to be effective.

2121 Safety

21211 Heat Producing Devices

Comply with fire and electrical safety procedures before insulating.

- Note all electrical devices which require safety clearance shielding, such as recessed lights without Type IC (insulation contact) rating, vent fans, flues, chimneys, door bell transformers and other heat producing devices.
- Install noncombustible barriers (i.e., metal or unfaced mineral fiber batts) around all heat producing sources to permanently maintain a

minimum 3 inch dead air space. All barriers should extend at least 4 inches above the height of the finished insulation.

- Metal used as a barrier around heating producing devices or chimneys must be fastened securely to attic joists in such a manner as to not allow the barrier to collapse. The metal must be 26 gauge galvanized and be sealed with high temperature caulk to the chimney and surrounding framing and finish materials.
- Clearance of insulation from attic furnaces must be provided in accordance with the governing code.
- Box around recessed light fixtures with gypsum board to prevent overheating and/or fire. Provide a minimum 3 inch clearance between the gypsum board box and the sides of the fixture. The box should be constructed to a height that will be 4 inches above the installed insulation. The box is not to be covered with insulation. If there is insufficient clearance to install a box 4 inches higher than the insulation, do not cover the box and use an appropriate barrier to keep insulation 3 inches away from the fixture.
- The perimeter of attic fans should be dammed with 1 inch thick common lumber, plywood or metal shielding.
- Wood-stove manufactured chimneys should have ventilated insulation shields.

21212 Knob-and-Tube Wiring

A home may have been rewired and the knob-and-tube (K&T) wiring left in place. It must be confirmed that the K&T wiring is not in service before covering it with insulation.

Even if there is attic flooring, knob-and-tube wiring and attic bypasses must be found and treated before insulation is added

See section 1381, “Knob-and-Tube Wiring”, for recommendations for insulating over active knob-and-tube wiring.

If the recommendations cannot be implemented, isolate K&T wiring in a permanent manner with a minimum 3 inch air space below and to the side of the wiring. All barriers must be permanently secured and made of materials that are consistent with building and fire code requirements. Do not blow insulation into floor cavities with live K&T wiring. When insulating above such cavities, make sure to seal the ends of the cavities to eliminate thermal bypasses.

Active attic K&T wiring may be replaced to achieve maximum attic insulation R-value if it can be done as 1) an incidental repair cost with DOE funds, 2) with non-

DOE funds or 3) as part of the total attic insulation measure if the cost of both replacing the K&T wiring and adding insulation are cost effective.

21213 Pests & Animals

Document the presence of any animal or insect pests in the attic. Note the presence of any animal or bird feces that may pose a health threat. Determine measures or personal protective equipment necessary to ensure the safety of weatherization workers in the attic.

2122 Preparation

21221 General

Review condition of ceiling. Ceilings must be able to support the added weight of insulation. Closed electrical junction boxes may be covered with insulation, if appropriately marked. Seal all holes to keep animals (birds, rodents, bats, etc.) out of the attic. Document poor ceiling conditions with digital photographs.

Note stored boxes or objects that may obstruct weatherization work. Consult with the client about removing these items. If the client is unable or unwilling to do this work, determine if it is feasible for weatherization workers to remove obstructions and obtain permission from the client.

21222 Bypasses

Check for completion of bypass sealing before installing any insulation. Remember that attic insulation is not an air barrier. Document the location of chaseways containing utility runs or ductwork in the sidewalls if any.

Some attics require much preparation work before they can be blown with cellulose

Seal joist spaces under knee walls by creating a rigid seal between the floor joists under the knee wall or by blowing short sections of the floor cavity with densely packed cellulose.
See section 2112, “Sealing Bypasses”, for additional information regarding attic bypasses.

21223 Mechanical Systems

All attic ductwork must be sealed prior to insulating (see section 2271, “Duct Sealing”). All attic water lines must be kept on the warm side of attic insulation.

21224 Moisture

Examine attic for moisture problems due to roof leaks, including missing or damaged flashing. Repair all roof leaks before insulating attic. If roof leaks cannot be repaired, attics are not to be insulated.

Inspect sheathing and rafters for discoloration, mold or rot. Note location of damage. Note interior plaster or gypsum board damage due to moisture problems in attic. Try to identify source of moisture and determine if corrective action can be taken under weatherization.

All kitchen and bath fans currently venting into the attic must be equipped with backdraft dampers and vented outdoors through roof or eave fascia boards. Fans without operating dampers should be repaired or the fan should be replaced with a low sone fan. Ribbed plastic vent material from bathroom and kitchen exhaust fans should be replaced with rigid aluminum, galvanized pipe whenever possible or flexible metal. Vent pipe should be insulated to prevent condensation. Additional information regarding proper bathroom and kitchen fan ventilation may be found in section 2442, “Ventilation”.

Inspect all flat or low-pitched attic sections that will be dense-packed with insulation to make sure that problems or hazards do not exist. Determine if corrective action measures are needed prior to installing insulation.

21225 Top Plates

Existing batt insulation over top plates should not be compressed with scrap wood or gypsum board. Remove compressed or ineffective insulation over top plates.

Eliminate wind washing through insulation where soffit venting exists. Block cavity over top plate to prevent blown insulation from falling into soffit and to maximize insulation over top plates. Cavity may be blocked with two-part spray foam, rolled fiberglass insulation or other rigid materials.

Mechanically fasten eave chutes between foam or blocking and roof sheathing to maintain ventilation passageway. Chutes or blocking material should not compress insulation.

In rafter cavities where a chute is not installed, ensure that cavity is blocked with a rigid barrier as described above to prevent over-spill into the soffit area. Where possible, place eave chutes in every rafter cavity that is vented. Chutes must be long enough to extend above the level of the finished insulation.

2123 Attic Access

The following information pertains to access to unfinished attics. See section 21265, “Knee Wall Hatch” for access to knee wall attics.

21231 Installation

Attic access openings may be installed to attics where access openings are not present. Interior access panels are not required if gable vents are large enough for attic access.

Attic hatches installed during weatherization should be large enough for a person to pass through and allow for a thorough inspection of the attic. Openings must be at least 4 square feet and at least 20 inches in width or length. Attic hatches must not be permanently sealed.

Install permanent blocking around ceiling attic hatches to prevent insulation from falling through openings. The blocking's purpose is to prevent loose-fill insulation from falling out of the attic when the attic hatch is opened. Rigid materials like plywood or OSB board should be used and be installed such that they will hold the weight of a person entering or exiting the attic. Window casing may be used as interior trim around ceiling access panels. Joints in the casing should be caulked prior to painting.

21232 Hatch Insulation & Air Sealing

Hatches to attics should be insulated to the attic insulation level. Hatches should also be air sealed with weatherstrip. Latches, sash locks or gate hooks should be used to provide positive closure. Attic hatches must not be permanently sealed.

A lightweight attic hatch may be cut from damaged insulated foam core doors. The door has an R-value around 7. Batt insulation may be attached to the back of the door panel to achieve desired R-value. The door panel is pre-finished, light-weight and requires no additional painting.

An open blow with cellulose in an attic

21233 Walk-up Stairway and Door

Careful consideration should be given as to how to establish a continuous thermal and air boundary around or over top of the attic stairway. If possible, install a hinged, insulated, and weatherstripped hatch door.

If attic is accessed by a stairwell and standard vertical door, blow dense-packed cellulose insulation into walls of stairwell leading to passage door of the unheated attic. Install threshold or door sweep, and weatherstrip door.

Dense-packed cellulose insulation should also be blown into the cavity beneath the stair treads and risers. Determine if blocking exists to stop insulation from filling other areas by mistake when planning to insulate walls and stairway. Balloon framed walls and deep stair cavities may prevent blown insulation from being cost effective.

21234 Retractable Attic Stairway

An insulated box may be built and placed over the stairway. Alternately, a manufactured stair-and-hatchway cover may be purchased.

2124 Attic Insulation Assessment

Estimate effective R-value of existing insulation taking into account age and condition of insulation. Condition should include settling, uniformity of coverage and extent of attic bypasses.

Evaluate effectiveness of existing batt insulation (see Table 212-1). Voids or gaps between batts diminish their effectiveness. Batts should be in firm contact with ceiling surface.

Effective R-values for Batt Insulation*

Table 212-1

	"Good"	**"Fair"**	**"Poor"**
Measured Batt Thickness (inches)	Effective R-value (2.5 per inch)	Effective R-value (1.8 per inch)	Effective R-value (0.7 per inch)
0	0	0	0
1	3	2	1
2	5	4	1.5
3	8	5	2
4	10	7	3
5	13	9	3.5
6	15	11	4
7	18	13	5
8	20	14	5.5
9	23	16	6
10	25	18	7
11	28	20	8
12	30	22	8.5

1. *Measure the insulation thickness.*
2. *Determine the condition of the installation using the following criteria:*

- ✓ *Good – No gaps or other imperfections*
- ✓ *Fair – Gaps over 2.5% of the insulated area. (This equals 3/8 inch space along a 14.5 inch batt.)*
- ✓ *Poor – Gaps over 5% of the insulated area. (This equals ¾ inch space along a 14.5 inch batt.)*

3. *Look up the effective R-value of the installed insulation using the condition and measured inches.*

**Derived from ASHRAE document "Heat Transmission Coefficients for Walls, Roofs, Ceilings, and Floors" 1996*

R-value of new attic insulation should be based on the "effective" R-value of the existing insulation. If effective R-value of attic insulation is less than R15, attics should be insulated to the recommended R-values established by the state weatherization program. For comparison purposes, The US Department of Energy recommends R49 attic insulation for new homes built in the Region V area heated with natural gas.

Follow state weatherization program guidelines for determining additional attic insulation when existing effective R-value is greater than 15.

It is recommended that blown insulation be used instead of batt insulation whenever possible because blown insulation forms a seamless blanket. Blowing attic insulation at the highest achievable density helps resist settling and reduce convection currents moving within the insulation.

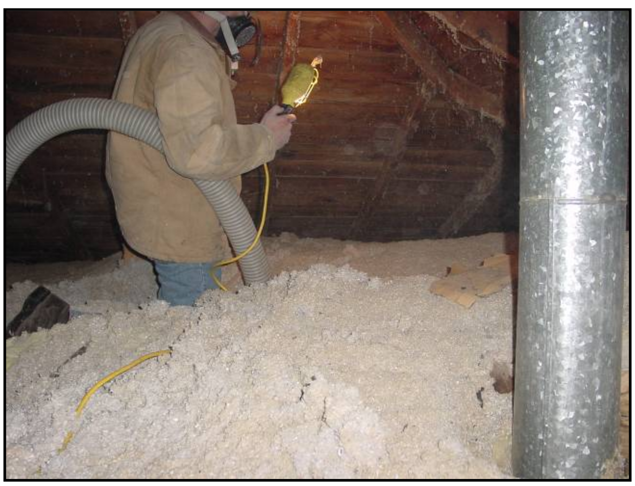
2125 Unfinished Attic Insulation

21251 Blowing Insulation

OSHA-approved breather masks must be worn when blowing insulation.

Blown insulation is recommended for unfinished attic cavities. Insulation shall be installed to a uniform depth according to manufacturers' specifications for proper coverage (bags per square foot ratio) to attain the desired R-value at settled density.

Cellulose insulation from most manufacturers is available in at least two grades that are characterized by the fire retardant added to the insulation. The fire retardants are usually 1) a mix of ammonium sulfate and boric acid or 2) boric acid only (termed "borate only"). It's recommended that cellulose insulation be the "borate only" grade.



"Did you say you wanted 12 inches or 12 feet?"

Do not blow loose-fill insulation tight against roof deck over top plates. Cellulose should not be specified where it may come in contact with exposed metal roofing.

Attic measuring sticks are required to be placed in the insulation showing insulation depth.

Ensure that intentional penetrations are free of insulation overblow and are not restricted.

Loose fill insulation installed around a furnace in the attic must have 12 inch clearance around all sides of the furnace and plenum.

Dense pack all attic cavities, such as slopes, window bays, flat roofs and attics if not accessible for other installation methods. Install blown cellulose to 3.25 to 3.75 lbs/ft^3 or blown fiberglass to 1.6 lbs/ft^3. Access these areas by drilling or removing the fascia board and tube filling each cavity. Ventilation is not needed when dense packing flat roofs.

21252 Floored Attics

Flooring should be removed at bypass locations for proper air sealing before insulation is installed. Insulation should completely fill the floor cavity. Install blown cellulose to 3.25 to 3.75 lbs/ft^3 or blown fiberglass to 1.6 lbs/ft^3. Flooring boards that have been removed should be re-installed. With owner permission, flooring boards may be drilled and the cavity filled with blown insulation. Entry holes should be sealed with plastic or wood plugs.

If client is not using a floored attic, insulation may be blown over flooring with client's permission. Blowing insulation over the flooring may be done in addition to blowing the floor cavity – ***not*** in lieu of blowing the floor cavity.

21253 Batt Insulation

Batt insulation must be installed in such a manner to ensure proper fit between ceiling joists. There should be no voids or gaps between batts, between batts and ceiling joists or between batts and ceiling finish. Insulation must fill joist cavity and provide uniform and complete coverage. If insulation has vapor barrier backing, the vapor barrier shall be toward heated space. When insulation with vapor barrier is installed over existing insulation, the vapor barrier should be removed.

21254 Cathedral Ceilings

Inspect interior ceiling finishes for unsound/weak areas. Either repair damaged ceiling areas or do not insulate. Inspect ceiling for knob and tube wiring, thermal bypasses, open electrical boxes, blocking and recessed lighting fixtures.

Chimneys must be blocked to keep cellulose at least two inches away from the masonry

Access rafter cavities in cathedral ceilings through soffit/fascia or interior ceilings.

Block top and bottom of open rafter cavities with fiberglass or other blocking material. Dense pack cavities with cellulose insulation installed to a density between 3.25 to 3.75 lbs/ft^3. Blown fiberglass is not recommended as it does not restrict the movement of air through it.

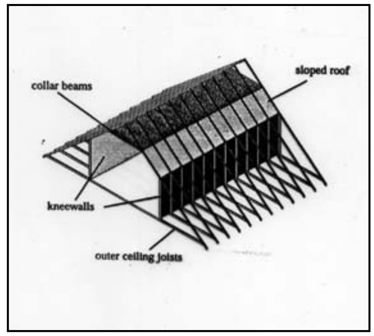
Properly plug interior access holes, seal and paint to match ceiling finish.

Ventilation is not needed when dense packing cathedral ceilings.

2126 Finished Attic- Insulation

The finished attic consists of five sections.

- Exterior finished attic walls (end walls of finished attic)
- Collar beams (above finished attic)
- Sloped ceiling (where wall/roof finish is installed directly to roof rafters)
- Knee walls (between finished attic and unconditioned attic space)
- Outer ceiling joists (between knee wall and top plate of exterior wall)



Finished attic sections

21261 Exterior Finished Attic Walls

Insulate exterior finished attic walls per section 213, "Sidewall insulation".

21262 Collar Beams & Outer Ceiling Joists

Insulate collar beams and outer ceiling joists as described in section 2125, "Unfinished Attic - Insulation".

21263 Sloped Ceiling

Sloped ceiling runs shall be tightly stuffed with fiberglass or some other stuffing material at either the top or the bottom of each run. Where possible, insulate sloped roof with dense pack cellulose installed to density of 3.25 to 3.75 lbs/ft^3.

If the sloped areas have existing fiberglass insulation, the top and the bottom of each cavity may be sealed and the cavity insulated with dense pack cellulose.

21264 Knee Walls

- Open cavity knee wall - Batts

  Insulate knee walls with maximum R-value as allowed by stud cavity depth. Extend batt insulation down to ceiling of conditioned space below. Ensure that joist cavity beneath knee wall has been air sealed with a solid material.

  Insulation should fit snugly between the studs. Vapor barrier facing on batt insulation should be installed toward the conditioned space.

  Batt insulation should be covered with an air barrier material to prevent convective looping within the insulation and to prevent fiberglass exposure. House wrap material, "belly patch" or ½ inch insulated foam sheathing may be used to cover the insulation.

- Open cavity knee wall - Dense pack

Close-in knee wall studs with house wrap material, “belly-patch” or ½ inch insulated foam sheathing tightly using plastic-ring head nails. Space nails no more than 3 inches apart. Secure material to top and bottom of knee wall to keep insulation in knee wall. If necessary, install additional horizontal or vertical strapping to secure material to studs prior to dense packing. Do not use polyethylene or similar vapor barrier material for knee wall enclosure.

Cut holes in knee wall material and insulate to a high density pack (3.25-3.75 lbs/ft^3 for cellulose and 1.6 lbs/ft^3 for fiberglass).

- Closed cavity knee wall
  Insulate closed cavity knee walls per section 213, “Sidewall Insulation”.

- Knee wall within conditioned space
  When the space behind the knee wall is considered part of the conditioned space, insulate rafter cavity with maximum R-value as allowed by rafter cavity depth. The attic floor cavity over the top plate must be air sealed and insulated to extend the thermal boundary from the sidewalls to the roof.

21265 Knee Wall Hatch

Access hatches to attics behind knee walls may be installed where none exist. New knee wall access should be located in an area agreeable with the client and conducive to the installation of the knee wall insulation.

Dense packing the back of a knee wall with cellulose

The access should be properly framed, be as wide as the knee wall stud cavity and be 20 inches high. The access cover should be a durable, rigid material and securely attached with appropriate hardware. Access hatch should be weatherstripped and insulated with a minimum of R13 batt or R7 insulated foam board. Window casing may be used as interior trim around hatch opening. Joints in the casing should be caulked prior to painting.

Existing knee wall access hatches should be weatherstripped and insulated with a minimum of R13 batt or R7 insulated foam board. A new access cover of a durable rigid material should be installed if necessary.

2127 Attic Venting

Attic venting was once thought to be the principle strategy for reducing attic moisture and condensation during the winter. Reducing the cooling load of the house during the summer and increasing the service life of shingles were thought to be additional benefits. However, research over the past few years indicates that attic ventilation has little to do with these issues.[17]

Controlling indoor humidity levels and sealing attic bypasses should be the primary means of controlling moisture in the attics. Other means, such as increased attic insulation and window shading, have a greater impact on reducing the cooling load of a home than attic ventilation. Shingle color and roof orientation have a far greater impact on shingle temperature than attic ventilation with lighter color shingles being more effective than darker shingles.

Installing or increasing attic ventilation may be part of an overall strategy for controlling attic air temperatures and should be considered an optional measure. The priorities should be on controlling indoor relative humidity issues, sealing attic bypasses and then attic ventilation. If attic vents are included as part of an overall attic air sealing/insulation strategy, the following guidelines should be met.

- Vent devices should not permit rain or snow to enter the attic.
- Ridge vents should not be installed on hip rafters.
- The structural integrity of a roof system should not be compromised for the sake of installing attic ventilation.
- Venting an attic does not make it acceptable to terminate bathroom, kitchen or dryer vents in an attic.
- If roof vents must be installed, try to do so on the least visible roof surface.

21271 Existing Vents

Ensure that existing vents are not blocked, crushed or otherwise obstructed. If the net free ventilation area of existing vents is not known, assume that it is half the area of the vent opening.

21272 Vent Ratios

Wherever possible, attic vents should be installed so there are equal amounts of low intake vents through soffit or eaves and higher exit vents on the roof. All separate attic spaces should be cross ventilated with one inlet and one outlet vent.

- 1 ft^2 of vent area for every 150 ft^2 of attic (1:150)
  - If no vapor barrier is present.
- 1 ft^2 of vent area for every 300 ft^2 of attic (1:300)

[17] "Venting of Attic and Cathedral Ceilings" by William B. Rose and Anton TenWolde from the ASHRAE Journal, October 2002.

- If a vapor barrier is present.
- If a vapor barrier is not present and 50% of the required venting area is provided by vents located in the upper portion of the roof with the remainder of the required ventilation provided by eaves or soffit vents.
- If air sealing work has been completed at the attic floor.

Attic vents are not to be closed in the winter months. Clients should be instructed that vents are to remain open.

21273 Low/High Venting

Low (intake) vents should be placed at a minimum of 12 inches above the finished level of attic insulation. Eave chutes or baffles should be provided over top plates where soffit and other low vents could cause blowing of loose fill insulation. The eave chutes or baffles should deflect air above the surface of the insulation and prevent blockage of the vents by the insulation.

High (exhaust) vents should be installed as close to the roof peak as possible in conjunction with lower intake vents. If eave vents are not practical, other vents should be installed low on the roof. Consideration should be given to maximizing cross ventilation.

Vents should be installed in accordance with manufacturers' instructions and sealed with an appropriate sealant. Vents should be installed in a manner to prevent the entrance of snow, rain, insects and rodents.

21274 Soffit Vents

Use soffit vent products specifically designed for this purpose. Soffit vents should be installed with the louvers facing toward the house. Vents may be nailed or screwed to the soffit.

Open area between eave chutes or baffles and the top plate must be blocked with a material, such as rolled fiberglass or two-part foam, to prevent spillage of loose fill insulation into the soffit area and potential blockage of the soffit vents.

21275 Gable Vents

Gable vents should be installed either as high or low venting in the gable and positioned to allow for cross ventilation. Install gable end vents as high in the gable end as possible and above the level of the attic insulation. Existing gable vents should be boxed if insulation comes up to the bottom of the vent.

Framing members are not be cut or removed if gable vents are placed over them. Vent openings must be neatly cut. The vent must be installed with nails or screws. Framing must be provided for the vent if there is no sheathing behind the siding.

The perimeter of the vent must be properly caulked to prevent water entry. A gable vent used as an attic access must be attached by screws and easily removable.

If gable vents are prone to wind driven rain or snow entry, install interior or exterior baffles.

21276 Roof Vents

Roof vents should not be installed on a roof that is in poor condition.

Roof vents are not to be installed over rafters. Vent openings must be neatly cut with close tolerance to ensure a proper fit. High-mounted vents must be installed as high on the roof as practical. Vents should be tucked under shingles as much as possible and may be either fastened with shingle nails and tarred with roofing cement or nailed with neoprene-washered nails to ensure a leak- free installation. Surface-mounted roof vents are not allowed.

2128 Attic Insulation Certificate

Contractors installing blown-in insulation must permanently fasten to the roof side of the attic access (or other accessible location specified by the agency) a signed certificate that attests to the company name, date installed, insulation brand name, R-value added, square footage, thermal resistance chart, conformance to federal specifications, and the number of bags installed in the attic and sidewalls.

213 Sidewall Insulation

Best Practice Recommendation:
- Dense-packing sidewalls with the one-hole tubing method.

Installing insulation with uniform coverage and density is very important because it maximizes the insulating value, minimizes insulation settling, and reduces air leakage through the sidewall.

Densely packed insulation should be added to uninsulated and poorly insulated walls when cost effective.

Insulation should be added to provide complete coverage where uninsulated wall sections exist. Perimeter walls that separate spaces from unconditioned areas (garages, unheated porches, etc.) should also be insulated.

The one-hole method for insulating sidewalls is described in this section as it achieves a dense pack that acts to reduce air leakage and assures that the insulation will not settle over time.

2131 Safety

Workers installing, cutting and handling insulation must wear appropriate respirators, eye protection and clothing while working with the insulation materials.

Correct any electrical hazards such as bare, frayed or uninsulated wiring on house connections prior to any other wall work. Correct any problems at exterior flues, gas or oil lines, or fuel tanks prior to beginning wall insulation.

Use appropriate safety measures before setting up near insect, plant, or animal hazards.

Set up ladders in a safe manner, using ladder levelers or other safety devices, to compensate for yard inclines or other physical obstructions to safe ladder use.

2132 Preparation

Inspect walls for evidence of moisture damage. If existing condition of the siding, sheathing, window/door framing (missing, rotting, deteriorated paint, etc), interior wall finish (weakened plate/drywall, water stains, etc) indicates an existing moisture problem, no sidewall insulation is to be installed until the moisture problem has been corrected.

Note the existence and condition of any exposed structural components, such as wall studs, sill plates and sole plates. Note the presence and condition of structural additions, such as porches and porch roofs. Also note any room additions to the main structure.

Seal gaps in external window trim and other areas that may leak water into the wall.

Note the existence and condition of all electrical outlets and switches on exterior walls. Note the location and condition of vent fan penetrations, clothes dryer vent terminations, wall heaters, and air conditioners. Identify chase ways or wall cavities containing utility runs or ductwork.

Wall cavities open to return air ducts or plenums are to be sealed so the cavity may be insulated. Upper story returns in sidewall cavities are to be sealed. Return air from upper stories is to be routed through the home. A balanced system is desired (see section 227, “Duct Improvements”).

Filling the hopper of the Krendl insulation blowing machine

Determine approximate age of the structure and type of wall construction with an awareness of regional/local construction details. Locate all critical framing junctures: wall/ceiling junctures, cantilevers, porch ceiling/wall connections, and plan the best way to insulate them.

Inspect indoor areas on exterior walls to assure that they are strong enough to withstand the installation process. Inspect for interior openings from which insulation may escape, such as holes, missing trim, pocket doors, wall cavities open at the top or bottom, openings above dropped ceilings, cabinets, soffits and closets. Seal and/or repair openings and weak surfaces such as paneling.

Inspect walls for live knob-and-tube wiring. Mark wall cavities containing knob-and-tube wiring. There may be a significant number of wall cavities that do not contain live knob-and-tube wiring where installing sidewall insulation is not an issue. See section 1381, “Knob-and-Tube Wiring”, for additional guidance with respect to knob-and-tube wiring.

Calculate the amount of cellulose insulation needed to insulate sidewalls to 3.25 to 4.0 pounds per cubic foot (lbs/ft^3). Blown fiberglass insulation, if used, should be installed to a density of 1.6 lbs/ft^3.

2133 Installation – Closed Cavity

21331 Wall Cavity Access

In some cases, access to wall cavities may be possible through open top or bottom plates (balloon construction) or other areas that don’t require siding removal or interior surface drilling. In most cases, however, access through the exterior and/or interior wall surfaces will be required.

Note the types of siding materials on the house especially if that material contains asbestos. Wherever possible, determine the presence and condition of previous layers of siding or sub-siding. Consult with the homeowner/authorized agent to determine the best sidewall insulation and access strategy. The favored method is lifting and/or temporarily removing the siding to gain access for drilling the subsiding. Written permission must be obtained in order to drill and plug the finish siding.

Knowledge of effective siding removal is very important

Remove as many rows of siding as is necessary to access all wall cavities. Access above windows and doors may require additional pieces of siding to be removed for full access.

- Vinyl and aluminum siding may be removed by un-hooking the bottom lip of the row with a "zip tool" manufactured for that purpose.
- Wooden clapboards may be removed by cutting or removing the nails of the row to be removed and the row directly above it with a flat pry bar. Care must be taken that the siding does not split. Wooden shingle siding can be scored/cut at the shadow line and removed.
- Cement board siding may be removed by cutting the nails and removing two rows of siding similar to the process of accessing clapboard siding. Cement board siding often contains some level of asbestos so care must be taken when handling this material. Refer to approved asbestos-safe work practices in your state. Drilling this type of siding is <u>not</u> an acceptable procedure.
- If a home cannot be insulated from the exterior, insulation may be installed from the interior after written approval from the homeowner is obtained. Refer to approved lead-safe work practices in your state. Holes drilled for insulation must be finished and returned to condition as close to the original as possible. Access holes in the walls should be patched or plugged with an appropriate material and the surface made ready for painting.

Probe all wall cavities through holes with a non-conductive probe, to identify fire blocking, diagonal bracing and other obstacles. Identify cavities located at corners and near windows and doors and whether cavities are present above windows so that they can be fully insulated. Additional access and probing may be necessary to determine how to best insulate around structural obstacles and critical junctures.

After probing, drill additional holes as necessary to ensure complete coverage.

Pack pulley wells with insulation if pulley wells are no longer used for window operation. Holes may be drilled through the jamb and sealed with plugs following installation of insulation.

Each application may have several installation methods that will do the job. Choosing the most effective is a very important challenge for the weatherization staff. Some jobs will require the installers to use several methods on the same house.

21332 One-Hole (Tubing) Method

Install insulation in accordance with the manufacturer's recommended application procedures.

Drill minimum 2 to 3 inch diameter holes to access stud cavity. Choose the most effective location for the row of holes that will access the most wall area without requiring additional access points. Avoid drilling holes in the vicinity of electrical outlets and switches.

Cellulose insulation must be blown at a minimum of 3.25 lbs/ft^3 to prevent settling. This minimum density translates into just over one pound per square foot in a two-by-four wall cavity. Uniformly blowing cellulose insulation to this density requires a fill-tube.

The one-hole method using a tube long enough to reach to the furthest corner of the cavity is the best way to dense pack walls

Cellulose insulation from most manufacturers is available in at least two grades that are characterized by the fire retardant added to the insulation. The fire retardants are usually 1) a mix of ammonium sulfate and boric acid or 2) boric acid only (termed "borate only"). It's recommended that cellulose insulation be the "borate only" grade.

The fill tube should be 1 inch or 1 ¼ inch inside diameter tubing with the appropriate stiffness for the job and outdoor temperature. The weatherization agency should have at least one winter and one summer grade tube.

Most installers prefer to blow up the wall cavity and then down. Research in the field has demonstrated that this usually results in a more uniform density than blowing down and then up. However, blowing down and then up is acceptable.

The installer must make sure that the end of the tube makes its way to within one foot of all areas within the cavity. A densely packed and uniform blow will not result unless this rule is followed.

Dense packed wall insulation is best installed using a blower equipped with separate controls for air and material feed. The recommended insulation blower takeoff pressure should be at least 2.9 pounds per square inch (80 inches of water column).

Marking the fill-tube in one-foot intervals allows the person blowing insulation to verify the amount of penetration of the tube into the wall. The installer must be careful to avoid a tube's tendency to bend over and reverse direction.

Starting with several full height, unobstructed wall cavities allows the crew to measure the insulation density and adjust the machine settings. Start with an empty hopper. Fill the hopper with a bag with a known weight. An eight-foot cavity should consume a minimum of 10 pounds of insulation. For most insulation brands, you will run out of insulation in the hopper just before you finish blowing the third 8 foot wall cavity, assuming about a 3.5 pounds per cubic foot density.

Except as previously noted, fill all wall cavities. In some cases wall cavities close to critical framing junctures will take more insulation to plug and fill those areas, which is often necessary in order to assure the proper air sealing of the house.

Seal the holes with expandable foam or stuff tightly with fiberglass. Cover the hole with a plug or with a piece of felt before replacing siding.

21333 Rim Insulation

The bandjoist area between floors in a multi-story homes should be included as part of a sidewall insulation retrofit. Only those parts of these floor cavities that border the exterior must be insulated.

In platform-framed buildings, these cavities must be accessed from the rim or band joists. In balloon framed buildings, these cavities are usually open to the walls, allowing access from the rim or band joists and also from the wall cavities above or below these floor cavities. The R-value of the insulation in these floor cavities must be at least equal to the R-value of the insulation installed in the adjacent wall cavities.

Follow “Safety” and “Preparation” guidelines as described above in sections 2131 and 2132. Pay particular attention to location of light fixtures, exhaust fans, wiring and ductwork located in ceilings between floors.

Remove exterior finish material as described in section 21331, “Wall Cavity Access”.

Drill 2 inch or 2-1/2 inch diameter holes to access each cavity between ceiling joists.

