North Dakota Weatherization Field Standards

Home Weatherization Assistance Program

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State of North Dakota
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The details of the *North Dakota Weatherization Field Standards* were selected as best practices for the northern United States and adapted for the North Dakota weatherization program.

This document was written by Rick Karg with the wise assistance of Cal Steiner, Coordinator of the Dickinson, North Dakota Community Action Program; Howard Sage, and members of the North Dakota weatherization technical committee. Members of this committee include:

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These *Standards* were reviewed and discussed over a three day period with the participation of Howard Sage, weatherization program coordinators, estimators, foremen, and crew members. All contributed to the quality of these *Standards*.

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Introduction

The North Dakota Weatherization Field Standards provide guidelines to the local administering subgrantees regarding the proper delivery of weatherization and heating system services for residential buildings. The purpose of the standards is to ensure that high quality service is given at a reasonable cost and delivered uniformly throughout the state. The success of this program depends upon subgrantees and contractors having a full understanding of the State's weatherization standards.

The Weatherization Program has changed substantially, both technically and administratively, since its inception almost three decades ago. The Weatherization process continues to evolve in response to changes in funding, weatherization technology, program rules and administrative personnel. The North Dakota Weatherization Field Standards will be used to implement and document these changes as they occur. From time to time, these standards may be amended and/or revised by the North Dakota Department of Commerce, Division of Community Services (DCS) to reflect changes in State or Federal regulations, new technology, and/or innovative approaches to weatherization. The Division of Community Services encourages subgrantees to submit suggested changes to these standards that will result in the delivery of services in a more cost effective manner while maintaining a high quality of work. Amendments to the standards will not be effective until thirty days after they have been approved by the DCS, except under the following conditions:

1. State or Federal law or regulation changes mandate immediate implementation; or
2. State office personnel determine that an emergency situation exists and the proposed amendment and/or revision is necessary for protecting the health and safety of clients or crew members.

The Field Standards are organized to easily accommodate changes. In this sense, the Weatherization Field Standards will never be complete. In preparing this addition, some topics were almost certainly overlooked. The manual will become more complete and comprehensive with use, as omissions are identified, and new topics are addressed with new policy or guidance.

1000 Administrative, Scope and General Requirements

1100 Effective Date

1. All weatherization measures performed or completed by the grantees on or after the date specified in the cover letter to these standards shall comply with these standards.
2. All dwelling units completed after the effective date shall comply with these standards.

1200 Scope

1. The Goal for the North Dakota Department of Commerce, Division of Community Service's (DCS) Home Weatherization Assistance Program (WAP) is:

   "To provide weatherization assistance which increases the energy efficiency of dwellings owned or occupied by low-income persons, reduce their total residential energy expenditures, and improve their health and safety, especially low-income persons who are particularly vulnerable such as the elderly, the handicapped, and children".

2. The North Dakota Program Field Standards shall be known as the Field Standards and may be referred to throughout this document as "The Standards", "WAP Standards", or "Field Standards".
3. The Standards shall apply to all local administering agencies (subgrantees) providing Weatherization Assistance Program (WAP) services.
4. The Standards provide guidelines for the installations of energy conservation measures and repairs. Materials and measures that are allowed or not allowed will be specifically designated.
5. Items designated as “preferred approaches” are not required nor are they mandatory. Subgrantees will be in compliance with WAP Standards if they choose not to implement items listed as “preferred”. However, the preferred approaches are provided as allowable options that will help to maximize the effectiveness of WAP services, protect the health and safety of clients and crews, and contribute to increased energy savings.
6. These Standards are not intended to abridge safety, health, environmental, or local codes or other ordinances. Such requirements, if more stringent than these, shall apply; if these Standards are more stringent, the Standards shall apply.

7. All questions concerning the content or implementation of the WAP Standards should be directed to the DCS WAP Program Administrator.

1300 Enforcement

1. Continued subgrantee inability or refusal to comply with applicable standards are grounds for the North Dakota DCS to suspend, terminate, or otherwise apply special condition(s) to the subgrantee's agreement to provide weatherization services.

1400 Amendments to Program Field Standards

1. From time to time the North Dakota Program Field Standards may be amended and/or revised by the DCS to reflect changes in State and Federal regulations, state-of-the-art technology and general experience of the weatherization community.
2. Amendments to the Field Standards will not become effective until thirty (30) calendar days from the date of DCS approval and subgrantee notification except under the following conditions, where amendments or revisions will become effective immediately:
   a. State or Federal law or regulation changes mandate immediate implementation; or
   b. The WAP State Office determines that an emergency situation exists, such as a potential threat to life, limb or personal property, and the proposed amendment and/or revision is necessary for the protection of the health and welfare of North Dakota citizens.
3. Any subgrantee personnel may submit comments and suggested changes or revisions to these Standards to the Division of Community Services at any time. Suggested changes to the Standards must be accompanied by supporting documentation.

1500 Monitoring by State

1510 General Procedure

1. Periodically the DCS WAP Administrator or a representative will conduct monitoring visits to subgrantees for the purpose of determining that all materials and services reported on the Building Work Order (BWO) have been installed or completed.
2. The effectiveness, safety, workmanship, overall appearance, and compliance with the WAP Field Standards will be evaluated during the monitoring visit.
3. Dwelling units inspected will be selected from a list of clients that will allow a comprehensive of a sample.

4. Inspection visits may focus on problem areas identified in previous inspection reports to ensure that problems have been corrected.
5. Recommended actions may be issued to subgrantee based on observations during these visits and such guidance will be noted on a report provided to the subgrantee.
6. If a measure or repair installed under WAP is not in compliance with the WAP Standards and a Field Standards waiver has not been issued, the expenditures for that measure might not be allowed.
7. Deficiencies noted during State monitoring that result in Major Findings or repeated Minor Findings may be considered as justification for requiring that the subgrantee re-inspect dwellings. Please refer to Section 1540 on page 4 for the details of Major and Minor Findings.

1520 Appeals Process for Inspection Reports

1. A subgrantee representative may appeal the findings of the monitoring inspection report to the WAP Program Administrator. This appeal should be sent in writing within ten working days of receipt of the inspection report.
2. A subgrantee that does not agree with the initial outcome of the inspection report appeal, may submit a subsequent appeal to the Director of the Division of Community Services.

1530 High-Risk Status

1. The occurrence of a substantial number of, or repeated, Major Findings may result in a decision by the WAP Administrator that a subgrantee be placed on high-risk status. Please see Section 1541, below, for an explanation of Major Findings.
2. If a subgrantee is placed on high-risk status, it is likely that special conditions will be placed upon the subgrantee financial assistance award until compliance with WAP Standards is met.

1540 DCS WAP Evaluation System

1541 Major Findings

1. Any of the following criteria generally constitutes a Major Finding:
   a. The health and safety of clients, subgrantee staff, and subgrantee subcontractors, or the integrity of the building structure is threatened by work completed with WAP funds.
   b. A health or safety problem is created by, exacerbated by, or not corrected by the delivery of WAP services.
   c. The omission of a required measure or technique with major energy savings potential, as determined by WXEOR or a required procedure that addresses health and safety concerns.

d. Poor quality of work that significantly affects the performance of measures or repairs.
e. Expenditure of WAP funds on measures that are not approved under WAP or required for health or safety reasons.
f. Major expenditure of funds on measures that do not yield an acceptable savings-to-investment ratio as defined in these standards.
g. Any action or lack of action that may result in a liability that threatens DCS financial assistance award funds.

2. An Inspection Visit Report that contains Major Findings:
   a. Requires an immediate response from the subgrantee receiving the finding.
   b. Requires corrective action be taken.
   c. May result in disallowed costs.
   d. May result in an increased inspection/monitoring rate.
   e. May result in the requirement of additional training for the subgrantee personnel.
   f. May result in the recommendation for High Risk Status for the subgrantee receiving the major finding(s). Please refer to Section 1530.
   g. Continued findings of this type may result in termination of DCS Weatherization Financial Assistance Award to the subgrantee.

1542 Minor Findings

1. All other areas of noncompliance with these Standards not considered a Major Finding shall be considered as a Minor Finding.
2. Minor Findings:
   a. Do not require a response unless specifically stated on an inspection visit report.
   b. May require corrective action be taken if similar findings relating to major energy savings measures, documentation requirements, or health and safety measures are found to be repeated.
   c. May be reclassified as a Major Finding if repeated, that is, if similar findings are found on more than two consecutive inspection visits.
   d. May result in the requirement of additional training for the subgrantee personnel.

1600 General Auditing and Weatherization Requirements

1. The correct use of the State approved computerized energy audit and associated priority list is required. Each Subgrantee is required to update all applicable information use by the computerized audit at

least annually (i.e. costs for measures, cost of materials, labor costs and fuel types). Additional information detailing the subgrantee method for insuring accuracy of the input data must be documented as well.

2. The health and safety of the clients, subgrantee staff, subgrantee subcontractors, and the integrity of the building structure must not be compromised by any work completed with WAP funds.
3. The subgrantee WAP coordinator has overall responsibility for proper implementation of the procedures detailed in the Field Standards.
4. All WAP installations, both repairs and conservation measures, must comply with applicable building codes and regulations.
5. Subgrantees are responsible for the quality control of all repair and energy conservation work.
6. If an eligible client moves during the course of the WAP weatherization work, the subgrantee should complete the repair and/or conservation work in progress and any other measures necessary to secure the well being of future occupants, the structure and the installed conservation materials. However, additional conservation or repair work should not be started.
7. Weatherization is not to proceed until problems beyond the scope of the program affecting either the integrity of installed WAP measures or the health and safety of the client or crew are remedied with non-WAP funds.
8. Health and safety related repairs within the scope of WAP include the following:
   a. Furnace replacements.
   b. Materials to mitigate excessive carbon monoxide.
   c. Heat exchangers replacements or repairs.
   d. Burner replacements or repairs.
   e. Combustion air venting system repairs or replacements.
   f. Materials to repair gas leaks.
   g. Repair of gas leaks.
   h. Chimney cleaning and lining.
   i. Water heater tank replacements. (not WAP conversion units)
9. The costs for health and safety repairs are not to be factored into cost-effectiveness analysis (savings-to-investment ratio SIR).
10. For reporting purposes, the costs for health and safety repairs listed above are to be allocated to the Health and Safety category on the Building Work Order (BWO).

11. Allowable repairs which can be completed with WAP funds must be associated with an eligible weatherization measure and are limited to the following:
    a. Mechanical ventilation system materials.
    b. Electrical repair materials.
    c. Plumbing repair materials.
    d. Structural repairs (include roofing, siding, ceiling, floor, foundation, and mobile home belly repairs) that are necessary for the installation of energy conservation measures.
    e. Vapor barrier installation.
    f. Drainage repairs or modifications.
    g. Clothes dryer venting.
12. When repairs are necessary and are not associated with a WAP measure or cannot be justified with a SIR over 1.00, the client and homeowner must be notified and referred to alternative resources (home rehabilitation programs, landlords, etc). This occurrence must be documented in the client file.
13. Subgrantees must guarantee work done under the Weatherization Assistance Program for a period of one year after completion (final inspection). A subgrantee may extend this work guarantee at its discretion and expense.

1610 Required Unit File Documentation

Documentation for each completed job file must contain:

1. A copy of an accurate WXEOR audit priority list that was used for the job.
2. All required combustion appliance documentation.
3. Documentation of the initial audit, including the auditor's name and the date of the initial audit.
4. Pre- and post-weatherization blower door test information and the building tightness limit value in units of CFM_{50}.
5. An explanation of reasons that any dwelling unit did not have a blower door test performed.
6. A final inspection form signed by a qualified subgrantee staff person. Please refer to Section 1700 on page 9.
7. Accurate records or documentation of all installed measures and their costs. Costs must include labor used to install the measure.
8. An explanation for reasons that any weatherization measures with a SIR greater than 1.25 were not installed.
9. State WAP approved waivers.

10. Brief documentation to clarify situations where a technical waiver was implemented.
11. Brief documentation indicating that owners and clients were notified of any potential or real health or safety problems that necessitated weatherization work to be terminated.
12. Air leakage measures that are done to address client comfort (e.g. storm window near reading chair, jamb-up kit on door near reading chair, etc.).
13. A complete record of the pressure diagnostics tests performed.
14. A signed client application which contains the needed client information.
15. Each unit inspected by crew personal will be assumed to have the final inspection completed on the date the work is completed (leave final inspection date field in Weather Tite open). Units for which the final inspection is conducted by an estimator/inspector must state the actual date the inspection took place. All inspection forms must include client and inspector signatures certifying satisfactory completion of work and presentation of client education.
16. A list of any conditions which are judged out of the ordinary (ex. non-operable egress doors and windows).
17. The signature of the dwelling unit owner must be contained in the file when the owner agrees to permanently sealing an unused fireplace.
18. Documentation of all safety tests and work done on combustion appliances.
19. Copy of an executed rental agreement is the weatherized dwelling is rental property.

1620 Subgrantee Inspection Methods

1. The subgrantee is responsible for inspecting all measures under the following conditions, until a consistent pattern of high quality workmanship is demonstrated:
   a. At the start of each program year.
   b. When new field staff are involved.
   c. When new subcontractors are used.
   d. When several findings are discovered during a monitoring visit.

1630 WAP Field Standards Waivers

1. Deviations from the WAP Field Standards require a waiver from the DCS WAP Administrator prior to the expenditure of funds, unless waived for technical reasons (see Technical Waivers below in Section 1650). Work may proceed after verbal authorization by the DCS WAP Administrator.

2. If a client/occupant refuses to allow a certain measure to be completed and this measure has a higher SIR than the remaining measures, no other measures may be installed with the exception of general heat waste and health and safety measures. Subgrantees should explain the potential energy savings to the client to ensure that they understand the ramifications of their decision. Subgrantees must document the reason the work was not performed.
3. Conversion of water heaters or furnaces to a different fuel type which will result in a different vendor providing the fuel to the replaced appliance requires a waiver from the DCS office.

1640 Heating System Replacement Waivers

1. Prior approval is required for the replacement of a *secondary* heating system.
2. Waiver of client health and safety contribution [RESERVED].

1650 Technical Waivers

1. Conservation measures and associated repairs may be omitted if the work cannot be completed because of health, safety, local codes, or other technical reasons. The following are examples of acceptable grounds for a technical waiver:
   a. Risk to client or subgrantee staff to health or safety risks such as fire, explosion, bodily harm, unruly pets, harmful combustion by-products, electric shock, friable asbestos, unsanitary conditions, or height clearance. Please see Section 2212 on page 18 for walk-away policy requirements.
2. Technical waivers do not require State approval, but a brief explanation must be documented in the unit file.

1700 Subgrantee Final Inspections

1. Weatherized units may be reported to the Division of Community Services (DCS) as complete only after the subgrantee has performed a final inspection. The purpose of the final inspection is to ensure that the work has been completed in a workmanlike manner and in accordance with the approved computerized audit (currently the WXEOR Program).
2. Qualifying inspection personnel:
   a. At least one-third of the dwelling units completed under any one grant must be inspected by a qualified subgrantee staff person other than a person who performed on-site work on the dwelling unit. This qualified inspector will usually be the estimator/inspector or the weatherization coordinator for the subgrantee.

i. The required dwelling units inspected must be a representative sample of each county served by the subgrantee.

b. The remaining two-thirds of the dwelling units may be inspected by the crew foreman or other on-site authorized subgrantee representative. In such a case, the inspector may be one of the personnel who performed on-site work on the dwelling unit.

3. The final inspection must document the materials installed and confirm that they were installed in a professional manner in accordance with the North Dakota Weatherization Field Standards. The final inspection form must be signed and dated by both the client and the person inspecting the job on behalf of the subgrantee.
4. The State WAP Office may require a subgrantee to inspect one hundred percent of installed measures if the quality of completed work is perceived to be deficient.
5. Deficiencies noted during State monitoring that result in Major Findings or repeated Minor Findings may be considered as justification for requiring that the subgrantee re-inspect dwellings. Please refer to Section 1540 on page 4 for the details of Major and Minor Findings.
6. Client or scheduling obstructions to final inspection:
   a. DCS recognizes that in some cases it may be impossible to complete a complete final inspection of the dwelling unit, even after repeated efforts to schedule the final inspection. In these cases, the subgrantee must document that an inspector made a significant effort to inspect the dwelling after completion of the weatherization work. At a minimum, a visual inspection of any exterior weatherization measures must be completed.
   b. A memorandum must be put in the client file, signed by the estimator/inspector and the weatherization coordinator, indicating the dates when the subgrantee attempted to inspect the residence.
      i. The subgrantee will also be required to mail an inspection form to the client for their signature, along with a letter explaining that the subgrantee was unable to complete a full on-site inspection.
      ii. If the client does not respond within two weeks, the subgrantee may report the unit as a completion. In this situation a second memorandum, signed by the estimator/inspector and weatherization coordinator and placed in the client file, should indicate that the client failed to return the final inspection form.
7. The final inspection of a unit, at a minimum, shall include:

a. Verification that all materials reported on the final inspection sheet are present or can be physically accounted for on the materials returned sheet during the on-site inspection by the state inspector.
b. Materials were installed in such a way as to be safe, effective, and neat in appearance.
c. All materials used on the home meet required North Dakota WAP standards.
d. Verification that all combustion systems are in safe operating condition.

8. The appropriate documentation must be in the client file. Please refer to Section 1610 on page 7 for the file document requirements.

1710 Allowable repairs

1. The cost of incidental or necessary repairs are allowable if they are necessary to protect the integrity of the installed weatherization materials.
2. The costs for necessary repairs (materials and labor) must be factored into the SIR calculation in the approved energy audit system (WXEOR) of the measure(s) they affect. Use the suggested allocation formulas listed below for distribution of costs among WAP installed measures:

a. For site-built homes and manufactured houses:

i. For electrical inspections and repairs, allocate one-half of the cost to the attic insulation, and one-half the cost to the sidewall insulation.
ii. For plumbing repairs, allocate one-half the cost to the floor/perimeter measures, and one-half to the sidewall insulation.
iii. For roofing repairs, allocate one-third the cost to the attic insulation, one-third to wall insulation, and one-third to the air leakage.
iv. For ceiling repairs, allocate one-half the cost to the attic insulation, and one-half to air leakage.
v. For siding repairs, allocate one-half the cost to wall insulation, and one-half to air leakage.

b. For mobile homes:

i. For belly repairs, allocate one-half to belly insulation, and one-half to air leakage.
ii. For electrical inspections and repairs, allocate one-half the cost to the attic insulation, and one-half the cost to the sidewall insulation.

iii. For plumbing repairs, allocate one-half the cost to belly insulation, and one-half the cost to air leakage.

iv. For roofing repairs, allocate one-third the cost to attic insulation, one-third to wall insulation, and one-third to air leakage.

v. For ceiling repairs, allocate one-half the cost to attic insulation, and one-half to air leakage.

vi. For siding repairs, allocate one-half the cost to wall insulation, and one-half to air leakage.

3. If repair costs, when factored together with the cost of eligible measures, results in a SIR less than 1.00, neither the measures nor the repairs may be done entirely with WAP funds. A subgrantee may use another source of funds to "buy down" the cost of repairs or request the client contribute funds to make the measure and the associated repairs eligible.
4. Costs for repair or replacement of existing mechanical ventilation or installation of new exhaust fans or systems shall be included under health and safety; therefore it will not be factored into the calculation of an SIR.