Insert hose nozzle in cavity. Reduce air setting and raise flow on the hopper. Spray insulation into cavity. The objective is to create an “insulation plug” in the ceiling cavity usually within 3 feet to 4 feet from the bandjoist. Alternately, a 90^o nozzle may be inserted into the cavity. An “insulation plug” will be created closer to the bandjoist by spraying insulation up against the subfloor.

Another method for insulating these cavities is the bag, or “bladder”, method. This method is probably the most cost effective when considering time and materials.[18]

Joist cavities on the remaining two sides of the home (where joists are parallel to bandjoist) should be completely filled with insulation. Insert rigid fill tube half the width of the cavity. Pack the joist cavity with insulation.

2134 Installation – Open Wall Cavity

21341 Batt Insulation

Batt insulation must be cut to the exact length of the cavity. A batt that is too short creates air spaces above and beneath the batt, allowing convection. A long batt that is too long will bunch up, creating air pockets. Air pockets and convection currents significantly reduce insulation’s thermal performance. Each wall cavity should be completely filled with batt insulation.

If possible, use unfaced friction-fit batt insulation. Fluff to fill entire wall cavity.

Staple faced insulation to outside face of studs, do not use inset stapling.

Split batts around wiring rather than letting the wiring bunch the batt to one side of the cavity. Insulate behind and around obstacles with scrap pieces of batt or rigid foam pieces before installing batt.

Depending upon the climate region, a vapor retarder may be required. The vapor retarder should have a perm rating of less than one. The vapor retarder should face the “warm in winter” side of the insulation. The vapor retarder should be fastened at all seams and edges.

[18] Woven plastic bags are available from NYP Cop., 805 East Grand Street, Elizabeth NJ 070201, 800-524-1052. Seconds might be available. For normal floor cavity use, bag size should be at least 24 inches wide.

Fiberglass insulation exposed to the interior living space must be covered with minimum ½ inch drywall or other material that has an ASTM flame spread rating of 25 or less.

21342 Wet Spray

Cellulose or rock wool insulation can be mixed with water and sprayed into an open cavity. The insulation is installed from the interior of the home. Note that trained installers and special equipment are required. Manufacturer's instructions with regard to equipment, amount of water to be added, application process and drying time should be followed.

If the insulation has not been pre-mixed with a dry adhesive, a wet adhesive is mixed during the installation process to assure cohesion and stability following application.

Wet spray cellulose being installed

Windows, junction boxes and other items from which insulation is to be excluded should be masked. All rough-in work on exterior walls should be completed prior to insulating walls.

Insulation should be installed to a density of 3.25-4.00 lbs/ft^3.

A "stud scrubber" is used to remove excess insulation. Face of insulation should be flush to face of studs. Floor area around application area should be clean of all debris as excess insulation is collected and placed back in the hopper.

Insulation should completely fill cavity between studs and should be continuous behind interior partition walls. Insulation should fit around all electrical boxes, wiring, conduit and pipes ensuring that all gaps and voids within the wall cavity are filled. Narrow spaces, such as between a junction box and the exterior sheathing, may be insulated with low expanding foam.

Exposed bandjoist between floors should be insulated to same depth as wall cavity.

Most authorities agree that vapor retarders of any type should not be used with spray applied insulations. This recommendation may conflict with some building codes, but knowledgeable code officials understand the special nature of spray-applied insulations and normally grant exceptions when this application process is used[19].

Wet spray cellulose exposed to the interior living space must be covered with minimum ½ inch drywall or other material that has an ASTM flame spread rating of 25 or less.

2135 Completion of Wall Insulation

Ensure that no insulation dust or debris have been left in or around the house.

The duct system should be inspected to assure that ducts are free of insulation. Turn on air handler and look for signs of insulation.

When sidewall insulation is not recommended as a retrofit or sidewalls cannot be insulated an explanatory note must be included in the file.

Provide information on the wall insulation application levels (R-value, quantity of insulation, etc.) required by the certificate of insulation to be posted in the home.

[19] Cellulose Insulation Manufacturers Association, Technical Bulletins #2 and #3.

214 Foundation Insulation

Best Practice Recommendations:

- Basements should generally be considered part of the conditioned space of a home.
- Foundation walls of crawl spaces containing mechanicals should generally be considered the thermal boundary.
- Foundation wall insulation should be a minimum R10.
- Floor joist cavity insulation should be the maximum R-value structurally allowable or highest SIR value in cases where the floor above the crawl space is the thermal boundary.
- Properly installed ground covers are recommended for crawl spaces, regardless of the thermal boundary location.
- Crawl space vents should be sealed where the foundation walls form the thermal boundary.
- Band joists should be both air sealed and insulated.

This section addresses basement wall insulation, crawl space wall and floor insulation, slab-on-grade insulation and rim joist insulation. Standards relating to ground moisture barriers and crawl space ventilation are also provided here.

2141 Identifying the Thermal Boundary

Basement walls are generally part of the home's thermal boundary. As such, the basement ceiling is not insulated nor are bypasses in the basement ceiling air sealed for energy savings. If it is determined that the basement walls are not part of the thermal boundary, the basement ceiling may be insulated and air sealed. Ceilings in basements with the following characteristics may be considered the thermal boundary.

- Space heating and water heating appliances are not located in the basement,
- It is clear that the occupants do not use the basement on a regular basis; for example, access to the basement is through an exterior door or hatch, or
- Basement moisture problems that weatherization work cannot solve.

Either the crawl space walls or floor above the crawl space form the thermal boundary in homes with crawl spaces. Determine whether to air seal and insulate the walls or the floor above the crawl space.

Zone pressure diagnostics can assist in determining whether a basement or crawl space is "more inside" or "more outside" the conditioned space. The existing thermal boundary may not be appropriate, however. Weatherization can alter this by appropriate air sealing. See section 112, "Zone Pressure Tests", for additional information.

In general, the crawl space walls should be considered the thermal boundary if plumbing and ductwork are located within a crawl space and if vents can be sealed. If there are no signs of standing water, the crawl space is dry, there is proper surface drainage and there is a properly installed ground moisture barrier (or one can be installed as part of weatherization), the crawl space walls may be insulated. Otherwise, the floor above the crawl space should be insulated. If the crawl space is connected to a basement, decide if isolating it from the basement is appropriate.

If the heating system is located in the crawl space, precautions must be taken to ensure that adequate combustion air is available. Consideration should be given to insulating the floor above the crawl space if a combustion appliance is located within it. Exposed pipes and ducts are to be insulated if the floor above a crawl space is the thermal boundary.

Floor insulation is generally preferred where crawl space moisture problems exist, the building has a relatively large perimeter for a relatively small floor area, or the foundation wall surface is too irregular to permit foundation insulation.

2142 Preparation

Inspect the foundation from the interior and exterior of the home. Identify all potential hazards and repair prior to air sealing and insulating. Pay particular attention to current or existing moisture problems, such as mold, mildew, wood rot or sewage leakage. Determine if problems can be corrected as part of weatherization.

An inspection from the exterior of the home should include an examination of the following:

- Foundation type and condition,
- Location of electrical, gas, oil and phone lines,
- Plumbing pipes,
- Existing moisture and drainage problems, and
- Existing structural problems.

An inspection from the interior of the home should include an examination of the following:

- Interior foundation wall type and condition,
- Location of electrical and plumbing utilities, and
- Moisture problems.

Make any necessary repairs before air sealing and insulating. Note presence and location of air leaks in the thermal envelope.

2143 Basement Wall Insulation

Basement wall insulation should be a minimum R10. Basement foundation insulation must be covered with a material that has an ASTM flame spread rating of 25 or less (such as ½ inch gypsum board).

Basement walls may be insulated with rigid foam board insulation or batt insulation. Insulation should be continuous from the top of the basement wall down to the basement floor.

21431 Rigid Foam Board Insulation

Foil-faced rigid insulation may be installed directly to the basement wall with mechanical fasteners and insulation compatible foam. Joints and seams in the insulation should be sealed with sheathing tape to form an air seal. A continuous bead of sealant should be used to seal the top and base of the insulation board to the foundation. Sealant should also be used to seal the insulation to foundation around windows and doors.

Installation of rigid exterior foundation insulation

Unfaced extruded or expanded insulation may also be used to insulate the basement wall. Joints and seams should be sealed as described above. Vertical edges of the insulation may be routed to accept a 1 inch x 2 inch or 1 inch x 3 inch furring strip. The furring strips may be used to help secure the insulation to the basement wall with power driven masonry nails. An acceptable flame spread material such as gypsum board or FSK[20] paper may be attached to the furring strips.

Wood furring strips and gypsum board (if used) shall be held off the basement floor by a minimum 1 inch to prevent capillary action from the basement floor.

21432 Batt Insulation

Use 3 inch or 6 inch thick, vinyl-faced, metal-building fiberglass insulation sometimes referred to as "basement blanket" or "perimeter wrap". The insulation is available in a 4 foot width with stapling flanges. The insulation is installed horizontally along the wall and attached to furring strips. The vinyl facing meets the flame spread rating.

Window and door openings should be furred-out. The insulation should be attached and sealed with sheathing tape. Joints between pieces of the insulation should also be sealed with sheathing tape.

Note that condensation may occur on the basement walls with this technique if the insulation is not well sealed and the basement is subject to high moisture loads.

[20] A vapor retarder laminate of foil/ scrim (reinforcement) kraft construction. Also known as FSK

Leaks that are not connected to the outdoors should not be sealed if the basement is a conditioned space. However, some penetrations in a basement ceiling, while initially appearing to be between two conditioned zones, might be connected to the outdoors through attics, open interior walls, exteriors wall, or unconditioned attached structures. These circuitous leaks are more likely found in a balloon framed construction. Leaks of this type should be sealed. The following procedure may be used to help identify circuitous basement ceiling leaks that are connected to the outdoors:

- Complete all attic bypass air sealing.
- Insulate the attic after completing the attic bypass air sealing.
- Insulate the house walls. The walls must be dense packed with cellulose unless conditions will not permit.
- Depressurize the house with the blower door after completing the attic air sealing and attic and wall insulation installation.
- With the blower door running, the door to the basement open, and the basement closed to the outdoors, search for leaks in the basement ceiling connected to the outdoors. If air is flowing through penetrations in the basement ceiling, this air is circuitously leaking in from the outdoors. Possible examples of these leaks include:
    - chimney chases
    - plumbing stacks
    - interior walls open to the basement

Basement ceiling penetrations are leaking air from the outdoors should be sealed Note that it is always best to stop these circuitous leaks by sealing attic bypasses or dense packing exterior walls with cellulose. However, in some cases, difficult air leaks remain after this work.

2144 Basement Ceiling Insulation

If basement ceilings form the thermal boundary, they may be insulated. See section 21452, “Crawl Space – Floor Above is Thermal Boundary”, if the thermal boundary of the basement is its ceiling.

Seal all significant leaks in the basement ceiling if the basement is defined as an unconditioned space. The blower door may be used to help find leaks in the basement ceiling by pressurizing the house. Close door to the basement and open an exterior basement window or door to the outside to help identify air leaks. See section 211, “Air Sealing”, before insulation is installed.

2145 Crawl Spaces

The insulation and air barrier should be adjacent to each other to establish an effective thermal boundary. Establishing an effective air barrier in crawl spaces – comparable to the air barriers in the sidewalls and ceiling – may be difficult, not practical or cost-effective.

If a crawl space is connected to a basement, determine if the walls or the floor above the crawl is the thermal boundary. Consider the presence of plumbing, heating ducts and accessibility to the crawl space when deciding. The foundation wall separating the basement and crawl space should be air sealed and insulated if it's determined that the floor above the crawl is the thermal boundary.

The following items are required regardless of the location of the crawl space thermal boundary.

- An effective ground moisture barrier must be present or one should be installed as part of weatherization.
- Exhaust fans that vent into a crawl space must be ducted to the outside before crawl space insulation is installed. See section 245, "Ventilation".

21451 Wall is Thermal Boundary

Crawl space foundation walls are not to be insulated unless existing moisture problems can be corrected.

Foundation wall insulation shall be a minimum R10 and should extend from the top of the foundation wall down to the crawl space floor.

Extruded polystyrene insulation is the most appropriate insulation for flat concrete or concrete block walls. For rubble masonry walls, use 3 inch or 6 inch thick, vinyl-faced, metal-building fiberglass insulation sometimes referred to as "basement blanket". Two-part foam is also an option for insulating foundation walls and care must be taken to assure that the proper thickness is obtained.

- Existing foundation vents are to be sealed. If foundation vents cannot be sealed, consideration should be given to insulating the floor above the crawl space. Foundation wall insulation is not to be installed unless the crawl space vents can be sealed.
- Air sealing the foundation wall is to be completed before foundation insulation is installed.
- A ground moisture barrier should be installed that runs up the foundation walls at least 6 inches. The barrier shall be sealed to the foundation walls with an appropriate sealant. See section 21433, "Ground Moisture Barrier".
- If the footing or foundation floor is not below the frost line, the insulation should extend two feet horizontally from the foundation wall along the crawl space floor.
- Insulation should be installed to butt snugly together and flush where pieces meet, and should be tight to surfaces at the top and bottom, fastened and protected in accordance with the manufacturer's instructions for the type of insulation utilized.
- Insulation installed horizontally on crawl space floor should be placed on top of the ground moisture barrier.
- Insulation should be kept a safe distance from heat producing sources.
- Insulation should be installed with no voids or edge gaps.
- If present, outside access hatches should be securely attached to foundation wall and insulated to minimum R10. Positive closure (latch,

sash locks, gate hooks, etc) should be installed to provide substantially airtight closure.

- Foundation insulation must be covered with a material that has an ASTM flame spread rating of 25 or less such as FSK paper or 1/8 inch masonite. Vinyl facing on the metal fiberglass insulation also meets this requirement.

  - Batt Insulation
  - Batt insulation should be securely fastened to the wall.
  - Batt insulation may be clamped to the sill plate by a wooden strip, nailed or screwed into the sill.
  - The bottom of the batts should have a weighted object placed at the fold to hold them in place. If there are no weighted objects, 16d nails may be stuck through the insulation batts and into the ground as close to the fold as possible.

  - Rigid Insulation
  - Mechanically fasten insulation and fire-rated material to interior surface, making sure that all surfaces, joints and edges are sealed.
  - Make sure all exposed edges are covered with appropriate materials to meet fire codes.

21452 Floor Above is Thermal Boundary

Floors above crawl spaces may be insulated if they form the thermal boundary.

Seal all significant leaks in the floor to establish an effective air barrier at the floor and prevent air from passing through or around the insulation. The blower door may be used to help find leaks in the floor above the crawl space by pressurizing the house. Close the interior hatch to the crawl space. Open an exterior crawl space hatch if present. See section 211, “Air Sealing”, before insulation is installed.

- Batt Insulation
  - Existing foundation vents may be ignored except where required to provide combustion air to heating appliances located in the crawl space. If heating appliances are located in the crawl space, vent sizes shall be checked to assure adequate combustion air supply.
  - Install full joist cavity insulation to the maximum R-value structurally allowable or highest SIR value recommended by audit.
  - Exposed pipes must be insulated. Any covered water valves should have a tag with “WATER VALVE” written on it and hung below the valve and insulation.
  - Exposed ducts must be sealed and insulated.

- **Insulation must contact the subfloor to prevent convection above the insulation.**
- Floor insulation must be fastened securely in place with wire fasteners, nylon mesh, or other appropriate methods (see below). Friction fitting or stapling of floor insulation is not considered an appropriate method for securing the material. House-wrap sheeting is not to be used to hold insulation in place. If a sheeting material is to be used, consider using netting or a 100 percent polypropylene fabric stapled to the bottom edges of the joists. Reinforce with wood lath as necessary.
  - Wood lath and galvanized nails may be used to hold the insulation in place with a maximum spacing of 18 inches on center. Twine used to hold the insulation in place must be made of polypropylene, nylon or polyester with a breaking strength of at least 150lbs. and 12" maximum spacing between anchor points on the same joist.
  - Wire used to hold the insulation must be zinc coated, stainless or similar corrosive resistant material with a minimum diameter of .035". Wire must be spaced no more than 18 inches apart. Supports and anchors must be zinc coated, stainless steel or similar corrosion resistant material. Staples for wood lath are to have a ¼ inch crown. Staples for wire and twine are to have a 3/8 inch crown and nails are to be galvanized and penetrate the joist at least 5/8 of an inch.
  - Wire hangers may also be used if spaced no more than 18 inches on center and have a minimum thickness of .090 inches. The hanger ends must penetrate the joist at least ½ inch.
  - Insulation supports should not compress insulation by more than one inch.
- Insulation should be fitted tightly around cross bracing and other obstructions.
- Faced insulation should be installed with the facing placed up towards the floor sheathing.
- Ensure that floor insulation is in direct contact with rim joist. If balloon framed, air seal stud cavities prior to installing insulation.
- Insulation should be installed without voids or edge gaps.
- Insulation must not be installed over knob-and-tube wiring.

- Rigid Insulation

Floor cavities may be enclosed and insulation blown into the cavity. Floor cavities may be enclosed with rigid insulation or "belly paper".

Reinforced polyethylene or house-wrap type sheeting is not to be used.

- Floors over crawl spaces may be insulated with rigid insulation board applied to the floor joists. The insulation board is then drilled and insulation is blown into the cavity. If dense pack cellulose is used, density should equal 3.5 pounds of insulation per cubic feet. Multiply 0.29 by the cavity thickness to determine amount of insulation needed per square foot of joist thickness. Plug all holes following insulation installation.
- Enclose floor cavity with belly-paper or similar product. The material used to enclose the floor cavity must be installed in such a manner to support the weight of the insulation. Blown fiberglass insulation may be used to insulate the floor cavity. Dense pack cellulose should not used because of its weight. Slit material and blow insulation into the floor cavity. Tape slits when complete.
- For enclosed floor cavities above unheated areas, loose fill insulation may be added. Insulation should be dense packed to ensure continuous contact with subfloor and to prevent thermal bypasses.
- Plumbing pipes left exposed following floor insulation must be insulated.

21453 Crawl Space Access

Crawl space access hatches from conditioned areas should be weatherstripped and insulated with a minimum of R10. Access covers must be easily removable for entrance into the crawl space.

A new access hatch and hardware may also be installed. The access cover should be constructed of minimum ¾ inch treated wood if access is located on the exterior of the home.

2146 Ground Moisture Barrier

Crawl space moisture can lead to condensation, mold and rot. Air passing through the soil can contain radon and pesticides. Covering the ground with an airtight moisture barrier establishes an air barrier and seals out moisture and soil gases.

Ground moisture barriers should be minimum 6 mil polyethylene plastic. Complete or partial coverage of ground moisture barriers will depend on the accessibility and working conditions in the space. If the entire crawl space floor is not accessible, cover as much as possible.

- Cover the ground completely with a ground moisture barrier without voids or gaps.
- Extend ground moisture barrier up foundation wall a minimum of 6 inches. Seal ground moisture barrier to foundation wall with acoustical sealant or other effective adhesive.

- Secure ground moisture barrier to foundation before installing insulation.
- Overlap ground moisture barrier seams at least 12 inches and seal seams with acoustical sealant, 3M #8086 builders' tape or equivalent.
- Seal the ground moisture barrier to concrete footings with acoustical sealant or other effective adhesive.
- Duct mastic may also be used to seal the ground moisture barrier to the foundation wall and to seal joints between sheets. Apply duct tape to temporarily hold the ground moisture barrier in place. Embed the duct tape in duct mastic assuring that the mastic extends a minimum of 3 inches beyond the edge of the duct tape.

Ground cover sealed to foundation walls

2147 Crawl Space Ventilation

Crawl space ventilation will not solve typical moisture problems found in crawl spaces. The source of the moisture must be identified and corrected.

Vents in crawl spaces with the foundation wall being the thermal barrier may be sealed with rigid insulation. If building codes prohibit sealing crawl space vents, non-operable vents should be replaced with operable vents. Clients should be instructed to close the vents during the heating season.

Vents should not be sealed in crawl spaces with heating appliances unless adequate provisions for combustion air are provided. Vents may be installed in crawl spaces that have combustion heating systems if there are no vents or if the vents are not properly sized for combustion air. Vents should be non-operable and the client should be informed that the vents are to remain open.

Vents should not be installed if the floor above the crawl space is the thermal boundary unless needed to provide combustion air to a heating appliance.

21471 Vent Requirements for Unconditioned Crawl Spaces

Follow local code requirements when installing vents in unconditioned crawl spaces (floor above crawl space is thermal boundary).

2148 Slab Edge Insulation

Perimeter of slabs-on-grade may be insulated with extruded polystyrene foam board insulation. Insulation should be a minimum of R5 and extend a minimum of 6 inches below grade. Attach insulation boards with glue or mechanical fasteners. Provide drip caps and flash behind sidewall exterior finish.

Insulation should be covered with a durable weather resistant coating or pre-coated insulation panels may be used. The coating must protect the insulation from ultra violet light and potential mechanical damage.

Backfill and tamp to prevent settling of soil at a later date. Maintain a minimum 6 inches between backfill and bottom edge of sidewall exterior finish. Provide positive drainage with a 5% slope away from the house (6 inch fall in the first 10 feet away from the house provides a 5% slope).

2149 Bandjoist Treatment

Seal penetrations in bandjoist before insulating. Two-part spray foam is recommended for air sealing and insulating the bandjoist. Polystyrene or polyurethane foam board may also be used, but the board must be caulked or foamed in place to provide an air seal.

Stuffing the band joist area with an "insulation pillow" (a plastic bag filled with fiberglass)

Fiberglass batt insulation is generally not recommended as it does not form a vapor seal between the conditioned space and rim joist. Even with kraft or vinyl-faced batt insulation, vapor can move between the batt and floor framing causing condensation on the bandjoist. This is particularly a problem in crawl spaces and basements with high moisture loads in cold climates.

Joist cavities that are parallel to the foundation wall may be sealed and blown with wall insulation unless moisture is present.

21491 Two-Part Spray Foam

Provide R10 or R-value recommended by audit with spray foam. Foam should make a good seal between the subfloor and bandjoist and between bandjoist and sill plate. Spray foam should also extend down past sill plate to seal sill plate to foundation wall.

21492 Rigid Foam Insulation

Provide a minimum R10 rigid insulation. Insulation board should be placed firmly against bandjoist. Insulation should be cut to fit tightly between floor joists and between subfloor and sill plate. Perimeter of insulation should be caulked or foamed to the floor joists, subfloor and sill plate.

215 Window Measures

Best Practice Recommendations:

- Window measures should be governed by cost effectiveness or the individual home's need for window repair. Window measures to solve minor comfort complaints should be avoided.
- Window measures should be accomplished using lead-safe weatherization practices.
- Replacement windows should be ENERGY STAR® rated.

Windows and doors were once thought to be a major air-leakage problem. However, the gaps and holes in a home's air barrier are usually much more significant than air leakage around windows and doors. Consequently, window and door air sealing has been deemphasized as part of weatherization.

A window's energy efficiency is improved in two primary ways: increasing thermal resistance and reducing air leakage. Limiting factors to the application of these measures are money and time. In the past, window measures – especially storm windows and replacement windows – were overemphasized. The application of window and door measures should be governed by cost effectiveness or the individual home's need for window repair. Expensive and time consuming window measures to solve minor comfort complaints should be avoided.

2151 Air Sealing

Window air sealing measures should be accomplished using lead-safe weatherization practices.

21511 Caulking

- To prevent air leakage, condensation, and rain leakage, seal between window frame and other building materials on interior or exterior walls. Remove loose or brittle material before caulking.
- If crack is deeper than 5/16 inch, install backer rod before sealing with caulk. Backing material includes flexible polyurethane, neoprene butyl rod, fiberglass or sponge rubber.
- Use sealants with rated adhesion and joint movement characteristics appropriate for both the window frame and the building materials surrounding the window. Caulking should be applied in a manner that seals the area thoroughly and is neat in appearance.

21512 Weatherstripping

- Large gaps between sash and sill and sash and stops may be weatherstripped. Meeting rails may also be weatherstripped or planed.
- Weatherstrip is to be secured by nails or staples, form a permanent airtight seal and not obstruct the operation of the sash.

- Replace/repair missing or non-functional top and side sash locks, hinges or other hardware if such action will reduce a significant amount of air leakage.

2152 Exterior Storm Windows

Storm windows are usually marginally cost effective even though they perform several tasks. A storm window only increases a single-pane window's thermal resistance from approximately R1 to R2 and it protects the primary window from weathering. Storm windows help increase the surface temperature of the prime window, improving comfort and reducing the potential for window condensation. Storm windows installed in kitchens, baths and other high moisture areas should be operable if they provide the only source of fresh air ventilation into the space.

Double hung sash with exterior aluminum storm window

Select metal exterior storm windows with the following qualities.

- Frame should have sturdy corners and not tend to rack out-of-square during transport and installation.
- The gasket sealing the glass should surround the glass edge and not merely wedge the glass in place against the metal frame.
- Storm window sashes must fit tightly in their frames.
- The window should be sized correctly and fit well in the opening. Storm windows must be securely fastened in place; installed straight, plumb, and level, and without distortion.
- Storm windows should be caulked around the frame at time of installation except for weep holes which are to remain open. If weep holes are not manufactured into new storm window, weep holes are to be drilled.
- Storm window sashes must be removable from indoors.
- New storm windows should not be used to replace existing storms if the existing storms are in good condition or can be repaired at a reasonable cost.
- Wood storm window inserts should fit neatly within window frame with the appropriate turn buttons, latches or closing hardware.
- Fixed storm windows should not restrict the exiting capacity and access required for emergency exits.

2153 Replacement

Primary window replacements are generally not cost effective. The decision to replace a window should be based on cost effectiveness and not on client requests. Replace windows when the window is missing, damaged beyond repair, or found to be cost effective.

Replacement window sash should be easily operable by the client.

Replacement windows should be Energy Star® rated and meet the US Department of Energy U-value recommendations.

State		U-Value
Minnesota, Wisconsin, Michigan	–	0.35 Btus/ft^2-^{o}FDay
Iowa, Missouri, Illinois, Indiana, Ohio	–	0.40 Btus/ft^2-^{o}FDay

Replacement windows should have U-values rated by the National Fenestration Rating Council (NFRC). U-value shall be window unit and not center-of-glass U-value.

When feasible, window repairs must be done, instead of replacement, whenever the total cost of the repair is less than seventy-five percent of the cost of a replacement window.

2154 Window Repair

Measures listed below are air-sealing measures and may be part of an overall air-sealing plan. Otherwise, they are repair items done to increase building durability. Cost for these measures should be considered within the overall weatherization budget of the home.

Window repair should be accomplished using lead-safe weatherization practices. The finished window shall operate smoothly, form a tight seal and be neat in appearance. All work to the window shall be neat in appearance.

It is not required to make windows sashes operable unless stipulated by building codes.

21541 Glass Replacement

Replace missing or broken glass or glass that is cracked and noticeably separated that affects the structural integrity of the window. Ignore glass cracks that are not noticeably separated.

- Glass should be secured with glazing points (2 inches from each corner and not less than 8 inches apart) and puttied with latex or oil based glazing compound, or sealed with plastic or vinyl glazing strips.
- Glass set in metal frames should have metal-glazing clips no more than 12 inches apart and within 4 inches of each corner and the joint between the two surfaces puttied.
- Glass over 25 inches in either dimension should not be less than “B” grade double strength.

- Safety glass is required in windows located within 12 inches of a door when the bottom edge is less than 60 inches above the floor or if panes are larger than 9 ft^2 when the bottom edge is less than 18 inches above the floor.

21542 Re-glazing

Re-glazing window sashes is best accomplished as part of a comprehensive window rehabilitation project. Without scraping, priming, and painting, re-glazing wood windows may not be a durable repair.

- Window glazing compound should only be replaced if the existing glazing is deteriorated to the degree that the window glass is in jeopardy of falling out if the sash.
- Caulk may not be used in place of a glazing compound.
- A coat of primer or linseed oil must be applied to wood sashes before the glazing compound is applied.
- Glazing compound is to be tooled smooth to form a concave surface and be neat in appearance.

21543 Stops

Window stops should be adjusted if large gaps exist between stop and jamb. Window stops should be installed in such a way as to insure a tight seal between the jamb, sash, and stop. Ensure that window operates smoothly following stop adjustment.

- Wood installed should be similar in size and shape to other existing window stop in the house.
- Installed window stop is to be planed or sanded smooth.
- New stop is to be painted or varnished to blend with current trim.
- Corners of installed materials are to be mitered or coped
- If matching window stop is not available, then all stop on the window is to be replaced.

Double hung sash with sash lock

21544 Sills

Factory made sills or sills made from copper treated lumber must be used for window sill replacements. CCA (chromated-copper-arsenate) lumber is not to be used.

- Sill is to be beveled flush with the interior wall.
- Sill shall be the same distance from the house as other window sills.
- Sill shall be installed at the same angle as other windows sills on the home.

- All seams shall be caulked after installation.
- Sills shall be painted to match the rest of the windows on the home.

21545 Sash Locks

The meeting rails of the upper and lower sashes are to be flush.

- Blocks under the sash lock or chiseling out part of the sash to recess the lock is not acceptable.
- Sash locks are to be centered on the check rails.
- Cam-type sash locks may be used. If they are, one must be installed at each side rail of the bottom sash.

21546 Sash Replacement

New sashes are to be installed in a manner as to allow the lower sash to stay in an open position when raised and down when closed. The client should be able to open and close sash easily.

- The lower sash must have the same bevel on the bottom rail as that of the sill.
- The top sash is to be caulked in place, but only if the old top sash was caulked or painted shut. The client must give permission before this is done.
- Sashes are to be painted or varnished to match the existing sashes.

216 Door Measures

Best Practice Recommendation:

- Door measures should be governed by cost effectiveness. Door related security and durability issues should be addressed within the overall budget context. Door measures to solve minor comfort complaints should be avoided.

Door measures are usually not cost effective unless they have a very low cost. Doors have a small surface area and their air leakage is usually more of a comfort problem than a serious energy problem most of the time. However, security and building durability issues are still very important door issues that should be addressed.

2161 Air Sealing

Door weatherstrip, thresholds and sweeps are marginally cost effective. These measures may be addressed if they are found to be cost effective. Otherwise, they are items done to increase building durability.

21611 Weatherstripping

Before weatherstripping, tighten door hardware and adjust door to close snugly against its stops. Weatherstrip is to consist of a semi-rigid strip with vinyl or neoprene flap. A bulb type weatherstrip is also acceptable if the bulb is made of siliconized rubber and a minimum of ¼ inch diameter. A third type that can be used is a tough vinyl tear-resistant skinned material enclosing cellular foam.

New weatherstrip must form a tight seal, be neat in appearance, and be fastened in such a way as to prevent buckling or gaps. Door should close without having to use excessive force following weatherstrip installation.

- All existing weatherstrip is to be removed from the door if installing new.
- Door trimming and adjustments, including hinge tightening and strike plate adjustments may be necessary and must be done before installing weatherstrip.
- A small bead of caulk is to be applied to make the weatherstrip and the door stop airtight.
- Nails or other fasteners are to be made of a non-rust material.
- Installation is to be in accordance

Exterior door metal/vinyl weatherstripping

with the manufacturer's instructions.

21612 Thresholds

Thresholds and door sweeps shall be installed to prevent infiltration while not preventing the door from operating properly.

- Thresholds are to be set entirely on the sill or a continuous shim from end to end so no gap exists between the threshold and doorsill.
- Thresholds are to fit snugly between the jambs and fastened to the sill and the floor with screws.
- Thresholds are to be caulked on both the interior and exterior to form a tight seal with the doorsill.
- All thresholds are to be wood with metal and vinyl insert.
- All unfinished wood installed is to be painted or varnished to a smooth finish.

21613 Sweeps

Sweep installation is to be neat in appearance, form an airtight seal and not interfere with the operation of the door.

Exterior door threshold sweep

- Sweeps are to be a metal strip with a vinyl or neoprene insert, or a brush type installed with screws on the interior side of the door.
- Sweeps are to be cut to the same width as the door.
- Sweep shall be secured within 2 inches of the door edge on each end.
- Sweeps shall have a threshold or carpet bar to seal against.

2162 Door Replacement

Door replacements are rarely cost-effective energy conservation measures. When feasible, a door must be repaired rather than replaced whenever the total cost of the repair is seventy-five percent or less than the cost of the replacement door. Tight uninsulated doors in good condition should not be replaced with insulated doors. It is not required to make existing stuck doors operable, except for meeting code with respect to egress.

21621 Replacement Doors

- All replacement doors should be exterior-grade foam core. Replacing an exterior panel door with another panel door is not allowed.
- Whenever possible, 1-3/4 inch thick doors are to be used.
- Replacement door should not have glass panes. If homeowner is persistent, install smallest glass pane as possible or a door viewer.
- All new wood doors are to operate smoothly, be sanded, and be painted or varnished to a smooth water repellent finish.

- Doors shall have a 5° bevel cut on the bottom to form an airtight seal between the bottom of the door and the gasket of the threshold.
- New 1-3/4 inch doors shall receive three new 4 inch x 4 inch butt hinges; 1-3/8 inch doors shall have three new 3 ½ inch x 3 ½ inch butt hinges that are mortised into the door and jamb.
- When installing a new door and jamb, the hinges are to be placed at 7 inches from the top of the door, 11 inches from the bottom of the door, and the third hinge centered between the top and bottom hinge.
- New door shall have a new door lock installed (whenever possible a 2-3/4 inch backset should be used unless using a pre-hung door that is pre-drilled for a 2-3/8 inch lockset). The client is to receive all keys - minimum two keys per lockset.

21622 Pre-Hung Replacement Doors

If a pre-hung door is needed, either a wood or steel foam filled door may be used.

- All door jambs must receive at a minimum, shims behind each hinge and lockset and any other area needed to support the door jamb.
- New jambs must be trimmed out to match existing interior and exterior trim.
- Galvanized casement nails must be used, counter sunk and filled.
- All doorsills installed must be flush with the floor of the house.

2163 Door Repair

Door repair items improve home security and building durability. Cost of these items should be addressed within the context of the overall weatherization budget for the home. All repair work must be within accepted carpenter standards. All replacement materials are to be of the type and size already existing on the door.

21631 Jambs

Remove damaged or deteriorated portion of the jamb and replace with matching materials, butting uniformly to adjacent members. All work is to be neat and form a tight seal.

- All loose sub members and casing is to be secured and all wood installed is to be finish grade or factory made jamb material.
- All installed lumber is to be planed or sanded smooth and painted or varnished to a smooth finish to match existing.
- Installer is to tighten or re-set hinges. Work is to be done in accordance with accepted carpentry standards. New installations require hinges to be mortised.
- Casing used is to match the existing casing on the house. If matching casing is not available, then all of the casing on the door is to be replaced. Wood is to be installed flush with the wall to insure a tight fit.
- Any damaged interior wall is to be repaired with like materials.
- Strike plate shall be tightened or re-set to hold the door flush with the doorstop.

- Strike plate is to be mortised into the jamb.

21632 Stops

Reposition stops if necessary. Seal gaps between the stop and jamb with caulk.

- Wood used for door stop is to be manufactured as doorstop.
- If a section of the stop is missing or must be replaced and the stop can not be matched to the existing stop, then the entire stop on that jamb is to be replaced.
- Joints are to be mitered or coped to form a tight corner joint.
- Wood installed is to be sanded smooth and painted or varnished to a smooth finish and approximately match the existing wood.

21633 Locksets/Strikeplates

Replace missing or inoperable lock sets; or reposition the lock set/strikeplate; or install a modernization kit so that the door can be held in a tightly closed position.

- Lock set is to be installed between 36 inches and 39 inches from the floor with a 2-3/4 inch backset whenever possible.
- Cover plates are to completely cover the hole drilled for the lockset cylinder.
- Faceplate and strike plates are to be mortised flushed with the wood of the door and jamb. Screws are to be installed straight and be flush with the face and strike plates.
- Strike plate must be installed in a manner as to allow the door to latch easily but with minimum play between the door and stop.

221 Clean & Tune – Gas & Oil Fired Furnaces & Boilers

Best Practice Recommendations:

- Heating systems should be cleaned and tuned to ensure that they are operating in a safe and efficient manner.
- Shell retrofits should not be done until health and safety issues, such as gas leaks, high CO readings or venting problems are corrected.
- Comprehensive testing protocols should be adopted to ensure proper operation, venting and combustion air supply for gas- and oil-fired space heating appliances.

Weatherization agencies have a responsibility to assure that their clients' heating systems are operating in a safe and efficient manner. As such, agencies should provide a full range of heating system services including safety testing, heating system repair and retrofit, and heating system replacement. Shell retrofits should not be done until health and safety issues, such as gas leaks, high CO readings or venting problems are corrected.

Weatherization agencies have two options with respect to heating systems:

- Heating systems can be tuned and repaired and then retrofitted for safe and more efficient operation, or
- Heating systems can be replaced.

Heating appliances that are non-operational or non-repairable may be replaced. Before deciding to replace a heating system, efforts to repair and retrofit it should be made. Repair is any work needed to bring a heating appliance up to manufacturer's specifications for proper operation. Repair items can include replacing blower motors and pumps, fixing vent connectors and chimneys, or tuning up burners.

This chapter provides standards for cleaning and tuning gas and oil-fired furnaces and boilers. Standards for heating system retrofits (222, "Heating System Retrofits") and heating system replacement (223, "Heating System Replacement") follow this chapter.

Servicing standards for the following heating systems are provided here.

- Gas-fired appliances,
- Oil-fired appliances,
- Furnaces, and
- Boilers.

2211 Gas Burner Servicing Requirements

The following standards apply to gas-fired furnaces, boilers, water heaters, and space heaters.

Maintenance and burner adjustment is not required unless one of the following is found:

- The appliance has not been serviced for two years or more,

- Carbon monoxide emissions measure greater than 100 ppm (as-measured) or 200 ppm (air-free),
- There are visual indicators of soot or flame roll-out,
- Steady-state efficiency (SSE) is less than 75 percent,
- Burners are visibly dirty, or
- Measured draft is low.

22111 Gas Burner Maintenance and Adjustment
Combustion test analysis shall be done following gas burner maintenance and shall meet the standards shown in Table 221-1.

- Remove causes of CO and soot, such as closed primary air intake, over-firing, and flame impingement. Measure CO before dilution air has entered the vent system. CO should be less than 100 ppm (as-measured) or 200 ppm (air-free).
- Remove dirt, rust, and other debris that may be interfering with the burners.
- Test gas valves to ensure that, in the event of a pilot outage, the flow of gas to the burners is interrupted. For gas valves with 100 percent safety shutoff, ensure that the flow of gas to the pilot is also interrupted in the event of a pilot outage.

Atmospheric natural gas burners on a large boiler

- Install new thermocouple (if an intermittent ignition device, or IID, is not being installed). Adjust pilot flame so that the hot tip of the thermocouple is enveloped by the flame.
- Adjust gas input if burners are over-fired or under-fired. Adjust input by adjusting gas pressure to between 3.4 and 4.3” water column (w.c.) for gas and 11” w.c. for propane, or replace the burner orifices.
- If the measured draft is inadequate, take action to correct. Poor draft can be caused by a leaking vent system, an obstructed chimney, lack of combustion or dilution air or leaking return air ductwork.
- Seal leaks in vent connectors and chimneys with high temperature sealant.
- Clean and adjust thermostat and check anticipator setting.
- Set heat anticipator to the proper amp setting by matching amp draw of the gas valve or per manufacturer’s instructions.

Acceptable Combustion Test Analysis Measurements - Gas

Table 221-1

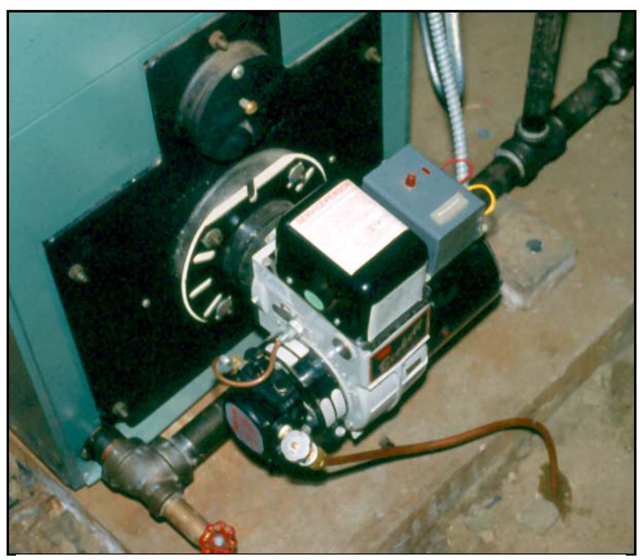
Heating Unit Type	Oxygen (O_2)	Carbon Dioxide (CO_2)	Stack Temperature	(CO) Carbon Monoxide Maximum ppm
Gas Atmospheric (natural gas, propane)	4 – 9%	NG: 9.6 – 6.8% LPG: 11.2 - 7.8%	300 – 600 ^oF	100 (as-measured) 200 (air-free)
Fan Assisted	4 – 9%	NG: 9.6 – 6.8% LPG: 11.2 - 7.8%	300 – 480 ^oF	100 (as-measured) 200 (air-free)
Condensing	PMI[1]	PMI[1]	PMI[1]	100 (as-measured) 200 (air-free)
Space Heaters	5 – 15%		300 – 650 ^oF	100 (as-measured) 200 (air-free)
Standard Power Burner	4 – 9%	NG: 9.6 – 6.8% LPG: 11.2 - 7.8%	276 – 550 ^oF	100 (as-measured) 200 (air-free)

[1] – Per Manufacturer's Instructions

2212 Oil Burner Servicing Requirements

Oil burners need annual maintenance to retain operational safety and combustion efficiency. Testing for steady state efficiency, draft, carbon monoxide, and smoke should be used to guide and evaluate the need and effectiveness of maintenance work. The following procedures pertain to oil-fired furnaces, boilers and water heaters.

Proceed with maintenance when any one of the following items is found with a gun-type burner. A flame-retention oil burner may be considered as an alternative to adjusting an existing gun-type oil burner (see chapter 222, "Heating System Retrofits").



Flame retention head oil burner on a wet base boiler

- The appliance has not been serviced within one year.
- The smoke number is greater than 2.
- Steady-state efficiency (SSE) is less than 75 percent.
- Carbon monoxide is greater than 100 ppm (as-measured).
- Improper flame color or combustion chamber impingement.
- Improper flame ignition and cut-off.
- The burner, combustion chamber, or heat exchanger is visibly dirty.

22121 Oil Burner Maintenance and Adjustment

Some or all of the following maintenance tasks may be needed to optimize safety and efficiency after evaluating the oil burner's operation. Combustion test analysis shall be done following oil burner maintenance and shall meet the standards shown in Table 221-2. Replacing the burner with a flame-retention burner may be alternative to adjusting the existing burner.

- Verify correct flame-sensor (cad cell) operation. Replace if necessary.
- Clean or replace burner nozzle according to the size on unit nameplate or post-weatherization heat loss calculations.
- Clean the burner's blower wheel.
- Clean or replace oil filter(s).
- Clean or replace air filter.
- Remove soot and sludge from combustion chamber.
- Remove soot from heat exchange surfaces.
- Clean the oil pump screen.
- Clean dust, dirt, and grease from the entire burner assembly.
- Set oil pump to 100 psi pressure or per manufacturer's instructions.
- Adjust air shutter for recommended smoke reading.
- Adjust barometric damper to about 0.04-to-0.06 inches w.c. draft downstream at the breech.
- Replace defective primary controls.
- Replace electrodes or adjust gap between electrodes to manufacturer's specifications.
- Repair ceramic combustion chamber, or replace it if necessary.
- Replace or adjust barometric damper.
- Measure CO in flue gases at the breech. CO should be less than 100 ppm (as-measured).
- Check oil tank for water (drain if necessary).

Acceptable Combustion Test Analysis Measurements - Oil

Table 221-2

Heating Unit Type	Oxygen (O_2)	Carbon Dioxide (CO_2)	Stack Temperature	Smoke Test	(CO) Carbon Monoxide Maximum ppm
Oil Gun Burner	4 – 9 %	12.5 – 8.8%	325 – 600 ^{o}F	2 or less	100 (as-measured)
Flame Retention	4 – 7%	12.5 – 10.3%	325 – 600 ^{o}F	2 or less	100 (as-measured)
Condensing	PMI[1]	PMI[1]	PMI[1]	2 or less	100 (as-measured)

[1] – Per Manufacturer's Instructions

2213 Improving Inadequate Draft

If measured draft is below the minimum draft pressures listed in Table 221-3, check for flue or chimney obstructions, disconnected vents, or an improperly designed vent system. Check the National Fuel Gas Code (NFGA) for proper vent sizing.

Minimum Draft Pressures

Table 221-3

Atmospheric Gas Appliances Only Acceptable Draft Test Readings for Various Outdoor Temperature Ranges					
ºF	<20	21-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column inches	-.02	-.016	-.012	-.008	-.004

Power Oil Burners Acceptable Draft Readings Overfire and at Breech	
Draft Reading Location	**Acceptable Draft**
Overfire Draft	-0.01 to -0.02 inches or -2.5 to -5 Pascals
Vent Connector or Breech	-0.04 to -0.06 inches or -10 to -15 Pascals

2214 Heating Appliance Venting

Venting problems are common in low-income housing and solving them is the responsibility of a weatherization agency. Proper venting is essential to operation, efficiency, safety and durability of combustion appliances. Many chimneys and vent connectors have been neglected for decades. Air tightening the home can weaken draft, and weatherization work can reduce a heater's operating time, resulting in a cooler flue. **Perform a draft test on all vented combustion appliances prior to and after weatherization to assure proper venting in accordance with the applicable NFPA code. See section 123, "Worst-Case Draft Testing".**

Inspect chimney, vents and vent connectors to ensure adequate draft, clearance, soundness and freedom from combustible deposits. Clean if necessary. Repair or replace sections of the venting system that are seriously corroded or rusted, contain cracks or holes, and/or are unsealed, loose, or disconnected.

Sizing vents and chimney liners and selecting venting materials are two important tasks when inspecting and repairing venting systems. Too large a vent often leads to condensation and corrosion. Too small a vent can result in spillage. The wrong vent materials can corrode or deteriorate from heat.

Ensure all venting materials meet clearances from combustible materials in accordance with the applicable NFPA code. When called for, correct cases where vent clearance requirements are not met.

Ensure that vent/chimney connections are securely fastened. Horizontal runs in the vent connector should have a rise of at least ¼ inch per foot. Existing connectors that do not meet this requirement are to be repaired <u>unless</u> the appliance drafts properly under worst-case draft conditions (see section 123, "Worst-Case Draft Testing").

A ‘Y’ connector is the preferred connection when a common flue is used for more than one appliance. Vent connections are not to be located directly across from each other when an induced appliance is used.

22141 Chimneys

Chimneys should terminate near the highest part of a roof and be at least 3 feet above the roof penetration and 2 feet above any obstacle within 10 feet of the chimney outlet. Chimneys should have a cap to prevent rain and strong downdrafts from entering. Install caps on metal chimneys if caps are missing.

An example of a very hazardous venting problem

Determine whether all chimneys and existing liners are in good condition and unobstructed. Repairs must be made if chimney is in disrepair or a new liner is necessary. See section 225, “Chimney Liners”.

Masonry chimneys should be lined with a fireclay flue liner or a retrofitted metal flue liner if the chimney is not properly sized or is in poor condition.

All disconnected chimneys in the attic must be plugged and sealed.

Clean solid-fuel chimneys that contain creosote. Wood-fired appliance metal chimney sections penetrating floor, ceiling, or roof should have approved thimbles, support packages, and ventilated insulation shields if the chimney passes through insulation.

22142 Venting Devices, Materials and Sizing

The National Fire Protection Association (NFPA) is the authoritative source for information on material choice and sizing for vent connectors and chimneys. The information in this venting section is based on the following NFPA documents. Consult these references for specific venting requirements and tables for vent and chimney sizing.

- NFPA 54: The National Fuel Gas Code
- NFPA 31: Standard for the Installation of Oil-Burning Equipment
- NFPA 211: Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel-Burning Appliances 1996 Edition

22143 Vent Connectors

A vent connector connects the venting outlet of the appliance with the chimney. Approved vent connectors for gas- and oil-fired appliances are made from the following materials.

- Galvanized-steel pipe ($\geq$ 0.018 inch thick),
- Type-B vent, consisting of a galvanized-steel outer pipe and aluminum, inner pipe ($\geq$ 0.027 inch thick),
- Stainless-steel pipe ($\geq$ 0.012 inch thick),
- Type-L vent, like Type-B only with a stainless-steel inner pipe, or
- Various manufactured vent connectors.

22144 Sizing Vent Connectors and Chimneys

Sizing tables and procedures for chimneys and vent connectors are found in NFPA documents numbered 54, 31 and 211 as described earlier. NFPA 54, the *National Fuel Gas Code*, Part 11 provides tables for sizing various types of chimneys and vent connectors.

22145 Orphaned Water Heaters

Water heaters formerly vented with a furnace must pass draft testing. Replacing an atmospherically vented furnace with a horizontally vented 90 percent plus furnace will necessitate relining the chimney with a liner sized for the water heater alone. This will prevent increased condensation and decay in the old chimney.

2215 Combustion Air

Combustion appliances located in most attics and crawl spaces get adequate combustion air from leaks in the building shell. Even when a combustion appliance is located within the home's living space, it usually gets adequate combustion air from air leaks in the building shell. However, if an appliance is located in a small room with tight walls and door, it may not get adequate combustion air. Also, if the home is very air-tight, the appliance may not get adequate combustion air.

In the absence of local codes, combustion air should be provided in accordance with the applicable NFPA code listed below.

- Natural Gas, Propane – NFPA 54, code #5.3
- Oil – NFPA 31, code #1-9
- Solid Fuels, NFPA 211, code #9-3

Generally, two combustion air openings are required to prevent wind from pressurizing or depressurizing the combustion zone. One opening is located near the ceiling and one near the floor. The preferred installation is for one or both openings to connect to a ventilated attic or crawl space or to some other unheated and non-airtight intermediate zone within the building. For openings connecting the combustion zone with outdoors, choose an outdoor location that is sheltered that does not sit at a right angle to prevailing winds. Wind blowing at a right angle to an opening tends to depressurize the opening and connected zone. Find and use applicable code for additional information.

2216 Forced Air System Standards

The overall system efficiency of a gas or oil fired forced air heating system is affected by blower operation, duct leakage, balance between supply and return air, and duct insulation levels.

22161 Furnace Operation Standards and Improvements

Apply the following furnace operation standards to maximize the furnace's seasonal efficiency and safety. Refer to Table 221-4 for furnace operating guidelines.

Category I fan-assisted gas furnace

- Check temperature rise after 10 minutes of operation. Refer to manufacturer's nameplate for acceptable heat rise (supply temperature minus return temperature). The heat rise should be between 40°F and 70°F with the lower end of this scale being preferable for maximum efficiency.
- The fan-off temperature should be between 85°F and 100°F, with the lower end of the scale being preferable for maximum efficiency.
- The fan-on temperature should be 90°F and 115°F if possible.
- The high-limit controller should shut the burner off before the furnace temperature reaches 200° F. Operate unit with blower disconnected to check high limit control and repair as necessary.
- Check for proper sequencing and operation of elements for electric furnaces.
- If needed, seal (with compatible sealing materials) unsealed blower compartment openings and blower compartment door.

Furnace Operating Temperatures

Table 221-4

Inadequate heat rise, Condensation and corrosion possible.	Heat rise good for both efficiency and avoidance of condensation.	Heat rise excessive. Check fan, heat exchanger, ducts and fan speed.
20^{o} 40^{o}	40^{o} 70^{o}	70^{o} 95^{o}
Heat rise = Supply temperature – Return temperature		

Excellent fan-off temperature if comfort is acceptable.	Borderline acceptable. Consider replacing fan control.	Unacceptable range. Savings possible by replacing fan control.
90^{o} 100^{o}	100^{o} 115^{o}	115^{o} 130^{o}
Fan-off Temperature		

Excellent. No action needed.	Fair. Consider fan control replacement only if fan-off is unacceptable.	Poor. Consider fan control replacement.
100^{o} 115^{o}	115^{o} 130^{o}	130^{o} 150^{o}
Fan-on Temperature		

If the heating system does not conform to the standards in Table 221-4, consider the following improvements.

- Reduce heat rise by cleaning or changing dirty filters, cleaning the blower, increasing fan speed and improving ducted air circulation.
- Adjust fan control to conform to the above standards or replace the fan control if adjustment fails (this control may be non-adjustable on some furnaces).
- Adjust the high-limit control to conform to the above standards or replace the high-limit control (this control may be non-adjustable on some furnaces).

In all cases, the following furnace measures will be done:

- Furnace filters should be cleaned or replaced. One extra filter should be left with the client.
- Blower fan and compartment should be cleaned (cleaning may entail vacuuming or wiping parts with cleaning solvents).
- Blower belt should be adjusted or changed if necessary.
- Inspect blower assembly's electrical wiring system for bad insulation and loose connections and repair as necessary. Inspect blower and squirrel cage for excessive free play and correct as necessary.
- Inspect pulleys and drive assembly for alignment, wear, and tension. Belt should free of cracks and have one inch of free play when measured between the pulleys. Replace as necessary.
- Lubricate the blower motor, if appropriate.

- Check for proper operation of the thermostat.

22162 Filter and Blower Maintenance

A dirty filter can reduce airflow significantly. Special high efficiency filters offer more airflow resistance than standard filters, especially when saturated with dust. Take action to prevent airflow restriction with the following:

- Ensure that filters are easy to change or clean.
- Stress the importance of changing or cleaning filters, and suggest to the client a regular filter maintenance schedule.

When the air handler is on there should be a strong flow of air out of each supply register, providing its balancing damper is open. Low airflow may mean that a branch duct is blocked, ductwork is disconnected, or that return air ductwork is restricted. When low airflow is a problem, consider the following improvements.

- Clean or change filter.
- Clean furnace blower.
- Lubricate blower motor and check tension on drive belt.
- Remove obstructions in the ductwork.
- Ensure all duct joints are properly connected.
- Add another return air duct (see section 2273, “Improving Duct System Airflow”).

22163 Cleaning Air Conditioning Coils

Dirty air conditioning coils are a common cause of low airflow and low heating and cooling efficiency. Follow the general guidelines listed below to clean air conditioning coils. See section 226, “Heat Pumps and Air Conditioners”, for additional information.

- Identify the coil location and the coil surface where the air enters – most of the dirt will be attached to this surface.
- Remove access panel in air handler or duct; or cut access panel in duct; or disassemble duct to gain access to air conditioning coil.
- Use a stiff hair brush to remove surface dust, dirt, and lint. Be very careful not to damage the delicate cooling coils.
- Spray the coil with cleanser and after a while spray water to rinse out the cleanser and dirt. Repeat the spraying if necessary.
- Ensure that the pan and drain hose are doing their job. Water and cleanser should be flowing out the end of the hose, not overflowing into the duct. Clean the pan and unplug the hose if necessary.

2217 Hydronic Standards

The following standards refer to hydronic systems commonly found in single family homes. Hydronic systems found in multifamily buildings are generally more complex and should be tested and evaluated by professionals experienced in their operation. Observe the following standards for servicing hydronic heating systems in single family structures.

- Repair water leaks in the system.

- Clean fire side of heat exchanger of noticeable soot buildup.
- Lubricate circulator pump if necessary.
- Boiler should not have low-limit control for maintaining a minimum boiler water temperature, unless the boiler is heating domestic water in addition to space heating.
- Test pressure tank for its rated air pressure.
- High-limit control should deactivate boiler at a water temperature of 200°F or less.
- Replace or add pressure relief valve if necessary.
- Bleed air from radiators and piping through vents in elbows or radiators. Most systems have an automatic fill valve. If there is a manual fill valve for refilling system with water, it should be open to push water in and air out.

Hot water baseboard distribution usually operates with a maximum water temperature from 180 to 200^{O}F

- Verify that the water pumps, low water cutoff, automatic feed control, and high-pressure controls are in operating condition and repair if necessary.
- Insulate hot water supply lines passing through unconditioned areas (see chapter 222, "Heating System Retrofits").
- Check and clean thermostat.
- Vacuum and clean baseboard unit fins, if appropriate.
- If necessary, adjust the aquastat high limit and pump control in with the manufacturer's suggested set-point.
- Ensure that thermostatically controlled zone valves are functioning properly. Repair or replace defective valves.
- If present, adjust aquastat high limit and pump control in accordance with manufacturer's recommendations. The maximum high limit setting is 200^{o}F.
- Check the compression tank for sufficient air pressure. Replace defective tanks.

For steam systems, observe the following.
- Check vents and traps. Clean or replace steam vents and steam traps as necessary.
- Verify that water pump, low water cutoff, automatic feed control and high pressure controls are in operating condition and repair as necessary.
- Replace/clean sight glass if water level cannot be seen due to dirt build-up on glass.

2218 Controls
Move improperly located thermostats to an area free from drafts or heat from the heating system, lights or appliances.

Replace defective thermostats.

Consider replacing existing single stage thermostats with automatic setback thermostats (see chapter 222, “Heating System Retrofits”).

2219 Certification

Once heating appliance has been serviced, the installer must place a sticker on the appliance certifying that the system has been properly serviced. Sticker shall indicate the date of service, name of service contractor and phone number of service contractor.

222 Heating System Retrofits

Best Practice Recommendations:

- The following heating system retrofits are recommended for the Midwest Region;
  - Automatic setback thermostat,
  - Intermittent ignition device and vent damper,
  - Boiler pipe insulation, and
  - Flame retention head burner.
- Heating system retrofits should be considered based on cost effectiveness, condition and life expectancy of heating system and client being served.

2221 Automatic Setback Thermostat

Assessors may recommend setback thermostats if it is determined that the client is capable and willing to use a setback thermostat. In homes with multiple heating zones setback thermostats should be installed in all zones in which the client will utilize a setback.

An electromechanical or electronic setback thermostat should be installed. The thermostat should have two setback periods, allowing residents to set the temperature lower (or higher for air conditioning) twice each day – once for sleep and once for vacancy, such as work and school. If the home is centrally air conditioned, a heating/cooling thermostat must be used. Installation of setback thermostat must be done in compliance with local codes by an HVAC contractor. Manual setback or large-lettered thermostats may be installed for seniors or people with visual impairments, as appropriate.

New setback thermostats should generally be installed in the same location as the old thermostats. In cases where the old thermostat is located in the kitchen, in direct sunlight, over a heat register or radiator, or other location which would impede performance, the new setback thermostat should be relocated.

All thermostats must be installed according to manufacturers' instructions. Thermostats are to be level and dirt free. Installation shall include an appropriate wall plate.

Clients shall be instructed on the setting and operation of new clock thermostats and the replacement of batteries for thermostats utilizing batteries

2222 Intermittent Ignition Device and Vent Damper

Older gas fired heating appliances have standing (constant) pilot flames for ignition. The pilot light provides for ignition when gas is supplied to the main burner. A standing pilot is also required to hold open the safety gas valve via the thermocouple that proves the presence of the pilot light. Though required for the above reasons, a standing pilot wastes energy during the non-heating season.

An intermittent ignition device (IID) eliminates the need for a standing pilot while maintaining the safety provided by a pilot/thermocouple. With an IID, the pilot flame is ignited by a spark, so the pilot only burns when needed. Gas flows to the main burner once pilot ignition is proven (a pilot burner is still used for ignition). Both the pilot and main burner are extinguished when the thermostat is satisfied.

A vent damper is a device installed within the vent system of the heating appliance that automatically closes the vent system when the appliance is off. The damper automatically opens during combustion. The damper prevents warm air from escaping through the chimney when the heating unit is not operating. The vent damper is only effective when the heating is off and the heating appliance is located in the conditioned space of the home. **Only electronic vent dampers may be installed – thermal vent dampers are not permitted.**

Thermal-mechanical vent dampers are not allowed

Installing an intermittent ignition device (IID) and vent damper can increase the steady-state efficiency of an atmospheric furnace or boiler to around 80 percent. Cost effectiveness of installing vent dampers/IIDs on furnaces is marginal and should carefully be checked. IIDs will be less cost-effective on boilers that also provide domestic hot water.

The IID and vent damper must be installed according to manufacturer's specifications and be AGA/UL approved.

- IID must be purchased as a complete system, consisting of control module, dual combination gas valve, igniter-sensor, and wiring.
- A vent damper may not be installed without an IID.
- The vent damper must be equipped with an interlocking switch to prevent gas valve opening, in the event of vent damper failure.
- The technician must watch the furnace or boiler cycle several times to ensure correct operation of the new IID and vent damper.
- The damper should never bind closed or fail to open completely while the burner is fired. There should be no spillage of flue gasses at the diverter. Control module must lock out in case of damper failure.
- Main burner must ignite without delay and without flame roll out.
- Vent dampers used on oil-fired systems must be approved for use on oil systems.

IIDs are not to be installed in damp areas. Assessors should verify that mold, mildew, excessive corrosion, rot or other evidence of moisture problems do not exist prior to scheduling IID installation.

2223 Pipe Insulation

All hot water and steam heating pipes and domestic water supply pipes which pass through unconditioned areas shall be insulated. A minimum R3.5 pipe insulation should be used.

All materials used in conjunction with pipe insulation must be capable of continuous operation at 180^{o}F and have a smoke density rating of 50 or less.

Install all insulation materials in accordance with requirements of the governing code and the manufacturer's recommendations. Additional support straps shall be provided for pipes, as necessary.

Fasteners shall not compress insulation more than 50 percent of its normal thickness. All "Ts," elbows, and bends shall be completely insulated. Pipe insulation shall be taped (using a high quality tape with good adhesion), caulked (with appropriate caulk to secure and adhere to insulation), or glued at all joints. Where freezing pipes are determined to be a potential problem, electric, freeze-prevention tape can be installed prior to insulating. Any freeze-prevention tape used must be UL labeled.

Notes: Allow 3 feet clearance between the furnace/boiler and insulation. Insulation shall be maintained a minimum 6 inches from exhaust vents (18 inches for single wall vents to oil, wood, and coal furnaces). Do not insulate over control and safety devices, pumps, valves, boiler feed lines, pressure relief devices, dampers, or vents.