2000 Health and Safety Requirements

The health and safety of clients, local subgrantee staff and subcontractors is a primary concern of the North Dakota Department of Commerce Division of Community Services (DCS) and its Weatherization Assistance subgrantees. The weatherization assistance provided by local agencies has the potential to affect the operation of and the interaction among the various "systems" within clients' homes. It is therefore important that subgrantee staff remain aware of the potential hazards associated with the weatherization process and not compromise the integrity of the building when installing weatherization measures.

While the primary purpose of the North Dakota Weatherization Assistance Program is to reduce the energy use in low income dwellings, it is necessary on occasion to make related repairs and to mitigate health and safety concerns which may not result in a decrease in energy use or result in a monetary savings. Therefore, as part of the North Dakota Weatherization Assistance Program, the following Health and Safety Standards have been developed with the objective of providing general guidance to subgrantees and subcontractors doing work within the program. All persons providing services under this program shall be governed by these standards.

Allowable measures under North Dakota Weatherization Health and Safety Standards will be limited to the following activities:

1. Those measures which pose a direct and immediate threat to the health and/or safety of clients and crews;
2. Health and safety measures which result from weatherization assistance; and

Each home weatherized must be individually assessed to determine the existence of potential hazards to workers or clients. When conditions within the home are such that the health and safety of the client, crew, or contractor will be jeopardized prior to providing assistance, weatherization must not proceed until such problems are remedied. In some cases mitigation of problems may be beyond the scope of the Weatherization Program. In these instances, the client must be notified in writing and referred to alternative resources for solution of the problem.

In those instances where the existing conditions pose a threat to the crew or contractor's health and safety, the North Dakota Weatherization Assistance Program allows *technical waivers* for any audit or inspection process, installation, or any portion of the weatherization activity.

Under the North Dakota Health and Safety Standards, the following health and safety assessments must be performed:

1. Hazardous Conditions Assessment
2. Air Quality Assessment (building tightness limit determination)
3. Combustion Systems Assessment (worst-case draft testing)
4. Assessment of Crew & Client Safety Concerns
5. Hazardous Materials Assessment

2100 Technician Health and Safety

1. It is the responsibility of the subgrantee to initiate and maintain programs that provide compliance with applicable Occupational Health and Safety Act Regulations (29 CFR 1910 & 1926), and any other applicable Federal and State laws enacted to protect worker safety.
2. The subgrantee must assess structural conditions and demonstrate caution when working in potentially dangerous areas.
3. Weatherization services must be provided in a manner that minimizes risk to workers.
4. Subgrantee employees shall take precautions to avoid contact with raw sewage or other unsanitary conditions.

2200 Health and Safety Procedures

The following section establishes areas of concern that may affect the health and safety of the workers and the clients. In most cases the best approach to limiting the health and safety risk is to minimize their exposure to the hazard. The inability to minimize exposure may result in some or all of the work being stopped on any particular dwelling.

The DCS expects the crews, contractors and auditors to be able to work under conditions that do not jeopardize their own health and safety. It is also expected that these field personnel will use caution and care while working on the client's home. The office, warehouse and other workspace owned or rented by each subgrantee should be a safe and healthy environment. For detailed information on worker health and safety, refer to Construction Industry OSHA Safety and Health Standards (29 CFR 1926/1910). The following are general guidelines for accident prevention and should be followed by agencies, crews, auditors and general contractors involved in weatherization work. In addition, this section outlines some of the employer responsibilities to the weatherization crews.

2211 Employer and Subgrantee Responsibilities

1. It shall be the responsibility of the employer to initiate and maintain such programs as may be necessary to comply with this part.

2. The employer shall provide training in the area of health and safety which will allow weatherization personnel to identify existing and potential threats to either the client's or crew's health and/or safety. Upon the identification of a threat to the client's health and/or safety the client will be informed in writing as to the available options for dealing with this threat.
3. The employer shall provide for frequent and regular inspections of the job sites, materials, and equipment to be made by competent persons designated by the employers.
4. The employer shall tag all machines, tools, materials, or equipment identified as being unsafe, make them inoperable by locking the controls, or physically remove them.
5. The employer shall permit only those employees qualified by training or experience to operate equipment and machinery.
6. The employer shall require its employees and its representatives to take all reasonable precautions against performing work on homes that will subject clients to health and safety risks. At the time of initial client contact, the weatherization worker will make a cursory evaluation of the individual health of the home's occupants. In cases where a person's health is fragile and/or the crew work activities constitute a health or safety hazard, the occupants will be asked to leave during the work activities.

The DCS will allow technical waivers for non-performance of audits, installations and/or inspections, or any portion of these functions, if such action will expose workers to conditions regarded as unsafe or unhealthy as determined by OSHA Construction Industry Standards.

Expenditure of weatherization funds for materials, protective clothing, respirators, medical exams, proper tools and equipment, and other items or activities related to the health and safety of clients and workers are allowable health and safety costs under the North Dakota WAP.

7. When in doubt, subgrantees should seek consultation services from an OSHA subsidized professional safety consultant (See: OSHA Publication # 3047, Consultation Service for the Employer) for identifying hazards and developing a worker health and safety program.
8. Subgrantees must have a Subgrantee Health and Safety Policy in place to protect worker health and safety. This program should contain the following:
   a. MSDS on the job site and available to medical personnel.
   b. Employees should know where to go for treatment.
   c. A written procedure for reporting medical emergencies.

d. A written procedure for reporting non-emergency accidents.
e. Provision for prompt medical attention for serious injuries.
f. Prompt transportation or a system for contacting an ambulance, in the case of a serious emergency.
g. Telephone numbers of physicians, hospitals, or ambulances should be conspicuously posted.
h. A First Aid program should be in place. It should include the following:
    i. First aid training provided to at least one member of each crew.
    ii. CPR training provided to at least one member of each crew.
    iii. One complete First aid kit per vehicle.
    iv. One eye-wash station with at least one refill per vehicle.

9. Subgrantees must establish a Personal Protective Equipment Program. This program should include the following:
    a. Respiratory Protection Procedures that provide employees with the following:
        i. The proper personal respiratory protection equipment.
        ii. Respirator fit testing, by a trained person.
        iii. Training to employees on respirator use.
        iv. Medical examination of pulmonary capacity with a frequency recommended by appropriate OSHA standards.
    b. Eye protection should be made available when appropriate.
    c. Gloves and protective coveralls should be made available when needed to protect worker health or safety.
10. Uniforms or washing machines and dryers at the weatherization shop.
11. Agencies should have in place a Tool Safety Program designed to protect employees from work place hazards. This program should ensure the following:
    a. Tools are safe and adequate for the job.
    b. Ground-fault protection is provided for power tools.
    c. Employees are trained in the safe and proper operation of tools and equipment used in their work.
    d. Safety guards are in place on all tools that come equipped with such devices.
    e. Ladders and scaffolding are adequate for use, have the proper weight rating, and are constructed of non-conductive material.
    f. That hearing/ear protection is provided to individuals working around high decibel equipment or in high dust environments.

12. It is preferred that the agencies have a Fire Protection Program. This program should include the following:
    a. Fire extinguishers are provided and are:
        i. Located in the subgrantee offices and warehouse.
        ii. Located in each vehicle.
        iii. Inspected regularly.
    b. Training on fire extinguisher use.
    c. Fire emergency procedures.
13. It is preferred that the agencies have a Job Hazards Identification Program. This program should include the following:
    a. Investigation for job specific safety hazards.
    b. Hazard Communication Procedures that include the following:
        i. Written policies for dealing with job hazards.
        ii. All hazardous materials containers labeled with:
            1. Hazardous chemical contents.
            2. Hazard warning appropriate for employee protection.
            3. Legible and prominent labels on all containers.
        iii. Means of Communication for non-Routine Tasks and unlabeled chemicals.
        iv. A means for the exchange of information between subgrantees and sub-contractors regarding hazardous materials.
    c. A catalog of Material Safety Data Sheets (MSDS) for all hazardous material should be made available to all employees, kept on file at the subgrantee offices, and on all jobs sites. The MSDS catalog should contain the following:
        i. Specific identity of chemical and common name.
        ii. Physical and chemical characteristics.
        iii. Known acute and chronic health effects and related heath effects.
        iv. Precautionary measures.
        v. Exposure limits.
        vi. Identification of carcinogens.
        vii. First aid procedures.
    d. Hazardous Material Communication Policy implementation. Such implementation should include the following:
        i. Information on where hazardous materials are located and where they are used.
        ii. Employee Information and Training on Hazardous Materials.

iii. Training conducted at the time of initial assignment or whenever a new hazard is introduced to the work environment.

iv. How to read and interpret labels and MSDS.

v. How to obtain and use hazard information, such as:

4. The hazards of the chemical.
5. Protective measures.

e. A Hazardous Chemicals List should be made available to employees.

f. Subgrantees should have written hazard evaluation procedures.

g. Subgrantees should have written materials on workplace Hazards.

2212 Required Subgrantee Walk-Away Policy

There are some situations in which a subgrantee should not or may choose not to weatherize an otherwise eligible unit. In order to deal with these situations each subgrantee must develop an approved a policy which, when implemented, allows weatherization staff to "walk away" from conditions and or circumstances that may be hazardous to their health or safety or that of the client's.

The following is a model walk-away policy intended to list the more common conditions and situations a subgrantee may encounter while delivering weatherization services. This list is not intended to be all inclusive of those instances in which a subgrantee may choose not to weatherize a unit. In some instances, corrective measures by the client/owner may allow program services to proceed. At a minimum, the subgrantee walk-away policy should contain the following:

1. *Procedure:* If an subgrantee can not or chooses not to weatherize a dwelling unit it must notify the client and owner/authorized agent in writing and include the following items:
   a. The nature and extent of the problem(s) and how the problem(s) relate to the determination to not weatherize the unit;
   b. Any corrective action required before weatherization services can be initiated;
   c. A time limit for correcting problems so that weatherization services may be rescheduled;
   d. The right of appeal; and
   e. All correspondence justifying the decision to "walk-away" must be kept in the client file.
2. *Withholding of Weatherization Services: A subgrantee may withhold weatherization services under the following conditions:*
   a. A dwelling unit is vacant.

b. A dwelling unit is for sale.
c. A dwelling unit is scheduled for demolition.
d. A dwelling unit is found to have serious structural problems that would make weatherization impossible or impractical.
e. A dwelling unit is deemed by the auditor to pose a threat to the health or safety of the crew or subcontractor.
f. A mobile home is improperly installed (for example, inadequate supports).
g. A dwelling unit is uninhabitable (for example, such as a burned out apartment).
h. When there are minor children in the dwelling but no adult client or adult agent of the client at the time of the estimate or at any other time subgrantee personnel must enter the dwelling.
    i. An adult client or adult agent of the client need not be present if the estimator or crew foreman feel satisfied with a signed note from an adult client or adult agent of the client stating their permission to enter the dwelling occupied by the minor children.
i. The client is uncooperative with the weatherization subgrantee, either in demanding that certain work be done and refusing higher priority work which is needed, or by being abusive to the work crew or subcontractor, or by being unreasonable in allowing access to the unit, every attempt should be made to explain the program and the benefits of the work. If this fails, work should be suspended and the State Weatherization Office consulted.
j. Obvious discrepancies are found between the information supplied by the client on the application and observed conditions at the time of weatherization. The subgrantee must resolve these discrepancies before weatherization work can continue.
k. If , at any time prior to the beginning or work (materials installed in a unit), the subgrantee determines that the client is no longer eligible or subgrantee personal believe that circumstances may have changed, the unit shall not be weatherized until updated information can be obtained from the client.
l. There are rats, bats, roaches, reptiles, insects, animals or other vermin that are inappropriately or not properly contained on the premises.
m. There are health or safety hazards that must be corrected before weatherization services may begin including, but not limited to:
    i. The presence of animal feces and/or other excrement,
    ii. Disconnected waste water pipes,
    iii. Hazardous electrical wiring, or

iv. Unvented combustion appliances.

n. There are illegal drugs or illegal activities occurring on the premises.

o. The client or owner is physically or verbally abusive to subgrantee personnel.

p. The dwelling unit or parts thereof are being remodeled and weatherization work is not coordinated with a housing rehabilitation program.

q. The eligible household moves from the dwelling unit where weatherization activities and services are in progress. In such a case, the subgrantee must determine whether to complete the work and the circumstances must be documented in the client file.

r. There are unusual situations, which in the judgment of the subgrantee staff, must be corrected before proceeding with weatherization.

i. No utility hookups (It is apparent that utilities have been shut off).

ii. Lack of cooperation from client.

iii. Dwelling units undergoing remodeling, or which have untreated areas that directly affect the weatherization process, shall not be weatherized.

s. If for any reason a worst-case draft test cannot be done in a dwelling requiring a worst-case draft.

2220 Asbestos Inspection Procedures

1. Prior to performing work or conducting tests, the energy auditor must conduct an inspection for materials suspected of containing asbestos if there is the possibility that they may be disturbed during the weatherization testing or work.
2. Decisions on approaches to weatherization work where asbestos is present shall be based on the judgment of the most qualified individual available to the subgrantee.
3. When major energy saving measures might be sacrificed as a result of suspected asbestos-containing materials, the subgrantee should have the suspected material tested for asbestos content.
4. All subgrantee workers must wear high quality respirators any time asbestos is worked with.
5. When materials containing asbestos are worked with, the asbestos materials should be dampened with water whenever possible to reduce the risk of airborne asbestos fibers.
6. Materials containing asbestos may not be cut, drilled, or disturbed in any manner that may cause asbestos fibers to become airborne.

7. Subgrantees may not use abatement contractors to remove or dispose of asbestos containing materials without prior authorization from the North Dakota Weatherization Program Administrator.

2230 Client Health and Safety

1. Weatherization services must be provided in a manner that minimizes risk to clients.
2. Dwellings with unvented or vent-free combustion appliances, with the exception of gas ranges, may not be weatherized until such appliances are properly vented (according to the appropriate code) to the outdoors.
3. Building owners and clients must be notified of any health or safety problems that require weatherization work to be terminated. Documentation of this notification must be included in the job file.
4. It is preferred that subgrantees minimize or restrict the use of materials that may be hazardous to the client, however if the subgrantee must utilize hazardous chemicals, it must be discussed with the client prior their use.
5. Special precautions must be taken if the occupant of the home has respiratory ailments, allergies, is pregnant, or has unique health concerns. Subgrantees should try and protect all clients from respirable particles, such as paint or insulation dust, during the weatherization process.
6. The installation of hazardous materials must be done in well-ventilated areas.
7. If strong smelling chemicals, such as formaldehyde, are detected in the client's home, subgrantees should not perform any weatherization measures that would reduce the natural air leakage of the dwelling.
8. At minimum, auditors and crewmembers should inform property owners of safety problems, code problems and other health and safety issues. For problems that are life-threatening or otherwise serious, the subgrantee supervisor should contact the jurisdiction having responsibility for the observed problem.

2240 Moisture Assessment and Repairs

2241 Assessment of Moisture Conditions

All homes should be checked for previous or existing moisture problems.

1. The moisture assessment section of the Estimator Field Form must be filled out along with special attention to the following signs:
   a. Evidence of condensation on windows and walls indicated by stains or mold.

b. Standing water, open sumps, open wells, dirt floors, water stains, etc. in basements. Also, check to see if firewood is stored in the basement and whether laundry is hung to dry during the winter months.

c. Leaking supply or waste pipes.

d. Attic roof sheathing shows signs of mold or mildew.

2. Identification of existing or potential moisture problems shall be documented in the client file.

3. If existing moisture problems are found, no air sealing should be done unless the source of the moisture can be substantially reduced or effective mechanical ventilation can be added to cost-effectively remove the moisture. In some cases, air sealing must be done in order to reduce the source of the moisture (i.e. sealing off crawlspaces from the house, or sealing attic leakage to eliminate condensation on the roof deck).

4. Because air tightening may cause an increase in relative humidity, client education should include information about moisture problems and possible solutions.

5. In the course of weatherization, any low-cost measures that help reduce the humidity levels in the house should be installed. Examples of these activities are venting dryers, venting existing bath or kitchen exhaust fans or installing moisture barriers on dirt floors.

6. A dwelling that has a CFM_{50} greater than the Building Tightness Limit (BTL) is no guarantee that moisture will not be a problem in that home.

2242 Repair or Elimination of Moisture Problems

Repair of moisture problems that might 1) result in health problems for the client 2) damage the structure over the short- or long-term, or 3) diminish the effectiveness of the weatherization measures, must be done before the weatherization job is completed.

1. Moisture problems can be reduced or eliminated by controlling the source of the moisture. This can involve:

   a. Installing a plastic ground cover on a crawlspace floor.

   b. Venting dryers to the outside of the building.

   c. Sealing the foundation.

   d. Providing positive drainage away from foundation.

   e. Repairing the roof, flashing, gutter, and downspout.

   f. Educating the client about the sources of moisture that they are able to control.

2. Moisture problems can be reduced or eliminated by ventilating areas where excessive moisture is produced, such as bathrooms and kitchens. This should include installation of a high quality exhaust fan in the subject area and informing the client of the related moisture issues and the proper operation and use of the fan. See Section 2260 on page 23 for exhaust fan installation guidelines.

2243 Dryer Vents

1. Electric dryers must be vented to the outdoors of the building whenever feasible; gas dryer vents must always be vented to the outdoors.
2. Mobile home dryer vents must be extended through the skirting to the outdoors.
3. Dryer vent ductwork should be smooth surfaced and, whenever possible, not exceed fourteen feet. No more than two 90^{o} elbows may be used in the vent system. Relocation of dryers may need to be considered to meet this vent pipe-length limitation.
4. Flexible metal vent pipe may be used if it does not exceed six feet in length.
5. Gas dryer vent pipe should not be installed with sheet metal screws or other intrusive fasteners that will collect lint (according to NFPA 54).

2250 Building Tightness Limits (BTL)

The building BTL value shall be recorded on the Diagnostic Field Form and placed in the client file. The calculated Building Tightness Limit value for the dwelling must be based on the ASHRAE 62 requirements of 15 CFM per person and 0.35 air changes per hour. Refer to page 105 for Building Tightness Limit calculation guidelines and use.

2260 Ventilation Systems for Acceptable Indoor Air Quality

2261 New Systems, Intermittent Operation

1. Exhaust fans that are intended for intermittent operation include kitchen and bathroom exhaust fans in dwellings that may or may not be tighter than the calculated Building Tightness Limit. These fans are intended for occasional use during cooking, baking, showering, and other times when moisture and odors are created by household activities.
2. High quality exhaust fans shall be used that have a sone level of 1.5 or less, are energy efficient, and have a CFM rating of at least 90.
3. Exhaust system ductwork shall consist of galvanized metal, rigid aluminum, PVC, or aluminum flex duct under six (6) feet in length.

4. Exhaust system ductwork shall be extended through the roof, sidewall, or soffit to the outdoors and be insulated.
5. For intermittently operated exhaust fans, controls may be by a push button switch timer, a separate on/off wall switch, an occupancy sensor switch, or hard wiring with a primary light switch (such as in a bathroom). Controls should be installed in the same room as the fan.

2262 New Systems, Continuous Operation

1. Ventilation systems are recommended in dwellings that are tighter than the calculated Building Tightness Limit (see page 105) or have a pre-existing moisture problem or other indoor air quality problem that cannot be corrected by any other means.
2. Ventilation systems are allowed in units that will receive substantial reductions in air leakage and as a result may encounter moisture problems. Exhaust fans installed for these reasons shall be operated continuously when the dwelling is closed up to the outdoor air during winter mechanical heating or summer mechanical cooling.
3. For proper sizing of fans for dwelling that are tighter than the calculated Building Tightness Limit, refer to page 105, Building Tightness Limits (BTL).
4. High quality exhaust fans shall be used that are rated for continuous use, have a sone level of 1.5 or less, are energy efficient, and have a CFM of at least 90.
5. Exhaust system ductwork shall consist of galvanized metal, rigid aluminum, PVC, or aluminum flex duct under six (6) feet in length.
6. Exhaust system ductwork shall be extended through the roof, sidewall, or soffit to the outdoors and be insulated.
7. For continuously operated exhaust fans, controls may be by a push button switch, a separate on/off wall switch, or hard wiring with a remotely located switch. Controls may be installed in the same room as the fan.
8. Fans should be located in a central hallway or bathroom.
9. When installing a continuously operating exhaust fan, educating the client about its use is extremely important. The client should be informed about:
   a. The purpose(s) of the exhaust fan installation.
   b. The importance of operating the fan whenever the house is closed up, such as during the heating season.
   c. The disadvantages of not operating the exhaust fan.

2263 Existing Exhaust Fans

1. Existing mechanical exhaust ventilation systems should be made to terminate outside the building shell by extending the ventilation duct through the roof or sidewall.
2. Replacement exhaust system ductwork shall consist of galvanized metal, rigid aluminum, PVC, or aluminum flex duct under six (6) feet in length and insulated.

2300 Carbon Monoxide Alarms

1. When appropriate, a carbon monoxide (CO) alarm should be installed in the client dwelling. Follow the manufacturer's recommendation for location and installation of the alarm.
2. The CO alarm manufactured by G. E. Kerr Companies, model "CO-Experts UL-1B" is recommended. (G. E. Kerr Companies, 19299 Katrina Lane, Eldridge, Missouri 65463, 800-643-5377, gekerr@tds.net) ***Combustion Appliance Safety Testing and Repairs***

1. All conventionally vented (this excludes direct-vent appliances) combustion appliances must be tested for proper draft using the worst-case draft procedures in Section 11700 on page 111.
   a. Worst-case draft testing MUST always be done after all weatherization measures are installed.
   b. Worst-case draft testing is suggested before weatherization work begins in dwellings where:
      i. There is ductwork installed in a Combustion Appliance Zone (CAZ); or
      ii. The auditor/estimator has reason to believe that worst-case draft testing would reveal useful information.
2. Subgrantees must seek to eliminate conditions where carbon monoxide levels are at or over the levels stated herein.
3. Carbon monoxide testing of space and water heating appliances must be done with a digital carbon monoxide meter before dilution air enters the vent system. If there is a flue opening for each burner, the test must be done in each flue opening individually.

Table 2-1

Carbon Monoxide (CO) Action Levels and Allowable Levels			
Appliance	***Action CO Level***	***Allowable CO Level***	***Comments***
Gas Furnace / Boiler	100 ppm / 200 ppm	200 ppm / 400 ppm	as-measured / air-free
Gas Water Heater	100 ppm / 200 ppm	200 ppm / 400 ppm	as-measured / air-free
Gas Range Bake Burner	800 ppm	800 ppm	air-free (see Section 111100, page 126)
Oil Furnace / Boiler	100 ppm	200 ppm	as-measured
Oil Water Heater	100 ppm	200 ppm	as-measured
"Action CO Level" indicates level above which repair or adjustment to appliance is recommended to lower CO emissions. "Allowable CO Level" indicates maximum CO emission levels allowed by the North Dakota Weatherization Program.			

4. In cases where an atmospheric combustion heating system is present in a mobile home, a new sealed combustion heating system may be installed.
5. When there is an atmospheric combustion appliance in a bedroom,
   a. The appliance must be isolated from the bedroom air by drawing combustion air from another appropriate source;
   b. If the appliance is replaced, a sealed combustion system must be installed; or
   c. The appliance should be moved to a more appropriate location.
6. A heat shield must be installed when it is determined that a venting system is too close to combustible materials or the venting system must be moved to ensure proper clearance.
7. All fuel lines must be tested for fuel leaks both outdoors and indoors, starting at the meter or LP tank.
8. Mobile home furnaces, on which a new limit switch has been installed, should have the new limit switch wired in series with the existing limit switch.
9. In cases where an unvented combustion appliance is used, the appliance should be removed or vented prior to weatherization completion.
10. Remove all non-functioning humidifiers from forced air furnace systems with prior client approval.
11. All gas valves should have at least a single safety. If a gas valve has no safety, then the subgrantee should replace the gas valve with the most cost-effective replacement:
    a. A 100% safety millivolt gas valve.
    b. A 100% safety 24 volt gas valve.
    c. A remote bulb gas valve.

12. When there is a suspicion that the pilot safety system is not functioning properly, subgrantees should perform a simple test of the pilot safety device to ensure that it is functioning properly.
13. It is recommended subgrantees use a non-contact voltage sensor to ensure that the main switch has properly turned off the electricity to a space heating unit.
14. All 110 volt wiring connections should be secured with wire nuts and electrical tape, and enclosed in an electrical junction box or other appropriate enclosure.
15. The proper size and type of wire should be used. The wire should have the correct rating for voltage, amperage, and heat exposure.
16. Draft hoods, draft diverters, and barometric dampers should be well secured to the appliance, level, and should not reduce or restrict the size of the vent.
17. All gas ranges should be tested for carbon monoxide according to Section 111100 on page 126.
18. Flexible gas connectors installed by subgrantees should be installed so that they do not pass through the appliance body.
19. All direct vent (sealed combustion) water heating and space heating appliances with visual indicators of a potential carbon monoxide problem, such as carbon build-up, must be tested for carbon monoxide.

2410 Response to Combustion Appliance Problems

It is often best to contact the local gas company or oil dealer to correct these problems. Gas utilities always have their own emergency response protocols; these should be respected. The items listed below are not intended to interfere with gas utilities emergency protocols (often called tagging procedures).

In each of the situations in Section 2410, the appliance technician will evaluate the client's situation, in consultation with the Subgrantee Weatherization Coordinator or Director, for the purpose of determining if:

1. The client can safely remain in the home if an alternative source of heat (portable electric space heaters) or must to be relocated for a short time.
2. If the technician believes the client cannot safely remain in the home, they will be advised to make arrangements to stay with family or friends until the unit can be occupied again.
3. If the client cannot make arrangements to stay in another location until the problem is solved, the subgrantee may use furnace repair and replacement funds to provide temporary shelter until other arrangements can be made.

Documentation supporting the needed repairs must be kept in the client file. Repairs done under the Weatherization Program must be included as part of the

SIR calculation computed by the WXEOR computerized audit unless done to protect the client's health and/or safety. Clients without heat during the heating season shall be provided with temporary heating appliances to ensure thermal comfort, stabilize the situation, and prevent damage to the dwelling.

2411 Emergency Situations, Immediate Follow-up Required

Some safety problems may warrant a discontinuing of the combustion appliance testing or shutting off the appliance until the repairs can be made. When this situation occurs for a space heating appliance, the client must be left with an alternative source of heat. Whenever a technician questions the safety of a situation, they should consult a supervisor.

Examples of this type of situation are:

1. *Major Natural Gas Leak:* Gas can be smelled more than two feet from the gas line.
2. *Major Propane or Natural Gas Leak:* Propane can be smelled more than three feet from the leaking fitting.
3. *Clogged or Disconnected Flue:* A clogged or disconnected flue that cannot be fixed, causing significant spillage of combustion products into a heated space, or working area of the technician.
4. *Backdrafting or Significant Spillage:* Any backdrafting of combustion products in combination with carbon monoxide indications, which cannot be fixed.
5. *Cracked Furnace Heat Exchanger:* Any visually identified cracked heat exchanger leaking combustion products in combination with positive carbon monoxide or others.
6. *Other Hazards:* Any other situation or combination of situations which the technician or supervisor judges hazardous to the health of the client or others.

2412 Non-Emergency, One-day Follow-up Required

Some situations may not warrant discontinuing testing or shutting down the heating system, but are serious enough to require attention within twenty-four hours. Examples of this type of situation are:

1. *Cracked Heat Exchanger:* Visually identified cracked heat exchanger that is leaking combustion products, with no carbon monoxide indications.
2. *Spillage:* Spillage but no carbon monoxide indications in a heated space.
3. *Propane or Natural Gas Leak:* Propane can be smelled, but not more than three feet from the leaking fitting.

4. *Carbon Monoxide:* Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25, and there must be an adequate draft and no spillage.
5. *No Limit Switch:* A furnace with no limit switch or a limit switch that is disconnected.

2413 Non-Emergency, Five-day Follow-up Required

All other safety related follow-up must begin within five days. Examples of this type of situation are:

1. *Draft:* Unacceptable draft with spillage in an unheated area.
2. *Propane or Natural Gas Leak:* Gas can be smelled, but not more than two feet from the gas line.
3. *Limit:* A furnace limit switch that does not shut the gas off by 225^{o} F.
4. *Suspicion of a Cracked Furnace Heat Exchanger*: A cracked heat exchanger is suspected, but there are no other apparent problems with the furnace.

2420 Required Safety Tests & Standards for Combustion Appliances

Test all active combustion heating systems and appliances whether they are primary, secondary, off-peak, or dual-fuel systems.

2421 Forced Air Systems

The subgrantee must document each situation in which the following specification cannot be met. All forced air systems should conform to the following standards:

1. *Gas-fired unit requirements*
   a. *Gas leaks:* All identified gas leaks should be referred to appropriate persons for repair or replacement. Hold the leak detector probe just below a propane gas line and just above a natural gas line.
   b. Flexible gas lines must be replaced under the following conditions:
      i. The line is badly kinked, corroded or shows signs of the physical wear.
      ii. The line connection is the soldered, two-piece type connection.
      iii. The line was manufactured before 1973. Sometimes there is a metal ring on the flexible line that is dated. If there is no dated metal ring, use one of the first two criteria listed just above.

c. *Cleaning and tuning:* All gas-fired units must be cleaned and tuned once every two to three years. Make sure the client is having this service performed regularly.

2. *Oil-fired unit requirements*

a. *Oil storage and piping:* Check the oil tank and piping for leaks and compliance with all appropriate codes.

b. *Cleaning and tuning:* All oil-fired units should be cleaned and tuned annually. Make sure the client is having this service performed regularly.

3. *Limit switch:* This switch should shut the gas valve off at approximately 200ºF, where appropriate. Some units should not be tested in this manner.

4. *Heat rise:* Heat rise should fall within the manufacturer's recommended temperature range. If this information is not available, the heat rise should fall within a 40º to 80ºF. range. The furnace must not cycle on the high-limit switch.

5. *Draft/spillage:* All furnaces must be properly vented. All non-sealed combustion furnaces must be tested with a draft-testing device and meet the acceptable draft requirements. There must be no spillage. The flue must not be clogged, disconnected, or rusted to the point that it leaks. All furnaces, with the exception of direct-vent units, must be tested with worst-case draft test procedures (see Section 11700 on page 111).

6. *Carbon monoxide (CO):* All non-sealed combustion heating systems must be tested with a CO testing meter. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.

7. *Ductwork:* Return ductwork located in the combustion appliance zone (CAZ) shall be sealed, if necessary, so that it does not create hazardous negative pressure in the CAZ during air handler operation. Please refer to worst-case draft testing procedures in Section 11700 on page 111. Please refer to Section 11922 on page 117 for details of duct testing and repair.

8. *Filter:* A clean filter should be installed in a location where the client can locate it for the purpose of replacing or cleaning it.

9. *Sizing Replacement Systems:* Actual appliance output must be determined and fall within a range of 100 to 130 percent of the required heat output of the heated space in its post-weatherized condition.

2422 Gravity, Space, Wall, and Floor Furnaces

All gravity, space, wall and floor furnaces should confirm to the following standards:

1. *Gas-fired unit requirements*

a. *Gas leaks:* All identified gas leaks should be referred to appropriate persons for repair or replacement. Hold the leak detector probe just below a propane gas line and just above a natural gas line.

b. Flexible gas lines must be replaced under the following conditions:

   i. The line is badly kinked, corroded or shows signs of the physical wear.

   ii. The line connection is the soldered, two-piece type connection.

   iii. The line was manufactured before 1973. Sometimes there is a metal ring on the flexible line that is dated. If there is no dated metal ring, use one of the first two criteria listed just above.

c. *Cleaning and tuning:* All gas-fired units must be cleaned and tuned once every two to three years. Make sure the client is having this service performed regularly.

2. *Oil-fired unit requirements*

   a. *Oil storage and piping:* Check the oil tank and piping for leaks and compliance with all appropriate codes.

   b. *Cleaning and tuning:* All oil-fired units should be cleaned and tuned annually. Make sure the client is having this service performed regularly.

   c. *Limit switch:* Gravity furnaces must be equipped with a working high limit switch that shuts the fuel supply off at approximately 250^{o}F.

3. *Draft/spillage:* All furnaces must be properly vented. All non-sealed combustion furnaces must be tested with a draft-testing device and meet the acceptable draft requirements. There must be no spillage. The flue must not be clogged, disconnected, or rusted to the point that it leaks. All furnaces, with the exception of direct-vent units, must be tested with worst-case draft test procedures (see Section 11700 on page 111).

4. *Carbon monoxide (CO):* All non-sealed combustion heating systems must be tested with a CO testing instrument. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.

5. *Filter:* If the manufacturer intended that the appliance have a filter, it should be checked for cleanliness. If a filter was not intended by the manufacturer, one shall not be installed.

6. *Btu/hour Input for gas freestanding, wall and floor units:* Actual appliance output must be determined and fall within a range of 100 to 130 percent of the required heat output of the heated space in its post-weatherized condition. If the existing appliance output rating

falls outside of this range, replacement for reasons of health and safety should be considered.

2423 Mobile Home Sealed Combustion Furnaces

All sealed combustion; mobile home furnaces should conform to the following:

1. *Gas-fired unit requirements*
   a. *Gas leaks:* All identified gas leaks should be referred to appropriate persons for repair or replacement. Hold the leak detector probe just below a propane gas line and just above a natural gas line.
   b. Flexible gas lines must be replaced under the following conditions:
      i. The line is badly kinked, corroded or shows signs of the physical wear.
      ii. The line connection is the soldered, two-piece type connection.
      iii. The line was manufactured before 1973. Sometimes there is a metal ring on the flexible line that is dated. If there is no dated metal ring, use one of the first two criteria listed just above.
   c. *Cleaning and tuning:* All gas-fired units must be cleaned and tuned once every two to three years. Make sure the client is having this service performed regularly.
2. *Oil-fired unit requirements*
   a. *Oil storage and piping:* Check the oil tank and piping for leaks and compliance with all appropriate codes.
   b. *Cleaning and tuning:* All oil-fired units should be cleaned and tuned annually. Make sure the client is having this service performed regularly.
3. *Limit switch:* This switch should shut the gas valve off at approximately 200ºF, where appropriate. Some units should not be tested in this manner.
4. *Heat rise:* Heat rise should fall within the manufacturer's recommended temperature range. If this information is not available, the heat rise should fall within a 40º to 80ºF. range. The furnace must not cycle on the high-limit switch.
5. *Carbon monoxide (CO):* All non-sealed combustion heating systems must be tested with a CO testing instrument. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.
6. *Non-sealed combustion furnaces:* These units should be replaced with sealed combustion furnaces.
7. *Sizing Replacement Systems:* Actual appliance output must be determined and fall within a range of 100 to 130 percent of the

required heat output of the heated space in its post-weatherized condition.

2424 Boilers

The subgrantee must document each situation in which the following specification cannot be met. All boiler systems should conform to the following standards:

1. *Gas-fired unit requirements*
   a. *Gas leaks:* All identified gas leaks should be referred to appropriate persons for repair or replacement. Hold the leak detector probe just below a propane gas line and just above a natural gas line.
   b. Flexible gas lines must be replaced under the following conditions:
      i. The line is badly kinked, corroded or shows signs of the physical wear.
      ii. The line connection is the soldered, two-piece type connection.
      iii. The line was manufactured before 1973. Sometimes there is a metal ring on the flexible line that is dated. If there is no dated metal ring, use one of the first two criteria listed just above.
   c. *Cleaning and tuning:* All gas-fired units must be cleaned and tuned once every two to three years. Make sure the client is having this service performed regularly.
2. *Oil-fired unit requirements*
   a. *Oil storage and piping:* Check the oil tank and piping for leaks and compliance with all appropriate codes.
   b. *Cleaning and tuning:* All oil-fired units should be cleaned and tuned annually. Make sure the client is having this service performed regularly.
3. *Draft/Spillage:* All boilers must be properly vented. All non-sealed combustion boilers must be tested with a draft-testing device and meet the acceptable draft requirements. There must be no spillage. The flue must not be clogged, disconnected, or rusted to the point that it leaks. All boilers, with the exception of direct-vent units, must be tested with worst-case draft test procedures (see Section 11700 on page 111).
4. *Carbon monoxide (CO):* All non-sealed combustion heating systems must be tested with a CO testing instrument. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.
5. *Sizing Replacement Systems:* Actual appliance output must be determined and fall within a range of 100 to 130 percent of the

required heat output of the heated space in its post-weatherized condition.

2425 Storage Water Heater Inspection

All gas fired water heaters must meet the following specifications:

1. All identified gas leaks should be referred to the appropriate person for repair. All gas leaks should be documented in client file.
2. All water heaters must be properly vented. All fossil-fuel water heaters, with the exception of direct-vent units, must be tested with worst-case draft test procedures (see Section 11700 on page 111).
3. All non-sealed and sealed combustion water heaters must be tested with a CO testing device. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.

2426 Combustion Air Supply

1. Atmospheric combustion appliances shall be provided with additional combustion air if there are indicators of inadequate combustion air. These appliances must be provided with at least 50 cubic feet of indoor space for every 1000 Btuh of appliance input rating in the combustion appliance zone (CAZ).
   a. If the CAZ contains or is properly connected with less than a volume of 50 cubic feet of indoor space for every 1000 Btuh of appliance input rating, it is defined as a “confined space” by the National Fire Protection Association (NFPA).[1] In this case, steps must be taken to correct the situation. Please refer to the latest edition of NFPA 31, *Standard for the Installation of Oil-Burning Equipment;* NFPA 54, *National Fuel Gas Code;* or NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances* for corrective measures.
   b. If the CAZ contains or is properly connected with a volume of 50 cubic feet or more of indoor space for every 1000 Btuh of appliance input rating, it is defined as an “unconfined space” by the National Fire Protection Association (NFPA). In this case, no corrective action is required, unless an appliance in the CAZ fails the worst-case draft test.
2. The dedicated combustion-air intake of sealed combustion (direct-vent) appliances must be inspected. The air intake must be physically connected to the appliance body and it must pull air from outside the building structure.

[1] Combustion appliances that are located in the space but do not take combustion supply air from the space, such as direct-vent appliances, should not be included in the confined/unconfined space calculation.

2427 Gas Range Inspection and Testing

1. Gas ranges should meet the following specifications found in Section 111100 on page 126.

2428 Flexible Gas Connectors

1. Flexible gas lines must be replaced under the following conditions:
   a. The line is badly kinked, corroded or shows signs of the physical wear.
   b. The line connection is the soldered, two-piece type connection.
   c. The line was manufactured before 1973. Sometimes there is a metal ring on the flexible line that is dated. If there is no dated metal ring, use one of the first two criteria listed just above.