2224 Flame Retention Head Burner

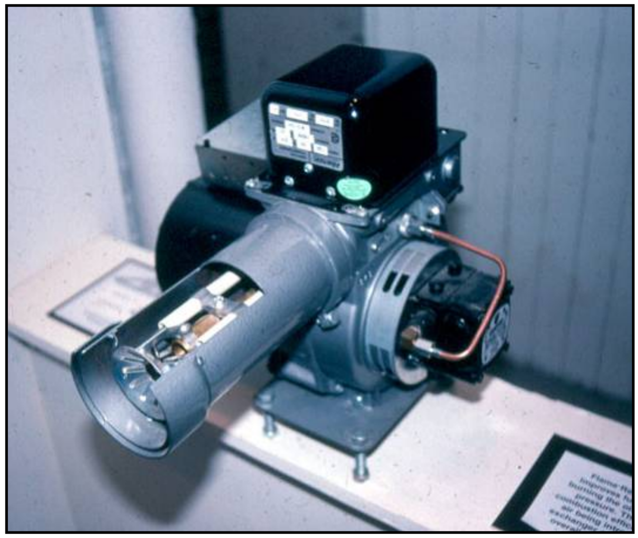
If an oil-fired furnace or boiler has a sound heat exchanger but the burner is inefficient or unserviceable, the burner may be replaced by a newer flame retention head burner. The new burner must be tested for efficient and safe operation.

A flame retention head burner is an oil burner that provides higher combustion efficiency by swirling the mist of oil and air to produce better mixing. Flame retention head burners waste less heat and have combustion efficiencies of 80 percent or slightly more. Replacing an existing gun-type burner with a flame retention model may be cost effective if the existing steady state efficiency (SSE) is less than 75 percent.

Many existing burners may be retention head burners as they have been available for about 35 years. If the existing burner has an RPM of 1725, it is a gun-type burner and should be replaced with a retention head burner. Steady state efficiency will increase by about 10 percent. If the existing burner has an RPM rating of 3450, it is already a retention head burner and replacement may not be cost-effective.

Installation of flame retention burners must be done by a licensed mechanical contractor and a mechanical permit shall be obtained from the responsible code enforcement authority, if necessary. Existing gun-type burners shall be replaced with a flame retention burner in accordance with governing code requirements and manufacturer's recommendations. In addition, the following shall be completed as needed:

- Size the burner and nozzle to match the building's heat load, making adjustments for new insulation and air sealing done during weatherization.
- Install new combustion chamber, choosing one that fits the size and shape of the burner flame. Or, change nozzles on the new burner to produce a flame that matches an existing combustion chamber that is still in good condition. Either way, the flame must fill the combustion chamber without impinging on it.
- Complete clean out and sealing of boiler sections, fire doors, flue pipe joints, and anywhere excess air can infiltrate the combustion area or flue passages.



Retention head burner with air blast tube cut away, exposing nozzle and electrodes

- Install new primary control.
- Over-fire draft shall be set according to manufacturer's specifications, usually at 0.01 or 0.02 inches of water column.
- Replace barometric damper and flue pipe as necessary.
- Replace any controls or wiring required for safe, reliable operation.
- Replace furnace filter.

Upon installation, heating appliances receiving a flame retention burner must meet the following requirements:

- An oxygen (O_2) reading of 4 to 7 percent (carbon dioxide of 12.5 - 10.3 percent).
- A maximum smoke of 2.
- Stack temperature between 300^{o}F and 600^{o}F.

223 Heating System Replacement

Best Practice Recommendations:

- Every effort to repair and retrofit heating appliances should be made prior to replacement. Heating appliances that are non-operational or non-repairable should be replaced.
- Replacement heating systems must be sized according to accepted calculations such as the *Residential Load Calculation* (Manual J) or approved computerized load calculation software. Sizing should account for lower heating loads resulting from insulation and air sealing work. Sizing calculations must be included as a permanent part of the client file.
- Replacement heating appliances should meet the guidelines and efficiency ratings as shown in the table below or be ENERGY STAR® rated unless shown not to be cost-effective or if existing conditions are not appropriate for their installation.

Natural Gas/LP Furnaces	90%, direct vent sealed combustion
Oil Furnaces	83%
Gas and Oil Boilers	85%

- Weatherization work shall not be done in any home with an unvented space heater where client does not permit its removal.

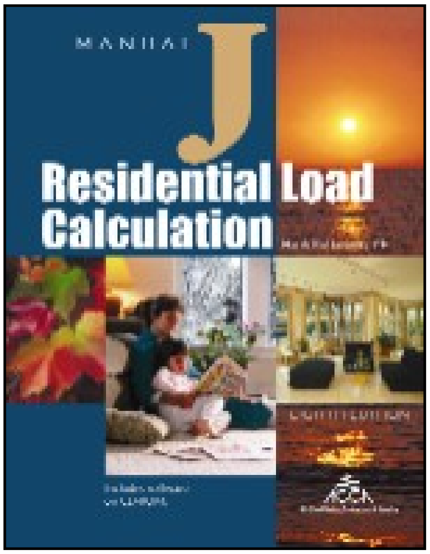
Heating appliances that are non-operational or non-repairable should be replaced. Before deciding to replace a heating system, every effort to repair and retrofit it should be made. Repair is defined as any work needed to bring a heating appliance up to manufacturer's specifications for proper operation. Repair items include replacing blower motors and pumps, fixing vent connectors and chimneys.

New heating appliances must be installed to manufacturers' specifications, following all applicable building and fire codes.

System sizing calculations must meet accepted standards such as *Residential Load Calculation* (Manual J), 7th or 8th edition, by the Air Conditioning Contractors of America or approved computerized load calculation software. Sizing should account for lower heating loads resulting from insulation and air sealing work. Sizing calculations must be included as a permanent part of the client file.

All new heating appliances shall carry a minimum one year warranty on workmanship. New condensing units must have a lifetime manufacturer warranty on the primary heat exchanger, and a 10-year warranty on the secondary heat exchanger.

Each client shall receive all manufacturer's product warranty information, clear maintenance instructions, educational information and a local telephone number for warranty problems.



Manual J, 8th edition is more difficult to use than the 7th edition, which is still in print from ACCA

If a home has central air conditioning and is a candidate for primary heating system replacement, the cost for the primary heating system replacement work must include reinstallation of the existing central air conditioning unit with the new primary heating system. Central air conditioning is not a candidate for repair or replacement.

New heating appliances that are to be installed on a concrete, dirt, or damp floor, should be raised a minimum of 1 inch above the floor surface, or per local code. Properly remove and dispose of existing unit. Seal openings in chimneys where atmospheric vented appliances are eliminated.

Replacement heating appliances should meet the guidelines and efficiency ratings as shown in Table 223-1.

- Natural Gas and LP Forced Air

Replacement gas furnaces should have a minimum AFUE of 90 percent and be direct-vent sealed combustion if shown to be cost-effective. Gas-fired atmospheric vented furnaces with efficiencies less than 75 percent steady-state <u>and</u> having less than a 5 year life expectancy are candidates for replacement. Propane-fired furnaces with efficiencies less than 80 percent steady-state <u>and</u> having less than a 5 year life expectancy are also candidates for replacement. Furnaces may also be replaced if they are old gravity units.

Non-condensing furnaces with a minimum AFUE of 80 percent can be installed if it is shown that the 90 percent replacement furnaces are not cost-effective. Furnaces with an 80 percent AFUE may also be installed where condensing units cannot be installed, such as attic installations where there is no place to drain condensate.

- Oil Forced Air

Replacement oil furnaces must have a minimum AFUE rating of 83 percent. Oil-fired furnaces with less than a 5-year life expectancy <u>and</u> less than 75 percent steady-state efficiency are candidates for replacement.

- Boilers

Boilers with a seasonal efficiency less than 80 percent and have less than a 5 year life expectancy are candidates for replacement. Replacement boilers must have a minimum AFUE of 85 percent. Boilers may also be replaced if they are a gravity unit.

- Wood Burning Units

Replacement wood heating system installation must conform to NFPA 211 and EPA requirements or local standards, whichever is most strict.

- Space Heaters used as the Primary Heat Source

Replace unvented space heaters with direct-vent sealed combustion space heaters. Replace vented space heaters greater than 10 years old with direct vent sealed combustion units. Vented space heaters less than 10 years old shall be inspected for health and safety problems. **Ventless space heaters shall not be installed under any circumstances.** If a client refuses to have an unvented space heater replaced, the house should not be weatherized.

Efficiency (AFUE) of Replacement Heating Appliances

Table 223-1

Natural Gas/LP Furnaces	90%, Direct vent sealed combustion
Oil Furnaces	83%
Gas and Oil Boilers	85%

2231 Fuel Switching

Switching from the existing fuel source to a different fuel source for use by the heating appliance is prohibited without written approval by the State Weatherization Office. Requests for fuel switching must describe the technical reasons for the decisions and include cost justification and written authorization from the party responsible for purchasing the fuel.

2232 Gas-Fired Heating Installation

- Check clearances of heating unit and its vent connector to nearby combustibles, according to NFPA 54, tables 6.2.3 (a) and 6.2.3 (b).
- All gas piping must be installed according to the American Gas Association (AGA) specification and any other appropriate codes.
- Test water heater to ensure that it vents properly after installation of direct vent sealed combustion appliance.
- Ensure proper sediment trap on gas line.
- Measure gas pressure to ensure that it is within manufacturer's specifications. Adjust gas pressure if necessary to obtain proper gas input. Verify Btu input by clocking gas meter.
- Set thermostat's heat anticipator to the amperage measured in the control circuit.
- Repair or replace sections of the venting system that are corroded, rusted, clogged or blocked, contain cracks or holes or are unsealed, loose or disconnected.
- Follow manufacturer's venting instructions and NFPA 54 Chapters 7 and 10 to establish a proper venting system.
- Repair or replace unsafe power supply to appliance.
- Install a properly sized and fused dedicated circuit to the heating appliance if one is necessary.

2233 Oil-Fired Heating Installation

- Examine existing chimney and vent connector for suitability as venting system for new appliance. The vent connector may need to be re-sized and the chimney may need to be re-lined. Venting should be in compliance with NFPA 31, chapters 1 through 11.
- Check clearances of heating unit and its vent connector to nearby combustibles, by referring to NFPA 31, tables 4-4.1.1, 4-4.1.2 and 5-5.1.
- Test oil pressure to verify compliance with manufacturer's specifications.
- Test transformer voltage to verify compliance with manufacturer's specifications.
- Adjust air, flue-gas temperature, and smoke number to within manufacturer's specifications.
- Inspect oil tank and remove deposits at bottom of tank as part of new heating system installation.
- Install new fuel filter and purge fuel lines as part of new installation.
- Bring tank and oil lines into compliance with NFPA 31, Chapters 2 and 3, and appropriate state regulations.
- Repair or replace an unsafe power supply to appliance.
- Install a properly sized and fused dedicated circuit to the heating appliance if one is necessary.

2234 Furnace Installation

Installers should give purchasing preference to furnaces with electronically commutated blower motors (ECM) or switched reluctance blower motors because these improved motors are significantly more efficient than standard split-capacitor blower motors.

Category I fan-assisted furnace

Observe the following standards in furnace installation.

- All furnace work must be in compliance with:
  The Uniform Mechanical Code
  National Fire Prevention Association (NFPA)
  Local Codes (where existing)
  Furnace Manufacturer's Specifications
- Furnace should be sized to the home's heating load, accounting for weatherization heat loss reductions.
- Installer must be prepared to add return ducts or supply ducts as part of furnace replacement to improve air distribution and to establish acceptable values for static pressure and heat rise.
- Supply and return plenums must be mechanically fastened with screws and sealed to air handler to form an essentially airtight connection.

- Heat rise (supply temperature minus return temperature) must be within manufacturer's specifications.
- High limit must stop fuel flow at less than 200°F. Furnace must not cycle on high limit.
- Fan control should be set to activate fan at 115°F and deactivate it at 90°F if possible. Slightly higher settings are acceptable if these recommended settings cause a comfort complaint.
- Static pressure, measured in both supply and return plenums, must be within manufacturer's specifications. Static pressure outside of manufacturer's specifications may not be corrected with the installation of a grille on the return air plenum.
- Blower must not be set to operate continuously.
- Filters must be held firmly in place and provide complete coverage of blower intake or return register. Filters must be easy to replace.
- Existing air conditioning coils must be re-installed with an airtight, removable panel, providing convenient access for cleaning.
- Furnaces which do not have a readily accessible filter access/location should have a filter rack with a cover, installed in the return air plenum, in an accessible location.
- Install a condensate pump where needed to reach an appropriate drain, if necessary.
- No used furnaces may be installed.
- Contractors must remove and dispose of equipment being replaced unless otherwise directed by the agency.

2235 Boiler Installation

- All boiler work must be in compliance with:
  The Uniform Mechanical Code
  National Fire Prevention Association (NFPA)
  Local Codes (where existing)
  Boiler Manufacturer's Specifications
- Boiler should be sized to the home's heating load, accounting for weatherization heat loss reductions.
- Maintaining a low-limit boiler temperature is not permitted unless the boiler is used for domestic water heating.
- An effective air-excluding device or devices must be part of a new hot water distribution system.
- The pressure tank must be replaced or tested for correct pressure during boiler installation.
- A pressure relief valve must be installed with the new boiler.
- Extend new piping and radiators to conditioned areas like additions and finished basements, currently heated by space heaters.

2236 Space Heater Installation

Replace combustion space heaters with direct-vent sealed combustion space heaters. Install exactly as specified by manufacturer. Installation of ventless space heaters is not permitted.

2237 Wood Heating Unit Replacement

Agencies are responsible for ensuring that:

- All installations meet manufacturer's specifications.
- All wood heating units are certified to meet the EPA phase II emission standards or local standards, whichever are most strict.
- Installed units are certified and labeled by:
  - a. National Fire Protection Association under 211; or
  - b. International Conference of Building Officials; or
  - c. Other equivalent listing organization.
- All clients receive in-home operation instructions to include proper wood-burning practices, safety information and proper maintenance, e.g., stack thermometers, the need for fire extinguishers, etc.

Replace old and hazardous space heaters with direct-vent, sealed combustion units

224 Water Heater

Best Practice Recommendations:

- Water heaters should be cleaned and tuned to ensure that they are operating in a safe and efficient manner.
- The following water heater measures are recommended for the Midwest Region;
  - Water heater temperature setting,
  - Tank insulation,
  - Pipe insulation, and
  - Replacement
- Mechanically vented, direct vent and tankless water heaters should be considered as replacement units based on cost-effective and appropriateness of existing conditions.

Standards for gas, propane, oil-fired and electric water heaters are provided here. Standards include water heater clean and tune, retrofit and replacement.

2241 Clean & Tune

Gas, propane, and oil-fired water heaters must be tested and repaired as described in the following sections:

- 2211 - Gas Burner Servicing Requirements,
- 2212 - Oil Burner Servicing Requirements,
- 2213 - Improving Appliance Draft, and
- 2214 - Heating Appliance Venting.

The following items shall be checked and corrected, if necessary.

- Visually inspect combustion chamber for rust, dirt and proper burner alignment. Clean and adjust if necessary.
- All water heaters must have a pressure and temperature relief valve and a safety discharge pipe. Install a relief valve and discharge pipe if none exists. The pipe must terminate 6 inches above the floor and be made of rigid metallic material or high temperature plastic.
- If pressure and temperature relief valve and discharge pipe are not present and cannot be installed, replace water heater.
- Ensure proper sediment trap on gas line.
- Flexible gas connections are not to be used on water heaters.
- Relocate water heater if required clearances to combustible materials do not meet NFPA code or manufacturer's requirements.
- Test water heater after a clean and tune to ensure that flame roll-out does not occur.
- If hazardous items are stored adjacent to water heater, inform client of fire hazard and move items.

- Determine whether the electric line on an electric water heater is a dedicated circuit that is properly sized and fused according to electrical codes.
- Make sure power to water heater is off before removing access panels on an electric water heater.

2242 Water Heater Measures

22421 Water Heater Temperature Setting

Adjust water heater temperature to 120^{o}F with client's approval unless client has an older dishwasher without an internal water heater. In this case, the setting should be 140^{o}F.

If an electric water heater has two heating elements, the thermostat on both heating elements must be adjusted when turning down water temperature. Set both elements to the same setting. Mark original water heater setting on thermostatic control.

22421 Tank Insulation

Water heaters manufactured after 1990 may not require additional insulation. Do not insulate water heater if the unit has a manufacturer's warning against adding additional insulation. Water heaters located in a living area should not be insulated as this measure is not cost effective.

Oil-fired water heaters are not common

Before insulating any water heater, be sure that the water heater is operating in a safe condition. Water heater must not be leaking.

Water heaters shall be insulated to at least R10. Insulation must be mineral fiber manufactured as a water heater blanket with vinyl or foil facing. The insulation must conform to ASTM C592-80 and ASTM 892-79 with a flame spread rating no higher than 25.

Water heater insulation shall not obstruct pressure relief valves, thermostat, high-limit switch, plumbing pipes or access plates.

Insulation shall be secured to the water heater utilizing:

- A minimum of three vinyl straps or belts commercially available for water heater jackets,
- A minimum of three metal banding straps or wires, or
- A minimum of three strips of vinyl tape commercially available for water heater jackets. Each strip shall form two complete wraps around the water heater jacket.

Fasteners should not compress insulation more than 50 percent of its normal thickness.

Insulation shall be cut and removed around all controls, service panels (including electrical access panels), air inlets, temperature/pressure relief valves, drain valves specifications and instruction panels.

No insulation should come in contact with the floor.

Gas, propane and oil-fired water heater insulation

- Insulation shall be kept at least 2 inches away from access door and burner.
- Water heaters with a thermal or electromechanical vent damper shall not be insulated.
- Insulation and tape shall be kept at least 3 inches from controls and/or air intakes.
- Keep tape or insulation blanket at least 6 inches from the exhaust hood.
- Top surface of gas-fired water heaters shall not be insulated.

Electric water heater insulation

- Set both upper and lower thermostat to keep water at 125°F before insulating water heater.
- Insulation may cover the top of the water heater if the insulation will not obstruct pressure relief valve.
- Access holes must be left in the insulation for the heating-element thermostats.
- Insulation shall not cover drain valve.
- Insulation shall be kept away from power supply to water heater by at least 2 inches.

22423 Pipe Insulation

- Repair plumbing leaks prior to insulating pipes.
- Insulate first 6 feet of both hot and cold water pipes.
- Cover elbows, unions and other fittings to same thickness as pipe.
- Keep pipe insulation at least 6 inches away from flue pipe.
- Interior diameter of pipe sleeve must match exterior diameter of pipe.
- Tape or otherwise seal longitudinal seams. Seal ends and butt joints.
- All material must have a flame spread rating of 150 or less and a smoke density of 50 or less.
- Insulation shall have a minimum R-value of 3.5.

2243 Water Heater Replacement

Replacement gas or oil water heaters must have an energy factor of at least 0.62. Replacement electric water heaters must have an energy factor of at least 0.92.

Water heaters may be replaced under the following conditions.

- Water heater is non-operational.

- The shell of the storage tank leaks and cannot be repaired.
- The water heater leaks at one or more of its pipe fittings, valves or heating elements (if electric), and a permanent watertight seal cannot be made.
- Excessive sediment is built up and cannot be flushed out.
- The tank is near the end of its estimated life (13 years) and is excessively oversized for the needs of the occupants. (In this case, reducing the size or installing a tankless water heater should be considered.)
- Water heater replacement is cost effective.

All water heater work must be in compliance with: the Uniform Mechanical Code, the National Fire Prevention Association (NFPA), local codes (where they exist), and the water heater manufacturer's specification.

Old and leaking water heaters should be replaced

No used water heaters may be installed.

All replacement water heaters must have a pressure relief valve and a discharge pipe extending within 6 inches of the floor.

The water heater temperature should be set at 120^{o}F. Educate the client how to use the water heater controls.

Natural draft water heaters may be used as replacement. However, consideration should be given to mechanically vented, sealed combustion (direct-vent) and tankless water heaters[21].

22431 Mechanically Vented and Direct-Vent Water Heaters

Mechanically vented or sealed combustion water heaters may be installed depending upon budget and conditions in the home. Replacement gas or oil water heaters must be either mechanically vented or direct-vented in tight homes or homes where these appliances are located in living areas. Direct-vent water heaters are preferred in tight homes where the water heater is installed in the living space.

22432 Tankless Water Heaters

Standard storage type water heaters keep water hot 24 hours a day, even though hot water is usually not used continuously over that period. Stored hot water loses heat through the sides of the tank and up the flue pipe (gas and oil water heaters). As the water temperature drops, the heater is activated to reheat the water again.

[21] In this document, a tankless water heater is defined as an automatic instantaneous water heater. It is not a tankless coil operating in conjunction with a space heating boiler. See section 22432, "Tankless Water Heaters".

As a result, the overall efficiency suffers. Tankless water heaters do not store hot water as water is heated only when needed, thus, their efficiency is higher.

Water flow through a tankless unit acts to ignite the burners or heating elements. Cold water enters a tankless water heater and triggers the burners (gas) or heating elements (electric) to turn on when a hot water tap is opened. Water is heated as it flows through the heat exchanger.

A water valve or thermostat controls the heating elements or burner flame to maintain a constant temperature if the water flow changes. The amount of energy used to heat the water is proportional to the volume of hot water being used. The water temperature can be adjusted to produce outlet temperatures ranging from 100° to 140°F. The burners or heating elements shut down when the hot water tap is turned off.

224321 Items to Consider when Installing a Tankless Water Heater

- Tankless water heaters cost more than standard storage tank water heaters. Cost effectiveness should carefully be considered.
- Tankless water heaters have larger BTU inputs than standard storage type water heaters. Tankless units input ratings range from 40,000 Btuh to 170,000 Btuh.
- Gas models either have a standing pilot light or an intermittent ignition device. Standing pilot light reduces efficiency of tankless water heaters.
- Gas models are either natural draft or mechanically vented.
- Flue size varies between 4 inches and 7 inches, depending upon gas input rate.
- Minimum flow rate to activate tankless water heater ranges from 0.50 gallons per minute (gpm) to 0.75 gpm. This may be a problem in homes with poor water pressure.
- Larger systems can handle two “major” simultaneous events (2 showers or 1 shower and the dishwasher, for example).
- The volume of hot water delivered is directly related to the amount of its energy input. The larger the burners or heating elements in the unit, the higher the volume of hot water it can deliver.

224322 Tankless Water Heater Advantage**s**

Advantages of tankless water heaters include:

- Energy savings because there is no storage energy loss.
- Efficiency will not decrease over time.
- Ideal for single or two person households that don’t have simultaneous hot water uses (2 simultaneous showers, for example).
- A tankless water heater will generally outlast a non-maintained standard storage type water heater.
- Works well in locations with hard water.

- When water flow is kept within range, tankless heaters can provide unlimited hot water.

224323 Disadvantages of Tankless Water Heaters

Disadvantages of tankless water heaters include:

- Cost more than standard storage type water heaters ($300 to $1,000).
- Both gas line size and venting or power supply (if electric) will probably need to be increased.
- Standard storage type water heaters (with adequate distribution plumbing) can serve multiple taps simultaneously. Tankless heaters are limited. Smaller gas models and essentially all electric models are meant for one person households. All but the largest gas units have difficulty serving multiple taps.
- If minimum flow rate isn't met, the heater will not work. If maximum flow is exceeded, water at the tap will cool down. Temperatures can fluctuate with changing water demand.
- Parts for tankless water heaters may be more difficult to get. Maintenance is more difficult than standard storage type water heater.

224324 Selecting a Tankless Water Heater

Tankless water heaters should be selected based on the maximum amount of hot water to meet the peak demand of the household. Measure actual flow rates if possible. Use the following assumptions on water flow for various appliances to find the size of unit that is suitable for the client:

Aqua Star tankless gas-fired water heater

- Faucets: 0.75 gpm to 2.5 gpm.
- Low-flow shower heads: 1.2 gpm to 2 gpm.
- Older standard shower heads: 2.5 gpm to 3.5 gpm.
- Clothes washers and dishwashers: 1 gpm to 2 gpm.

Unless the actual incoming water temperature is known, assume that the incoming water temperature is 50°F. The water needs to be heated to 120°F for most uses, or 140°F for dishwashers without internal heaters. Subtract the incoming water temperature from the desired output temperature to determine the needed temperature rise. In this example, the needed rise is 70°F.

List the number of hot water devices that the client may have open at any one time and add their flow rates. This is the desired flow rate for the tankless water heater. Select a manufacturer that makes such a unit. Most tankless water heaters are rated for a variety of inlet water temperatures. Choose the model of water heater that is closest to the needs of the client.

For example, assume the following conditions: One hot water faucet open with a flow rate of 0.75 gpm and one person bathing using a shower head with a flow rate of 2.5 gpm. The combined flow rate is 3.25 gpm. If the inlet water temperature is 50°F, the needed flow rate through the tankless water heater would need to be no greater than 3.25 gpm. Faster flow rates or cooler inlet temperatures will reduce the water temperature at the most distant faucet. Using low-flow shower heads and water-conserving faucets are a good idea with tankless water heaters.

225 Masonry-Chimney Liners

Best Practice Recommendations:

- A flue may be left unlined if the appliance is not to be replaced and the flue and chimney appear to be in good condition.
- Rebuilding a chimney, lining or relining should be considered for unlined chimneys, when existing liners are in poor condition or if the cross-sectional area of the chimney is oversized for the appliance(s).
- It is recommended flues be properly lined for solid-fuel appliances that are used as a primary or frequent secondary space heating source.

2251 Introduction

A chimney liner is a clay, ceramic, or metal conduit installed inside of a chimney flue, intended to contain the combustion products, direct them to the outside atmosphere, and protect the chimney walls from heat and corrosion.

As higher efficiency heating systems are installed over the years, chimney liners become more important because the combustion gases from efficient appliances are cooler, making acidic condensation within the chimney flue more likely.

When inspecting a flue serving a gas- or oil-fired appliance, the flue may be left unlined if the appliance is not to be replaced and the flue and chimney appear to be in good condition. If an unlined chimney or an existing liner is in poor condition, the assessor should consider rebuilding the chimney and/or lining or relining.

If a client regularly uses a solid-fuel appliance, it is strongly recommended that the appliance vent into a properly lined flue. A liner helps protect surrounding materials in the case of a chimney fire.

Accept as noted below, unlined flues are not required to be lined as part of weatherization.

2252 Advantages of Lined Chimneys

Lined chimneys have a number of advantages over unlined chimneys. These advantages include:

- The liner helps create an airtight flue, which can result in a more favorable draft for the appliances connected to the flue.
- A lined chimney is a more durable chimney. The lining protects the masonry surrounding the liner from degradation caused by acidic condensation.
- Lined chimneys are safer during a chimney fire because the liner protects the house from heat transfer to combustibles.
- A chimney liner can serve to reduce the size of a flue that is too large for the appliance(s) it vents.

2253 Appliance Replacement

Whenever a combustion appliance is replaced the flue should be carefully inspected and lined, if necessary. If a gas-fired appliance replaces an oil- or solid-fuel appliance. . . "the chimney passageway shall be examined to ascertain that it is clear and free of obstructions and shall be cleaned. . ."[22] It is important that this inspection and cleaning be completed because the buildup of creosote or soot from solid fuel or oil can be softened by the high degree of water vapor and condensation from gas emissions, causing possible blockage of the flue.

The *National Fuel Gas Code* (NFPA 54) states all chimney flues shall be lined in accordance with the *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances* (NFPA 211).[23] However, the *National Fuel Gas Code* also includes this exception: "Existing chimneys shall be permitted to have their use continued [that is, without a liner] when an appliance is replaced by an appliance of similar type, input rating, and efficiency."[24]

Chimneys can be blocked by the strangest objects

This section of the National Fuel Gas Code indicates that:

- When a gas-fired appliance replaces an oil- or solid-fuel fired appliance in a flue, the flue must be lined.
- When a gas-fired appliance replaces another gas-fired appliance in a flue, the flue must be lined if the replacement appliance is not a similar type, input rating, and efficiency. This means that an unlined flue will just about always have to be lined when replacing a heating system. However, lining an unlined flue when replacing a natural draft water heater with another natural draft water heater will usually not be necessary.

2254 Types of Chimney Liners

Clay tiles are the most common type of masonry chimney liner and are most often used when constructing a new chimney. They are inexpensive, readily available, and, when properly maintained, perform quite well for all fuel types. However, clay tiles are difficult to insert properly into an existing unlined chimney.

There are two disadvantages to clay tiles. First, a sudden change in temperature from a chimney fire can cause the tiles to crack and break. In severe cases of tile failure, broken pieces can partially or totally block the flue. Second, a clay lined chimney cannot always adequately contain the condensation produced by more efficient modern gas appliances.

[22] *National Fuel Gas Code* (NPFA 54), 2002 edition,10.5.4.1, page 49.
[23] *National Fuel Gas Code* (NPFA 54), 2002 edition,10.5.4.2, page 49.
[24] *National Fuel Gas Code* (NPFA 54), 2002 edition,10.5.4.2, page 49.

Metal chimney liners, usually made of stainless steel or aluminum, are primarily used to upgrade and repair existing chimneys. These liner systems are U.L. tested and listed, and if properly installed and maintained, are extremely safe and durable. Stainless steel is suitable for solid-fuel, gas, or oil appliances. It is usually required that high temperature insulation be used in conjunction with the liners for safety and proper performance.

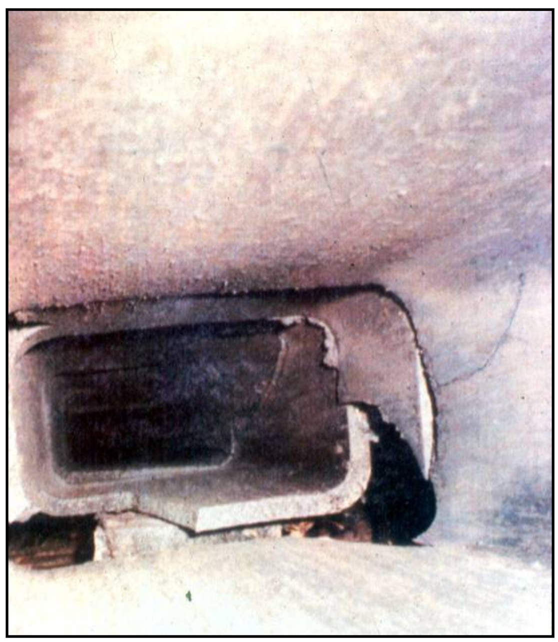
Cast-in-place liners are lightweight, cement-like materials that are installed inside the chimney, forming a smooth, seamless, insulated passageway for the flue gasses. They can improve the structural integrity of aging chimneys, and are permanent liners suitable for all fuels.

2255 Installation

For chimney liner regulations, refer to the *Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel Burning Appliances* (NFPA 211) by the National Fire Protection Association. For specific installation instructions, refer to NFPA 211 and the manufacturer's installation guidelines for approved chimney liners. To properly size the liner, the installer should also refer to the *National Fuel Gas Code*(NFPA 54) for gas-fired appliances and *Standard for the Installation of Oil-Burning Equipment* (NFPA 31) for oil-fired appliances.

"Where masonry chimneys are relined, the liner shall be listed or of approved material that resists corrosion, softening, or cracking from flue gases at temperatures appropriate to the class of chimney service."[25]

Cleanout doors are an important part of a masonry chimney system. NFPA 211 states: "Cleanout openings or a means for cleaning shall be provided in all chimney flues. Cleanout openings shall be equipped with ferrous metal, precast cement, or other approved noncombustible door and frames arranged to remain tightly closed and secured when not in use."[26] At the time a chimney is relined, make certain that the cleanout door complies with the details of this code.