2429 Fuel Leaks

1. All identified fuel leaks on all lines and controls within the structure must be repaired.

24210 Heat Exchangers

2. All space-heating systems with an identified crack in the heat exchanger must be replaced. Exceptions are those cases where a very small hole, such as a pinhole, or any other inconsequential defect resulting from the manufacturing process may exist, and carbon monoxide (CO) readings are within the acceptable range when CO emission tests are performed both with the air handler running and off.

24211 Draft, Backdrafting, and Spillage

All fossil-fuel combustion appliances, with the exception of direct-vent units, must be tested with worst-case draft test procedures (see Section 11700 on page 111) to ensure proper draft during worst-case conditions.

24212 Venting Combustion Appliances

1. The combustion venting system of all combustion appliances must be inspected.
2. All venting systems shall comply with the latest edition of NFPA 31, *Standard for the Installation of Oil-Burning Equipment;* NFPA 54, *National Fuel Gas Code;* or NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances.*
3. Combustion venting systems that are clogged, disconnected, improperly terminated or corroded to the point that they leak combustion products into the building, must be repaired so that all combustion gases vent outside the building structure.

24213 Wood/Coal Stoves and Fireplaces

1. Whenever possible, ask the client to start the wood or coal stove after the use of any blower door testing has been completed. With the stove operating, check around the solid-fuel appliances for carbon monoxide (CO) emissions. If there are any indications of CO leaking from the stove into the ambient air, repair it, or replace the stove if it is the primary means of space heating.
2. All venting systems and installations shall comply with the latest edition of NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances.*
3. The client shall be notified of any unsafe conditions.

2500 Blower Door Safety

1. If a dwelling is tightened to a CFM_{50} level less than the calculated Building Tightness Limit for that dwelling, properly sized continuously operating mechanical ventilation is recommended. Please refer to Section 11400 on page 105 for instructions about determining the Building Tightness Limit CFM_{50} value.
2. Do not conduct a depressurization blower door test while a wood stove, fireplace, or a vented space heater is operating.
   a. If one of these appliances is operating, it will not be considered sufficient reason for never conducting a blower door test. It is expected that weatherization personnel will shut down the appliance to conduct the test or that they will revisit the dwelling at a time when the appliance is not operating.
3. Do not conduct a depressurization blower door test when any combustion appliance is operating.
   a. It will be considered standard practice to positively shut off conventionally vented combustion appliances before the blower door test is conducted. A procedure should be in place to ensure that the appliance is returned to the pretest condition. Exceptions to appliance shut down include:
      i. Direct-vent (sealed combustion) appliances.
      ii. Unvented gas appliances, such as most gas ranges.

2600 Electrical Safety

2610 Knob-and-Tube Wiring

1. If knob-and tube wiring is active in an attic, any insulation must be keep at least three inches from the wiring. Blown insulation must be appropriately dammed to keep the insulation from advancing closer than three inches from the knob-and-tube wiring.

2. If active knob-and-tube wiring is found in a dwelling attic, walls, or basement, the walls of the dwelling must not be insulated.
3. If knob-and-tube wiring has been deactivated and the dwelling has been rewired with BX, Romex, or other approved electrical cable, the attic and walls may be insulated without special precaution.

2620 Ground-Fault Interrupt Circuits

1. Ground-fault circuit interrupter (GFCI) devices should be tested to ensure that they are working properly in dwelling bathrooms and kitchens.
2. If a GFCI is not installed in a dwelling bathroom, a subgrantee may have one installed if appropriate.

3000 Energy Audit Requirements

3100 Field Audit

1. A field audit of each unit must be conducted and documented in the unit file.
2. The field audit must include:
   a. A health, safety, and hazards assessment of the unit as well as the combustion appliances;
   b. A cost-effective analysis using the approved energy audit system;
   c. An air leakage/ventilation assessment;
   d. A ductwork assessment;
   e. An insulation assessment; and
   f. A general heat waste assessment.
3. The prescriptive installation of weatherization materials or repairs without appropriate justification from an approved energy audit is not allowed.
4. The thermal boundary of each dwelling must be determined during the field audit. This includes the identification of each part of the thermal shell or envelope.
5. All building cavities that define the thermal boundary between the conditioned space and unconditioned must be inspected and measured for existing insulation R-values, structural integrity, and the need for repairs.
6. The field audit must identify the most appropriate methods for:
   a. Reducing air leakage and convective bypasses, and
   b. Increasing the insulating value of thermal boundary surfaces, when appropriate.

3200 Computerized Energy Audit

1. Each client file must have an accurate work order generated by the State approved computerized audit.
   a. *Exception:* In the case of multi-family units – those for which the State approved audit does not address, such as high rise units three stories or greater, units with large central heating systems, or units with large common areas – agencies must work in consultation with the DCS WAP Administrator in the development of appropriate priority lists.
2. An acceptable work order means one for which all WAP installed measures have a Savings to Investment Ratio (SIR) of 1.00 or greater.

a. Measures for which SIR values are less than 1.00 are ineligible.
b. Measures for which SIR values are 1.00 to 1.24 are optional.
c. Measures for which SIR values are greater than 1.24 are mandatory.

3. If the estimator is aware of more than one method of installing an energy conserving measure, he must be able to justify, in writing in the client file, the selection of a method that does not have the highest SIR of the possible methods.
4. If repairs must be done in order to protect the integrity of an eligible measure, the repair costs must be included with that measure's cost when the associated SIR calculated.
5. Values and methods used for the State approved computerized audit will be periodically updated by either the subgrantee or statewide WAP committees as follows:
   a. Labor and material cost estimations used for the approved audit must be updated at least once each year and procedures used to derive these estimated costs must be documented by the subgrantee.
      i. Labor costs shall include fringe benefits as defined by the subgrantees accounting system.
      ii. Insulation cost estimates must be based on at least the manufacturers recommended minimum installation density.
   b. A technical committee made up of representatives from all the State subgrantees will determine and update each year:
      i. The typical service life of each energy-saving measure. The service life values must be discounted for use in the calculation of SIR in accordance with Department of Energy guidelines.
      ii. A consistent method determining the cost of fuels to be used in the WXEOR audit.
      iii. Maximum insulation levels.

4000 General Heat Waste Measures

Although no prescriptive list of treatments is applicable to every dwelling type, there are treatments that are typically cost-effective when applied to most dwellings. For most all dwellings, the order of work and applied measures is the same:

1. Perform pre-installation energy audit.
2. Determine and seal major leakage areas in the building envelope.
3. Perform heating system efficiency measures.
4. Pressure balance, seal, and insulate ducts.
5. Insulate pipes and water heater.
6. Install energy-saving shower heads.

These are the general heat waste measures.

4100 Air Sealing Requirements

Air sealing is a general heat waste item. This means that no savings-to-investment ratio (SIR) must be calculated for air sealing work.

Before air leakage reduction measures are installed, the building envelope must be defined and existing health and safety problems must be corrected.

Infrared scanning should be used as a tool to identify areas of excessive air leakage. The infrared scanning device is a powerful tool for finding air leaks when used in conjunction with a blower door. Subgrantees are advised to use infrared scanning whenever the equipment is available and the use is practical.

4110 Blower Door Use

1. Pre- and post-weatherization CFM_{50} measurements must be completed on each unit and documented in each client file. A one point CFM_{50} blower door measurement is preferred over the multi-point computer-derived method. See Section 11100 page 101 for proper blower door setup and use.
   a. Pre- and post-weatherization blower door tests may be waived due to the following circumstances:
      i. Problems may be created in the unit due to a lack of structural integrity.
      ii. Suspected friable asbestos-containing material may be significantly disturbed.
      iii. Other documented extenuating circumstances.
2. Blower door testing should continue during air-leakage reduction work as part of blower-door-guided air sealing. Please refer to

Section 11300 on page 104 for cost-effective guideline procedure instructions.

3. Before air leakage and convective bypass measures are installed, the building envelope must be defined and existing health and safety problems must be corrected.

4120 Cost-Effective Air Sealing Guidelines

1. Before blown insulation is installed, all obvious leaks should be sealed. These leaks might include, but are not limited to:
   a. Open top plates (usually in balloon-frame dwellings).
   b. Chases around masonry and metal chimneys.
   c. Chases around plumbing stacks.
   d. Missing window sashes or lights.
   e. Installation of sash locks on double- and single-hung windows. Two cam-type locks per window sash are preferred.
   f. Doors that are misaligned in their frames.
   g. Missing drywall or other interior finish materials.
   h. Missing or misaligned attic doors or hatches.
   i. Missing or misaligned outside access doors in basements.
   j. Other obvious holes or leaks in the dwelling envelope that:
      i. Are cost-effective to seal,
      ii. Prevent the structure from damage, or
      iii. Are necessary for the proper installation of insulation.
2. All major tasks and measures should be completed before additional air leakage reduction measures are implemented:
3. Whenever feasible and more cost-effective, the installation of tube-filled, high density cellulose insulation in sidewalls, cathedral ceilings, convective bypass areas, open top plates/drop ceilings and other air leakage locations is preferred over the use of air sealing techniques using air barrier materials for achieving reductions in air leakage.
4. Cost-effective guideline procedures should be used if appropriate *during* air sealing activities.
5. Please refer to Section 11300 on page 104 for cost-effective guideline procedure instructions.
6. Documentation of materials, labor, and CFM_{50} reductions must be retained in the client file.

4130 Room-to-Room Pressures

1. Room-to-room pressure(s) should be measured in all rooms with forced air heating return or supply ducts and operable doors, after all

weatherization installations have been completed. Please refer to Section 11800 on page 115 for detailed instructions.

4140 Penetrations and Holes

1. All penetrations through the exterior sidewalls of a unit that are sealed must be sealed from the interior with the exception of:
   a. Foundations, which may be sealed from either interior or exterior.
   b. Any hole or penetration requiring sealing to keep out rain or snow.
2. Before blown insulation is installed, all obvious leaks should be sealed. These leaks might include, but are not limited to:
   a. Open top plates (usually in balloon frame dwellings).
   b. Chases around masonry and metal chimneys.
   c. Chases around plumbing stacks.
   d. Missing window sashes or lights.
   e. Doors that are misaligned in their frames.
   f. Missing drywall or other interior finish materials.
   g. Missing or misaligned attic doors or hatches.
   h. Missing or misaligned bulkhead doors in basements.
   i. Other obvious holes or leaks in the dwelling envelope that:
      i. Will be unquestionable cost-effective to seal,
      ii. Will prevent the structure from damage, or
      iii. Are necessary for the proper installation of insulation.
3. Openings in recessed light fixtures must not be sealed unless the fixture is rated as an “IC” fixture.
4. A fire-rated material, such as at least 26 gauge galvanized tin, must be used to seal gaps around heat sources such as masonry or metal chimneys. This fire-rated material must be sealed with high temperature caulking to the chimney and to surrounding framing and finish materials.
   a. Unfaced fiberglass insulation of at least 3 ½ inches in thickness must be used to wrap the chimney above this fire-rated material. This fiberglass serves as a fire shield for cellulose installed against the fiberglass.
   b. If an existing chimney or flue is treated incorrectly, correct it to comply with these standards. If it is not reasonable to bring a chimney up to these standards, document this fact in the client file and include photographs.

4150 Zonal Pressure Diagnostics

1. The completion of Zonal Pressure Diagnostics (ZPD) testing to assist in the determination of the location thermal boundaries of the unit and

the effectiveness of air sealing measures is highly recommended in some dwellings. Please refer to Section 111000 on page 123 for the details of ZPD procedures.

4160 Fireplace Plugs, and Equipment Covers

1. Removable fireplace "plugs" should be installed in a manner that prohibits the use of the fireplace unless the "plug" is removed.
2. Covers for evaporative coolers, whole house fans, and window air conditioners should be easy to remove and reinstall.

4200 Ducted Distribution Requirements

Ductwork treatment is a general heat waste item. This means that no savings-to-investment ratio (SIR) must be calculated for ductwork treatment.

4210 Ductwork Inspection, Cleaning, and Sealing

1. Ductwork must be tested and sealed according to Section 11900 on page 116, Duct Leakage Testing.
2. Delivery and return ductwork must be cleaned as necessary to remove large objects and debris, which may impede airflow through the heating system.
3. Uncover any blocked registers or grilles. Explain to the client the importance of maintaining the unrestricted airflow.
4. As necessary, delivery and return air grilles and registers must be removed and cleaned to remove excessive dirt and debris, which may impede airflow.
5. When appropriate, remove ducts, registers, and grilles located in unconditioned spaces.
6. Ductwork outside the thermal envelope of the dwelling must be connected and sealed.
7. All accessible return air ductwork within a combustion appliance zone (CAZ), except gravity systems, must be sealed enough to eliminate the potential for backdrafting. Please refer to Section 11700 on page 111 for Worst-Case Draft Testing procedures.
8. Ducts and registers into non-living areas of the structure may be sealed off with owner permission.
9. Existing crawl-space plenums should be abandoned and replaced with a sealed duct system.
10. *Cloth duct tape shall never be used for duct sealing.*
11. Ductwork sealing shall be done with mastic, mesh tape, sheet metal, or pressure sensitive metal tape.
    a. Gaps of 1/8 inch or less may be sealed with:
        i. Duct mastic.

ii. Pressure sensitive metal tape

b. Gaps between 1/8 inch and 1 inch shall be sealed with:

i. Duct mastic embedded with fiberglass mesh.

c. Gaps larger than 1 inch shall be covered with sheet metal or valley flashing, fastened with screws, and sealed with mastic.

12. New ductwork installations may not include panned joists or stud cavities for ducts. All passageways for distribution air must be hard ducted.
13. If the boot is loose to the floor it shall be reattached to the sub floor with roofing nails or staples. Wood screws may also be used. Ensure that the heads of the screws do not prevent the register or grille from fitting into the boot.
    a. If gaps exist between the boot and the floor and the space below the floor is unconditioned, fill the gaps with mastic or other appropriate materials.

4220 Ductwork Sealing Materials

1. *Cloth duct tape shall never be used for duct sealing.*
2. Existing duct tape must be removed before installing duct mastic or other approved sealing materials
3. Mastic shall meet the following requirements:
    a. Non-toxic and water resistant.
    b. UL listed and labeled per UL 181A or 181B standards.
    c. Shall be compatible with the duct material to which it is applied.
4. Mesh fabric used to reinforce duct mastic shall meet the following requirements:
    a. Comply with the mastic manufacturer's specifications.
    b. Made of fiberglass.
    c. Have at least a 9 x 9 weave per inch.
    d. Be at least 0.006 inches in thickness.
5. Pressure sensitive metal tape shall meet the following requirements:
    a. UL listed and labeled per UL 181A or 181B standards.
    b. Tape width must be at least 2 inches.
    c. Butyl adhesive must be at least 15 mils thick.
6. Draw bands used to support or seal ductwork shall meet the following requirements:
    a. Comply with the manufacturer's installation instructions.
    b. Weather- and UV-resistant duct ties or stainless steel worm drive clamps

c. Loop tensile strength must be at least 150 pounds.
d. Service temperature rating must be at least 165^{o}F.

7. Duct supports shall conform to the duct manufacturer's installation instructions and must be corrosion resistant.

4230 Ductwork Insulation

1. Ductwork outside the thermal envelope must be insulated or repaired if damaged.
   a. Prior to installing insulation, ductwork must be sealed according to these standards.
   b. *Exception:* Inaccessible parts of the distribution system do not require thermal insulation. Inaccessible means nearly impossible to insulate because of location or obstructions.
2. Supply and return ducts and plenums in conditioned spaces do not require thermal insulation.
   a. *Exception:* There might be cases where duct insulation is appropriate in a conditioned area, such as a basement. For example, if there is not adequate heat getting to a room, the branch duct may be insulated for reasons of thermal comfort as long as the following items have been checked and/or implemented first:
      i. There are no branch duct obstructions to airflow.
      ii. The branch duct balancing damper is fully open.
      iii. The branch duct air leakage has been checked and sealed, if necessary.
3. Combustion or exhaust vents should not be insulated.
4. Install a minimum of R-8 (preferably R-11, when possible) on ducts and plenums.
   a. If ductwork is already insulated to a level of R-4 or greater, no additional insulation is required, however, make appropriate repairs to the existing insulation.
5. Insulation must have a flame spread rating no greater than 25.
6. Only vinyl-backed or reinforced foil duct wrap is to be used on ducts.
7. The duct insulation should be installed with the vapor barrier on the outside, which will serve to cover the insulation.
8. Do not wrap duct insulation so tightly that it is excessively compressed. It should not be compressed more than 50 percent of normal thickness.
9. Maintain a minimum of 6 inches between duct/pipe insulation and all heat sources;
10. Install protective covering around the insulation where required by local regulations.

4240 New Ductwork Installations

1. Ducts, supply registers, and return grilles should be sized and selected according to the latest editions of *Residential Duct Systems*, Manual D, by ACCA; Residential *Comfort System Installation Standards Manual* by SMACNA; or a comparable industry-accepted method.
2. Attempt to install all new ductwork within conditioned spaces.
3. Do not install ductwork within exterior walls.
4. All distribution-air enclosures must be hard-ducted, that is, building frame cavities, closets, crawl spaces, and chases must not be used as distribution-air enclosures. However, ductwork may be housed by, or pass through these spaces.
5. Ductwork must be installed at least 4 inches from any bare earth.
6. Panned floor joists may not be used for air distribution.
7. A crawl space may not serve as a distribution plenum.
8. Existing crawl-space plenums should be abandoned and replaced with a sealed duct system.
9. Do not use a dropped ceiling cavity as a plenum.
10. The installation of new ductwork into areas of a structure not currently served by the central space heating system may be cost-effective when the area of the home is currently being heated with a more expensive energy source.

4300 Piped Distribution Requirements

Treatment of distribution pipes for hot water or steam heat, or for domestic hot water treatment is a general heat waste item. This means that no savings-to-investment ratio (SIR) must be calculated for such treatment.

4310 Steam and Hot Water Heating Distribution Pipes

1. Make certain there are no leaks in hot water or steam distribution pipes.
2. Supply and return lines in unconditioned spaces must be insulated, ensuring that the pipes are completely covered.
3. Pipes may be insulated within the living space if it is determined that the space does not require heating or is overheated.
4. Pipe insulation must be sized to the pipe being insulated.
5. Secure the pipe insulation with mechanical fasteners or appropriate tape.
6. Pipe insulation must have mitered cuts at corner joints. Tape joints appropriately.

7. Pumps, valves, pressure relief devices, or vents should not be insulated. Do not insulate over heat tape.
8. Closed cell foam, high temperature rated insulation or elastomeric pipe insulation should be used that has a flame spread rating no greater than 25.
9. Maintain a minimum of 6 inches between pipe insulation and all heat sources.

4320 Domestic Hot Water Pipes

1. Make certain there are no leaks in domestic hot water pipes.
2. Insulate the first 9 feet of hot water pipe and the first 3 feet of cold water pipe with ¾ inch pipe insulation.
3. Closed cell foam, high temperature rated insulation or elastomeric pipe insulation should be used that has a flame spread rating no greater than 25.
4. Maintain a minimum of 6 inches between pipe insulation and all heat sources.
5. Domestic hot water pipes running through unconditioned spaces must be insulated if accessible.

4330 Water Heater Blankets

The installation of water heater blankets on electric water heaters in conditioned spaces is recommended unless this will void the warranty. Gas water heaters should not be insulated.

Water heaters located in unconditioned areas should be moved to a conditioned area, if possible. If the water heater cannot be moved, the heater and distribution pipes, both hot and cold, must be insulated.

4331 Water Heater Blanket Materials

1. The water heater blanket must be fiberglass batt insulation with a protective covering.
2. An R-11 water heater blanket is preferred on all tanks not labeled with a prohibition to installing additional insulation to that already installed by the manufacturer.
3. A water heater blanket must be secured to the water heater with at least two (2) straps with buckles. The installed straps must not excessively compress the water heater blanket.

4332 Installation

1. The water heater tank must be inspected to determine the type of water heater (gas, electric, other), and whenever possible, the amount of existing insulation.

2. If there are signs that the water heater is leaking, this problem must be solved before insulation is added.
3. Electric water heaters outside the living space, including mobile home water heaters in exterior closets, must be insulated if the total existing tank insulation is less than R-11.
4. A water heater blanket must not be installed when a temperature and pressure relief valve does not exist or when the existing temperature and pressure relief does not operate properly.
5. A water heater blanket must not cover the following:
   a. The temperature and pressure relief valve on an electric unit.
   b. The drain valve on an electric unit.
   c. The electrical line attaches to an electric unit. Insulation must be keep at least two inches away from where this electrical line attaches to the water heater.

4340 Domestic Hot Water Temperature

1. Whenever feasible, the domestic hot water temperature must be measured and reduced to 120^{o}F. or less with the approval of the client/owner.
2. The client/owner must be informed that lowering the temperature of the water will result in less thermal energy stored in the hot water; therefore, they will run out of hot water sooner.
3. The original water temperature setting must be marked on the thermostatic control.

4350 Energy-Saving Showerheads

1. An energy-saving (low-flow) showerhead may be installed with client permission, if the existing showerhead flow is measured at greater than 3 gallons per minute (gpm) and the installation does not require the use of a plumber.
2. The energy-saving showerhead must have a flow rating of 2.5 gpm or less.
3. If an energy-saving showerhead is installed in conjunction with lowering the domestic hot water temperature, the chances are high that the client will not notice less hot water for showering, as they might if the temperature is reduced without installing the new showerhead.

4360 Water Heater Fuel Conversions

1. Homes that have both electric and gas supplied by the same provider are eligible for water heater conversions or fuel switching from electric to gas. Fuel switching refers to replacing the existing electric water heater with a new gas water heater. Gas water heaters may be

replaced with electric water heaters if it is necessary to seal off an orphaned flue.

2. Clients have the option of declining or waiving a water heater conversion for personal reasons. For example, if a conversion requires that a new venting system be run through finished space and the client does not like the appearance, the client may decline the conversion.
3. Agencies must first provide client education regarding the advantages and disadvantages of switching to gas water heating. If the client declines the conversion, they must sign a statement in the client file waiving the water heater conversion.
4. With the use of the approved audit, water heater fuel switching costs should be analyzed for cost effectiveness.
5. Water heater conversions must be completed by qualified personnel in compliance with applicable building codes.

4400 Combustion Appliance Requirements

The efficient operation of heating systems is a critical aspect of general heat waste. Detailed combustion system safety and efficiency standards are found in Section 2300 beginning on page 25 and Section 8000 beginning on page 83.

4410 Combustion Appliance Work Documentation

1. Each client file must include documentation of all efficiency work and adjustments made to the water heating and space heating combustion appliances, when applicable.
2. Client file documentation must include information on the applicable combustion appliance efficiency tests (see Section 8120 on page 83) and components (see Section 8130 on page 84).
3. Before the work on a combustion appliance may be considered complete, a representative of the subgrantee must have completed a review of all combustion appliance forms and determined that the combustion appliance(s) meet the specifications in Sections 2000 and 8100.

5000 Insulation Requirements

5100 Attic Insulation

5110 Inspection and Repairs

1. Prior to installing insulation, a thorough inspection of the attic area should be performed.
2. The inspection should include the determination of the R-value and integrity of existing insulation, location of air leakage passage from the conditioned spaces to the attic, and the suitability of the structure for receiving insulation.
3. The inspection should determine any repair work associated with the installation of the attic insulation. Repairs should be completed before installing insulation.

5111 Moisture Inspection and Repair

1. Roof leaks and all other attic moisture problems shall be repaired prior to the installation of attic insulation.
2. All mechanical vents from exhausting and combustion appliances must be vented through the roof or sidewall.
3. Repair any moisture problems that will degrade or diminish the effectiveness of weatherization measures.

5112 Electrical Safeguards

1. Correct electrical problems such as unsafe wiring, uncovered junction boxes, or electrical situations which must be corrected prior to performing any other work in the attic(s). If insulation exists, ensure that wiring is safe and meets applicable codes.
2. All visible electrical junctions must be flagged and be installed in covered junction boxes if additional insulation is installed.
3. All electrical fixtures, excluding IC (insulation contact) rated recessed lights and covered junction boxes, shall be blocked with rigid material, to ensure a minimum insulation clearance of 3 inches and a maximum clearance of 6 inches.
4. Knob-and-tube wiring:
   a. If knob-and tube wiring is active in an attic, any insulation must be keep at least three inches from the wiring. Blown insulation must be appropriately dammed to keep the insulation from advancing closer than three inches from the knob-and-tube wiring.

b. If knob-and-tube wiring has been deactivated and the dwelling has been rewired with BX, Romex, or other approved electrical cable, the attic may be insulated without special precaution.

5113 Treatment of Other Hazards

1. Use appropriate personal protective equipment and work practices in the presence of animal or insect hazards. Ensure personal safety during work.
2. Repair any rotted, broken, or damaged attic structural components. Ensure that the ceiling will safely hold the weight of the insulation. Repair or replace any weakened, damaged, or missing interior ceiling surface.

5114 Attic Access

1. When it is necessary to install an interior access in the ceiling, it must be at least 20 inches by 30 inches, and shall be weatherstripped and insulated to the same level as the attic floor or to at least R-19.
2. A ceiling access shall have an insulation dam, made of rigid materials, that exceeds the height of the insulation to be installed. The dam must be strong enough to hold the weight of a person entering or exiting the attic.
3. If there are no interior accesses, at least one exterior access to each attic space shall be left for inspection purposes.
4. When it is necessary to install an interior access in a kneewall, it must be at least the kneewall stud cavity width x 24”, and shall be weatherstripped and insulated to the same R-value as the kneewall. A latch shall also be installed to ensure air tightness.

5115 Insulation Shielding and Blocking

1. All electrical fixtures, excluding IC (insulation contact) rated recessed lights and covered junction boxes, shall be blocked with rigid material, to ensure a minimum insulation clearance of 3 inches and a maximum clearance of 6 inches.
2. No insulation, including fire-rated insulation shall be installed above recessed light fixtures, except IC (insulation contact) type, so as to entrap heat or prevent free air circulation.
3. Blocking must be installed so that it is effective in shielding the heat source from the insulation, and no insulation shall be left within the blocked area.
4. Metal blocking must be notched so that it does not contact electrical wiring.

5. If insulation is added to the attic, rigid permanent blocking is required around the attic access openings if they open into a living area and adequate clearance exists.
6. A fire-rated material, such as at least 26 gauge galvanized tin, must be used to seal gaps around heat sources such as masonry or metal chimneys. This fire-rated material must be sealed with high temperature caulking to the chimney and to surrounding framing and finish materials.
   a. Unfaced fiberglass insulation of at least 3 ½ inches in thickness must be used to wrap the chimney above this fire-rated material. This fiberglass serves as a fire shield for cellulose installed against the fiberglass.
   b. If an existing chimney or flue is treated incorrectly, correct it to comply with these standards. If it is not reasonable to bring a chimney up to these standards, document this fact in the client file and include photographs.
7. Requirements for furnaces installed in attics:
   a. Attic furnace blocking must be installed to ensure a minimum free air clearance of 18 inches, but not more than 24 inches.
   b. If a working platform is present for an attic furnace, or if one is installed by the subgrantee, 30 inches of clearance adjacent to the furnace controls must be provided.
   c. Attic furnaces must be checked after adding attic insulation to ensure they are free of insulation and operate properly.

5120 Installation Methods for Attic Insulation

1. Locate and seal attic thermal bypasses, chases, and open-topped partition walls. Properly treat ceiling height changes and stairwells as necessary to stop leakage. Seal kneewall floor cavities. Check for completion of bypass sealing before installing any insulation.
2. Attic insulation must be installed in such a manner that ensures complete coverage over heated areas, and is installed at an even depth except where physical constraints may exist.
3. Insulation must be installed according to the manufacturer's specifications for coverage and R-Value. Calculating the number of bags to be installed per the manufacturer's specifications is the best method for meeting manufacturer's specifications for loose fill insulation.
4. Attics should be tested using zonal pressure diagnostics when the housing construction type or the air leakage rate indicates that there may be hidden air leakage or bypass pathways into the attic. This test should be used to determine quality and completeness of air leakage and bypass sealing, prior to, and then after, installing

insulation. Please refer to Section 111000 on page 123 for instructions.

5. It is preferred that cellulose insulation be installed in site built homes.

5121 Insulation Coverage and Density

1. Insulate uninsulated open-joist attics to R-50 in all dwelling heated with any fuel by electric resistance and to R-60 for electric resistance heat. Add insulation to other areas as necessary or as directed by the WXEOR audit program.
2. At the beginning of each job, measure the density of the insulation for a selected test area before beginning the major installation. This should be done for insulation blowing jobs using any nozzle type or tubing method. The density of blow insulation must be within the range of the values listed below.
3. Insulate enclosed areas (under floors, slopes, under kneewall cavities, etc.) to high density level as follows:
   a. Blown cellulose 3.25 to 3.75 lb/ft^3
   b. Blown fiberglass 1.6 lb/ft^3
4. Insulate kneewall areas as follows:
   a. Blown cellulose 3.25 to 3.75 lb/ft^3
   b. Blown fiberglass 1.6 lb/ft^3
   c. Fiberglass batts R-19
5. Densely packing cellulose insulation is preferred as a method for sealing air leakage paths and bypass leakage in attics, where feasible.
6. Calculating the number of bags is the preferred method for determining the proper amount of material to be installed into an attic area at a given R-value.
7. Where the combined material and labor costs can be reduced, it is preferred that dropped soffits and similar construction details be filled with cellulose insulation.
8. When a vapor barrier is installed with the insulation, the barrier should be installed on the warm side of the insulation and never more than 1/3 of the R-value away from the warm-side surface.
9. Add necessary insulation to eliminate voids and areas of incomplete coverage. Cut or pull back existing fiberglass batts two feet from the soffit and blow and dense pack the perimeter. Prepare floored areas or other restricted zones with existing insulation for high-density application.

5122 Enclosed Ceiling Cavities

1. When insulating enclosed ceiling cavities, it is preferred that insulation be installed from a location other than the through roofing material. Such locations may include rafter cavities that open into an attic area, through the eve, or from the interior of the home.

5123 Storage Space

1. Where attic space is being used for storage, subgrantees should request the client remove storage items from the area.
2. In cases where the client is physically unable to perform this task, subgrantees should include the removal of items in the cost-effective analysis of installing insulation, and proceed with the measure if it is cost-effective (savings-to-investment ratio of 1.00 or greater).

5124 Attic Access Insulation

1. If attic insulation is added, access doors over living areas must be insulated as close as possible to the same R-value as the attic or at least R-19.

5125 Ductwork Insulation

1. Install a minimum of R-8 (preferably R-11 or greater, when possible) on ducts and plenums. It is preferred that attic ducts be draped with an unfaced blanket insulation and blown over with loose fill insulation, to at least the depth of the surrounding insulation. If faced duct insulation is installed, it is preferred that the facing be to the outside.
2. Ductwork must be sealed appropriately with the proper materials (duct mastic) before insulation is installed. Refer to Section 4220 on page 45 for instructions.
3. A minimum of 6 inches clearance between duct insulation and heat sources must be maintained, unless the material is rated for closer proximity.

5126 Drill-and-Blow Patching

1. If a drill-and-blow method is used for installing ceiling insulation, holes must be properly plugged, secured with adhesives, and sealed.

5130 Attic Ventilation

5131 General Installation

1. Ensure that existing vents are not blocked, crushed or otherwise obstructed. Correct problems as necessary, or replace.

2. When attic insulation is installed, a reasonable amount of attic ventilation should be in place, unless local codes supersede.
3. When roof vents are installed they should be nailed and well sealed to the roof, to prevent water leakage.
4. All ventilation openings should have suitable louvers and screens to prevent snow, rain and insects from entering the attic.

5132 High-Low Vents

1. Roof vents should be installed close to the peak.
2. Install high gable vents at least 3 feet above the soffit or gable vent used for low venting.

5133 Gable Vents

1. Gable-end vents should be installed as high in the gable as possible and positioned to provide cross ventilation.
2. Steps shall be taken to prevent wind washing of insulation around the attic vents.

5134 Knee Wall Ventilation

1. Kneewall attics or attic spaces that are sealed from other attic spaces may need to be ventilated as if they are a separate attic.

5135 Attic Vent Area Guideline

1. When attic ventilation is installed, the following guideline is allowed:
   a. If air-sealing work has been completed at the attic floor then one square foot of net-free ventilation may be installed for every 300 square feet of attic floor area.

5200 Sidewall Insulation

5210 Inspection and Repairs

1. An inspection from the interior and exterior of the home should be performed prior to installing insulation. This inspection should identify all potential hazards and needed repairs.
2. An inspection from the exterior of the home should include an examination of the following:
   a. Building construction details.
   b. Siding type and condition.
   c. The location of electrical, gas, oil and phone lines.
   d. Plumbing pipes.
   e. Existing moisture and drainage problems.

f. Existing structural problems.

3. An inspection from the interior of the home should include an examination of the following:
   a. Interior wall siding type and condition.
   b. Electrical and plumbing utilities.
   c. Duct work in wall cavities.
   d. Dropped or suspended ceilings.
   e. Moisture problems.
4. An inspection from the attic should include an examination of the following:
   a. Open top plates and balloon framing.
   b. Type of electrical wiring in the walls.
   c. Knee wall areas.

5211 Moisture Inspection and Repair

1. Any leaks or other moisture problems must be repaired prior to the installation of wall insulation.
2. Repair any moisture problems that will degrade or diminish the effectiveness of weatherization measures.

5212 Electrical Safeguards

1. Correct electrical problems such as unsafe wiring, uncovered junction boxes, or electrical situations which must be corrected prior to performing any other work in the attic(s). If insulation exists, ensure that wiring is in a safe and meets applicable codes.
2. Knob-and-tube wiring:
   a. If active knob-and-tube wiring is found in a dwelling attic, walls, or basement, the walls of the dwelling must not be insulated.
   b. If knob-and-tube wiring has been deactivated and the dwelling has been rewired with BX, Romex, or other approved electrical cable, the walls may be insulated without special precaution.

5213 Treatment of Other Hazards

1. Use appropriate personal protective equipment and work practices in the presence of animal or insect hazards. Ensure personal safety during work.
2. Remove any items that need to be moved in order to install wall insulation effectively.
3. Repair any rotted, broken, or damaged structural components. Ensure that the finished wall material will safely withstand the

pressure of the insulation. Repair or replace any weakened, damaged, or missing interior wall surface.

4. 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.

5214 Interior Inspection and Repairs

1. Repair or replace weak or damaged drywall or lath and plaster sections. Locate any interior areas of paneling with no sub-wall surface, or that are not securely fastened. Determine an insulation strategy which will not damage the paneling. Repair or replace damaged or missing baseboard, casing, jambs, etc., that may allow insulation to escape from the wall cavity. Holes drilled for insulation must be finished and returned to a condition as close to the original as possible.
2. Locate the positions of all wall-mounted switches and outlets before beginning insulation work. Locate all chases, utility runs, duct runs, wall heaters, vent fan penetrations, etc. prior to insulating. Block around these areas, if possible. If it is not possible to block around an area, avoid that area when insulating.
3. Find any interior soffit areas, pocket doors, or other structural details which may need preparation prior to insulating, and prepare as necessary. Locate critical framing junctures and ensure adequate insulation density.

5215 Exterior Inspection and Repairs

1. Note all types of siding material. Note siding material which may contain asbestos. Wherever possible, determine the presence and condition of previous layers of siding or sub-siding. Determine the best drilling strategy (the tubing method or the nozzle method). As the primary acceptable method, the siding must be lifted or temporarily removed to gain access for drilling. Permission is needed from the client to drill through any type of exterior siding.
2. Repair or replace severely deteriorated window or door components as directed by the work order. Replace all missing glass.
3. Patch holes in exterior walls.
4. Determine the source and correct any problem which has led to moisture in wall cavities prior to installing insulation. Repair or replace damaged, rotted, or deteriorated siding to ensure the integrity of the insulation. If any missing siding, flashing, etc. would allow disintegration of installed insulation, replace it with a compatible material.

5. Access structural additions and critical junctures to determine the ability of these areas to contain high-density insulation. Correct any openings or gaps prior to installing insulation.

5220 Installation Methods for Wall Insulation

1. Wall areas above windows and doors (except in mobile homes), and the area below windows must be insulated, whenever possible.
2. Uninsulated exterior walls without drywall, paneling or other interior finishing material, must be insulated if adding interior finishing material and insulation is deemed cost-effective.
3. Fiberglass insulation must not be left exposed in living areas.
4. It is recommended that the tubing method be used rather than the nozzle method.
5. Removal of siding is required before drilling the sheathing unless conditions make this impossible.
6. The tubing method may be used to install insulation into sidewall by drilling one hole per story. A flexible tube is inserted in the hole, the end being pushed to the area to be insulated. As the insulation fills the area, the tube is slowing pulled out of the drilled hole, filling the entire cavity as the tube is retracted.
7. When blowing brick walls from the exterior, a minimum of a 5/8 inch hole is recommended when installing insulation through a mortar joint.

5221 Blocking

1. Construction details that allow insulation to escape from sidewall cavities such as balloon framed walls must be blocked or packed with insulation or other material in a manner that effectively retains the insulation material.

5222 Materials

1. *In site-built dwellings:*
   a. Insulate all closed-cavity sidewalls to 3.25 – 3.75 lbs/ft^3 with cellulose insulation unless this is not possible. If it is not possible, documentation for the reason must be included in the client file.
   b. Insulate open cavity walls with fiberglass, faced or unfaced, using a density and thickness appropriate for the cavity. Cover any flammable insulation facing or vapor barrier installed in a living space with a fifteen-minute fire rated material such as ½ inch drywall (taped once) or ¾ inch plywood.
      i. A fifteen-minute fired rated covering is not required in an unconditioned or conditioned space that is also a living space.

c. Rigid plastic insulation may be used when appropriate. Cover any rigid insulation or vapor barrier installed in a living space with a fifteen-minute fire rated material such as ½ inch drywall (taped once) or ¾ inch plywood.

   i. A fifteen-minute fired rated covering is not required in an unconditioned or conditioned space that is also a living space.

2. For mobile home wall insulation materials, refer to Section 7800 on page 80.

5223 Insulation Coverage, Density, and Voids

3. Sidewall insulation must be installed according to manufacturers' recommended density, and in such a manner that does not allow settling of the material to occur.
4. Determine the appropriate sidewall insulation technique(s) to be used. Insulate all sidewalls to 3.25 – 3.75 lbs/ft^3 with cellulose insulation, unless a technical barrier prevents this technique.
5. When using blown fiberglass, install at a density of 1.6 lb/ft^3.
6. Subgrantees should obtain a warranty, of at least one-year, against voids of more than 5 percent from subcontractors installing wall insulation.