Even tile liners can fail from excessive thermal stress

2256 Chimney Maintenance

All chimneys and flues should be inspected during combustion appliance cleaning and tuning. The interior of all flues used by combustion appliances should be inspected with a

[25] *Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel Burning Appliances* (NFPA 211), 2000 edition, 4;1.10, page 18.

[26] *Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel Burning Appliances* (NFPA 211), 2000 edition, 4;1.4.1, page 17. In the next paragraph of this code, 4-1.4.2, it states that the lowest edge of a cleanout door must be at least 16 inches from the lowest accessible floor level.

mirror and flashlight. In addition, the outer masonry of the chimney should be inspected where ever possible. In cold climates portions of a chimney exposed to the weather are likely to deteriorate first. These exposed sections should always be inspected.

If the use of a chimney flue is altered from one fuel to another, for example, from oil to gas, the flue must be properly lined (see 2253, "Appliance Replacement"). If the existing flue is properly lined and sized correctly, it should be professionally cleaned before switching fuels.

Any flue used for solid fuels, such as wood, should be cleaned periodically during the heating season. The frequency of cleaning will depend on the wood species, the moisture content of the wood, the type of wood stove, and the manner in which the stove is operated. Cleaning a solid-fuel flue at the beginning of the heating season and then again one-half of the way through the season is a good rule to follow. However, to ensure safe operation, some solid-fuel flues require cleaning more often than twice each heating season.

226 Heat Pumps and Air Conditioners

Best Practice Recommendations:

- All air-source heat pumps with electric auxiliary must be served by a control system – thermostat(s) – to minimize the operation of the electric heaters.
- Clients should be informed about routine maintenance and operation of heat pumps and air conditioners.
- When a heat pump requires more than simple maintenance, a professional service technician should be hired to check coil air flow, inspect for refrigerant leaks and charge, inspect and adjust controls, and perform other specialized testing and adjustment.
- Replacement heat pumps and air conditioners should be sized properly and ENERGY STAR® rated.

2261 Introduction

The savings realized by adding insulation and making homes tighter is usually only a benefit during the winter. However, if a client has a heat pump or a central or window air conditioning unit, energy will also be saved during the cooling months. Generally these summer energy savings are not included in the savings-to-investment calculations performed by energy audits. However, it is important to remember that weatherization not only cuts fuel use and makes a house more comfortable in the winter, it can also cut fuel use and make a house more comfortable in the summer.

2262 Heat Pumps

Heat pumps are generally a better option for the more temperate climates or the sunbelt states because they cool and heat with the same piece of equipment. However, heat pumps will occasionally be found in low-income homes in northern states.

The efficiency for new heat pumps is designated as Seasonal Energy Efficiency Rating (SEER) for cooling performance and Heating System Performance Factor (HSPF) for heating performance. New heat pumps have SEERs ranging from 10.0 to over 16.0 and HSPFs from 8.0 to over 10.0. For split heat pump systems with an indoor and outdoor coil, the system efficiency varies with the match of these coils. The manufacturer should be consulted to determine the combined efficiencies.

Heat pumps in cooling mode work in a manner very similar to central air conditioners. However, in heating mode, their operation is quite different from a typical furnace. For an air-source heat pump, useful thermal energy is extracted from the outdoor air by the vapor compression cycle which uses a refrigerant liquid/gas, an electrically-driven compressor, an indoor condensing coil, and an outdoor evaporator coil.

At an outdoor temperature above about 35^{O}F, the typical heat pump is designed and installed to supply all the heat a dwelling requires. When the temperature drops below 35^{O}F, heat pumps begin to utilize auxiliary heat; as the outdoor temperature drops, more auxiliary heat is staged in. This auxiliary heat is usually electric resistance coils staged in 5 kW increments.

Some dual-fuel heat pumps use fossil fuel furnaces or boilers for auxiliary heat rather than electric resistance coils. When these auxiliary systems are used, there is no incremental staging, instead the heat pump shuts down at a set outdoor temperature – usually about 35^{O}F – and the fossil fuel auxiliary system takes over. Most heat pump thermostats will indicate when the auxiliary heat is operating.

Unlike the auxiliary heat, the emergency heat control on a heat pump thermostat must be manually activated with a switch on the thermostat. The emergency switch setting allows the auxiliary heat to operate when the heat pump needs service or is not working properly.

22621 Assessment and Replacement of Equipment

The median service life of a residential air-source heat pump is fifteen years, meaning one-half of those studied lasted more than fifteen years and one-half lasted fewer than fifteen years. If a client has a heat pump that is significantly older than this median life, it is likely that it will fail soon or require significant repair.

Carrier residential air source heat pump

It is not appropriate for an assessor to test or tune a heat pump; this should always be left to specialists. However, there are routine maintenance tasks that can be performed by the client; it might be appropriate for the energy auditor to inform the client of these tasks. It is important that the assessor and the client be able to recognize when a heat pump problem is beyond routine maintenance and requires professional help. Routine maintenance and professional service tasks are explained below.

There are heat pump related items that the auditor/inspector should examine in the field. An important one is the integrity of the ductwork. Of course, ductwork that is outside of the conditioned envelope of the dwelling should be well sealed and insulated. Because ductwork used for heat pumps is used most months in a year, duct leakage and lack of insulation can lead to significant energy loss.

All air-source heat pumps with electric resistance auxiliary must be served by a control strategy to minimize the operation of the electric heaters. One of the following options may be used:

- A standard non-programmable or time-clock programmable indoor thermostat may be installed with an outdoor thermostat, or equivalent. The outdoor thermostat should be installed and set so that auxiliary heat does not activate above 35^{O}F, except when supplemental heat is needed during outdoor coil defrost cycle or for emergency heat in the event of refrigeration cycle failure.
- A microprocessor controlled (smart, or adaptive intelligent recovery, or ramping) indoor thermostat may be installed with an enabled heat pump recovery function. The installer should inform the occupants on proper operation of the thermostat. If this strategy is used in conjunction with an outdoor thermostat (this is optional), the first stage of the auxiliary heat should be allowed to operate independently of the outdoor thermostat.

22622 Sizing Heat Pumps

The cooling capacity of the cooling mode of heat pumps is rated by the number of British thermal units (Btu) of heat removed per hour. Within the industry, it is quite common for the cooling mode of a heat pump to be sized by the "ton". One ton is approximately equal to 12,000 Btus.

Unlike central air conditioners, heat pumps also heat homes during the winter, so a heat pump must be properly sized for cooling and heating. It is common to size a heat pump primarily for the cooling load and then evaluate the heating performance after the heat pump package is selected.

The required size of a heat pump depends upon many characteristics of the house and occupants, including:

- The size of the dwelling and the number of windows.
- The amount of insulation.
- The tightness of the home. It is important to remember that the air change per hour (ACH) value used in most weatherization work in the Midwest Region is a winter calculation. The ACH during the cooling season – that which is used in cooling load calculations – is usually significantly less. Properly sizing a heat pump requires the use of the winter and the summer ACH values.
- The amount of shading on windows, walls and roof.
- The number of occupants and the degree of internal heat gain they generate.

It is very important to size a heat pump properly – there are significant disadvantages to under or over sizing. The most common sizing method is *Residential Load Calculation, Manual J*, by the Air Conditioning Contractors of America. If weatherization staff is assisting in any way with the installation of a new or replacement heat pump, they should make certain that the subcontractor submits a load calculation report as part of the bid. This calculation should always be based upon the *Manual J* methods. For northern states, heat pumps should be selected so that total capacity does not exceed state and local code requirements and is no greater than 125 percent of the total calculated cooling load.

Another important resource for heat pump selection is *Residential Equipment Selection, Manual S*, by the Air Conditioning Contractors of America. This manual explains the unique sizing and selection procedures for air-source heat pumps.

22623 Routine Maintenance and Operation of Heat Pumps

Heat pumps and central air conditioners generally require the same regular maintenance. Please refer to Section 22633, “Routine Maintenance of Central Air Conditioners”, for a list of maintenance items, many of which can be performed by the client.

One item that is a unique maintenance task for an air-source heat pump is the occasional observation and care of the outdoor coil in the winter. Unlike the outdoor coil of a central air conditioner, the outdoor coil of a heat pump must operate during cold weather to capture heat from the outdoor air. If appropriate, inform the client of the following:

- Water must drain away from this outdoor coil to prevent damage from ice buildup. Snow should be cleared away to promote the necessary drainage.
- The outdoor coil will occasionally make hissing or gurgling noises and a cloud of steam might rise from the unit. This is all normal and should not concern the client.
- Frost and small amounts of ice usually accumulate on the outdoor coil, especially during damp days with air temperatures just above freezing. If the coil is completely covered with frost, the client should not worry. However, if a significant amount of hard, clear ice builds up on the coil, a service person should be called to check the operation of the defrost cycle.

Additionally, during heating mode, the thermostat should not be set back at night or during the workday unless a “smart” programmable heat pump thermostat is used. Setting the temperature back during heating season with the wrong thermostat can actually increase the heating cost because the auxiliary heat will be activated more often. On the other hand, if a smart Adaptive Intelligent Recovery (or ramping) thermostat is used, one or more temperature setbacks each day will save energy. The microprocessor in a ramping thermostat senses the temperature differential to be overcome during temperature pickup and increases the temperature gradually without activating the auxiliary heat. This minimizes the use of the electric resistance heat.

22624 Professional Maintenance of Heat Pumps

When a client's heat pump needs more than simple maintenance, a professional service technician should be recommended or subcontracted. Ensure that a subcontracted technician completes the following:[27]

- Measure air flow across the indoor coil. Airflow across this coil should be 400 CFM per ton for a wet coil (condensation on coil) and 425 CFM per ton for a dry coil (no condensation on coil), plus or minus 50 CFM.
- Check for correct amount of refrigerant. Follow the manufacturer's specification for refrigerant charge. The airflow across the indoor coil should be adjusted and verified before the refrigerant charge is checked. Any refrigerant that must be evacuated must be captured rather than illegally releasing it to the atmosphere. For systems with fixed metering devices (capillary tube of fixed orifice), the evaporator superheat method should be used along with the manufacturer's recommendations. For systems with thermostatic expansion valves (TXV), the subcooling method should be used along with the manufacturer's recommendations.
- Test for refrigerant leaks using a leak detector.
- Check for and seal duct leakage in central systems. Duct sealing and insulation is especially important for ductwork running through unconditioned spaces.
- Inspect electric terminals, clean and tighten connections, and apply a non-conductive coating if necessary.
- Oil motors and check belts for tightness and wear.
- Check the accuracy of the thermostat.
- Check for proper functioning of the outdoor lockout thermostat. The outdoor lockout thermostat must lock out the auxiliary heat (usually electric resistance) when the outdoor temperature is greater than the heat pump balance point (usually 25^0F to 40^OF, depending on the climate).
- Test for proper operation of the heat pump defrost control. This control for the outdoor coil must be adjusted to optimize heating efficiency.

2263 Central Air Conditioners

22631 Assessment and Replacement of Central Air Conditioners

Today's best air conditioners use 30 to 50 percent less energy than air conditioners made in the 1970s. Even if a client's central air conditioner is only 10 years old, they may save 20 to 40 percent of cooling costs by replacing it with a newer, more efficient model. The median service life of a central air conditioning unit is 15 years, so if a client's unit is 25 years old, the chances of it requiring replacement soon are quite high.

Replacement central air conditioner should be ENERGY STAR® rated. ENERGY STAR® qualified central air conditioners have a higher seasonal efficiency rating (SEER) than standard models, which makes them about 25% more efficient.

[27] See *Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems*, Karg and Krigger, Consortium for Energy Efficiency, 2000. This document is available at http://www.cee1.org/resid/rs-ac/hvac.php3.

22632 Sizing Central Air Conditioners

Air conditioners are rated by the number of British thermal units (Btu) of heat they remove per hour. Within the industry, it is quite common for air conditioners to be sized by the "ton". One ton is approximately equal to 12,000 Btus.

The required size of a central air conditioning unit depends upon many characteristics of the house and occupants, including:

- The size of the dwelling and the number of windows.
- The amount of insulation.
- The tightness of the home. It is important to remember that the ACH value used in most weatherization work in the Midwest Region is a winter calculation. The ACH during the cooling season – that which is used in cooling load calculations – is usually significantly less.
- The amount of shading on windows, walls, and roof.
- The number of occupants and the degree of internal heat gain they generate.

It is very important to size an air conditioner properly – there are significant disadvantages to under or over sizing. The most common sizing method is *Residential Load Calculation, Manual J*, by the Air Conditioning Contractors of America. If weatherization staff is assisting in any way with the installation of a new or replacement central air conditioner, they should make certain that the subcontractor submits a load calculation report as part of the bid. This calculation should always be based upon the *Manual J* methods. Cooling capacity should be no more than 115 percent of the calculated cooling load.[28]

22633 Routine Maintenance of Central Air Conditioners

An air conditioner's filters, coils, and fins require regular maintenance for the unit to function effectively and efficiently throughout its years of service. Neglecting necessary maintenance ensures a steady decline in air conditioning performance while energy use steadily increases. Many of the items listed here can be regularly done by clients.

<u>Air Conditioner Filters</u>

The most important maintenance task that will ensure the efficiency of a central air conditioner is to replace or clean its filters monthly. Clogged, dirty filters block normal air flow and can reduce a system's efficiency significantly. Filters are located in the return duct, usually in return grilles or in the air conditioner itself. Filters may need more frequent attention if the air conditioner is in constant use, is subjected to dusty conditions, or if there are fur-bearing pets in the dwelling. The client should not attempt to clean a filter that is designed to be thrown away.

[28] The air conditioner does not ALSO have to satisfy heating load. The heat pump is sized primarily for cooling load and secondarily for heating load, so excess capacity is needed on the heating side. Remember, the value here is for cooling; the 125% is for heat pump heating.

Air Conditioner Coils

An air conditioner's evaporator (indoor) and condenser (outdoor) coils collect dirt. This dirt reduces air flow, insulates the coils, and reduces efficiency. To prevent this reduction in efficiency, the coils should be checked each year and cleaned, if necessary. It is usually best if these coils are cleaned by a professional.

If appropriate, suggest to the client that dirt and debris near the condenser (outdoor) unit be minimized. Dryer vents, falling leaves, and lawn mowing are all potential sources of dirt and debris. Cleaning the area around the coil, removing any debris, and trimming foliage back at least 2 feet will allow for adequate air flow around the condenser.

Evaporator and Condenser Coil Fins

The delicate aluminum fins on evaporator and condenser coils are easily bent. These bent fins can block air flow through the coil and reduce efficiency. Air conditioning wholesalers sell a tool called a “fin comb” that will place these fins back into nearly original condition.

Evaporator coil for residential central air conditioning system

Sealing and Insulating Air Ducts

An enormous waste of energy occurs when cooled air escapes from supply ducts or when hot attic air leaks into return ducts. Field studies indicate that a much as 35 percent of the conditioned air in an average central air conditioning system escapes from the ducts.

For central air conditioners to be efficient, ducts must be airtight and insulated when they run through unconditioned areas. Refer to Sections 113 and 227 for instructions for duct leakage testing and repair.

Obstructions can impair the efficiency of a duct system almost as much as leaks. Make sure that clients have not obstructed the airflow from supply registers or to return grilles with furniture, drapes, or tight fitting closed interior doors. Of course, dirty filters and clogged evaporator coils can also be major obstructions to air flow.

22634 Professional Maintenance of Central Air Conditioners

When a client's air conditioner needs more than the regular maintenance, a professional service technician should be recommended or subcontracted. Ensure that a subcontracted technician completes the following:[29]

- Measure air flow across the evaporator coil. Airflow across the indoor coil should be 400 CFM per ton for a wet coil (condensation on coil) and 425 CFM per ton for a dry coil (no condensation on coil), plus or minus 50 CFM.
- Check for correct amount of refrigerant. Follow the manufacturer's specification for refrigerant charge. The airflow across the indoor coil should be adjusted and verified before the refrigerant charge is checked. Any refrigerant that must be evacuated must be captured rather than illegally releasing it to the atmosphere.
- Test for refrigerant leaks using a leak detector.
- Check for and seal duct leakage in central systems. Duct sealing and insulation is especially important for ductwork running through unconditioned spaces. Chances are high that the weatherization workers already completed this inspection and work.
- Verify the correct electric control sequence and make sure that the heating system and cooling system cannot operate simultaneously.
- Inspect electric terminals, clean and tighten connections, and apply a non-conductive coating if necessary.
- Oil motors and check belts for tightness and wear.
- Check the accuracy of the thermostat.

2264 Window Air Conditioners

22641 Assessment and Replacement of Window Air Conditioners

Window air conditioners usually range from 5,500 Btu per hour to 14,000 Btu per hour in cooling capacity. National appliance standards require room air conditioners built after January 1, 1990, to have an Energy Efficiency Rating (EER) of 8.0 or greater. Any window air conditioner purchased for use in the Midwest Weatherization Region should have an EER of at least 9.0.

Between 1972 and 1991, the average EER of a window air conditioner rose 47 percent. Clients with units manufactured before 1990 should consider replacing these older units. If a client owns a 1970s-vintage window air conditioner with an EER of 5, cooling costs can be cut in half if it is replaced with a new unit having an EER of 10.

The median service life of a window air conditioner is ten years, meaning one-half of those studied lasted more than ten years and one-half lasted fewer than ten years. If a client has a window unit that is significantly older than ten years, the chances of it failing soon are quite high.

[29] See *Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems*, Karg and Krigger, Consortium for Energy Efficiency, 2000. This document is available at http://www.cee1.org/resid/rs-ac/hvac.php3.

If a window air conditioning unit is replaced with weatherization funds, it is important to properly dispose of the old unit as part of the replacement process. The weatherization agency must ensure the old unit is not allowed to reenter the marketplace as a used unit. In addition, the refrigerant from the old unit must be reclaimed according to federal guidelines.

22642 Maintenance of Window Air Conditioners

Window air conditioners will last longer and remain more efficient if they are maintained properly. Inform clients with window air conditioners to do the following:

When not in use, window air conditioners should be removed and properly stored or covered with an air tight, protective fabric

- It is best to remove a window air conditioner from its wall sleeve or window during the heating season. This will usually reduce air leakage and increase the longevity of the unit. If a unit cannot be removed, it is best to install an airtight cover on the outside of the unit.
- Clean the air conditioner filter every month. This filter is usually located behind the front grill and can usually be washed with soap and water. After allowing the filter to dry, it should be put back in its position. If the filter looks worn or has holes in it, it should be replaced.
- Clean obvious obstructions such as newspaper and leaves from around the exterior of the unit.
- An air conditioner should not be short-cycled by turning it off and then back on right away. Wait at least ten minutes after shutting the unit off before turning it back on. This gives the pressure in the refrigeration system time to equalize and prolongs the life of the air conditioner.
- The condenser coil of the unit should be cleaned annually. Most agree it is best to clean this coil at the beginning of the cooling season. This coil is at the back (outside) of the air conditioner and requires proper airflow for maximum efficiency and longevity. Clean the coil by blowing compressed air across it, by using a soft bristle brush to remove the dirt, or by using a special chemical cleaning solution.
- Rather than store a window air conditioner in a garage during the winter, it is better to store it in a basement or utility room away from mice and other small animals. Rodents can cause damage to the unit by chewing on wiring and insulation. Wasps, hornets, and bees find air conditioners attractive places to nest. This can reduce airflow, cut into efficiency, and decrease the air conditioners cooling capacity.

227 Duct Improvements

Best Practice Recommendations:

- Ducts located in unconditioned areas must be sealed and insulated.
- Duct system airflow should be checked and corrected if necessary in response to client comfort complaints.

The distribution system of the house is a critical part of the building system. An efficient heating/cooling unit and a well insulated/air sealed building envelope is of little use if the conditioned air doesn't reach the main living spaces of the house. Duct leakage, poor filter and blower maintenance, a clogged evaporator coil, and inadequate supply and return ducting can all contribute to significant energy, comfort, safety and durability problems.

2271 Duct Sealing

Duct leakage is a major energy waster in homes where the ducts are located outside the home's thermal boundary, such as an attic or garage. The weatherization work must include duct sealing and duct insulation for any ductwork in unconditioned areas.

22711 Duct Leakage Sites to Seal

The following joints in ducts located outside the thermal boundary should be inspected and sealed. These same joints will also be found on ducts located within the thermal boundary, such as basements and crawl spaces. Sealing joints on ducts located within the thermal boundary will not save energy, but may solve other problems (see chapter 113, "Duct Leakage Tests"). Generally the sealing begins at the air handler cabinet and proceeds out to the register boots.

- Seal holes in the air handler cabinet and joints between the air handler and the supply and return plenums. The filter slot should have system that will cover the opening but is easy for the homeowner to open and close.
- Seal leaky joints between main supply and return plenums and their branches.
- Seal leaky joints between building materials composing cavity return ducts, such as panned floor cavities and furnace return platforms. Even better: replace cavity return ducts with new metal return ducts.
- Seal leaky joints between supply and return registers and the floor, wall, and ceiling to which they are attached.
- Secure metal duct joints with screws, seal them with mastic, and support joints with duct hangers.
- Flex duct runs should be mechanically attached to the plenum/trunk/boot with clamps or cable ties and sealed.
- Patch or replace metal ducts that have rusted through and ducts with holes cut in them.
- Seal penetrations in ducts made by wires or pipes. Even better: move the pipes and wires and patch the holes.

- Seal the ends of wall cavities used as ducts or chase ways that contain ducts that are open to unconditioned spaces or the outside.
- Close and seal return air grilles located in the basement.
- If there is asbestos on the duct surfaces be sure to avoid disturbing friable material and work in an asbestos safe manner.
- Re-check temperature rise or static pressure to assure that it is within the operating limits of the furnace (see section 2273, "Improving Duct System Airflow").

22712 Duct Sealing Materials

Duct sealing mastics and tapes should be UL181A or UL181B labeled.

Sealing a register boot with duct mastic

- Duct mastic: the preferred material because of its superior durability and adhesion. Apply at least 1/16-inch thick and use reinforcing mesh for all joints wider than 1/8 inch or joints that may experience some movement.
- Tape: An approved aluminum duct tape may be used when duct mastic is not used. The duct surfaces around the joint need to be clean in order for the tape to adhere properly. Tape should never be expected to hold a joint together nor expected to resist the force of compacted insulation or joint movement. Joints should rely on mechanical fasteners to prevent joint movement or separation.
  - Butyl-aluminum tape: High quality tape designed for duct sealing is effective and durable when applied to clean surfaces.
  - Cloth and Aluminum duct tape are **not** acceptable duct sealant materials because of their history of adhesive failure.

2272 Duct Insulation

Insulate supply and return ducts located outside the thermal boundary, such as unconditioned crawl spaces and attics. Use a minimum R8 insulation on supply ducts.

- Always perform necessary duct sealing before insulating ducts.
- Use fiberglass insulation 3 to 6 inches thick (minimum R8) with foil-scrim-kraft facing or vinyl facing. Vapor barrier must be placed to the outside with no exposed insulation.
- Insulation should cover all exposed ducts. This is especially important in air-conditioned homes because the insulation must prevent condensation. Even a small void in the insulation can dampen a large section of insulation through condensation.

- Insulation should be fastened by mechanical means such as stuck-ups, twine, clamp/bag staplers or plastic straps. Tape can be effective for covering joints in the insulation to prevent air convection, but tape will usually fail if expected to resist the forces of compressed insulation or the insulation's weight.
- If the ducts are in the attic and it is feasible, blow cellulose over the ducts to increase the R-value.

2273 Improving Duct System Airflow

If occupants complain of lack of heat (or cooling), there may be inadequate airflow. The airflow capacity of the air handler may be checked in relationship to the size of the furnace or air conditioner. For combustion furnaces there should be 110 to 150 cfm of airflow for each 10,000 Btu of output. Central air conditioners should deliver 450 cfm of airflow per ton of cooling capacity, and heat pumps should deliver 400 cfm of airflow per ton of heating capacity. A contributing factor in some houses for lower than desired air flows through the supply registers is the presence of significant leakage in the ducts running though otherwise conditioned basements and crawlspaces. Diverting this flow from the basement to the living spaces can increase occupant comfort.

22731 Filter and Blower Maintenance

A dirty filter can reduce airflow significantly. Special air cleaning filters may cause more resistance than standard filters, especially when saturated with dust. Take action to prevent filter-caused airflow restriction by the following steps:

- Ensure that filters are easy to change or clean.
- Stress the importance of changing or cleaning filters, and suggest the client follow a regular filter maintenance schedule.

When the air handler is on, there should be a strong flow of air out of each supply register, providing its balancing damper is open. Low airflow may mean that a branch is blocked or separated, or that return air is not sufficient. When low airflow is a problem, consider the following improvements.

- Clean or change the filter.
- Clean the furnace blower.
- Lubricate the blower motor and check the tension on the drive belt.
- Add another return air duct (see section 22733, "Duct Improvements to Increase Airflow and Improve Comfort").

22732 Cleaning Air-Conditioning Coils

Dirty air conditioning coils located in main ducts or air handlers are a common cause of low airflow and resultant low heating and cooling efficiency. Follow the general guidelines listed below to clean air conditioning coils.

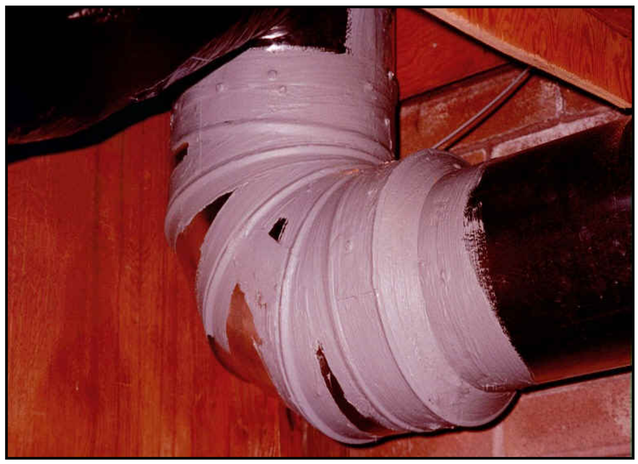
- Identify the coil location and the coil surface where the air enters – most of the dirt will be attached to this surface.
- Remove access panel in air handler or duct; or cut access panel in duct; or disassemble duct to gain access to air-conditioning coil.
- Using a stiff hairbrush, carefully remove surface dust, dirt, and lint.

- Spray the coil with cleanser and after a while spray water to rinse out the cleanser and dirt. Repeat the spraying if necessary.
- Observe whether the pan and drain hose are doing their job. Water and cleanser should be flowing out the end of the hose, not overflowing into the duct. Clean the pan and unplug the hose if necessary.

22733 Duct Improvements to Increase Airflow and Improve Comfort

Consider the following improvements in response to customer complaints, conditions observed during a thorough duct inspection and measurements such as the temperature rise across the heat exchanger or high static pressure (higher than recommended by furnace manufacturer).

- Make sure that the fan control is adjusted to the optimum fan on/off temperatures and functioning so that the furnace fan is cycling at the desired temperatures.
- Remove obstructions to registers and ducts such as rugs, furniture, and objects placed in ducts, like children's toys and water pans for humidification.
- Remove kinks from flex duct, shorten longer than necessary flex duct sections and replace collapsed flex duct and fiber duct board.



Use duct mastic to seal all ductwork in unconditioned spaces

- Extend supply and return ducts as needed to provide heated air throughout the building, especially into additions to the building.
- Add retrofit crossover ducts.
- Install registers and grilles where missing. Do not install return air grilles in basements or crawl spaces.
- Seal significant supply and return leaks in the basement that may be diverting excess distribution air away from the main living spaces of the house. If there is an excessive number of supply registers in the basement (more than two is usually excessive) close and seal them.
- Undercut bedroom doors, especially in homes with central return systems. Installing a transfer grille between the bedroom and main body of house may also be done to help improve airflow (see section 1142, "Duct-Induced Room Pressures").

22734 Duct Improvements to Solve Improper Draft

Consider the following steps to help establish proper draft (see chapter 1213, "Draft Testing").

- Seal return duct leaks in the combustion appliance zone (CAZ). See section 1114, “Depressurization Tightness Limit” for depressurization limits.
- Seal supply leaks in unconditioned zones.
- Isolate furnace from return registers, exhaust fans, and clothes dryers by air sealing between the combustion zone and zones containing these depressurizing forces.
- Provide combustion air inlet and outlet to combustion zone (see section 2215, “Combustion Air”).

2274 New Ductwork

New ductwork should not be installed in unconditioned spaces unless absolutely necessary. If ductwork is located in unconditioned spaces, joints should be sealed and the ducts insulated as described in sections 2271 and 2272 (“Duct Sealing” and “Duct Insulation”).

- New ductwork must be physically connected to the existing distribution system or to the furnace.
- New supply branches with operable registers must be provided to rooms currently heated by space heaters.
- Return air ducts and registers shall be provided as needed to improve air circulation.
- If flex duct is used, sections longer than 14 feet should be joined with a metal connection, mechanically fastened and the seams properly sealed. All flex duct must be supported according to the manufacturer’s specifications.

230 Baseload

Best Practice Recommendations:

- Fluorescent lamps used for replacement should be ENERGY STAR® rated.
- Low-flow showerheads should be included as part of weatherization services.
- Measuring kWh or referring to http://www.waptac.org/sp.asp?id=68 should be used to determine electrical consumption for refrigerators being considered for replacement.
- Replacement refrigerators should be ENERGY STAR® rated.

Electric baseload usage can account for over 40 percent of a household's energy use. Electric baseload usage includes lighting, refrigerators/freezers, and other electrical appliances.

231 Fluorescent Lighting

Fluorescent lighting is among the most cost-effective measures that can be installed, particularly for lights that are on for long periods. Energy savings are the greatest for those lights that are used the longest periods of time. Assessors should ask the client which lights are on most often as those lights are the best candidates for fluorescent lighting. Fixtures controlled by dimmers should not be considered unless proper lamps are available to the installer. Incandescent fixtures may be replaced with fluorescent fixtures that accept only fluorescent lamps where cost-effective. Fluorescent lamps and fixtures used for replacement should be ENERGY STAR® rated.

Fluorescent lamps use from 50 to 75 percent less electricity than incandescent lamps. Over the life of one compact fluorescent lamp (CFL), a client can avoid replacing up to 13 incandescent lamps.

Fluorescent lighting technology has improved to the point that it is often very difficult to distinguish between the quality of light provided by incandescent and fluorescent lighting. The new CFLs provide high quality, warm light without the flickering or humming of older fluorescent lamps. Many new CFLs also meet the stringent criteria of Energy Star® for long life, energy savings, and brightness.

Generally, incandescent lamps that are on for more than 2 hours a day should be considered for replacement. For example, if a 60 watt incandescent lamp burns 4 hours a day for an entire year, the cost of electricity will be $8.76 (at $0.10/kwh). If replaced with a 13 watt fluorescent lamp, the cost will be $1.90, for a yearly savings of $6.86.

The fluorescent lamp should be sized at approximately one-third the wattage of the incandescent lamp that is being replaced to provide the equivalent lumen, or light, output (see table 230-1). Lumen output for fluorescent lamps is generally displayed on the packaging.