5224 Plugs and Patching

1. Where possible, exterior lap siding must be removed and sheathing be drilled for the installation of insulation. If the exterior siding is properly shedding water, than patching of holes in the sub-siding is not required. Small pieces of fiberglass insulation can be inserted into the hole to prevent wicking of moisture from outside.
2. Plugs that are compatible with the siding or wall type must be used to cover the exposed surface that has been drilled.
3. Plugs must be sealed tightly and glued. They must be primed when exposed to weather.
4. Subgrantees should paint and may texture to match plugs to the surrounding wall, but may not paint or texture the entire wall.

5225 Brick Siding

1. Interior drill and blow techniques are preferred for homes with brick veneer siding that are going to receive sidewall insulation.

5226 Quality Control

1. When possible infrared scanning should be used as a quality control tool to check wall insulation work and identify areas of excessive air

leakage. The infrared scanning device is a powerful tool for finding air leaks when used in conjunction with a blower door. Subgrantees are advised to use infrared scanning whenever the equipment is available and the use is practical.

5300 Foundation Insulation

This section addresses rim joist insulation, basement wall insulation, and crawlspace wall insulation.

5310 Inspection and Repairs

1. An inspection from the interior and exterior of the home should be performed prior to installing insulation. This inspection should identify all potential hazards and needed repairs.
2. An inspection from the exterior of the home should include an examination of the following:
   a. Building construction details.
   b. Foundation type and condition.
   c. The location of electrical, gas, oil and phone lines.
   d. Plumbing pipes.
   e. Existing moisture and drainage problems.
   f. Existing structural problems.
3. An inspection from the interior of the home should include an examination of the following:
   a. Interior foundation wall type and condition.
   b. Electrical and plumbing utilities.
   c. Moisture problems.
4. Make any necessary repairs before installing insulation.

5311 Moisture Inspection and Repair

1. All units must be inspected for problems associated with excess moisture.
2. Identification of potential moisture problems shall be documented in the client file.
3. Repair any moisture problems that will degrade or diminish the effectiveness of weatherization measures.
4. For crawlspaces, whenever conditions warrant, install a 6 mil polyethylene moisture barrier on the dirt floor. This barrier should overlap at least 6 inches at joints and the polyethylene should extend 6 inches up the crawlspace wall. Note: If the entire dirt floor is not accessible, cover as much as possible.

5. For basements with dirt floors, whenever feasible, install a 6 mil polyethylene moisture barrier on the floor. This barrier should overlap at least 6 inches at joints and the polyethylene should extend 6 inches up the crawlspace wall. Lay rolled roofing on top of this polyethylene to provide a safe walkway for clients. Talk with clients about where this rolled roofing should be placed and try to minimize the amount used.

5312 Wall Moisture Barrier

1. If there is evidence of water leakage or moisture coming through the foundation wall from the exterior, a moisture barrier must be attached to the sill plate in a manner that drains the moisture behind the insulation, and covers the insulated section of the foundation or crawlspace wall.

5313 Electrical Safeguards

1. Correct electrical problems such as unsafe wiring, uncovered junction boxes, or electrical situations which must be corrected prior to performing any other work. If insulation exists, ensure that wiring is in a safe and meets applicable codes.
2. Knob-and-tube wiring:
   a. If active knob-and-tube wiring is found in a dwelling attic, walls, or basement, the walls of the dwelling must not be insulated.
   b. If knob-and-tube wiring has been deactivated and the dwelling has been rewired with BX, Romex, or other approved electrical cable, the attic walls may be insulated without special precaution.

5314 Treatment of Other Hazards

1. Use appropriate personal protective equipment and work practices in the presence of animal or insect hazards. Ensure personal safety during work and refer to the walk-away policy in Section 2212 on page 18.
2. Repair any rotted, broken, or damaged structural components.

5315 Defining the Thermal Boundary

1. If the basement or crawlspace houses a heating system and other appliance, it should be treated as a conditioned area. In this case – the most common – the basement or crawlspace walls are part of the boundary of the conditioned envelope. Therefore, it is preferred to air seal and insulate the basement or crawlspace walls because this strategy encloses the furnace, ducts, pipes, water heater, and other appliances within the conditioned envelope.

2. Basements and crawlspaces should be tested using zonal pressure diagnostics when the housing construction type or the air leakage rate indicates that there may be hidden air leakage or bypass pathways into the basement or crawlspace. This test should be used to determine quality and completeness of air leakage and bypass sealing, prior to, and then after, installing insulation. In addition, this test can help determine the appropriate location of the thermal boundary. Please refer to Section 111000 on page 123 for instructions.
3. If the appropriate thermal boundary is determined to be the basement or crawlspace wall, rather than the floor above the basement/crawlspace, then the basement or crawlspace wall should be sealed, as necessary, before any insulation is installed on these surfaces.

5320 Installation Methods

5321 Storage Space

1. Where the basement or crawlspace is being used for storage, subgrantees should request the client remove storage items from the area.
2. In cases where the client is physically unable to perform this task, subgrantees should include the removal of items in the cost-effective analysis of installing insulation, and proceed with the measure if it is cost-effective (savings-to-investment ratio of 1.00 or greater).

5322 Materials

1. *Interior basement wall insulation:*
   a. If the wall is studded out on the interior, it may be filled with unfaced fiberglass batt of an appropriate thickness or with vinyl-faced fiberglass (metal building insulation). A polyethylene vapor barrier should be installed.
   b. Vinyl-faced fiberglass (metal building insulation) may be fastened at the band joist area and hung down four feet.
   c. Interior rigid insulation may be glued and fastened to the basement wall.
2. *Exterior basement wall insulation:*
   a. Foundation panels (factory pre-finished on exterior) may be used if they are glued and fastened, has drip caps installed, and is sealed around windows. They must extend at least 6 inches below the finished grade.
   b. Extruded polystyrene may be used that is not pre-finished if glued and fastened, has drip caps installed, and is sealed around

windows. The insulation must extend at least 6 inches below the finished grade. The exterior surface of these panels must be covered with a material that will protect it from ultra-violet light.

5323 Insulation Coverage

1. Insulation must be installed in a manner that provides as continuous a thermal boundary as possible.
2. Perimeter insulation must not be installed in a manner that excessively compresses the insulation material.

5324 Rim Joist Insulation

1. Rim joist insulation must be a minimum of R-10.
2. Fiberglass, rigid, or foam insulation may be used for this application. Whichever is used must result in a savings-to-investment ratio of at least 1.00.
3. If there is significant air leakage, the band or rim joist area must be properly sealed before the insulation is installed.
4. The insulation must be secured in a permanent manner.

5325 Foundation Insulation

1. Route any exhaust fans to the outside using dampered vents, smooth-bore rigid pipe, and an appropriate termination fixture.
2. If necessary, repair or replace exterior doors or door components to reduce air leakage. If necessary, replace all missing glass and repair or replace window components to reduce air leakage.
3. Foundation walls should be insulated so that no portion above grade is left uninsulated.
4. Fiberglass insulation must not be left exposed in living areas.
5. Mechanical fasteners must be used to secure perimeter insulation in a permanent manner.
6. Basement wall insulation must be a minimum of R-7.5.
7. Interior-wall installation
   a. Stud out wall and insulate with fiberglass or use rigid insulation glued and fastened.
   b. An alternative method for installing perimeter insulation is to attach metal-building insulation at the floor above the rim, so that the blanket extends from the floor above four feet down the foundation wall. It should be run horizontally in a continuous manner to eliminate as many seams as possible. The blanket may be slit at each floor joist to allow installation in a manner that minimizes gaps around the joist. The bottom of the bottom of this fiberglass batt

insulation should be air sealed to the wall with a strip of wood nailed to the foundation or by sealing the vinyl facing to the wall with adhesive caulk.

c. Other insulation types and methods may be used with the approval of the DCS.

8. Exterior-wall installation

a. Foundation insulation may be installed on the exterior, but this requires digging a one-foot deep trench around the foundation. If this method is used, the rigid insulation must be extruded polystyrene at least one-inch thick with an R-5 and it must be protected from sunlight and exterior mechanical damage by an appropriate rigid material.

5326 Crawlspace Insulation

1. Separate an unconditioned crawl space from an adjoining conditioned basement with suitable materials.
2. Seal all direct air leakage sites into the crawl space.
3. Seal all bypasses and chases into and through the conditioned areas of the house.
4. Route any exhaust fans to the outside, using dampered vents and smooth bore rigid pipe and an appropriate termination fixture.
5. Install perimeter insulation from the band joist to the crawl space floor. The crawl space wall insulation shall extend downward 1) to a distance that is two feet below the exterior grade or 2) to the crawlspace floor and then horizontally across the floor for two feet, which ever is appropriate. Mechanically fasten the insulation and seal all joints with tape.

5. An alternative method for installing interior perimeter insulation is to attach metal-building insulation at the floor above the rim, so that the blanket extends from the floor above to four feet down the wall. It should be run horizontally in a manner that minimizes the number of seams. The blanket may be slit at each floor joist to allow installation in a manner that minimizes gaps around the joist. This insulation should extend downward 1) to a distance that is two feet below the exterior grade or 2) to the crawlspace floor and then horizontally across the floor for two feet, which ever is appropriate. Mechanically fasten the insulation and seal all joints with tape.

5400 Floor Insulation

5410 Inspection and Repairs

1. Precautions must be taken to insure adequate combustion air is being supplied, through non-operable vents, for combustion appliances in crawl spaces.

5411 Moisture Inspection and Repairs

1. All units must be inspected for problems associated with excess moisture.
2. If floor insulation is installed over a crawlspace area, the crawlspace floor should be covered with a 6 mil polyethylene moisture barrier when conditions warrant. This polyethylene must be lapped at least 6 inches and joints and extended up the crawlspace wall by 6 inches.
3. Identification of potential moisture problems shall be documented in the client file.
4. Repair of moisture problems that will degrade or diminish the effectiveness of weatherization measures.

5412 Electrical Safeguards

1. Correct electrical problems such as unsafe wiring, uncovered junction boxes, or electrical situations which must be corrected prior to performing any other work in floor. If insulation exists, ensure that wiring is in a safe and meets applicable codes.
2. Do not use any metal mesh material, such as chicken wire, to support floor insulation. This can cause an electrical hazard to the installers.
3. Floor cavities containing active knob-and-tube wiring may not be insulated.

5413 Treatment of Other Hazards

1. Use appropriate personal protective equipment and work practices in the presence of animal or insect hazards. Ensure personal safety during work.
2. Repair any rotted, broken, or damaged structural components.

5414 Defining the Thermal Boundary

1. If the basement or crawlspace houses a heating system and other appliance, it should be treated as a conditioned area. In this case – the most common – the basement or crawlspace walls are part of the boundary of the conditioned envelope. Therefore, it is preferred to air seal and insulate the basement or crawlspace walls because this

strategy encloses the furnace, ducts, pipes, water heater, and other appliances within the conditioned envelope.

2. Basements and crawlspaces should be tested using zonal pressure diagnostics when the housing construction type or the air leakage rate indicates that there may be hidden air leakage or bypass pathways into the basement or crawlspace. This test should be used to determine quality and completeness of air leakage and bypass sealing, prior to, and then after, installing insulation. In addition, this test can help determine the appropriate location of the thermal boundary. Please refer to Section 111000 on page 123 for instructions.
3. If the appropriate thermal boundary is determined to be the floor above the basement or crawlspace, rather than the walls of the basement or crawlspace, then this floor should be sealed, as necessary, before any insulation is installed under it.

5420 Installation Methods for Floor Insulation

1. Install a minimum of R-19 insulation between the floor joists.
2. The insulation should be installed without voids or gaps. Fit insulation tightly around cross bracing and any obstructions.
3. Floor insulation must be fastened securely in place with wire fasteners, nylon mesh, or other appropriate methods. Friction fitting or stapling of floor insulation is not considered an appropriate method for securing the material. Do not support insulation with Tyvek or Typar sheeting stapled to the bottom edges of the joists.
4. Install insulation so that it is in contact with the underside of the sub floor above.
5. Faced fiberglass insulation must have the facing upward toward the heated area.
6. Ensure that floor insulation is in direct contact with the rim joints. If the dwelling is balloon framed, air seal the bottom of the stud cavities prior to installing insulation.
7. Fiberglass insulation must not be left exposed in living areas.

5421 Materials

1. Fiberglass, faced or unfaced, insulation is preferred for perimeter and floor insulation material.
2. It is preferred that vinyl faced insulation not be used for floor insulation.

5422 Insulation Coverage

1. Floor insulation must be installed in a manner that provides as continuous a thermal boundary as possible.

2. Floor insulation must not be installed in a manner that excessively compresses the material.

5423 Storage Space

1. Where the basement or crawlspace is being used for storage, subgrantees should request the client remove storage items from the area.
2. In cases where the client is physically unable to perform this task, subgrantees should include the removal of items in the cost-effective analysis of installing insulation, and proceed with the measure if it is cost-effective (savings-to-investment ratio of 1.00 or greater).

5424 Ducts and Pipes

1. When floor Insulation is installed, ductwork below the floor insulation must be sealed and insulated. Please refer to Section 4230 on page 46 for instructions.
2. When floor Insulation is installed, any water pipe that is susceptible to freezing, and all furnace supply and return ducts below the insulation, must be insulated as part of the floor insulation measure. Please refer to Section 4310 and 4320 starting on page 47 .
3. Do not insulate over pumps, valves, pressure relief devices or vents; do not insulate over heat tape unless manufacturers' specification indicate that such insulation is safe.

5430 Crawlspace Ventilation

1. Conditioned crawl spaces:
   a. If crawlspace walls are insulated, the crawlspace shall not be vented to the outdoors.
2. Unconditioned crawl spaces:
   a. Crawl space ventilation is not necessary if the crawl space is well drained and dry.
3. Crawlspace vents shall be louvered and screened or otherwise designed to prevent the entry of snow, rain and critters into the building.
4. If operable crawlspace vents are installed, the client must be informed of the benefits of closing the vents in winter and opening the vents in summer.
5. If excess ventilation is present, it is preferred that it be closed off with removable rigid insulation. Where possible, close off vents on the windward side of the crawlspace. Do not close off combustion air vents.

6000 Window and Door Replacements

6100 Primary windows

6110 Window Assessment

1. Windows must be assessed with the WXEOR audit to determine the need for potential repair for air leakage reduction and comfort-related problems.
2. All existing egress windows must remain operable.
3. Non-operable windows may receive air leakage work based on the guidelines in Section 4100.

6120 Window Replacements

1. The following window air leakage measures may be installed based on the guidelines in Section 4100:
   a. Missing, broken and severely cracked windows.
   b. Glazing replacement (prime and storm windows).
   c. Minor cracked windows caulked or taped (prime and storm windows),
   d. Window frame repair or replacement.
   e. Window hardware adjustment or replacement.
   f. Window replacement.
2. Double-glazed replacement window units are preferred if their cost is justified by the WXEOR audit.
3. Subgrantee installed storm windows in kitchens, baths and other high moisture areas should be operable if they provide the only source of fresh air ventilation into the space.
4. Window replacements must be based primarily on an energy-conservation decision process rather than client requests or aesthetics.

6130 Window Air Leakage

1. Window air leakage measures such as caulking and weather-stripping must be determined to be cost-effective based on the guidelines in Section 4100.

6140 Window Repairs

1. 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.

2. Window glazing compound shall 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.
3. It is not required to make windows sashes operable unless stipulated by building codes.

6150 Window Replacements

1. Replacement of windows must be justified by the WXEOR audit.

6200 Storm Windows and Insulation Systems

6210 Interior Storm Windows

1. Interior storm windows shall be installed whenever feasible in mobile homes.
2. Exterior storm windows shall be installed whenever feasible in site-built homes.
3. A one half-inch to two-inch air space between the prime window and the installed storm window is preferred.
4. Storm windows shall be installed over single-pane windows, and according to cost-effectiveness as determined by the approved North Dakota energy audit program, WXEOR.
5. Allowable storm windows include:
   a. Rigid framed single- and double-strength glass.
   b. Rigid and flexible framed Plexiglas.
   c. Framed and unframed plastic "kits" with a minimum thickness of six mils.
6. Repairs to prime windows must be done to keep moisture out before an interior storm window may be installed over the prime window.
7. Storm windows must be securely fastened in place; installed straight, plumb, and level, and without distortion.
8. Storm windows may be installed as a replacement for non-repairable existing storm windows when determined to be cost-effective by the approved North Dakota energy audit program.
9. Metal storm windows should not come in contact with frames or fasteners constructed of dissimilar metals.
10. Subgrantee installed storm windows in kitchens; baths and other high moisture areas must be operable if they provide the only source of ventilation into the space.
11. Operable storm windows shall move freely.

6220 Movable Window Insulation Systems

1. Movable window insulation systems are only allowed based on the following:
   a. The systems are determined to be cost-effective by an approved the energy audit;
   b. For technical reasons, no interior or exterior storm windows are able be installed;
   c. All other weatherization measures with a higher SIR values exist or have been installed, and;
   d. The client has been trained in the operation of the movable insulation system.

6230 Non-Allowable Window Materials

1. Tinted window films, all sun shields and heat reflective materials are not allowable WAP expenses.

6300 Doors

6310 Door Assessment

1. Doors must be assessed to determine the need for repair, for air leakage reduction and comfort-related problems.
2. All existing egress doors must remain operable.
3. Non-operable doors may receive air leakage work based on the guidelines in Section 4100.

6320 Door Repairs

1. The following door air leakage measures may be installed based on the cost-effectiveness guidelines in Section 4100:
   a. Door hardware adjustment or replacement.
   b. Door jamb kit installation.
   c. Door sweep installation.
   d. Door threshold installation or repair.

6330 Door Air Leakage

1. With the exception of isolated installations to address client comfort, door air leakage measures, such as jamb-up kits, sweeps, and thresholds, must be determined to be cost-effective based on the guidelines in Section 4100 on page 41.

6340 Door Repairs

1. 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.
2. It is not required to make existing stuck doors operable.

6350 Door Replacements

1. Individual replacement doors may only be installed if the cost of the repair justified the WXEOR audit
2. Pre-hung replacement doors may be installed if determined to be more cost-effective than the repair of the existing door and frame, or the installation of a door that is not pre-hung.
3. The cost of the purchase and installation of all hardware and the material associated with the replacement of a door must be included in the calculation of the SIR used to justify the door replacement.
4. Replacement doors may include one light (pane of glass) if the replaced door had one or more lights. The cost any other extra features must be borne by the client.

7000 Mobile Home Requirements

The same general procedures described in all other sections of these WAP Standards shall apply to mobile homes unless otherwise stated or stated more specifically in this section.

7100 Inspections and Repairs

1. The structure shall be properly supported, leveled, and restrained (if required) at the homeowner's expense before weatherization measures are installed.
2. Structural problems affecting insulation measures must be completed prior to installing insulation.
3. Belly rodent barrier repairs must be repaired if insulation will be installed or if significant air leakage is occurring.

7110 Moisture Problems

1. If moisture problems are present in the ceiling or sidewalls, insulation should not be added until the moisture source and/or site of penetration, including leaks, is identified and eliminated.
2. Exhaust-fan ducts terminating in ceiling cavities, crawl spaces, or other spaces, shall be extended through to the outdoors, and sealed to prevent exhaust air from returning back into the conditioned space.

7120 Electrical Inspections

1. In units that are receiving insulation measures, electrical wiring and the electrical circuit breaker/fuse box must be assessed for adequacy as follows:
   a. #12 Aluminum or #14 copper wiring must be protected with 15 amp fusing or breakers;
2. Care must be taken to ensure that electrical wiring was not damaged during insulation work. This can be done by testing electrical outlets and switches following completion of work.
3. If there is reason to believe, before or after installing wall insulation, that a mobile home has aluminum wiring, it is recommended that an electrical inspection be performed by a licensed electrician following the completion of the insulation work.

4. The client should be asked about any known existing electrical problems

7200 Air Leakage Reduction Requirements

1. Except for the sealing of ductwork and large holes to prevent insulation from entering the living space, all insulation measures should be completed before additional air sealing work is done, whenever possible.
2. Air sealing activities should comply with the cost-effective air sealing guidelines in Section 11300 on page 104 of these standards.
3. Air sealing activities should comply with the building tightness limit procedure and calculation Section 11400 on page 105 of these standards.
4. Air leakage reduction measures shall not be installed when the starting CFM_{50} measurement is below the calculated building tightness limit, except for the following:
   a. Ductwork sealing.
   b. Insulation preparation work.
   c. Major repairs.
   d. Air sealing work that is necessary to block moisture migration into ceilings and walls.
5. Air leakage installations that are done to address client comfort (for example, storm window near reading chair, jamb weatherstrip kit on door near reading chair, etc.) must have a brief explanation documented in the client file.
6. Snap fasteners and/or weatherstripping shall be used whenever possible to reduce air leakage and/or to stop water from entering primary windows.
7. Major air leakage problems around single pane windows that cannot be eliminated with sidewall insulation or snap fasteners, shall have an interior storm window installed, or the window replaced, whichever is most cost-effective.
8. It is recommended that caulking be done around all interior casing when there is an interior storm window.
9. When accessible, the joint between the two sections of a double-wide must be filled and sealed from underneath the structure.
10. Large holes in water heater closets with an exterior wall must be sealed, with care taken not to seal off combustion air from the outside.

7300 Insulation, General

1. Insulation shall be installed only in areas of the mobile home envelope that separate conditioned from unconditioned space.

7400 Ceiling Insulation

1. Recessed lighting fixtures and fan/light combinations that are Type-IC rated by UL may be covered with insulation.
2. Ventilation fans may be covered with insulation if all holes and penetrations are sealed with a nonflammable sealant.
3. Thermal insulation shall not be installed within 3 inches of fans, lights, and heaters that are not Type-IC.
4. All combustible insulation materials shall be kept at least 2 inches from metal flues and chimneys.
5. The ceiling and roof condition must be inspected and assessed before installing insulation.
6. If cost effective, ceilings that appear weak shall be repaired or reinforced, especially in heavy snow load areas, before installing insulation.
7. Combustion appliance vent blocking is required when insulation is installed, except where combustion air is pulled through a combustion air pipe that surrounds the combustion appliance vent pipe (concentric pipe system). Follow manufacture's recommendation for clearances between vent and combustible insulation.
8. Ceiling insulation must be installed in such a manner that ensures complete coverage over heated areas, except those areas requiring and receiving a technical waiver.
9. Average insulation densities for loose fill insulation installed in mobile home ceiling cavities shall be:
   a. Fiberglass – 1.25 to 1.75 pounds per cubic foot.
10. Mobile home ceilings shall not be dense-packed or over filled so as to create ceiling structural problems.
11. If an interior drill-and-blow method is used for installing insulation, holes must be plugged and sealed properly. In addition, the whole pattern must be adequate to ensure complete coverage.
12. If an exterior installation method or side-opening method is used, all roof penetrations and areas of potential leakage must be sealed with elastomeric sealant (when compatible with roof materials), or with other equivalent sealant, as necessary. Areas that are to be patched must be cleaned to the metal roof surface.
13. It is preferred that fiberglass insulation material be used for mobile home ceilings.

14. It is preferred that cutting of large holes and the use of screws on top of metal roofs not be done, especially in heavy snow load areas.
15. In heavy snow load areas, client education should be given whenever ceiling insulation is added, explaining the possibility of increased snow depths on the roof because of reduced heat loss. To reduce the possibility of creating leaks, clients should be advised to refrain from shoveling snow off the roof. Instead, they should use a push broom, if absolutely necessary.

7500 Ductwork

1. Mobile home belly return air systems must be permanently sealed from the living space. A living-space return air system must be created by 1) either removing the furnace closet door or installing an adequately sized return air grille(s) in the furnace closet door; 2) allowing for return airflow under closed bedroom and bathroom doors; and 3) sealing the return air grill in the furnace closet. Please refer to Section 7700 on page 79 for more details about this conversion.
2. For duct leakage, follow the instructions in Section 11900 on page 116.
3. For ductwork sealing and insulation, follow the instructions in Section 4200 on page 44 .
4. *Crossover duct repair and treatment:*
   a. Crossover ducts shall be installed in a manner that prevents compressions or sharp bends, minimize stress at connections, avoid standing water, and avoid excessive length. When skirting is not present, the crossover duct shall be protected against rodents, pets, etc.
   b. Flexible crossover ducts shall have a minimum R-8 insulation. They shall be secured with mechanical fasteners (for example, stainless steel worm drive clamps, plastic/nylon straps applied with a tightening tool, etc.) and sealed with mastic or aluminum foil backed butyl or equivalent pressure-sensitive tape.
   c. Existing flexible crossover duct with an insulation of R-4 or less which has been damaged may be replaced with new flexible duct with R-8 insulation.
   d. The crossover must be replaced if the inner lining is brittle or made of mesh. If in doubt, replace it. In many cases, a leaky crossover can be repaired by cutting out the section of duct containing the leak. A fabricated sheet metal sleeve can be inserted between the remaining pieces of crossover duct. The metal sleeve must be attached to the flex duct crossover using ratcheting plastic straps.

e. Crossover ductwork must be appropriately secured above the ground. It may be supported by strapping or blocking.

f. Flexible duct shall not be allowed to sag more than 12 inches for a span of eight feet.

5. Fiberglass (with the exception of duct board) shall not be left exposed in ductwork.

6. Any portion of the ductwork that extends beyond the last register or grille may be sealed.

7. Trunk end sweeps are only allowed if it is determined that duct air leakage reduction will result from installation.

   a. End sweeps shall be made from sheet metal or aluminum valley flashing. Two-part foam may not be used unless it is adequately protected with a fifteen-minute fired rated material. Any metal sweeps must be mechanically attached to the duct system. Gaps between the sweep and the duct must be sealed with mastic.

7600 Floor (Belly) Insulation

7610 Floor Insulation Requirements

1. Belly rodent barriers must be inspected for general condition, structural strength, and major air leakage, prior to installing insulation.

2. Necessary belly rodent barrier repairs must be made if additional insulation will be added or if holes in the belly allow significant air movement between the belly cavity and the outside atmosphere.

3. Belly cavities must be inspected to determine the location of the plumbing, any existing plumbing leaks, and the R-value of existing insulation. Leaks should be fixed prior to weatherization

4. If water pipes are located at the bottom of the belly rodent barrier and it is not possible to get at least two inches of insulation between the pipes and the rodent barrier, then the following must be attempted, if cost effective and feasible:

   a. The pipes must either be insulated with additional insulation, either inside the belly or on the exterior of the rodent barrier; or

   b. The pipes shall be moved closer to the floor above or the insulation above the pipes should be removed.

   Note: If these items cannot be completed, then the belly shall be insulated using the perimeter method.

5. Belly insulation shall be installed only after all repairs have been made, major holes in the rodent barrier and floor have been sealed, and all ductwork has been sealed according to Section 11900 on page 116.

6. Belly insulation must be installed in such a manner that ensures complete coverage under heated areas except those areas requiring and receiving a technical waiver.
7. Holes that have been made in belly rodent barriers for the installation of insulation must be patched and sealed.
8. Rim joists may not be drilled if they are determined to be a structural component of the foundation support system.
9. Average insulation densities for loose fill insulation installed in mobile home bellies shall be:
   a. Fiberglass – 1.25 to 1.75 pounds per cubic foot
10. Bellies shall not be dense-packed or over filled so as to create undue stress on the belly rodent barrier.

7620 Floor Insulation Methods

1. Fiberglass is the preferred insulation material for mobile home bellies.
2. Bellies that are 8 inches height and less in the center area shall be filled entirely with insulation blown at the required densities.
3. Bellies that are greater than 8 inches in height at the center area shall be insulated using the perimeter method only after attempts have been made to bring the rodent barrier closer to the floor above. This must be done with care to avoid damaging the duct trunk line or water lines in the belly.
4. Access through the rim joist and the use of a metal fill tube is preferred for installing mobile home belly insulation whenever possible.
5. If bellies cannot be insulated through the rim joist and must be insulated from underneath, the use of the insulation hose or a large diameter fill tube is preferred; a 90-degree nozzle may not be used.
6. When insulation has to be installed from underneath the belly, the installation of a 6 mil vapor barrier on the ground by the first person to go underneath is preferred, in order to reduce health risks to the installers from animal feces.
7. The preferred methods of securing belly patches are through the use of adhesives, clinch staples, screws and lath strips whenever possible to provide a lasting patch.
8. Preferred patching materials for large holes in belly rodent barriers include insulated sheathing board, fiberboard, and nylon reinforced belly bottom material specifically manufactured for mobile homes.
9. Ductwork shall be inspected for insulation that might have accidentally entered during insulation work, and the furnace is cycled to assess proper operation.

10. Upon completion of insulation work, rim joists that have been drilled shall be plugged with a wood plug. The plug shall be sealed in the hole with an adhesive compound.

7700 Mobile Home Belly-Return Conversion

7710 Introduction

Belly-return systems in mobile homes are notoriously leaky. These leaky return systems can significantly increase the space heating costs and lead to thermal discomfort and indoor air quality problems.

All belly-return systems shall be converted to a living space return system. Follow the procedures below.

7720 Conversion Process

When converting a belly-return system in a mobile home to a living-space 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 and tight air barrier being careful to find hidden registers under built-ins, behind furniture, and in kitchen kick spaces.
3. Completely block 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. 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 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.
    c. Close the furnace closet door completely.
    d. 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 your thermometer.
    e. Subtract the house air temperature – the return air – from the supply air temperature. The difference is the temperature rise.
    f. 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.

g. 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 your supply air temperature measurement.

h. If the temperature rise is out of range, repair the cause by removing any restriction to airflow or repairing leaks. Check the temperature rise again. Once the temperature rise is within the recommended range, move on to the next step.

5. Measure room-to-room pressure differences and relieve pressure differences that are greater than 3 Pascals.

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:
        1. The door must be undercut.
        2. 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.

6. Return dwelling to the pre-test condition.

7800 Sidewall Insulation

7810 Sidewall Insulation Requirements

1. Mobile home sidewalls should be insulated when the WXEOR audit shows it is cost-effective.
2. The exterior siding and the interior wall materials must be inspected prior to the installation of insulation.
3. Weak or damaged wall materials must be repaired or reinforced prior to installing insulation.
4. Electrical precautions:

a. Electrical wiring and the electrical circuit breaker/fuse box must be assessed for adequacy (please refer to Section 7120 on page 73). The client should be asked about any existing electrical problems, especially in the wall outlets or switches.

b. If aluminum wiring is present, extra care must be taken to insure the electrical system is not damaged during insulation work. The following steps must be taken:
    i. Each cavity that contains an outlet, switch, or light fixture should be clearly identified and marked on the outside siding prior to the installation of the insulation, and these cavities should be carefully tubed rather than stuffed with a batt or, if excessive movement of the wires will still occur, then the cavity should not be insulated and;
    ii. Each outlet, switch, or light fixture must be checked for proper operation immediately following the completion of the insulation work with a receptacle tester.
c. If any one of the above two steps cannot be completed, the sidewalls shall not be insulated and documentation stating the reason for omission must be placed in the client file.

5. Installing insulation above windows and doors is usually not feasible or cost-effective and is not required in mobile homes.
6. Mobile home sidewalls shall not be dense-packed or over filled so as to create siding or interior wall structural problems.

7820 Sidewall Insulation Methods

1. Vinyl faced fiberglass batt insulation and loose fill fiberglass are the preferred insulation materials for mobile home sidewalls.
2. The batt-stuff method is the favored technique for insulating wall cavities.
3. For cavities that cannot or should not be insulated with the batt-stuff technique, the fill-tube method with loose fill fiberglass is recommended.
4. If there is reason to believe, before or after installing wall insulation, that a mobile home has aluminum wiring, it is recommended that an electrical inspection be performed by a licensed electrician following the completion of the insulation work.

7900 Water Pipe Insulation

1. Water pipes that have not been covered by under-floor insulation should be insulated to a minimum of R-3 by the owner.
2. The piping shall be free from water leaks and properly secured to support the weight of the piping and insulation.
3. The insulation product may be either flat and capable of being molded to the outside surface of common pipe size, or preformed to fit standard pipe diameters. If the product is preformed, dimensions shall be appropriate for the pipe size.

4. If the insulation is exposed to the weather, it shall be resistant to degradation from moisture, ultra-violet light, and extremes in temperature, or a jacket or facing shall be installed that protects the insulation from these conditions.

71000 Water Heater Closets

1. At a minimum, water heater closets with an exterior wall must be treated as follows:
   a. The exterior access door and associated exterior walls of closets containing electric or gas water heaters shall be insulated, if possible. If the door and associated wall can be insulated, the water heater shall not be wrapped with insulation.
      i. Cover air vents if they are present in the door or associated exterior wall.
      ii. Bring combustion air from underneath the belly or through the skirting by installing an appropriately sized metal chute with a rodent barrier.
   b. If it is not possible to insulate the closet door and associated wall area:
      i. The tank should be wrapped with an insulation blanket. Please refer to Section 4330 on page 48 for instructions.
      ii. Large holes in the closet walls that allow air leakage into the interior must be sealed.
      iii. All plumbing within the closet that is susceptible to freezing must be insulated.
      iv. An adequate amount of combustion air must be provided to gas water heaters.

71100 Combustion Systems

1. If interior combustion air is used for the furnace, replacement with a sealed combustion (direct-vent) furnace is mandatory.

8000 Combustion Appliances and Air Conditioners

8100 Combustion Appliance Requirements

The efficient operation of heating systems is a critical aspect of general heat waste. Detailed combustion system safety and efficiency standards are found in Section 2300 on page 25.

The replacement of heating systems or major components of heating systems is allowable as a resolution of health and safety concerns if the appliance is operable at the time of initial assessment. Minor repairs that will result in an operable appliance are allowable.

8110 Combustion Appliance Work Documentation

1. Each client file must include documentation of all efficiency work and adjustments made to the water heating and space heating combustion appliances, when applicable.
2. Client file documentation must include information on the applicable combustion appliance efficiency tests (see Section 8120 on page 83) and components (see Section 8130 on page 84).
3. Before the work on a combustion appliance is complete, a representative of the subgrantee must have finished a review of all combustion appliance forms and determined that the combustion appliance(s) meet the specifications in Sections 2000 and 8100.

8120 Combustion Efficiency and Analysis

Acceptable combustion test analysis values are found in Table 8-1.

1. The steady-state efficiency of a central heating system should be checked to determine:
   a. If it is in need of cleaning and tuning.
   b. If it functioning as efficiently as it was intended.

   (Refer to Section 8135 on page 91 for steady-state efficiency testing instructions.)
2. Replace the heating system if it is determined with the WXEOR audit that it is cost-effective to do so.

Table 8-1

Acceptable Combustion Test Analysis Values			
Heating Unit Type	***Oxygen (O_2)***	***Net Stack Temp.***	***Smoke Test***
Gas			
Atmospheric	4-9 percent	300-600°F	NA
Fan-assisted	4-9 percent	300-480 °F	NA
Condensing	See man. Info.	See man. Info.	NA
Standard Power Burner	4-9 percent	300-650 °F	NA
Oil (No. 1 & 2)			
Oil gun burner	4-9 percent	325-600 °F	1 or less
Flame Retention burner	4-7 percent	325-600 °F	1 or less

8130 Space Heating System Requirements

1. Health and safety requirements for space heating systems are required. Please refer to Section 2300 on page 25 for details. These details are repeated, with additional requirements, in this section.

8131 Forced Air Systems

An efficiency safety check should be conducted by a qualified technician on all operable natural gas or propane fired heating systems. Tests should be performed on all oil-fired systems that have a smoke reading of two or less. Modifications and repairs, when possible, should meet the following specifications (applicable to type) and/or comply with the follow-up procedures. The subgrantee must document each situation in which the following specification cannot be met. All forced air systems should conform to the following standards:

1. *Gas-fired unit requirements*
   a. *Gas Leaks:* All identified gas leaks should be referred to appropriate persons for repair or replacement. Hold the leak detector probe just below a propane gas line and just above a natural gas line.
   b. Flexible gas lines must be replaced under the following conditions:
      i. The line is badly kinked, corroded or shows signs of the physical wear.
      ii. The line connection is the soldered, two-piece type connection.
      iii. The line was manufactured before 1973. Sometimes there is a metal ring on the flexible line that is dated. If there is no dated metal ring, use one of the first two criteria listed just above.
   c. *Cleaning and tuning:* All gas-fired units should be cleaned and tuned once every two to three years. Suggest the client have this service performed regularly.
2. *Oil-fired unit requirements*

a. *Oil storage and piping:* Check the oil tank and piping for leaks and compliance with all appropriate codes.

b. *Cleaning and tuning:* All oil-fired units should be cleaned and tuned annually. Make sure the client is having this service performed regularly.

3. *Thermostat/gas valve:* The furnace must have a thermostat in working condition and must be compatible with the control circuit type (24 volt vs. millivolt). For 24-volt system type, the anticipator on the thermostat should be set equal to the measured control circuit amperage. Non-electric setback thermostats with an adjustable anticipator may be installed under the following conditions:

   a. Client lifestyle indicates potential for energy savings;

   b. Client is receptive to the installation; and

   c. Appropriate client education is provided on the operation of the thermostat.

4. *Fan on/fan off:* Ideally the fan-off temperature is between 95º and 100ºF., but never below 80ºF. The fan-on target range is between fan-off and 130ºF., but never to exceed 140ºF.

5. *Limit switch:* This switch should shut the gas valve off at approximately 200ºF, where appropriate. Some units should not be tested in this manner.

6. *Heat rise:* Heat rise should fall within the manufacturer's recommended temperature range. If this information is not available, the heat rise should fall within a 40º to 80ºF. range. The furnace must not cycle on the high-limit switch.

7. *Blower belts and pulleys:*

   a. Cracked or broken blower belts shall be replaced.

   b. If a larger pulley is installed on a belt drive furnace blower, the motor amperage must be measured. If the amperage draw is more than the motor's rated amperage, a smaller pulley must be installed, and the motor amperage measured again.

8. *Draft/Spillage:* All furnaces must be properly vented. All non-sealed combustion furnaces must be tested with a draft-testing device and meet the acceptable draft requirements. There must be no spillage. The flue must not be clogged, disconnected, or rusted to the point that it leaks. All furnaces, with the exception of direct-vent units, must be tested with worst-case draft test procedures (see Section 11700 on page 111).

9. *Carbon Monoxide (CO):* All non-sealed combustion heating systems must be tested with a CO testing instrument. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.