Table 230-1

Incandescent Lamp Wattage (lumen output)	Equivalent Fluorescent Lamp Wattage
25 watts	~ 9 watts
40 watts (500)	~ 14 watts
60 watts (870)	~ 20 watts
75 watts (1190)	~ 25 watts
100 watts (1750)	~ 32 watts
150 watts	~ 50 watts

Exterior incandescent lamps may also be replaced with fluorescent lamps. Exterior fluorescent lamps should be rated for exterior use with a minimum 27 watts with a starting temperature of -12^{o}F and a minimum initial rating of 1,600 lumens. Fluorescent lamps with less than 27 watts may not provide adequate lighting for exterior conditions.

232 Low-Flow Showerheads

Typical flow rates for standard showerheads range between 6 gallons per minute (gpm) to in excess of 10 gpm. Low-flow showerheads are rated between 1.2 to 2.5 gpm. The installation of low-flow showerheads will save the client energy both on their water heating and water usage bills.

Showerheads with flow rates greater than 3.0 gpm may be replaced with low-flow models. The following method may be used to determine the flow rate of an existing showerhead. Cut the top of a one-gallon plastic milk jug to fit over the showerhead. If the container fills in less than 20 seconds, the flow rate is greater than 3.0 gpm.

New showerheads and necessary adapters should be installed according to the manufacturer's instructions. Threads shall be properly sealed with plumbers tape to prevent leaks.

233 Refrigerator Replacement

Refrigerators manufactured before 1990 usually consume over 1000 kilowatt-hours per year. New Energy Star® rated refrigerators use less than 550 kilowatt-hours per year. Replacement should be considered on a case-by-case basis depending on existing refrigerator energy consumption and cost effectiveness (see section 2332, “Measuring Existing Consumption”).

Refrigerators may also be replaced for the following reasons:

- non-operable (if it is the only unit in the home),
- continuously running compressor, and
- unable to maintain safe food storage temperature (temperatures of refrigerator and freezer compartment may be checked during the inspection).

Existing refrigerators must be removed from the client's home and demanufactured in an environmentally friendly manner. The units should be taken to a facility licensed to reclaim the refrigerant. Refrigerators that are replaced are not to be returned to service.

2331 Replacement Requirements

Replacement refrigerators should be Energy Star® rated. At a minimum, replacement models must meet Federal National Appliance Energy Conservation Act (NAECA) ratings. All replacement refrigerators must meet the UL-250 standard.

All new replacement refrigerators must have a fifteen year expected life. The warranty on all replacement refrigerators must meet or exceed a one year full warranty on parts and labor and a minimum five year warranty on the compressor.

The assessor must ensure that the new refrigerator will fit into the space available. Make sure the doors, walls, stairways, etc. will accommodate the moving of the existing and the new refrigerator. Leave ½ inch for clearance. The door to the refrigerator can be taken off if needed to gain 1½ inches.

The size of the replacement unit, barring other physical constraints, should be based on cost-effectiveness, dwelling unit and family size, allowing local flexibility within available models for extenuating circumstances:

- 15 CF unit for one to two bedroom units with up to three residents.
- 18 CF unit for three bedrooms with up to five residents (or two bedrooms with four residents).
- 21 CF for units with four or more bedrooms or five or more residents.

An upgrade in size based on family need may be installed when replacing multiple refrigerators with one where the client agrees to give up more than one refrigerator.

Replacement refrigerators should have the following features:

- White in color
- Freezer on top
- Auto defrost
- Standard shelving
- No ice maker
- No water dispenser
- Reversible doors
- Easy-roll wheels
- Up-front controls

In most cases, replacing a side-by-side unit with another side-by-side unit should not be done because of the higher cost and greater energy consumption of side-by-side units. However, replacement units may be side-by-side if:

- A member of the household is confined to a wheelchair,
- A member of the household has a handicap that makes it difficult to use a top-freezer model, or

- Space limitations dictate the use of a side-by-side (less door-swing space required).

2332 Measuring Existing Consumption

The annual kilowatt-hours (kWh) consumption of existing refrigerators may be determined in one of three ways.

23321 Internet

The annual consumption of tens of thousands of different refrigerators manufactured after 1975 may be found at http://www.waptac.org/sp.asp?id=68. The manufacturer and model number of the existing refrigerator are required (model number may be found on the nameplate). The annual consumption figures are estimates of the refrigerator when it was new. These values should be adjusted by the following degradation factors.

Refrigerator Degradation Factors	
Refrigerator Age	***Factor***
Less than 5 years	1.0
5 to 10 years	1.1
10 to 15 years	1.2
More than 15 years	1.3

23322 KWhr Measurement

Measuring refrigerator energy consumption may be performed during the assessment. A recording kilowatt-hour meter is required and the consumption of the refrigerator should be recorded for at least two hours.

- Connect the refrigerator to the recording kilowatt-hour meter.
- If the refrigerator is an automatic defrost model, check several times during the two hour test to ensure that the automatic defrost has not activated.
- Divide the number of kilowatt-hours by the hour duration of the test. This provides the number of kilowatts. Multiply this number by the total number of hours in a year: 8760 hours. The product of this calculation is annual kWhr.

For example, if a refrigerator's measured consumption is 0.32 kilowatt-hour over a 2-hour period, the annual consumption would be calculated as:

0.32 kilowatts/2 hours = 0.16 kilowatts/hour
0.16 kilowatts/hours * 8760 hours/year = **1,402 kWh/year**

23323 Estimating kWhr/yr

Some refrigerators may be replaced without checking the WAPTAC Website or by metering the consumption. If these refrigerators cannot be found in the AHAM data or cannot be metered, use the estimated kwh/yr consumption listed in parenthesis when determining the cost effectiveness of replacement.

- Units manufactured before 1973 (1,700 kWh/yr)
- Units manufactured from 1973 to 1980 (1300 kWh/yr)
- Units manufactured from 1981 to 1984 (1050 kWh/yr)
- Units manufactured from 1985 to 1988 (1000 kWh/yr)
- Units manufactured from 1989 to 1990 (900 kWh/yr)
- Units that run continuously (2000 kWh/yr)

240 Health & Safety

Best Practice Recommendations:

- At least one smoke alarm should be installed in each weatherized home.
- Fire extinguishers should be given to each weatherization client if they do not already have one.
- At least one CO alarm should be installed in each weatherized home having combustion appliances, when the home has an attached or tuck-under garage or when assessors believe that there are other health and safety situations related to CO.
- CO alarms should also be installed when weatherization services must be deferred due to unsafe combustion appliances.
- Whole house ventilation should be added to homes that are below the BTL or BTLa ventilation rates.
- Consideration should be given to providing whole house ventilation in all homes according to ASHRAE Standard 62.2-2004, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*.
- Exhaust fan ducts should be sized according to ASHRAE 62.2-2004.
- Disconnected or improperly vented clothes dryers should be corrected as part of weatherization.
- Missing or damaged gutter systems should be repaired or replaced if causing an indoor moisture problem.
- Weatherization staff should be knowledgeable of mold remediation procedures and outside funding sources available to remediate moldy surfaces in clients'

241 Smoke Alarms

At least one smoke alarm is required in each home weatherized.

2411 Installation

Install smoke alarms according to manufacturer's instructions. Assure that smoke detectors are properly located.

- Smoke detectors should be installed on the ceiling or six inches below the ceiling on the wall.
- Install one smoke detector on each level of the home.
- One smoke detector should be located at the base of the basement stairwell.
- One smoke detector should be located within 15 feet of every room used for sleeping.
- Do not locate smoke detectors near kitchen stoves or bathroom showers.
- Do not locate smoke detectors within 12 inches of exterior windows and doors.
- Do not locate smoke detectors in front of supply air registers.

Relocate existing smoke detectors as necessary.

2412 Operation

Assure that existing smoke alarms have new batteries. Test all smoke alarms for proper performance following installation.

Hard-wired smoke alarms should be wired to a circuit that is energized at all times. They should not to be wired to a ground-fault circuit interrupter (GFCI).

2413 Client Education

Review smoke alarm testing procedures with clients following alarm installation and advise regarding battery replacement as appropriate.

2414 Specifications

- Smoke alarms that are powered by a battery must emit a signal when the battery is losing power.
- All installation hardware, including a screw mounting bracket, should be included with the alarm.
- Smoke alarms must be approved by Underwriters Laboratories (UL).

242 Fire Extinguishers

Fire extinguishers are an eligible weatherization expense that may be purchased and given to weatherization clients.

Fire extinguishers should be labeled as a combination Class A and Class B (A-B) extinguisher. Class A extinguishers will put out fires from ordinary combustibles such as wood and paper. Class B extinguishers are to be used on fires involving flammable liquids such as grease or gasoline.

Combination A-B extinguishers carrying the Class C rating (A-B-C) are also acceptable. Class C indicates that the extinguisher may be used on electrical fires.

Clients should be instructed on use of the fire extinguisher. The term “PASS” may be used for this explanation.

P = PULL the pin (this unlocks the operating handle).
A = AIM the extinguisher at the base of the fire.
S = SQUEEZE the operating handle discharging the fire fighting agent.
S = SWEEP from side to side, carefully moving in on the fire sweeping back and forth across the base of the fire.

243 Carbon Monoxide (CO) Alarms

CO alarms should be installed in all homes with fuel burning appliances, gas ranges, wood stoves or fireplaces. CO detectors should also be installed in homes with attached or tuck-under garages.

In addition, carbon monoxide alarms should be installed, on a permanent basis, when an agency has to delay weatherization services due to an unsafe furnace, water heater, stove, fireplace or oven.

2431 Location and Placement

CO alarms must be installed according to the manufacturer's directions. Manufacturers generally recommend that CO detectors be installed on each separate living level of the home where household members frequently spend time. Since most fatalities caused by CO occur while families are sleeping, a CO alarm should be installed in, or just outside of, bedrooms occupied by adult members of the household. CO alarms may also be installed in basements.

Do not install alarms in the following areas:

- Near bathrooms or in shower areas,
- In closets,
- Crawl spaces or unheated areas where extreme hot or cold temperatures occur,
- Within 5 feet of fuel burning appliances,
- Close to adjacent walls or in corners,
- Near bathtubs or basins,
- Directly above or below return air grilles or supply registers, and
- Behind drapes, furniture, or other objects that could block air flow to the CO alarm.

2432 Specifications

CO alarms shall:

- Meet or exceed UL2034-98 and/or IAS696 standards.
- Have a manual test and reset button.
- Have a five-year warranty on the detector and sensor. Expiration date, as warranted by the manufacturer, must be written on the front of the alarm in permanent ink.

Assessors should educate clients about the purpose and features of the CO alarms and tell them what to do if the alarm sounds.

244 Ventilation

2441 Required Ventilation

It is recommended that state weatherization programs consider providing whole house ventilation in all homes according to ASHRAE Standard 62.2-2004, *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*.

Ventilation requirements may be met by exhaust only, supply only, balanced or a combination of these system types. The ventilation system may be designed to run continuously or intermittently. Intermittent systems will require a larger flow rate than continuous systems.

Note that exhaust only systems may cause negative pressure in the combustion appliance zone (CAZ). Conduct a worst-case draft (see section 123, “Worst-Case Draft Test”).

2442 Bathroom Exhaust Fans

All full-baths (bathrooms that include a tub or shower) should have an operable exhaust fan vented to the outside. The following requirements should be met.

24421 Fan Requirements

- Minimum 70 CFM at 0.25 in. w.c.
- Sone rating no higher than 1.5.

24422 Controls

One of the following three types of controls should be utilized for exhaust fans in full baths.

Fan-Delay Timer

Fan-delay timers may be used where a single-switch controls both the light and exhaust fan. The fan delay timer allows the fan to continue to operate when the light is turned-off (the Home Ventilating Institute recommends that a bathroom fan operate for 20 minutes following showering or bathing). When the switch is turned-on, both the light and fan operate. When the light is turned-off, the fan continues to operate for an extended period of time ranging from 1 to 60 minutes. The adjustable timer dial is located beneath the cover plate. The fan delay timer fits in a single-gang box.

Mechanical Timer

A simple mechanical timer may be used in place of an on/off switch that controls only the exhaust fan. The timer operates the fan up to 60 minutes.

Programmed Controller

A programmed controller may be used when the bathroom fan will be used as the whole house ventilation system. The controller cycles the fan on and off, at preset times, throughout the day and/or night. It automatically controls the fan speed and cycle time, while allowing the occupant access to a full speed boost cycle when needed. A similar type of controller (constant duty) may be used to control the bathroom fan when continuous ventilation is desirable. This type of controller is not compatible with all exhaust fans.

2443 Exhaust Fan Ductwork

Smooth metal duct should be used in place of plastic or metal flex duct whenever possible. Minimum duct diameter should be 4 inches. Exhaust ducts should be vented to the outside. Collars used to connect exhaust ducts to termination caps should be tight to prevent the escape of moisture. Exposed exhaust fan ducts in unconditioned spaces should be insulated.

Refer to Table 240-1 for maximum duct length based on bathroom fan CFM and type of exhaust duct. Use the next highest Fan Rating for fan capacities not shown in the table.

Exhaust Fan Duct Sizing[1]

Table 240-1

Duct Type	**Flex Duct**				**Smooth Duct**			
Fan Rating CFM @ 0.25 in. wg	50	80	100	125	50	80	100	125
Diameter (in)	**Maximum Length (ft)**							
4”	70	3	X	X	105	35	5	X
5”	NL	70	35	20	NL	135	85	55
6”	NL	NL	125	95	NL	NL	NL	145

[1] – Taken from ASHRAE 62.2-2003
X – not allowed
NL – no limit on duct length

The duct lengths shown in Table 240-2 assume no elbows. Reduce length by 15 feet for every elbow. Note that for all intents and purposes, 4 inch flex duct can never be used with the suggested 70 CFM bathroom exhaust fans. If flex duct is being used, it should be 5 inch diameter.

For example, a fan rated at 70 CFM at 0.25 in. w.c. will be installed to replace a non-operable bathroom exhaust fan. The existing fan is vented into 4 inch flex. There is one elbow in the duct at the fan. According to Table 240-2, the 4 inch flex duct may only be vented 3 feet with no elbows and is therefore not sufficient for the new fan. The flex duct may be replaced with 5 inch flex (assuming that the duct length is no more than 55 feet) or 4 inch smooth metal if the duct length is no more than 20 feet.

If flexible duct is used, the entire length should be supported with braces or hangers every 18 inches to prevent sagging. Elbows should be minimized. Elbows with a long radius angle should be used. There should be a 2 foot to 3 foot horizontal run out of the fan before the first elbow.

2444 Kitchen Exhaust Fans

Kitchen exhaust fans should be vented to the outside. Recirculating kitchen hoods should be replaced with kitchen exhaust fans. Kitchen exhaust fans should have a minimum exhaust capacity of 100 CFM. Through-the-wall or ceiling mounted exhaust fans may be used when exhaust range hoods cannot be installed. Refer to Table 240-2 for properly sizing exhaust fan duct.

2445 Continuous Exhaust-Only

Continuous exhaust-only ventilation may be considered when the house is below its BTL or as required by ASHRAE 62.2, 2004. In addition, there may be instances of chronic moisture loads in a home caused by high occupancy, lifestyle or other circumstances that cannot be addressed by weatherization where a continuous exhaust-only system may be considered.

Duct systems for continuous exhaust-only systems should meet the requirements shown in Table 240-2 in this chapter.

Continuous exhaust-only systems force air out of the home while drawing air in through leaks in the building shell. These systems are generally recommended for heating climates.

Continuous exhaust systems may place the home under negative pressure. Depressurization of the combustion appliance zones may occur as a result of continuous exhaust. Attached or tuck-under garages should be well-sealed from the living space so as not to depressurize the garage. Soil gases, radon and moisture may also be drawn into the home as a result of depressurization.

When installing a continuously operating exhaust fan, educating the client about its use is extremely important. The client should be informed about:

- The purpose(s) of the exhaust fan installation.
- The importance of operating the fan whenever the house is closed up, such as during the heating season.
- The disadvantages of not operating the exhaust fan.

Controls of the operation of these systems should be clearly marked.

24451 Bathroom Exhaust Fan as a Continuously Operating System

Some low sone bathroom exhaust fans are rated to operate continuously. These fans are quiet and therefore are not likely to cause noise complaints from the clients. Alternate to operating the fan on a continuous basis, a programmable controller may be utilized (see 24422, “Controls”).

Power consumption of exhaust fans should be considered. Many low sone fans have high efficiency electric motors that minimize operating costs. An example for determining annual operating cost for an exhaust fan that will operate continuously is shown below.

A fan rated for continuous operation has been selected for a 3-bedroom, 1,600 ft^2 home. The fan is rated at 60 CFM at 0.25 in. w.c. with a power consumption of 17 watts. The annual operating cost for electricity is $14.89 a year at $0.10/kwh.

(17 watts/1000 watts/kWh) x 8,760 hours/year x $0.10/kWh = $14.89

24452 Inline Fan as a Continuously Operating System

An inline fan rated for continuous operation may be used instead of a bathroom exhaust fan. The fan is mounted in the attic, above the insulation, to lessen the noise. Up to three bathrooms may be ducted to the fan. Small ceiling grilles are installed in the bathrooms. A low/high switch may be installed to provide a base level of ventilation (20 CFM from each bathroom, for example), but provides the client with the capability to boost the ventilation rate during showering or bathing.

2446 Supply-Only Ventilation

Supply-only systems use a fan to force outside air into the building while air leaks out of the home through holes in the building shell. A simple supply-only system uses the furnace air handler as the ventilation fan and the heating ducts as the distribution system.

Flex duct is installed from the outside of the home to the return side of the furnace. Whenever the air handler operates, fresh air is drawn in from the outside and mixed with the return air. A balancing damper may be installed to control the amount of air being introduced to the home.

Insulated flex duct should be used to reduce condensation during the winter. A filter should be installed between the flex duct and the return duct. A wall cap with insect screen should be installed on the fresh air intake on the outside of the wall.

This supply-only system has some disadvantages. Using the furnace air handler to circulate air may be an expensive way to circulate air throughout the home. The electric cost of using the furnace air handler as the ventilation fan may be significant. Power consumption of the air handler should be considered using this system. Electric costs[30] for using the air handler as part of the ventilation system in Chicago are shown below.

Inefficient Air Handler (700 watts) = $432
Efficient Air Handler (250 watts) = $152

Secondly, during mild weather, the air handler doesn't operate often and there are extended periods when ventilation is not provided unless a timer control is installed (see below). Finally, supply-only systems place the home under a positive pressure, forcing warm moist air into cool building cavities during the heating season. For this reason, supply-only systems are generally recommended for mixed and hot climates only.

Fresh air grille inlets should be located away from sources of poor air supply. Inlets should be located at least 10 feet away from automobile parking areas, side-vented furnaces and water heaters, dryer vents or other sources of poor air quality.

[30] @ $0.09/kwh

Inlets should be installed at least 12 inches above grade so that they will not be covered with snow. The inlet should be designed to prevent rain entry and must have a rodent screen with a mesh not less then ¼ inch to prevent the entry of large particles. Inlets will require periodic cleaning as they tend to become clogged with dirt, debris and insect nests. They should be located for easy accessibility. The client should be instructed about cleaning the intake grille.

This system provides ventilation throughout the entire home, but only when the air handler is operating. The air handler is less likely to operate during the spring and fall (summer also if central air conditioning is not present). A timer control, such as the AirCycler®, may be installed to assure ventilation year round.

The AirCycler® is mounted on the furnace cabinet and wired to the air handler and tracks the operation of the air handler. If the air handler has not run for a certain period of time (20 minutes, for example), the AirCycler® will operate the fan for a period of time (10 minutes, for example). Both the “fan-off” and “fan-on” times are adjustable between 1 and 99 minutes. During periods of high heating or cooling, the air handler will probably run often and the AirCycler® will not affect fan operation.

2447 Balanced Ventilation Systems

Balanced systems provide equal rates of supply and exhaust air, preventing the problems that depressurization (exhaust-only) or pressurization (supply-only) may create in a home. Air that is exhausted from the home is replaced with an equal amount of fresh air.

Balanced systems may be either separate supply and exhaust systems working together for balanced air flow or a package unit that provides heat recovery in addition to ventilation. In tight buildings with limited natural infiltration, a balanced ventilation system can meet the ventilation requirements of a home without creating depressurization or pressurization problems.

Package units can be either heat recovery ventilators (HRV) or energy recovery ventilators (ERV). HRV systems exchange household air with fresh outside air. Sensible heat in the exhausted household air is recovered and transferred to the incoming outside air as both airstreams pass through a heat recovery core. An HRV system is recommended for heating climates when air conditioning is not used in the home.

An ERV system is recommended when cooling is used in the home. An ERV system transfers both sensible and latent (heat and moisture) energy. Heat and moisture in the incoming outside air is transferred to the outgoing exhaust air an ERV so as not to increase the cooling load of a home.

For most effective operation, balanced systems should supply fresh air to all the important living spaces, such as bedrooms, living, dining and family rooms.

Exhaust air should be removed from spaces in which moisture and odor are generated, generally kitchens, bathrooms and utility rooms. The duct system should be well-sealed.

The following items should be considered when installing an HRV or ERV system.

- New ductwork should be installed for the HRV or ERV system. If existing ductwork is used, there is a potential that air will “short-circuit” and not circulate around the home. The furnace air handler may be needed to circulate the air around the home. Unless the air handler has an efficient motor, there may be a significant increase in electric consumption (see section 2446, “Supply-Only Ventilation).
- HRV and ERV systems require filter cleaning. Units should be located for easy accessibility. Client must be willing to maintain system on a regular basis. Fresh air intake must be cleaned of dirt and debris on a regular basis.
- Condensate will form on the cool side of an HRV during the summer. Provisions for draining the condensate must be provided.
- Fresh air grilles should be located away from sources of poor air quality.
- The balanced ventilation systems should be professionally designed, installed and balanced.

Operation instructions should be posted in the vicinity of the installation to avoid occupant override or misuse.

245 Dryer Venting

Disconnected or improperly vented clothes dryer vents should be corrected as part of weatherization.

Dryer vents should be smooth-surfaced aluminum or galvanized rigid duct. Non-combustible flexible metal duct approved for dryer venting may also be used (UL labeled “Clothes Dryer Transition Duct”). Plastic or vinyl flex duct is not to be used.

Duct joints should be lapped taking account of the direction of air flow. Duct sections should be connected with foil-backed metallic tape or approved clamps. Screws or fasteners that extend into the duct are <u>not</u> to be used.

Minimum duct diameter should be 4 inches and length should not exceed 25 feet from the dryer outlet to the termination point (no more than 8 feet for “Clothes Dryer Transition Duct”). If duct length is greater than 25 feet, 5 inch diameter duct should be used. Assume a reduction in maximum length of 2.5 feet for every 45 degree bend and 5 feet for every 90 degree bend. Clothes dryer transition duct should be installed without dips or sags. Dryer vent duct extending through non-conditioned spaces are to be insulated.

Outdoor dryer vent caps should have a backdraft damper that closes when the dryer is not being used. Insect screens or small wire cages are not to be installed over the vent cap because they can become clogged with lint.

246 Gutters & Downspouts

Missing or damaged gutter systems may be repaired or replaced under weatherization to the extent they can be completed within the incidental energy-related repair budget. The gutter system includes the gutters, downspouts, leaders and splash blocks.

- Use minimum 0.027 gauge aluminum gutters. The heavier gauge 0.032 is preferred for heavy ice and snow locations.
- Gutters should be pitched to downspouts at 1 inch for every 16 feet of run. Short gutters may be hung level. In areas with a moderate amount of trees, gutters and downspouts should be oversized where leaves and debris can be flushed more easily.
- Seal gutter connections with mastic or caulk to prevent leaking.
- Half-round gutters are least affected by snow and ice. If unavailable or too costly, the "K-style" gutters may be used.
- Use heavier versions of hangers and secure gutters every 24 inches (18 inches where heavy ice and snow may be a problem). Hangers should be firmly fastened to the fascia, rafter end or truss tails. At a minimum, heavier hangers should be used at stress points, such as corners and downspouts.
- Downspouts may be oversized to help reduce clogging. Elbows and straight sections should be fastened together with pop rivets—screws that project into the downspout can lead to clogging.
- Secure downspouts to house with 3 fasteners, rather than 2.
- Use 1 downspout for every 40 feet of gutter.
- Leaders and splash blocks should be used to direct water away from the home. Water from downspouts should come out at least 3 feet away from a house that has a crawl space and 5 feet away from homes with basements.

247 Mold Remediation

Mold remediation is not an allowable DOE weatherization expenditure. Other funding sources should be sought to cover the cost of cleaning or remediating moldy surfaces.

Recognize, however, that weatherization services may help solve a mold problem. Mold growth on cool interior surfaces may be eliminated by elevating surface temperatures with the addition of insulation and appropriate air sealing. Installation of ventilation systems will help remove moisture from bathrooms and kitchens. Repairing or installing gutter systems and clothes dryer vents are also allowable weatherization measures.

The following is provided as background information for mold remediation activities.

Mold remediation must go "hand-in-hand" with solving the moisture problem lying at the root of a mold problem. It is naïve to clean mold and believe that the mold problem has been resolved without solving the underlying moisture problem. Mold problems will come back if they are not dealt with properly; that is, the moisture problem must be corrected.

Mold can be cleaned with water and a mild detergent. Sometimes a biocide, such as household bleach, may be used. Biocides are substances that can destroy living organisms. The use of a biocide that kills is not recommended as routine practice for mold cleanup. There may be instances, however, when its use may be justified. If disinfectants or biocides are used for mold cleaning, always ventilate the area and exhaust the air to the outdoors. Biocides, such as bleach, are irritating to the eyes, nose and throat. Never mix chlorine bleach solution with other cleaning solutions or detergents that contain ammonia; toxic fumes could be produced.

Note that mold may cause staining and cosmetic damage that will be apparent following its cleaning.

In some cases, what appears to be mold may simply be water stains. Mold will lose its color or disappear if some drops of household bleach are dropped on it. If there is no change in its appearance, it probably isn't mold.

The presence of mold in a home does not mean workers or the occupants will have any health effects from it. Individuals have different sensitivity to mold exposure.
Most people are not affected by exposure to mold unless they are exposed to high concentrations of it. Those who do have an allergic reaction to mold may only have "cold-like" symptoms such as a running nose, congestion, cough, and itchy eyes. Although there is evidence documenting severe health effects of mold in humans, most of the evidence is derived from ingestion of contaminated foods, or exposures in agricultural settings where inhalation exposures were very high. Such high-level exposures are not expected to occur while performing weatherization work.

Exposure to mold will more likely result in severe reactions in persons with the following medical conditions.

- Decreased immune function,
- HIV/AIDS,
- Respiratory problems,
- Asthma,
- Emphysema,
- Severe allergies,
- Persons having undergone recent surgery,
- Infants less than 12 months old, and
- Other serious health concerns.

It is critical to remediate mold and solve a water problem in homes where one of the above conditions exist. Mold remediation guidelines provided here are limited to mold areas that are no more than 30 ft^2 in area. Areas larger may require the services of a professional mold remediator.

2471 General Mold Remediation Guidelines

The procedures are designed to protect the health of the occupants and cleanup personnel during remediation. These procedures are based on the area and type of material affected by water damage and/or mold growth. Asthmatic or allergic individuals should refrain from cleaning mold.

Non-porous (metals, glass, and hard plastics) and semi-porous (wood and concrete) materials that are structurally sound and visibly moldy can be cleaned and reused. Cleaning can be done using a detergent solution. Most porous materials (ceiling tiles, insulation, gypsum board, fabrics) cannot be cleaned and should be removed and discarded.

The following protective equipment should be worn when cleaning mold.

- Respirator

  N-95 respirators are recommended. Some N-95 respirators resemble a paper dust mask with a nozzle on the front, others are made primarily of plastic or rubber and have removable cartridges that trap most of the mold spores from entering. The respirator or mask must fit properly to be effective. The instructions supplied with the respirator should be followed carefully.

- Rubber Gloves

  Long rubber gloves that extend to the middle of the forearm are recommended. When working with water and a mild detergent, ordinary household rubber gloves may be used. Gloves made from natural rubber, neoprene, nitrile, polyurethane or PVC should be worn if a disinfectant, chlorine bleach or a strong cleaning solution is being used.

- Goggles

  Goggles that do not have ventilation holes are recommended.

Common sense should be exercised. Old clothes should be worn and eating should not be done in the moldy area. Try to avoid touching the face and skin with the working gloves.

2472 Small Isolated Areas (10 ft^2 or less per affected area)

Containment of the work area is not necessary. Vacating people from spaces adjacent to the work area is not necessary but is recommended in the case of children less than 12 months old. People suffering from any of the above health conditions should be kept away from the area being cleaned.

The mold should be cleaned with a mild detergent solution. Sponge with a clean, wet rag and let the area dry.

Discarded material should be put in a sealed plastic bag before being disposed. There are no other special requirements for the disposal of the moldy material.

2473 Mid-Sized Isolated Areas (10 ft^2 to 30 ft^2 per affected area)

The work area should be unoccupied. Vacating people from spaces adjacent to the work area is not necessary but is recommended in the case of children less than 12 months old. People suffering from any of the above health conditions should be kept away from the area being cleaned.

The work area should be covered with plastic sheets and sealed with tape before cleaning to contain any dust or debris. Seal duct registers to prevent mixing and circulation of air from the clean-up area. Using an exhaust fan to the outside to keep the area under negative pressure is also helpful.

Misting surfaces (to suppress dust) should be done prior to cleaning. Mold should be cleaned with a mild detergent solution. If it's determined that a bleach solution is required, use a solution of 10% household bleach (1-1/2 cups of bleach in a gallon of water). Wash the mold area with the solution and let stand for 10 minutes.

The work area should be HEPA vacuumed. Discarded material should be put in a sealed plastic bag before being disposed. There are no other special requirements for the disposal.

2474 Cleaning Moldy Gypsum Board

Small mold areas on gypsum board may be cleaned with a damp rag using baking soda or a bit of detergent. Do not allow the gypsum board to get too wet.

Badly damaged or larger areas of gypsum board will have to be removed. Cover the moldy gypsum board area with a piece of 6 mil polyethylene large enough to cover the mold area and at least 8 inches beyond. Secure the edges of the poly with sheathing or duct tape. Cut around the border of the taped area and remove the gypsum board. Bag the moldy material in heavy-duty garbage bags or wrap in 6 mil poly, tape the joints and dispose. Wash the surrounding area with a mild detergent solution and dry quickly.

300 Mobile Homes

Best Practice Recommendations:

- Air sealing should be limited to sealing ductwork and large holes needed to hold insulation in place until all insulation measures have been completed and a blower door test has been conducted.
- Cost effectiveness of insulating floors, sidewalls and roof cavities should be examined by State Weatherization Programs. If cost effective, actions should be taken to increase local agency capacities to include these measures as part of production.
- Replacement windows should be double-glazed.
- Pressure-pan testing should be done in all mobile homes.
- Replacement water heaters should be done with HUD approved units.

Construction practices used in mobile homes differ from those used in site-built homes. As a result, there are a number of inherent thermal deficiencies in mobile homes not found in site-built homes. It is not surprising then that the thermal performance of mobile homes is generally poorer than site-built homes. This section addresses those thermal deficiencies unique to mobile homes. Otherwise, procedures described in other sections of this Guide apply.

The manufacture of mobile homes was not governed by any code prior to the mid-1970s. In 1976, the Department of Housing and Urban Development (HUD) established a national code governing mobile home assembly. Known as the HUD Code, this minimum standard improved both the quality and thermal performance of mobile homes.

Mobile homes manufactured prior to the 1976 HUD Code may be identified from the following characteristics:

- 2”x 2” or 2”x 3” sidewall studs,
- Little or no insulation in the walls, floors and ceilings,
- No vapor barrier in the ceiling,
- Uninsulated ducts in the floor or ceiling, and
- Jalousie windows.

It should come as no surprise that pre-1976 mobile homes suffer from poor thermal performance given the above characteristics. Thermal performance improved as a result of the HUD Code, but some minimum requirements still lagged behind what was typically found in site-built homes. Mobile homes built after 1976 may be identified by the following minimum characteristics.

- 2”x 4” sidewall studs,
- Minimum R7 sidewall and floor insulation and R11 ceiling insulation,
- Ceiling vapor barrier,
- Insulated ducts or ducts intended to be located within the conditioned space, and
- Single-hung or slider windows.

The HUD code was further modified again in 1985 and 1994. These changes improved both the indoor air quality and thermal performance of mobile homes. In addition, the term “manufactured home” started to replace “mobile home”. In fact, it is often difficult to distinguish between new double-wide manufactured homes and site-built homes. Construction techniques and thermal performance between the two housing types are now comparable.

This section addresses mobile homes built prior to 1985. It is in these homes where the thermal resistance of the floors, walls and roof cavity is poor and additional insulation may save significant energy. Duct leakage is often a significant problem that can also provide significant energy savings. Air leakage and poor heating system efficiency are also common problems in these older mobile homes.

310 Air Leakage

A Building Tightness Limit (BTL) should be established for mobile homes per Section 1113, “Building Tightness Limit”. See section 1115 for determining air sealing guidelines.

Because insulating mobile home floors, walls and roof cavities often make a mobile home tighter, it is recommended that air sealing be limited to sealing ductwork and large holes needed to hold insulation in place until all insulation measures have been completed and a blower door test has been conducted. Additional air sealing may then be done if the existing air leakage rate is above the mobile home’s BTL.

3101 Air Leakage Locations

The following are common air leakage problems in mobile homes.

- Plumbing penetrations in floors, walls, and ceilings.
- Water heater closets with exterior doors having large openings into the bathroom and other areas.
- Torn or missing underbelly, exposing flaws in the floor to the space beneath the mobile home.
- Gaps around the electrical service panel box, light fixtures, fans, and flue pipes.
- Joints between the halves of double-wide mobile homes and between the main dwelling and additions.
- Under bath sinks, around dryer vents, furnace flues and return air registers.

320 Mobile Home Insulation

Effective methods for insulating mobile home floors, walls and roof cavities have been developed over the past 25 years. Insulation should not be installed if moisture problems found in wall and roof cavities cannot be corrected. Mobile home floors should not be insulated if a plumbing leak cannot be repaired. Note, however, that insulating mobile home floors may help keep exterior moisture from moving-up into the mobile home. See section 133, “Moisture Assessment”, for additional information regarding moisture problems.

3201 Floor Insulation

Mobile home floor insulation is a beneficial measure for heating climates. Existing insulation was fastened to the bottom of the floor joists during assembly leaving the cavity uninsulated and subject to convection currents. The floor cavity may be blown with fiberglass insulation.

32011 Preparing for Mobile Home Floor Insulation

The belly material of the mobile home should be inspected prior to blowing floor insulation. Crawling under the mobile home to inspect the belly may be a problem, but is necessary to ensure that problems with the belly can be corrected prior to or as part of the floor insulation job.

Ensure that floor cavity is not being used as a belly-return air plenum. The belly-return must be converted to central return[31] before floor cavity is insulated. See section 34043, "Converting Belly-Return Systems".

Test ducts to ensure that they are tight (see section 3404, "Ductwork"). Seal all holes in the duct system before insulating floor cavity. Ensure that duct boots are securely fastened to sub-floor and main trunk.

Determine location of water pipes in the floor cavity. There must be a minimum of 3 inches between the belly material and pipes for floor insulation. If it is not possible to get 3 inches of floor insulation between the belly material and pipes, the pipes must be insulated or moved closer to the floor above. Otherwise, the floor cavity should not be insulated.

Tightly seal all holes in the floor to prevent loose insulation from blowing into the living space.

Seal large holes in the belly material and ensure that all plumbing problems are solved before insulating. Patch holes with insulated foam board, fiberboard or belly-paper (nylon reinforced material specially manufactured for mobile homes). Secure patches with stitch-staples and caulk, screws or lath strips.

Install a ground moisture barrier if there are signs of ground moisture problems. The ground barrier also makes it easier and cleaner for crews to work under the mobile home.

32012 Insulating the Floor

Floor cavities should be insulated with blown fiberglass installed to a density of 1.25 lbs/ft^3 to 1.75 lbs/ft^3. Cellulose is not to be used because of weight. Dense-packing cellulose may also damage the belly material. Carefully estimate number of bags needed to insulate floor cavity so as to avoid putting excessive pressure on belly material.

Blowing a mobile home floor

[31] A central return is defined as a return air system with one return air grille. Return air may be ducted to the furnace or, as in the case of mobile homes, air returns to the furnace through louvered doors to the furnace closet.

There are two favored methods of insulating mobile home floors. The side-blow method involves drilling through the rim joist and blowing insulation through a grey PVC fill tube to reduce static electricity. The belly-board method involves blowing fiberglass insulation with a flexible fill tube through holes cut in the belly material.

During the insulation process, periodically inspect interior of mobile home and ducts to ensure that loose insulation is not getting into the home or ducts.

320121 Side Blow Method

Each joist cavity in the floor is insulated through holes cut in the rim joist. Remove trim pieces to expose the rim joist. Drill carefully to avoid wiring located adjacent to rim joists. Block drilled holes with wood plugs following insulation. Seal plugs with adhesive prior to replacing trim.

Ducts running Crosswise to the Mobile Home

Drill two 2-9/16 inch holes into adjacent joist cavities on opposite sides of the mobile home to avoid excessive weakening of the rim joist. The belly-board may have sags in it where it dropped down from the joists, especially near the center where the duct is located. It may be necessary to push the belly-board up and secure to the joists to avoid installing unnecessary amounts of insulation. Leave a minimum 3 inch space between the belly material and bottom of duct and pipes for insulation.

Ducts running the Length of the Mobile Home

The rim joists on the short sides of the mobile home are non-structural. Drill two 2-9/16 inch holes into each cavity at the front and rear of the home as it may be difficult to insulate the entire joist run from one side. Insulate half the cavity from each end of the home.

Attach sections of rigid fill tubes as needed to fill each cavity.

320122 Belly-Board Method

For crosswise joists, use existing holes or cut slits near the center of the home. Extend a flexible fill-tube out to the rim joist. Fill cavity from edge back towards hole. Repeat procedure on other side of joist cavity.

Secure sections of belly-board to floor joists where sags are present to avoid blowing an unnecessary amount of insulation into the cavity. Leave a minimum 3 inch space between the belly-board and bottom of duct and water pipes for insulation.

For ducts that run the length of the mobile home, cut holes into each joist cavity. Space holes along the floor cavity at approximately the same length as the fill-tube.

3202 Sidewall Insulation

Mobile home walls are usually partially insulated. It is common for the existing insulation to fill only half of the wall cavity's thickness. The cost effectiveness of installing mobile home sidewall insulation should always be determined.

Sidewalls should not be dense-packed or over-filled. Inspect exterior siding and interior panels and repair or reinforce sections as necessary before insulating. Seal holes and cracks in interior wall panels to keep loose insulation from getting into the home.

32021 Electrical Assessment

The client should be asked about any known existing electrical problems. Assess type and condition of electrical wiring. Electrical #12 aluminum or #14 copper wiring must be protected with 15 amp fuses or breakers. Cavities should not be insulated if excessive movement of the wires will occur. Each outlet, switch, or light fixture should be checked for proper operation with a receptacle tester before and immediately following the completion of the insulation work.

If aluminum wiring is present, an electrician should check that the wiring is safe both prior to and after installing sidewall insulation. If an electrician cannot certify the safety of the wiring, wall cavities containing aluminum wiring are not to be insulated.

32022 Insulation Methods

Access to mobile home walls is from the bottom of the siding. If horizontal siding is present, the bottom section of siding is removed. If vertical siding is present, the siding is loosened by removing the bottom row of screws. Joints in the vertical siding pieces may need to be secured with short sheet-metal screws.

Fiberglass batts or blown fiberglass insulation should be used. Cellulose should not be used because of moisture absorption, density and weight. Areas above windows and doors are difficult to access and probably not worth insulating.

The client should remove wall hangings where the nail is in the cavity before the walls are insulated.

Walls may be insulated using the batt-stuffer method or may be blown.

Batt-stuffing a mobile home wall cavity

320221 Batt-stuffing Mobile Home Walls

This method works on about 50 percent of metal-sided mobile homes. It is faster than blowing the wall and works well for partially insulated walls or wall cavities with obstructions. Poly encased or vinyl faced fiberglass insulation is preferred for this application, however kraft-faced and unfaced batts will also work.

- Use a batt stuffer made of quarterinch Lexan® (polycarbonate plastic), 10 or 11 inches wide and 96 inches long.

- On the ground, lay a piece of plastic sheeting, measuring approximately the same size as the unfaced batt and the stuffer.
- Cut batts approximately 8 inches longer than the wall cavity height.
- Lay the batt on the plastic and the batt-stuffer on the batt.
- Lap a few inches of the batt and plastic sheeting over the top of the batt-stuffer. Stuff the batt up into the wall between existing insulation and the interior paneling, with the plastic sheeting against the wall paneling. The plastic sheeting may remain in place.

320222 Blowing Mobile Home Walls

Blowing mobile home wall cavities is recommended for cavities that cannot be stuffed with batts. Additional insulation is blown between existing insulation and interior paneling with a flexible fill tube with a 1-1/4 inch inside diameter. The end of the hose should be cut on a 45 degree angle to facilitate movement up the wall cavity. Use the natural curvature of the tube to help push the tube up the wall cavity. Ensure that interior paneling is sound.

- Remove screws from bottom of exterior siding.
- Pull siding and existing insulation away from studs.
- Insert tube to the top of the wall cavity with tip sliding against interior paneling.
- Avoid overfilling the cavity and bulging the exterior siding.

To prevent over-filling the wall cavity, loose blow the bottom of the cavity with an unfaced batt stuffed in the bottom of the cavity to prevent insulation from blowing out of the wall cavity.

3203 Roof Cavity Insulation

Blowing a closed mobile home roof cavity is similar to blowing a closed wall cavity, only the insulation does not have to be as dense. Fiberglass blowing insulation is preferred. Cellulose should not be used because of moisture absorption, density and weight.

Venting mobile home roofs is optional. Vent installation may be considered part of an overall strategy to keep moisture out of the roof cavity.

Ensure that electrical problems do not exist in roof cavity before insulating (see section 32021, "Electrical Assessment").

Occupants of mobile homes in heavy snow load areas should be advised that snow loads will likely increase due to roof cavity insulation. Occupants should be advised not to shovel snow off of the roof, but rather use a push broom if there are concerns.

There are two common methods for blowing mobile home roof cavities. The first is cutting a square hole in the metal roof and blowing fiberglass through a flexible fill-tube. The second is disconnecting the metal roof at its edge and blowing fiberglass through a rigid fill-tube.

32031 Preparing to Blow a Mobile Home Roof

See section 21211, “Heat Producing Devices”, for information with respect to insulation clearances. Generally, insulation should be kept a minimum of 3 inches from heat producing devices such as non-Type-IC rated recessed lights.

- Inspect the ceiling and seal all penetrations.
- Reinforce weak areas in the ceiling.
- Inspect seams and joints on the roof. Seal open seams and joints before or during insulation installation.
- Take steps to maintain safe clearances between insulation and recessed electrical fixtures.
- Assemble patching materials such as metal patches, sheet-metal screws, putty tape, and roof coating.

32032 Blowing a Mobile Home Roof from the Edge

This procedure requires a scaffold to be performed safely and efficiently. The roof cavity may have to be accessed from both sides of the mobile home if a “strongback”[32] is present in the roof assembly and the fill tube won’t fit under it. Mobile home metal roofs are usually fastened only at the edge, where the roof joins the wall.

- Remove the screws from the metal j-rail at the roof edge. Also remove staples or other fasteners. Scrape off putty tape.
- Pry the metal roof up far enough to insert a 2 inch diameter, 14 foot long rigid fill tube.
- Blow insulation through the fill-tube into the cavity. Loose blow the last few feet (nearest installer) to prevent insulation from blowing out. Stuff the last foot or two with unfaced fiberglass batts.
- Re-attach roof edge to the wall using new putty tape and larger screws. Re-attach rain gutter.

32033 Blowing Through the Top

This procedure is not recommended for metal roofs in heavy snow load areas. Instead, install insulation from the roof edge (section 32032) in these areas.

- Cut 10 inch square holes at the roof’s apex on top of every second truss. Each square hole allows access to two truss cavities.
- Existing aluminum roof coating around hole must be removed before new patch is installed. The coating must be heated and then may be scraped-off.
- Use a 2 inch or 2 ½ inch diameter fill-tube. Insert the fill-tube and push it out toward the

Blowing a mobile home roof from the edge

[32] A beam used as a stiffener in some mobile home roofs and floors.

edge of the cavity.

- Blow fiberglass insulation into each cavity. Install insulation to a density between 1.25 lbs/ft^3 and 1.75 lbs/ft^3. Do not overfill cavity.
- Stuff the area under each square hole with a piece of unfaced fiberglass batt so that the finished patch will stand a little higher than the surrounding roof.
- Patch the hole with a 14 inch square, 26 gauge galvanized steel. Seal with roof cement and screw into the existing metal roof.
- Cover the patch with a second 18 inch square patch of *Peal and Seal*.

330 Windows and Doors

3301 Window Replacement

Replacing windows and doors should only be done if determined to be cost-effective.

New jalousie or awning type windows are not acceptable as replacements. Replacement windows are to be double glazed with a thermal break. Cost effectiveness of low-E double glazed replacement windows should also be checked. Replacement windows with an emergency release are available and should be considered for replacement windows in bedrooms.

Inspect the condition of rough opening members when replacing windows. Replace deteriorated, weak or rotted framing members.

Prepare replacement window by lining the perimeter of the inner lip with 1/8 inch thick putty tape or 100% silicone caulk. Caulk exterior window frame perimeter to wall after installing window.

3302 Mobile Home Storm Windows

Interior storm windows are an allowable measure if determined to be cost-effective. Replacement of existing storm windows is not allowed unless the existing storm windows cannot be re-glazed or repaired.

Two kinds of interior storm windows are common in mobile homes. RDG storm windows clip into a frame that is then screwed into the wall. RDG storms are installed over awning and jalousie windows. Interior sliding storm windows are used with sliding windows.

3303 Mobile Home Doors

Mobile-home doors are available in two basic types: the mobile-home door and the site-built house door. Mobile home doors swing outward and site-built house doors swing inward.

Door replacement is an allowable expense only when the existing door is damaged beyond repair and constitutes a severe air leakage problem.

340 Mobile Home Furnaces

A great majority of mobile homes are equipped with downflow furnaces, designed specifically for mobile homes. Mobile home furnaces are different from conventional furnaces found in site-built homes in the following ways:

- Mobile home furnaces are sealed combustion units that use outdoor combustion air vented directly to the unit.
- Gas-fired furnaces contain kits that allow the use of either propane or gas as fuel.
- Return air to the furnace usually passes through a large opening in the furnace rather than a ducted return. Supply air is returned to the furnace through the living space. The furnace closet door must have louvers or grilles that allow the air back to the furnace return air opening.

3401 Furnace Replacement

Mobile home furnaces must be replaced by furnaces designed and listed for use in mobile homes. See section 223, “Heating System Replacement Standards”, for heating system replacement guidelines.

3402 Furnace Maintenance

Mobile home furnaces should comply with the combustion safety and efficiency standards as discussed in sections 2211 and 2212, “Gas Burner Servicing Requirements” and “Oil Burner Maintenance and Adjustment”.

3403 Furnace Venting

Mobile home furnaces often use manufactured chimneys that include a concentric passageway for combustion air. When replacing a mobile home furnace, note any differences between the old and new furnace supply air paths. Follow manufacturer’s instructions exactly.

Inspect the vent for signs of rust, cracks, holes or unsealed or disconnected sections. Repair or replace if necessary.

3404 Ductwork

34041 Duct Leakage Locations

The following locations have been identified as the most serious duct problems in mobile homes.

- Floor cavities used as return-air plenums. Plenum return systems should be eliminated and replaced with central return systems through the living space back to the furnace (see section 34043, “Converting Belly-Return Systems”).
- The joint between the furnace and the main duct. The main duct may need to be cut open to access and seal these leaks.
- Joints between the main duct and its boots – the short duct sections joining the main duct to the floor register.
- Joints between duct boots and

Using metal and mastic to seal mobile home duct boots

floor.

- Disconnected, damaged or poorly joined crossover ducts, end of duct runs.

34042 Duct Leakage Standards

See section 113, “Duct Leakage Tests” for discussion regarding duct leakage. See section 11353, “Pressure-Pan Test Procedures” for recommended testing procedures.

Pressure pan readings must be adjusted based on a zone pressure in the floor cavity. Measure the pressure difference between the floor and living space alongside the boot cavity. Adjust pressure pan readings accordingly. See Table 1 for Pressure Pan Multipliers in section 113, “Duct Leakage Tests”.

The following duct leakage standards should be applied to mobile homes.

- For a central return system, all pressure pan readings should be 0 while a blower door is depressurizing the dwelling to -50 Pascals.
- For a central return system, a sum of 3 Pascals for the pressure pan readings is acceptable if:
  - The floor boots are sealed with mastic, as necessary; and
  - The ends of the supply trunk ducts are sealed.

  Goal: Attempt to reduce the sum of the pressure pan readings to zero Pascals.

- For a central return system, a sum of 5 Pascals for the pressure pan readings is acceptable if:
  - The floor boots are sealed with mastic, as necessary;
  - The end of the supply trunk ducts are sealed;
  - Any crossover ducts are visually inspected, repaired and sealed, as necessary (make sure these ducts are supported properly); and
  - The furnace plenum is sealed with mastic.

  Goal: Attempt to reduce the sum of the pressure pan readings to zero to 3 Pascals.

If difficulty is experienced meeting the goals, use a “pillow” (fiberglass insulation inside of a plastic bag) to block and segment sections of the ducted system to assist in finding leaks. Additionally, the duct may be inspected with a mirror and a strong flashlight.

34043 Converting Belly-Return Systems

Belly-return systems in mobile homes are notoriously leaky. Leaky return systems can significantly increase space heating costs and lead to thermal discomfort and indoor air quality problems.

When converting a belly-return system in a mobile home to a central return, follow the following procedures.

1. Add a grill with at least 200 in^2 of net free area to the furnace closet door.

2. Block all floor return registers with a durable material to keep floor insulation from being blown into the home. Look carefully to find hidden registers under built-ins, behind furniture, and in kitchen toe-kick spaces.
3. Completely block and seal all floor openings in the furnace closet using a fire retardant air barrier, being careful to not seal the combustion air inlet.
4. Check the temperature rise of the furnace to ensure that the airflow is not restricted after floor insulation has been installed. The temperature rise should be within the range specified on the manufacturer's label or between 40^o and 80^o F.
   a. Inspect the plenum/furnace joint at the floor before measuring the temperature rise. Repair this joint, if needed, before measuring temperature rise.
   b. Make sure all interior doors are open, except the furnace closet door which should be completely closed.
   c. Turn on the furnace and allow the temperature of the supply air to stabilize. Measure the temperature at the register closest to the furnace, making sure that the airflow to this register is not blocked and that there is no significant duct leakage between the furnace and the thermometer.
   d. Subtract the house air temperature – the return air – from the supply air temperature. The difference is the temperature rise.
   e. If the temperature rise is greater than the recommended range the airflow is restricted by an:
      i. Undersized opening in the furnace closet door, or
      ii. Another restriction in the ductwork
   f. If the temperature rise is less than the recommended range, there might be:
      i. Significant leakage at the furnace/plenum joint, or
      ii. Significant leakage in the duct between the furnace and the supply air register where the temperature was measured.
5. Once the temperature rise is within the recommended range, measure room-to-room pressure differences and relieve pressure differences that are greater than 3 Pascals. Additional information on this test may be found in section 1142, "Duct Induced Pressures".
   a. Close all interior doors. Measure the pressure difference across all interior doors. Pressure test and record measurements for all rooms with reference to the main body of the house.
   b. Take action if room pressure difference exceeds 3 Pascals. Provide pressure relief by:
      i. Opening the door slightly while measuring the pressure difference across the door. Open the door until the pressure difference is 3 Pascals or less and measure the square inches of opening. This is the number of square inches:
         - The door must be undercut, or
         - A direct grille, offset grilles, or jump duct must be installed properly relieve the pressure imbalance caused by the distribution system when the door is closed.

34044 Crossover Ducts

Crossover ducts are generally made with flex duct. Inspect crossover ducts for the following conditions and correct as necessary.

- Ducts should not be compressed nor should sharp bends be present.
- Ducts should be insulated to a minimum R8.
- Sags in crossover ducts should be limited to 12 inches over an eight foot span.
- Ducts should be mechanically secured to belly of mobile home.
- Joints should be sealed with mastic or aluminum foil-backed butyl tape.

Damaged crossover duct work should be replaced. Cut-out damaged sections. Insert and secure metal sleeve between remaining pieces of duct. Seal joints with mastic or aluminum foil-backed butyl tape.

34045 Duct Sealing

Any portion of the duct work that extends beyond the last register or grille may be sealed.

Trunk end blocks are only allowed if it is determined that duct air leakage reduction will result from installation. End blocks should be made from sheet metal or aluminum flashing. A fire rated two-part foam may also be used. Any metal end blocks must be mechanically attached to the duct system. Gaps between the end block and the duct must be sealed with mastic. If possible, install the trunk end block at least one foot beyond the last register location. Duct "sweeps" or sloped end blocks are not to be used.

See sections 2271, "Duct Sealing" and 2273, "Improving Duct System Airflow" for additional information regarding duct sealing procedures and methods for improving airflow.

350 Mobile Home Water Heaters

3501 Water Heater Replacement

Water heaters installed at the time of mobile home assembly were HUD approved for mobile home installation. Consider the following when replacing mobile home water heaters:

- Become familiar with the HUD code for water heaters and apply those standards when advising about, working on, or replacing water heaters in manufactured homes.
- Water heaters, whether gas or electric, should be installed to discourage storage of combustibles around these heat producing appliances. Clearances around water heaters should be minimized to avoid this problem, but must be in accordance with manufacturer's instructions.
- Installation of gas- or propane-fired water heaters must provide for the complete separation of the combustion air and the conditioned space[33]. Replacement water heaters should be HUD approved for mobile homes.
- Water heaters should be installed with a drain pan.

[33] HUD Code, #3280.709(d)

3502 Water Heater Closets

At a minimum, water heater closets with an exterior wall must be treated as follows:

Mobile home water heater closet with gas-fired water heater

- The exterior access door and adjacent exterior walls of closets containing water heaters should be insulated. If the door and adjacent wall can be insulated, the water heater should not be wrapped with insulation.
  - Cover any air vents in the door or adjacent exterior wall.
  - Bring combustion air from underneath the belly or through the skirting by installing an appropriately sized metal chute with a rodent barrier. If the mobile home is skirted, this metal chute must extend to the outside of the skirting.
- If it is not possible to insulate the closet door and adjacent wall area:
  - The tank should be wrapped with an insulation blanket (see section 22422, "Tank Insulation").
  - Large holes in the closet walls that allow air leakage into the interior must be sealed.
  - All plumbing within the closet that is susceptible to freezing must be insulated.
  - An adequate amount of combustion air must be provided to gas- and propane-fired water heaters.

360 Water Supply Systems

Water pipes that have not been covered by floor insulation should be insulated to a minimum of R3.5. Piping should be free from water leaks and properly secured to support the weight of the piping and insulation. Pipe insulation should be preformed to fit standard pipe diameters. Pre-formed dimensions should be appropriate for the pipe size. If the insulation is exposed to the weather, it should be resistant to degradation from moisture and ultraviolet light. If the insulation cannot provide this protection, a jacket or facing should be installed that protects the insulation from these conditions.

To prevent freezing, box the individual water supply system pressure tank with 2 inches of extruded polystyrene insulation. Ensure the outer surface of this insulation is protected from direct sunlight.

400 Final Inspection Tests

Best Practice Recommendations:

- Blower door tests should be done when all weatherization work has been completed to evaluate effectiveness of air sealing work. If this test was not done, it must be completed during the final inspection.
- Homes should be visually inspected for evidence of effective air sealing work. Zone pressure diagnostics may be helpful to evaluate air sealing activities when “hidden” air sealing has occurred (bypass sealing under attic insulation, for example).
- Visual inspection and duct testing should be done during the final inspection to verify work results when duct repair and sealing has been specified.
- If a worst-case draft test was not done after weatherization work was completed, it must be completed during the final inspection.
- If a steady-state combustion efficiency test for gas- and oil-fired appliances was not done and thoroughly documented following completion of heating system work, it must be completed during the final inspection.
- If gas range inspection and testing was not done and thoroughly documented during the weatherization work, it must be inspected and tested during the final inspection.

411 Blower Door Testing

4111 Introduction

A blower door test should be done at the final inspection in order to determine that the air sealing work for the job was successful. Some programs require the weatherization workers to perform a blower door test after all the work has been completed, but before final inspection. This is the preferred method. For these programs, the final inspector performs a blower door test to verify that the post-weatherization CFM_{50} value determined by the workers is correct.

In other programs, the only post-weatherization blower door test is done by the inspector. This method is not recommended because the inspector might find problems that require the workers to return to the site. This is expensive and can upset schedules. If the workers perform a post-weatherization blower door test themselves, it is likely that they will find any weatherization deficiencies themselves. It is always better for crews or contractors to perform a post-weatherization blower door test and strongly recommended that blower door testing be performed during the air sealing activities to help guide those tasks.

The job file should be examined for documentation of other blower door test readings taken before, during, and after the weatherization process. These results should be checked for reliability; the progressive tightening of the dwelling should demonstrate a realistic reduction in the blower door readings.

4112 Blower Door Test Setup

The house setup for the blower door test performed during the final inspection must be the same as the setup for the pre- and post-weatherization blower door tests. The inspector should set the blower door up in the same opening and the house must be setup the same way. In order to do this, the inspector must have a record of the house opening used and other details so the previous tests can be replicated.

Please refer to Section 111, "Blower Door Test" for the instructions on the proper setup and operation of the blower door. Also, refer to the blower door operation manual.

In addition to proper setup, it is important, especially in cold climates, that the inspector know the exterior temperature at the time of the inspection test and at the time of the other significant tests, such as the pre- and post-weatherization tests. For every $10^{O}F$ reduction in temperature between one test and another with an open fan, there is a 50 CFM_{50} reduction.[34] For example, if the post-weatherization test was done at 70 ^{O}F outdoors, but the final inspection test was done at 10 ^{O}F outdoors, the 60 degree temperature difference will result in a final inspection test 300 CFM_{50} lower.

4113 Interpretation of Results

The results of the final inspection blower door test should be significantly less than the pre-weatherization blower door test results and similar to the post-weatherization blower door test, if one was performed.

As stated in Section 1115, "Air Sealing Guidelines", the guidelines established for air leakage reductions may take the form of a cost limit per 100 CFM_{50} reduction or may be based on the existing CFM_{50} leakage rate.

If a cost-effective guideline per 100 CFM_{50} is not established, target CFM_{50} levels based on a range of existing leakage rates may be used. Target CFM_{50} levels relate existing CFM_{50} leakage rates to expected post-weatherization leakage rates. Refer to Section 1115, Table 5 for target CFM_{50} levels.

The final inspection blower door test should verify that:

- The CFM_{50} reduction level achieved met the cost-effective guideline for the dwelling. This will require the appropriate data in the job file recorded by the crew or contractor.
- If cost-effective air sealing guidelines were not established for the job, the target CFM_{50} level was reached, based on Table 5 in Section 1115.
- That there is no evidence of remaining significant air leakage in the dwelling. This will require a walk-through inspection during blower door operation.

If significant air leakage is discovered during the final inspection, verify that:

[34] This assumes a depressurization blower door test and an open fan. If the "A" ring is used in the fan, there is a 20 CFM_{50} reduction for each 10 ^{O}F reduction in outdoor temperature. If the "B" ring is used in the blower door fan, there is a 10 CFM_{50} reduction for each 10 ^{O}F reduction in outdoor temperature.

- The weatherization installers made every reasonable attempt to reach the cost-effective guideline or target.
- Further air sealing was not cost effective, or
- The home is at or below the BTL.

When significant air leakage is discovered, there must be a written explanation for the reason in the job file.

412 Zone Pressure Diagnostics Testing

4121 Introduction

Using zone pressure diagnostics (ZPD) pre- and post-weatherization can be a very useful tool for determining the thoroughness of weatherization work. As explained in Section 112, "Zone Pressure Diagnostics", ZPD methods can indicate the square inches[35] of leakage in a pressure boundary, such as the total square inches of leakage in an attic floor.

Whenever possible, inspect the parts of the dwelling that have been air sealed during the weatherization process. In most cases, there should be evidence of air sealing. For example, if the basement walls were tightened, there will be clear indication of the work. However, in some cases, it is very difficult to visually inspect air sealing work. The best example of this "hidden" air sealing work is that done to an attic floor before the insulation is blown. At final inspection, all of this air sealing work is covered by the insulation, making it very difficult, if not impossible, to perform a visual inspection. In such cases zone pressure diagnostics can be very useful.

4122 Inspection Procedures

41221 Zone Pressure Diagnostics for Primary Zones

Primary zones are spaces that can be physically accessed and inspected. Typical primary zones include attics, crawl spaces, basements, and attached garages. Because temporary openings can be created to the house and/or to the outdoors from these primary zones, an air leakage rate (CFM_{50}) between the house-to-zone and zone-to-outside can be determined.

These methods can determine the effectiveness of air sealing efforts. For example, if the pre-weatherization leakage area in an attic floor was 200 square inches and the inspector determines the post-weatherization leakage area is 40 square inches, it is obvious that air sealing was a success.

Whether to perform ZPD during a final inspection should be guided by the work order. If ZPD was done before or during weatherization, it is usually helpful to

[35] This is done by determining the flow in units of CFM_{50} through the pressure boundary and then dividing the CFM_{50} flow by 10. For example, if the flow through the attic floor is 2000 CFM_{50}, the approximate leakage in this pressure boundary is 200 square inches.

use ZPD during the final inspection to either verify other ZPD results and/or to determine the effectiveness of air sealing efforts.

If ZPD was not done before or during weatherization, it is usually not very useful to perform during a final inspection. However, if there is suspicion the air sealing work was performed poorly or not at all, determining the leakage area in a pressure boundary with ZPD may be helpful.

41222 Zone Pressure Diagnostics for Secondary Zones

Secondary zones are spaces where only pressure differences can be determined, the inspector cannot determine CFM_{50} flow nor square inches of leakage in a pressure boundary.

As described in Section 112, ZPD for secondary zones can be very misleading because the house-to-zone and zone-to-outside pressures always add up to 50 Pa. When using ZPD techniques for secondary zones, the inspector must be very careful to interpret the results correctly.

413 Duct Leakage Testing

4131 Introduction

Duct leakage test procedures and standards are discussed in Section 113, "Duct Leakage Tests". When duct repair and sealing has been specified on the work order, inspection and testing should be done during the final inspection to verify work results. Duct repair and sealing is most important for mobile homes.

4132 Inspection Procedures

During final inspection, ensure that:

- All disconnected ducts have been repaired.
- Boots are sealed as specified in the work order.
- Ductwork is sealed as specified in the work order.
- All duct sealing is done with the proper materials.
- Ductwork is insulated as specified in the work order.
- Ensure that temperature rise of furnace is within range.
- Pressure pan values measured during the final inspection are similar to those measured by the workers.
- Duct Blaster™ results obtained during the final inspection are similar to those measured by the workers.

414 Duct-Induced Pressure Testing

4141 Introduction

Dwellings with ductwork, mobile homes in particular, should be tested for duct-induced room pressure differences during final inspection. Refer to Section 114, "Duct-Induced

Pressures", for instructions. Significant pressure differences from one room to the next can cause wasted energy by increasing air leakage and can lead to occupant discomfort. In homes with ductwork, this testing should be completed before the worst-case draft test is performed.

4142 Inspection Procedures

Follow the procedures for duct-induced room pressure testing, including proper house setup. Confirm that the pressure difference from each room to the main body of the dwelling is 3 Pa or less when the door to the room is closed and the air handler is operating.

If a mobile home has been converted from a belly-return system to a central return, make sure that:

- All return registers in the floor have been properly sealed.
- The return grate in the floor of the furnace closet has been properly sealed.
- The furnace room closet door has been changed to a louvered door.
- The return air system is performing as it should.

421 Worst-Case Draft Testing

4211 Introduction

Worst-case draft testing is a very important health and safety procedure. This test must be carefully completed after all weatherization work is completed and the workers are about to leave the job. Please see Section 123, "Worst-Case Draft Testing", for step-by-step instructions. Chances are that this test will have been completed by the time of the final inspection with a record of the test results in the job file. If the test has not been done, it must be completed by the inspector.

Worst-case draft testing must be done in all dwellings. The following are *exceptions* to this requirement:

1. If the house or mobile home is all-electric with no combustion appliances, woodstoves or fireplaces, or all combustion appliances are sealed combustion (direct vent) or unvented (vent free).
2. If the dwelling has a boiler and/or an atmospheric water heater ***and*** has no exhaust equipment, including clothes dryers, vented bath and kitchen fans, vented central vacuum systems, fireplaces, woodstoves, etc.
3. If the CAZ is located outside of the thermal boundary, such as mobile home water heater closet or a garage, a worst-case draft test does not have to be performed. However, always perform this important test if the CAZ in is in a basement.
4. In apartments with no combustion appliances other than unvented or direct-vent combustion appliances.

Before the final worst-case draft test is done, make sure all weatherization work and all diagnostic testing has been completed, particularly the duct-induced room pressure test.

4212 Inspection Procedures

Inspect the job file for a record of worst-case draft test results. If there is no record of worst-case draft testing and you are certain that none was performed, conduct the test according to the procedure in Section 123.

If any vented combustion appliances fail the worst-case draft test, specify corrective action as soon as possible. Warn the client of the potential backdrafting hazard and condemn the failed appliances, if appropriate.

422 Combustion Efficiency Testing

4221 Introduction

A steady-state combustion efficiency test for gas- and oil-fired furnaces and boilers is usually done before the final inspection by either an assessor or a heating system subcontractor. Check the job file for a record of these test results. If there is no record of a test and an efficiency test is appropriate, perform the steady-state efficiency test according to the procedure in Section 121, “Furnaces and Boilers”. Acceptable combustion efficiency results should be within the range of Table 121-1 in that section.

4222 Inspection Procedures

Follow the procedures in Section 121 for completing the final inspection. The final inspection procedures include conducting these tests:

- Smoke test (oil-fired units only).
- Combustion efficiency testing.
- Worst case draft testing.
- Carbon monoxide testing.
- Gas leak testing for gas distribution lines and gas appliances.
- Temperature rise for forced air furnaces.

In addition, ensure that combustion air requirements are in accordance with NFPA 54 for gas-fired systems, NFPA 31 for oil-fired systems, and NFPA 211 for solid-fuel appliances.

423 Gas Range Testing

4231 Inspection Procedures

Follow the procedures in Section 124, “Gas Range Testing”, for completing the final inspection of gas ranges. The final inspection procedures should include conducting these tests:

- General range inspection.

- Range top inspection.
- Oven area inspection.
- Range top burner carbon monoxide emissions testing.
- Oven bake burner carbon monoxide emissions testing.

Appendix 111 Blower Door Tests

A11131 Building Tightness Limit (BTL method), Basic Calculation

Occupancy

BTL based on occupancy is based on actual number of people living in the home or number of bedrooms plus one person, whichever is larger. A minimum of 5 occupants shall be used for each home.

$BTL_{occupancy}$ = Occupants x 15 CFM/person x n

where:

$BTL_{occupancy}$ = CFM_{50} based on occupancy,
Occupants = number of occupants (or number of bedrooms, plus one),
15 CFM/person = requirement of ASHRAE 62-2001,
n = LBL correlation factor (varies between 9.8 and 25.8); see http://homeenergy.org/archive/hem.dis.anl.gov/eehem/93/930309.html.

Consider increasing the number of occupants for each of the following conditions.
1. Add one additional "occupant" for each smoker in the home.
2. Add one additional "occupant" for every pet or group of pets over 75 pounds that live in the home.

Volume

Determine BTL based on the volume of the home. Include the volume of the basement if it is a conditioned space and could be converted to living space in the future.

BTL $CFM_{50volume}$ = (Volume x 0.35 x n) ÷ 60

where:

BTL $CFM_{50volume}$ = BTL based on house volume,
Volume = volume of house (ft^3), above grade and conditioned,
0.35 = air changes/hour natural (ACH), requirement of ASHRAE 62-2001,
n = LBL correlation factor (varies between 9.8 and 25.8),
60 = minutes/hour.

A11132 Building Tightness Limit (BTLa method), Advanced Calculation

The complexity of this calculation requires the use of a computer or programmed calculator. For the advanced BTLa method, these values must be entered into the computer or programmed calculator:

- House CFM_{50},
- Weather factor,
- House square footage,
- House volume,
- House height, and
- Number of occupants (or bedrooms, plus one).

The program then determines the output values of:

- Effective leakage area,
- Equivalent leakage area,
- Natural air leakage, CFM,
- Air Changes per Hour (ACH),
- Natural air leakage CFM per person,
- Minimum CFM of fresh air required,
- CFM_{50} Building Tightness Limit (BTLa), and
- CFM of mechanical ventilation, if needed.

Some versions of The Energy Conservatory software for Windows called TECTITE calculate the output values listed above, except for the CFM_{50} Building Tightness Limit (BTLa). For information, see www.energyconservatory.com.

The ZipTest Pro and ZipTest Pro^2 software for the Texas Instruments TI-86 programmable calculator calculate all of the output values listed above. For information, see www.karg.com/software.htm.

A1115 Air Sealing Guidelines

A commonly used cost-effective guideline format is to calculate the maximum dollar amount (labor and material) that should be spent to produce a 100 CFM_{50} reduction. Air leakage reduction is checked by performing a "one-point" blower door test every one or two hours by the crew or contractor as they perform their air sealing activities. If the cost to achieve the last 100 CFM_{50} reduction is greater than the cost-effective guideline, air sealing work should stop. If the cost per 100 CFM_{50} reduction is less than the guideline, then air sealing work should continue until the guideline is exceeded.

Annual heating and cooling savings per 100 CFM_{50} reduction must first be calculated. Cooling savings should be calculated and added to space heating savings if cooling is present in the home. These calculations are shown next. Annual savings must then be converted to life cycle savings and labor and material cost must then be determined to calculate cost effective. The manner in which life cycle savings is determined and estimating local labor and material costs are left to the State Weatherization Programs.

- Annual Heating Savings/100 CFM_{50}
  \$ Heating Savings/100 CFM_{50} = [(26)(100)(HDD)(\$ Fuel)/(n)(SE)] x 0.60

where:

26 = constant
HDD = typical annual heating degree days, base 65°F
\$ Fuel = cost of fuel per Btu
n = LBL correlation factor (varies between 9.8 and 25.8)
SE = seasonal efficiency of heating system
0.60 = correction factor

- Annual Cooling Savings/100 CFM_{50}

$ Cooling Savings/100 CFM_{50} = [(0.037)(100)(CDD)($ Fuel)/(*n*)(SEER)] x 0.60
where:

0.037 = constant
CDD = typical annual cooling degree days, base $70^{o}F$
$ Fuel = cost of fuel per Kwh
n = LBL correlation factor (varies between 9.8 and 25.8)
SEER = seasonal efficiency of cooling system
0.60 = correction factor

The ZipTest Pro[2] software for the Texas Instruments TI-86 programmable calculator calculates the cost-effective guideline for air sealing work. The user of the software is instructed to continue or stop air sealing, depending on the information entered during a series of air sealing work sessions. For information, see www.karg.com/software.htm.

Appendix 112 Zone Pressure Diagnostics

CFM_{50} flow rates may be measured between the house and zones or between zones and the outside. Leakage areas between the house and zones or zones and outside may then be determined.

Total path air leakage (CFM_{50}) between the house and outside through zones may also be determined. Total path air leakage provides an indication of total house leakage that may be attributed to air flows through zones. For example, a house has an existing leakage rate of 3800 CFM_{50}, total path air leakage from the attic measured 800 CFM_{50} and total path air leakage from the conditioned crawl space measured 500 CFM_{50}. Therefore, a total of 1300 CFM_{50} leakage is occurring through these two zones and 2500 CFM_{50} is occurring through the remaining shell of the home (walls, windows and doors).

A1121 Flow Rates with Opening Created between House and Zone

House-to-zone flow rates may be determined when an opening can be made between the house and zone. An estimate of the leakage area between the house and zone may then be determined. Typical zones and openings between the house and zone are listed below.

- Unfinished attic (hatch, door)
- Space behind knee walls (hatch)
- Attached garage (door between house and garage)
- Crawl space (hatch between house and crawl space)
- Basement (door between basement and house)

1. Select zones where pressure readings will be taken. Determine where openings between the house and zone (hatches, doors) may be created. The opening should be created in the pressure boundary with the highest pressure difference reading. For example, if the house-to-attic pressure is 40 Pascals and the attic-to-outdoors pressure is 10, it is best to create the opening between the house and the attic.

2. Depressurize the house to -50 Pa (pressurization may be used, also).

3. Record the house-to-zone pressure with the opening closed. This is P1.

4. Open the door or hatch to the zone to drop the house-to-zone pressure by at least 15 Pa while maintaining the house-to-outdoor pressure at -50 Pa with the blower door. Now record the house-to-zone pressure with the air flowing through the temporary opening. This is P2.

5. Measure the size of the opening.

6. Refer to Table A112-1. Find the house-to-zone pressure from step 3 in the left-hand column (P1). Find the house-to-zone pressure with air flowing through the

opening from step 4 at the top of the table (P2). Read down and across to find the CFM_{50} per square inch of opening added.

7. Multiply the value from step 6 by the area of the opening (step 5) to find the CFM_{50} flow between the house and zone.

8. Using Table A112-2, the flow from the zone to the outside can be determined with P1 and the house-to-zone flow rate determined in step 7. Find the initial P1 (step 3) and multiply the corresponding value by the house-to-zone flow rate (step 7).

- Leakage Area

Leakage areas from the house to the zone and from the zone to the outdoors are approximately 10% of the calculated CFM_{50} values.

- Total Path Air Leakage

Using Table A112-3, total path air leakage may be determined from P1 and the flow rate from step 7. Find the initial P1 (step 3) and multiply the corresponding value by the house-to-zone flow rate (step 7). This represents the combined flow, in units of CFM_{50}, taking into account the resistance of *both* of the pressure boundaries.

Unfinished Attic Example (Opening between House and Zone)

An initial house-to-attic pressure of -42 Pa was measured (step 3, P1). The attic hatch was opened and the blower door was adjusted to bring the house back to -50 Pa. The house-to-attic pressure measured -14 Pa (step 4, P2). The value from Table 2 is 2.0 CFM_{50} per square inch of opening.

HOLE ADDED BETWEEN HOUSE & ZONE

CFM_{50} (House-to-Zone) per Square Inch of Added Hole

Table A112-1

P2

P1	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**
14	3.7																	
16	3.2	5.5																
18	2.7	4.6	6.8															
20	2.4	4.0	5.7	7.8														
22	2.1	3.4	4.9	6.5	8.6													
24	1.9	3.0	4.2	5.5	7.1	9.2												
26	1.7	2.6	3.6	4.7	6.0	7.6	9.6											
28	1.5	2.3	3.1	4.0	5.1	6.3	7.8	9.8										
30	1.3	2.0	2.7	3.5	4.3	5.3	6.5	7.9	9.8									
32	1.2	1.8	2.4	3.0	3.7	4.5	5.4	6.5	7.9	9.6								
34	1.0	1.6	2.1	2.6	3.2	3.8	4.5	5.3	6.4	7.6	9.3							
36	0.9	1.4	1.8	2.2	2.7	3.2	3.8	4.4	5.2	6.1	7.3	8.8						
38	0.8	1.2	1.5	1.9	2.3	2.7	3.1	3.6	4.2	4.9	5.7	6.8	8.2					
40	0.7	1.0	1.3	1.6	1.9	2.2	2.6	2.9	3.4	3.9	4.5	5.3	6.2	7.4				
42	0.5	0.8	1.1	1.3	1.5	1.8	2.0	2.3	2.7	3.0	3.5	4.0	4.6	5.4	6.4			
44	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.3	2.6	2.9	3.4	3.9	4.5	5.3		
46	0.3	0.5	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.6	1.8	2.0	2.3	2.6	2.9	3.4	4.0	
48	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.6	1.8	2.1	2.4

The size of the opening to create this pressure drop was 8” x 36” (288 in^2). The area of the opening is multiplied by 2.0 CFM_{50} per square inch, giving a CFM_{50} flow rate of 576 CFM_{50} between the house and attic without the opening.

The total area of bypasses between the house and zone is approximately 10% of the flow rate, or 58 in^2 (576 CFM_{50} x .10 = 57.6 in^2).

The zone-to-outside flow rate may be calculated with Table A112-2 with the initial house-to-zone pressure (P1) and house-to-zone flow rate. In the above example, the initial house-to-attic pressure was -42 Pa and the flow from the house to the attic was 576 CFM_{50}. From Table 3, 2.9 is multiplied by 576 CFM_{50} to yield an attic-to-outside flow of 1670 CFM_{50}.

Pressure Without Added Hole (P1)
Zone-to-Outside (CFM_{50})
Table A112-2

P1	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
	0.4	0.6	0.7	0.8	0.9	0.9	1.1	1.2	1.3	1.5	1.6	1.8	2.1	2.5	2.9	3.7	4.9	7.9

Total leakage area is about 10% of the flow rate, or approximately 167 in^2 (1670 CFM_{50} x .10 = 167 in^2) between the attic and outside. This value provides an approximate area of vents and roof construction air leakage (damaged soffits, missing fascia, etc. and typical air leakage).

Using Table A112-3, the initial house-to-attic pressure of -42 Pa and the house-to-zone flow of 576 CFM_{50} is used to determine total path air leakage. Total path air leakage from the outside to the house through the attic is 518 CFM_{50} (0.9 x 576 CFM_{50} = 518 CFM_{50}). This represents the combined flow, in units of CFM_{50}, taking into account the resistance of *both* of the pressure boundaries.

Total Path Air Leakage (House-to-Zone-to-Outside)
CFM_{50}
Table A112-3

P1	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8

A1122 Flow Rates with Opening Created between Zone and Outdoors

Zone-to-outside flow rates may be taken where an opening can be made between the zone and outside. An estimate of the leakage area between the zone and outside may then be determined. Typical zones and openings between the zone and outside are listed below

- Attached garage (garage door to outside)
- Crawl space (exterior access hatch, vents)
- Basement (basement windows or door between basement and outside)

1. Select zones where pressure readings will be taken. Determine where openings between the zone and outside may be made or opened (hatches, vents, windows, doors).

2. Depressurize the house to -50 Pa (pressurization may be used, also).

3. Record the house-to-zone pressure with the opening closed. This is P1. Note that this is the house-to-zone pressure – not the zone-to-outside pressure.

4. Create the opening from the zone to the outside to increase the zone-to-outside pressure by at least 15 Pa while maintaining the house to outdoor pressure at -50 Pa with the blower door. Now record the house-to-zone pressure with the air flowing through the temporary opening. This is P2.

5. Measure the size of the opening.

6. Refer to Table A112-4. Find the house-to-zone pressure from step 3 in the left-hand column (P1). Find the house-to-zone pressure with air flowing through the opening from step 4 at the top of the table (P2). Read down and across to find the CFM_{50} per square inch of opening added.

7. Multiply the value from step 6 by the area of the opening (step 5) to find the CFM_{50} flow between the house and the outdoors.

8. Using Table A112-5, the flow from the house to the zone can be determined with P1 and the zone-to-outside flow rate determined in step 7. Find P1 (step 3) and multiply the corresponding value by the zone-to-outside flow rate (step 7).

- Leakage Area

  Leakage areas from the house to the zone and from the zone to the outdoors are approximately 10% of the calculated CFM_{50} values.

- Total Path Air Leakage

  Using Table A112-6, total path air leakage may be determined from P1 and the flow rate from step 7. Find the initial P1 (step 3) and multiply the corresponding value by the house-to-outdoor flow rate (step 7). This represents the combined flow, in units of CFM_{50}, taking into account the resistance of *both* of the pressure boundaries.

Crawl Space Example (Opening between Zone and Outdoors)

An initial pressure of -20 Pa (step 3, P1) was measured between a house and crawl space. An exterior hatch was opened. The blower door was adjusted to bring the house back to -50 Pa. The house-to-crawl space pressure increased to -38 Pa (step 4, P2). The value from Table 5 is 5.3 CFM_{50} per square inch of opening.

HOLE ADDED BETWEEN ZONE & OUTDOORS

CFM_{50} per Square Inch of Added Hole

Table A112-4

P2

P1	14	18	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
2	2.4	2.1	1.8	1.6	1.4	1.3	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.5	0.4	0.4	0.3	0.2
4		4.0	3.4	2.9	2.6	2.3	2.0	1.8	1.6	1.4	1.3	1.1	1.0	0.9	0.7	0.6	0.5	0.3
6			5.3	4.5	3.9	3.4	2.9	2.6	2.3	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4
8				6.4	5.4	4.6	4.0	3.5	3.0	2.7	2.3	2.0	1.8	1.5	1.3	1.1	0.8	0.5
10					7.4	6.2	5.3	4.5	3.9	3.4	2.9	2.6	2.2	1.9	1.6	1.3	1.0	0.7
12						8.2	6.8	5.7	4.9	4.2	3.6	3.1	2.7	2.3	1.9	1.5	1.2	0.8
14							8.8	7.3	6.1	5.2	4.4	3.8	3.2	2.7	2.2	1.8	1.4	0.9
16								9.3	7.6	6.4	5.3	4.5	3.8	3.2	2.6	2.1	1.6	1.0
18									9.6	7.9	6.5	5.4	4.5	3.7	3.0	2.4	1.8	1.2
20										9.8	7.9	6.5	5.3	4.3	3.5	2.7	2.0	1.3
22											9.8	7.8	6.3	5.1	4.0	3.1	2.3	1.5
24												9.6	7.6	6.0	4.7	3.6	2.6	1.7
26													9.2	7.1	5.5	4.2	3.0	1.9
28														8.6	6.5	4.9	3.4	2.1
30															7.8	5.7	4.0	2.4
32																6.8	4.6	2.7
34																	5.5	3.2
36																		3.7

The size of the opening to create this pressure difference is 7" x 24" (168 in^2). The area of the opening is multiplied by 5.3 CFM_{50} per square inch yielding a CFM_{50} flow rate of 890 CFM_{50} between the crawl space and outdoors without the opening.

The total area of leakage between the crawl space and outside is approximately 10% of the flow rate, or 89 in^2 (890 CFM_{50} x .10 = 89 in^2).

The house-to-zone flow rate may be then calculated with Table A112-5 with the initial house-to-zone pressure (P1) and house-to-outdoor flow rate determined from Table 5. The initial house-to-crawl space pressure was -20 Pa and the calculated house-to-outdoor flow was 890 CFM_{50}. From Table 6, 1.3 is multiplied by 890 CFM_{50} for a house-to-crawl space flow of 1157 CFM_{50}.

Pressure without Added Hole (P1)

House-to-Zone (CFM_{50})

Table A112-5

P1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
	7.9	4.9	3.7	2.9	2.5	2.1	1.8	1.6	1.5	1.3	1.2	1.1	0.9	0.9	0.8	0.7	0.6	0.5

Total leakage area between the house and crawl space is approximately 116 in^2 (1157 CFM_{50} x .10 = 115.7 in^2).

The initial house-to-crawl space pressure of -20 Pa and the house-to-outdoor flow of 890 CFM_{50} is used to determine total path air leakage from Table A112-6. Total path air leakage from the outside to the house through the crawl space is 623 CFM_{50} (0.7 x 890 CFM_{50} = 623 CFM_{50}). This represents the combined flow, in units of CFM_{50}, taking into account the resistance of *both* of the pressure boundaries.

Pressure without Added Hole (P1)

Total Path Air Leakage (House-to-Zone-to-Outdoors) CFM_{50}

Table A112-6

P1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.4

HOLE ADDED BETWEEN HOUSE & ZONE

CFM_{50} per Square Inch of Added Hole

Pressure with Added Hole (P2)

Pressure Without Hole (P1)	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
14	3.7																	
16	3.2	5.5																
18	2.7	4.6	6.8															
20	2.4	4.0	5.7	7.8														
22	2.1	3.4	4.9	6.5	8.6													
24	1.9	3.0	4.2	5.5	7.1	9.2												
26	1.7	2.6	3.6	4.7	6.0	7.6	9.6											
28	1.5	2.3	3.1	4.0	5.1	6.3	7.8	9.8										
30	1.3	2.0	2.7	3.5	4.3	5.3	6.5	7.9	9.8									
32	1.2	1.8	2.4	3.0	3.7	4.5	5.4	6.5	7.9	9.6								
34	1.0	1.6	2.1	2.6	3.2	3.8	4.5	5.3	6.4	7.6	9.3							
36	0.9	1.4	1.8	2.2	2.7	3.2	3.8	4.4	5.2	6.1	7.3	8.8						
38	0.8	1.2	1.5	1.9	2.3	2.7	3.1	3.6	4.2	4.9	5.7	6.8	8.2					
40	0.7	1.0	1.3	1.6	1.9	2.2	2.6	2.9	3.4	3.9	4.5	5.3	6.2	7.4				
42	0.5	0.8	1.1	1.3	1.5	1.8	2.0	2.3	2.7	3.0	3.5	4.0	4.6	5.4	6.4			
44	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.3	2.6	2.9	3.4	3.9	4.5	5.3		
46	0.3	0.5	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.6	1.8	2.0	2.3	2.6	2.9	3.4	4.0	
48	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.6	1.8	2.1	2.4

Zone-to-Outside (CFM_{50})

Pressure Without Added Hole (P1)

P1	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
	0.5	0.6	0.7	0.8	0.9	0.9	1.1	1.2	1.3	1.5	1.6	1.8	2.1	2.5	2.9	3.7	4.9	7.9

CFM_{50} Total Path Air Leakage (House-to-Zone-to-Outside)

Pressure Without Added Hole (P1)

P1	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.8

HOLE ADDED BETWEEN ZONE & OUTDOORS
CFM_{50} per Square Inch of Added Hole

Pressure with Added Hole (P2)

Pressure Without Hole (P1)

	14	**18**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**
2	2.4	2.1	1.8	1.6	1.4	1.3	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.5	0.4	0.4	0.3	0.2
4		4.0	3.4	2.9	2.6	2.3	2.0	1.8	1.6	1.4	1.3	1.1	1.0	0.9	0.7	0.6	0.5	0.3
6			5.3	4.5	3.9	3.4	2.9	2.6	2.3	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4
8				6.4	5.4	4.6	4.0	3.5	3.0	2.7	2.3	2.0	1.8	1.5	1.3	1.1	0.8	0.5
10					7.4	6.2	5.3	4.5	3.9	3.4	2.9	2.6	2.2	1.9	1.6	1.3	1.0	0.7
12						8.2	6.8	5.7	4.9	4.2	3.6	3.1	2.7	2.3	1.9	1.5	1.2	0.8
14							8.8	7.3	6.1	5.2	4.4	3.8	3.2	2.7	2.2	1.8	1.4	0.9
16								9.3	7.6	6.4	5.3	4.5	3.8	3.2	2.6	2.1	1.6	1.0
18									9.6	7.9	6.5	5.4	4.5	3.7	3.0	2.4	1.8	1.2
20										9.8	7.9	6.5	5.3	4.3	3.5	2.7	2.0	1.3
22											9.8	7.8	6.3	5.1	4.0	3.1	2.3	1.5
24												9.6	7.6	6.0	4.7	3.6	2.6	1.7
26													9.2	7.1	5.5	4.2	3.0	1.9
28														8.6	6.5	4.9	3.4	2.1
30															7.8	5.7	4.0	2.4
32																6.8	4.6	2.7
34																	5.5	3.2
36																		3.7

House to Zone (CFM_{50})
Pressure without Added Hole (P1)

P1	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**
	7.9	4.9	3.7	2.9	2.5	2.1	1.8	1.6	1.5	1.3	1.2	1.1	0.9	0.9	0.8	0.7	0.6	0.5

Total Path Air Leakage (House-to-Zone-to-Outdoors - CFM_{50})
Pressure without Added Hole (P1)

P1	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**
	1.0	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.4

Appendix 114 Duct-Induced Pressures

In order to keep supply air from pressurizing closed rooms by more than 3 Pa, transfer grilles or jump ducts are installed to allow supply air to flow back to the central system return. The transfer areas and ducts are sized based on the equation shown below. To calculate the finished grille size, no more than 80% free area should be assumed, requiring that the transfer area – A – be divided by at least 0.8.

$$A = Q/1.853$$

where:

A = area in square inches
Q = air flow rate (ft3/min)

For example, a bedroom supply register has a flow rate of 100 CFM. The free area required for return air is 54 in^2 (100/1.853 = 54). If a transfer grille is to be installed between the bedroom and hallway, the area of the grille should be at least 68 in^2 (54/0.8 = 68).

Appendix 130 Health & Safety

Water may be found in three physical states; solid (ice), liquid (water) and gas (vapor). The liquid and gaseous states of moisture are the most important to weatherization because they can impact occupant health and building durability. It is helpful to understand the four moisture movement mechanisms. Understanding these principles can help identify solutions to indoor moisture problems.

Moisture Movement Mechanisms

1. Liquid - Moisture can enter a building as a liquid. Examples are rain or water resulting from poor subsurface drainage. Roofs should be watertight. Gutters and downspouts should direct water away from the home. The grade around the home should be sloped away from the home.

2. Capillary - This is the movement of water through tiny pores in a material and is the mechanism by which water is drawn into the leaves of trees or what happens when the corner of a paper towel is dipped in water. Capillary action also readily occurs in concrete and bricks. If there is no capillary break in a concrete foundation wall, water can be drawn up the wall. Installing a capillary break is usually outside the scope of weatherization, however, the source of the moisture should be identified and corrected if possible. The moisture source is often poor drainage around the home.

3. Air transported - Air will carry water vapor along with it (think of the moisture as hitch-hiking with the air). Moisture that gets into building cavities is often carried there by air. During the winter, warm air moves upward in a home and into the attic through bypasses. This warm air will carry water vapor with it. Depending upon the amount of air movement and its moisture content, the moisture may condense on cold attic surfaces. Air sealing attic bypasses will stop this moisture movement. Air transported moisture is stopped by creating an air barrier in the building assembly separating the conditioned spaces from the outdoors. Examples of air barriers are polyethylene plastic, drywall, and most rigid insulation materials.

4. Diffusion - This is the movement of water vapor through microscopic spaces in a material. The direction of this moisture movement is always from an area of high moisture content to one of lower moisture content. Moisture movement by diffusion is slowed – or retarded – by vapor barriers or retarders. Examples of vapor retarders include polyethylene plastic, aluminum foil, and special vapor retarding paints.

It is always more important to first control the source of the moisture before other remedial measures are done. For example, if rain water drains towards the building and, as a result, there is water in the crawl space, the rain water should be directed away from the foundation before a ground cover is installed and the crawl space walls insulated.

Bulk & Chronic Moisture Loads

Moisture problems may be related to bulk moisture or chronic moisture loads. Bulk moisture loads are periodic events caused by poor site drainage, a leaky plumbing fitting or an unvented clothes dryer. These events may temporarily elevate moisture levels in the home but do not necessarily cause problems because the home can dry over time. Chronic moisture problems are constant and may lead to persistent mold growth in the home. Chronic moisture problems include wet crawl spaces with no ground covers or unvented space heaters.

Health & Safety Assessment Form[1]

Client Name: ____ File Number: ________________________

Address: ____City, Zip: ___________________________

Phone Number: ____ ☐ Rent ☐ Own

1. Moisture Areas

Existing conditions *(check all that apply)*

	Damp atmosphere in house
	Client complaint of allergy-like symptoms
	Visible mold growth *(if "Yes", go to #2)*
	Evidence of water penetrating the home *(stains, moist areas)*
	Evidence of conditions that might allow water in the home *(poor grading, bad flashing, bad/missing gutters)*
	Actual construction defect or deterioration that allows water into the home *(roof, decks, windows, concrete slabs, lack of vapor barrier, missing crawl space ground cover)*
	Plumbing defects *(leaking drains, pipes or toilet seats, missing caulk on sinks or tubs, non-operable sump pump)*
	HVAC problems *(dirty, moist filters, poor condensation drainage, unvented space heater)*
	Dryer vented indoors, inadequate ventilation for a kitchen, bath or other high moisture area
	Any source of condensation

2. Mold Areas

Checklist		Existing Mold	Sq. Ft. of Area	Cleanup to be Done by Client/Landlord
	Bath *(location)* ______________________	☐		☐
	Shower *(location)* ____________________	☐		☐
	Kitchen	☐		☐
	Laundry area	☐		☐
	Basement walls	☐		☐
	Crawlspace	☐		☐
	Exterior walls	☐		☐
	Attic/Ceilings	☐		☐
	Other *(specify)*______________________	☐		☐

☐	Existing mold was found in your home. The mold is located in the areas checked under the Existing Mold column.	
	☐	Weatherization work cannot be done until the mold in the areas checked under the Cleanup column has been cleaned up. You (or your landlord) are responsible for the cleanup.
	☐	Any item checked in the Existing Mold column but not requiring client cleanup will either be cleaned by the agency or will not be disturbed during the weatherization work and therefore, does not need to be cleaned up in order to proceed with weatherization. However, it is advisable to clean up all mold.

Additional Comments: ____

By signing below, I acknowledge that I have been notified there is existing mold in the home prior to any weatherization work being done. If the mold has to be cleaned up before weatherization work can begin, I agree to have it cleaned up and then contact the agency so the weatherization work may proceed.

Client Signature: ___________________________________ Date: ____

Agency Representative: ______________________________ Date: ____________ Phone Number: _____________