10. *Ductwork:* Return ductwork located in the combustion appliance zone (CAZ) shall be sealed is such sealing prevents hazardous negative pressure in the CAZ during air handler operation. Please refer to worst-case draft testing procedures in Section 11700 on page 111. Please refer to Section 11922 on page 117 for details of duct testing and repair.
11. *Filter:* A clean filter should be installed in a location where the client can locate it for the purpose of replacing or cleaning it.
12. *Blower or air handler:* The air handler blower should be visually inspected to determine if it requires cleaning. If necessary, it should be cleaned. The motor and blower must be oiled (where applicable).
13. Central air conditioning coils should be accessed and cleaned whenever airflow is excessively restricted by dirt on the coil.
14. Unused or non-functional central air conditioning coils should be removed to increase airflow.
15. *Other cleaning:* Other necessary cleaning should be done, where applicable, including air intakes, burners, furnace controls, heat exchangers, blower compartment and return air plenum, registers and grilles.

8132 Gravity, Space, Wall, and Floor Furnaces

All gravity, space, wall and floor furnaces should confirm to the following standards:

1. *Gas-fired unit requirements*
   a. *Gas Leaks:* All identified gas leaks should be referred to appropriate persons for repair or replacement. Hold the leak detector probe just below a propane gas line and just above a natural gas line.
   b. Flexible gas lines must be replaced under the following conditions:
      i. The line is badly kinked, corroded or shows signs of the physical wear.
      ii. The line connection is the soldered, two-piece type connection.
      iii. The line was manufactured before 1973. Sometimes there is a metal ring on the flexible line that is dated. If there is no dated metal ring, use one of the first two criteria listed just above.
   c. *Cleaning and tuning:* All gas-fired units must be cleaned and tuned once every two to three years. Make sure the client is having this service performed regularly.
2. *Oil-fired unit requirements*

a. *Oil storage and piping:* Check the oil tank and piping for leaks and compliance with all appropriate codes.

b. *Cleaning and tuning:* All oil-fired units should be cleaned and tuned annually. Make sure the client is having this service performed regularly.

3. *Thermostat/gas valve:* The furnace must have a thermostat in working condition and must be compatible with gas valve circuit type (24 volt vs. millivolt). For 24-volt system type, the anticipator on the thermostat should be set equal to the measured gas valve circuit amperage. Those appliances not equipped with thermostatic control should not have a thermostatic control added. Non-electric setback thermostats with an adjustable anticipator may be installed under the following conditions:

   a. Client lifestyle indicates potential for energy savings;

   b. Client is receptive to the installation; and

   c. Appropriate client education is provided on the operation of the thermostat.

4. *Limit switch:* Gravity furnaces must be equipped with a working high limit switch that shuts the fuel supply off at approximately 250^{o}F.

5. *Draft/Spillage:* All furnaces must be properly vented. All non-sealed combustion furnaces must be tested with a draft-testing device and meet the acceptable draft requirements. There must be no spillage. The flue must not be clogged, disconnected, or rusted to the point that it leaks. All furnaces, with the exception of direct-vent units, must be tested with worst-case draft test procedures (see Section 11700 on page 111).

6. *Carbon Monoxide (CO): Carbon Monoxide (CO):* All non-sealed combustion heating systems must be tested with a CO testing instrument. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.

7. *Filter:* If the manufacturer intended that the appliance have a filter, it should be checked for cleanliness. If a filter was not intended by the manufacturer, one shall not be installed.

8. *Other cleaning:* Other necessary cleaning should be done, where applicable, including air intakes, burners, furnace controls, heat exchangers, blower compartment and return air plenum, registers and grilles.

9. *Btu/hour Input for gas freestanding, wall and floor units:* Actual appliance output must be determined and fall within a range of plus or minus 20 percent of the required heat output of the heated space in its post-weatherized condition. If the existing appliance output rating falls outside of this range, replacement for reasons of health and safety should be considered.

8133 Mobile Home Sealed Combustion Furnace

All sealed combustion, mobile home furnaces should conform to the following:

1. *Gas-fired unit requirements*
   a. *Gas Leaks:* All identified gas leaks should be referred to appropriate persons for repair or replacement. Hold the leak detector probe just below a propane gas line and just above a natural gas line.
   b. Flexible gas lines must be replaced under the following conditions:
      i. The line is badly kinked, corroded or shows signs of the physical wear.
      ii. The line connection is the soldered, two-piece type connection.
      iii. The line was manufactured before 1973. Sometimes there is a metal ring on the flexible line that is dated. If there is no dated metal ring, use one of the first two criteria listed just above.
   c. *Cleaning and tuning:* All gas-fired units must be cleaned and tuned once <u>every two to three years</u>. Make sure the client is having this service performed regularly.
2. *Oil-fired unit requirements*
   a. *Oil storage and piping:* Check the oil tank and piping for leaks and compliance with all appropriate codes.
   b. *Cleaning and tuning:* All oil-fired units should be cleaned and tuned <u>annually</u>. Make sure the client is having this service performed regularly.
3. *Thermostat/gas valve:* The furnace must have a thermostat in working condition and must be compatible with gas valve circuit type (24 volt vs. millivolt). For 24-volt system type, the anticipator on the thermostat should be set equal to the measured gas valve circuit amperage. Those appliances not equipped with thermostatic control should not have a thermostatic control added. Non-electric setback thermostats with an adjustable anticipator may be installed under the following conditions:
   a. Client lifestyle indicates potential for energy savings;
   b. Client is receptive to the installation; and
   c. Appropriate client education is provided on the operation of the thermostat.
4. It is preferred that mobile home thermostats be located on an interior wall.
5. *Fan-on/fan-off:* Ideally the fan-off temperature is between 95º and 100ºF., but never below 80ºF. The fan-on target range is between

fan-off and 130ºF., but never to exceed 140ºF. In addition, all appliances that are not direct vent combustion and have inaccessible flue pipes must have a spillage check done to verify that no significant spillage is present.

6. *Limit switch:* This switch should shut the gas valve off at approximately 200ºF, where appropriate. Some units should not be tested in this manner.
7. *Heat Rise:* Heat rise should fall within the manufacturer's recommended temperature range. If this information is not available, the heat rise should fall within a 40º to 80ºF. range. The furnace must not cycle on the high-limit switch.
8. *Carbon Monoxide (CO):* All non-sealed combustion heating systems must be tested with a CO testing instrument. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.
9. *Ductwork:* Please refer to Section 11921 on page 117 for details of testing and repair.
10. *Filter:* A clean filter should be installed in a location where the client can locate it for the purpose of replacing or cleaning it. No filters shall be installed on furnaces that do not have separate heat exchanger/blower compartments (International and Intertherm).
11. *Blower or air handler:* The air handler blower should be visually inspected to determine if it requires cleaning. If necessary, it should be cleaned. The motor and blower must be oiled (where applicable).
12. *Other cleaning:* Other necessary cleaning should be done, where applicable, including air intakes, burners, furnace controls, heat exchangers, blower compartment and return air plenum, registers and grilles.
13. *Non-sealed combustion furnaces:* These units should be replaced with sealed combustion furnaces.

8134 Boilers

A boiler efficiency safety check should be conducted on all operable natural gas or propane fired heating systems. Tests should be performed on all oil-fired systems that have a smoke reading of two or less. Modifications and repairs, when possible, should meet the following specifications (applicable to type) and/or comply with the follow-up procedures. The subgrantee must document each situation in which the following specification cannot be met. All boiler systems should conform to the following standards:

1. *Gas-fired unit requirements*
   a. *Gas Leaks:* All identified gas leaks should be referred to appropriate persons for repair or replacement. Hold the leak

detector probe just below a propane gas line and just above a natural gas line.

b. Flexible gas lines must be replaced under the following conditions:
   i. The line is badly kinked, corroded or shows signs of the physical wear.
   ii. The line connection is the soldered, two-piece type connection.
   iii. The line was manufactured before 1973. Sometimes there is a metal ring on the flexible line that is dated. If there is no dated metal ring, use one of the first two criteria listed just above.

c. *Cleaning and tuning:* All gas-fired units should be cleaned and tuned once every two to three years. Suggest the client has this service performed regularly.

2. Oil-fired unit requirements

a. *Oil storage and piping:* Check the oil tank and piping for leaks and compliance with all appropriate codes.

b. *Cleaning and tuning:* All oil-fired units should be cleaned and tuned annually. Make sure the client is having this service performed regularly.

3. *Constant temperature boilers* in single family residences must be converted to cold-start type boilers, whenever feasible.

4. *Thermostat/gas valve:* The furnace must have a thermostat in working condition and must be compatible with the control circuit type (24 volt vs. millivolt). For 24-volt system type, the anticipator on the thermostat should be set equal to the measured control circuit amperage. Non-electric setback thermostats with an adjustable anticipator may be installed under the following conditions:

   a. Client lifestyle indicates potential for energy savings;

   b. Client is receptive to the installation; and

   c. Appropriate client education is provided on the operation of the thermostat.

5. Zone values: Malfunctioning zone valves in intentionally heated areas must be made operable, when feasible.

6. *Aquastat operation:* The aquastat control settings should be within the range of the manufacturer's recommendations.

7. *Draft/Spillage:* All boilers must be properly vented. All non-sealed combustion boilers must be tested with a draft-testing device and meet the acceptable draft requirements. There must be no spillage. The flue must not be clogged, disconnected, or rusted to the point that it leaks. All boilers, with the exception of direct-vent units, must

be tested with worst-case draft test procedures (see Section 11700 on page 111).

8. *Carbon Monoxide (CO):* All non-sealed combustion heating systems must be tested with a CO testing device. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.
9. *Circulator(s) on hot water boilers:* The motor must be checked for proper operation and oiled (where applicable).
10. *Hot water or steam distribution:* The distribution system should be checked for leaks, proper balancing, and adjustment. Dirty or clogged convectors/radiators must be cleaned.
11. *Other cleaning:* Other necessary cleaning should be done, where applicable, including air intakes, burners, furnace controls, and heat exchangers.

8135 Related Heating System Measurement Techniques

1. *Steady-state efficiency*
   a. *Gas systems:* Follow these procedures for conducting a steady-state efficiency test of a gas heating system.
      i. Inspect unit for hazardous conditions.
      ii. Locate an existing hole or drill and appropriate sized hole for measuring the draft.
      iii. Allow unit to reach steady state after firing the burner. Measure the temperature *before dilution* air enters the vent system. When the temperature has stabilized, steady-state conditions have been reached.
      iv. With combustion analyzer, measure the oxygen (O_2) percentage in the flue gas.
      v. Measure the net stack temperature at the same spot(s) the oxygen percentage was measured.
      vi. Determine the steady-state efficiency from these values.
      vii. Proceed to measuring the draft.
   b. Oil systems: Follow these procedures for conducting a steady-state efficiency test of an oil heating system. If a visual inspection indicates a cleaning and tuning is necessary, do so before an efficiency test is taken. *Note: Before the efficiency of an oil-fired system is measured, the smoke reading must be taken. If the smoke reading is two or less, proceed with the efficiency test. If the smoke reading is more than one, do not perform an efficiency test on the heating unit. Instead, order a cleaning and tuning for the burner and heating unit.*
      i. Inspect unit for hazardous conditions.

ii. Locate an existing hole or drill and appropriate sized hole for measuring the breech draft. This hole is also used for measuring the smoke, the oxygen percentage, and the temperature.

iii. Allow unit to reach steady state after firing the burner. When the temperature has stabilized, steady-state conditions have been reached.

iv. With combustion analyzer, measure the oxygen (O_2) percentage in the flue gas.

v. Measure the net stack temperature at the same spot(s) the oxygen percentage was measured.

vi. Determine the steady-state efficiency from these values.

vii. Proceed to measuring the draft.

2. Draft measurement

a. Gas systems: Proper draft hole test location is two feet down steam from draft hood or draft diverter in straight section of the flue pipe; or, if the two-feet measurement falls on an elbow, in the first straight section of flue pipe beyond two feet. Acceptable draft values for atmospheric gas systems are listed in Table 8-2.

Table 8-2

Atmospheric Gas Appliances Only Acceptable Draft Test Readings for Various Outdoor Temperature Ranges					
°F	<20	21-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column inches	-.02	-.016	-.012	-.008	-.004

b. Oil systems

i. Overfire draft: This draft reading is taken just above the oil burner through an opening into the firing chamber, if present. The overfire draft reading should be -5 Pascals or -0.02 inches of water gauge (W.G.). It should not be less.

ii. Flue pipe or breech draft: This draft reading should be taken through an appropriately sized hole – usually ¼ inch or slightly larger – drilled about 12 inches from the heating unit and at least 6 inches before the barometric damper (draft regulator). This draft reading should be from -10 to -15 Pascals (-0.04 to -0.06 inches W.G.).

iii. Acceptable draft values for oil-fired systems are listed in Table 8-3.

Table 8-3

Power Oil Burners Acceptable Draft Readings Overfire and at Breech	
Draft Reading Location	**Acceptable Draft**
Overfire Draft	-0.02 inches or -5 Pascals
Vent Connector or Breech	-0.04 to -0.06 or -10 to -15 Pascals

3. *Measurement of heat rise across heat exchanger*
   a. *Up-flow furnaces*
      i. *Supply side:* Drill a hole and insert the thermometer in the supply plenum as close as possible to the heat exchanger*, but "out of sight" of the heat exchanger* (this ensures that the reading will not be affected by radiant thermal energy from the heat exchanger). In the furnace plenum houses a central air conditioning coil, be very careful to avoid damaging this coil. Drill the hole beyond the cooling coil.
      ii. *Return side:* Drill a hole and insert the thermometer into the return plenum approximately two feet before the filter. Where an integral humidifier with a cross-over duct is present, drill the hole before the cross-over duct from the supply plenum so that the temperature is not affected by the warmer air in the cross-over duct.
   b. *Horizontal-flow furnaces*
      i. Drill a hole and insert the thermometer in the supply plenum as close as possible to the heat exchanger*, but "out of sight" of the heat exchanger* (this ensures that the reading will not be affected by radiant thermal energy from the heat exchanger).
      ii. *Return side:* Drill a hole and insert the thermometer into the return plenum approximately two feet before the filter.
   c. *Down-flow furnaces (mobile home):* The furnace compartment door should be closed while taking the temperature readings.
      i. *Supply side:* Test the supply side air temperature at the supply register closest to the furnace. Insert the thermometer probe into the register for the most accurate reading.
      ii. *Return side:* Test the return side air temperature by placing the thermometer probe at or through the slots in the blower compartment cover near the top of the furnace.
4. *High-limit furnace control (supply-side measurement only).* In some cases this should not be tested on newer furnaces. Refer to the manufacturer's equipment manual.
   a. *Up-flow and horizontal-flow furnaces:* Same location as for supply-side heat-rise measurement.

b. Down-flow furnaces (mobile home): Place the thermometer through the slots in the top center of the blower compartment cover with the cover in place.

5. Heat exchanger integrity:

a. When performing a steady-state efficiency test on a furnace, the CO, CO_2, or O_2 values change when the furnace distribution blower fan starts, it might indicate a cracked or defective heat exchanger.

8136 Storage Water Heater Inspection

All gas fired water heaters must meet the following specifications:

1. All identified gas leaks should be referred to the appropriate person for repair. All gas leaks should be documented in client file.
2. All water heaters must be properly vented.
3. All fossil-fuel water heaters, with the exception of direct-vent units, must be tested with worst-case draft test procedures (see Section 11700 on page 111).
4. All non-sealed and sealed combustion (direct-vent) water heaters must be tested with a CO testing device. Measured carbon monoxide levels must comply with Table 2-1 in Section 2300 on page 25.
5. All gas- and oil-fired and electric water heaters must have a water temperature test. If water temperature was found above 120°F, at a faucet near the water heater, the client should be informed about the advantages and disadvantages of lowering the water temperature. If the client agrees to adjustment, lower the water temperature to 120°F. Mark the old setting on the control as a reference point.
6. Visually inspect the combustion chamber for rust, dirt and proper burner alignment. Visually inspect venting, plumbing and gas piping. Check the tank for water leaks and note any code violations.

8137 Minimum Combustion Air Requirements

Please refer to Section 2426 on page 34 for requirements.

8138 All Other Heating Systems

The DCS WAP Administrator must be consulted before beginning work on heating systems other than those specifically addressed in these standards.

8200 Air Conditioner Requirements

8210 Air Conditioner Work Documentation

1. Each client file must include documentation of all work and adjustments made to air conditioning equipment.

8220 Central Cooling Systems

1. Central cooling systems installed or replaced by subgrantees must be properly sized using the Manual J method by the Air Conditioning Contractors of America (ACCA).
2. Setup of new central air conditioners should include:
   a. Measurement and verification of proper airflow across the indoor coil.
   b. Ensuring proper refrigerant charge.
   c. Proper insulation and protection of refrigerant lines.

8230 Window Air Conditioners

1. Window air conditioners installed or replaced by subgrantees must be properly sized according to the manufacturer's sizing chart, usually located on the air conditioner box.

9000 Client Education

9100 Client/Owner Education Recommendations

1. Client education should be provided during all phases of the weatherization process. This includes, but is not limited to:
   a. During client intake and scheduling.
   b. During the initial field audit.
   c. During the installation and repair of conservation measures.
   d. During the final job inspection.
2. Whenever possible, demonstrate to educate. Get the client involved in the educational process, if possible.
3. The use of up-to-date written materials and videotapes are encouraged as client education materials.
4. Client education should include an explanation of what measures were installed. In addition, the client should be informed of any course of action required by the client or owner to maintain the measure and to gain the greatest benefit from it. Client education should include:
   a. An explanation of installed energy-saving measures.
   b. The advantages of repairing plumbing fixture leaks.
   c. If the domestic water temperature is lowered for a storage water heater, the client must be informed that lowering the temperature of the water will result in less thermal energy stored in the hot water; therefore, they will run out of hot water sooner.
   d. The use of an infrared camera with the client.
5. The benefits and drawbacks of the potential energy conservation measures should be provided to the client or owner.
6. Client or owner authorization for installation of all energy conservation measures is preferred.
7. The benefits of periodically draining a small amount of water from a newer water heater should be explained to the client. (This procedure is not recommended on older tanks that have never been drained and/or have drain valves that are difficult to operate.)
8. Client education should be provided with the installation of a forced-air furnace filter, including a demonstration to the client of how to remove, clean, and reinstall the furnace filter.
9. The benefits of a lower thermostat setting and night set backs must be explained to the client.

10000 Electric Efficiency Measures

10100 Refrigerator Analysis and Replacement

1. When refrigerators are replaced with Federal funds, documentation must be in the client file. This documentation must include the details used for the cost-effectiveness analysis (SIR) for the replacement.
2. Replacing a refrigerator must yield a savings-to-investment ratio (SIR) of at least 1.00 to qualify for replacement.
3. Refer to Section 111210 on page 134 for instructions on refrigerator analysis and replacement
4. Refrigerators taken out of service must be discarded in an environmentally sensitive way. Old units contain refrigerant gases that must be reclaimed at licensed stations. No appliance taken out of service through this program may be returned to service by sale, barter, or for free.
5. Disposal and recycling fees must be added to the replacement cost and included in the cost-effectiveness analysis for the determination of SIR.

10200 Compact Fluorescent Lamp (CFL) Replacement

1. When compact fluorescent lights are installed, documentation must be in the client file. This documentation must include the number and wattage replaced.
2. Refer to Section 111220 on page 139 for instructions on replacing incandescent bulbs with compact fluorescent lamps.
3. Installation of CFLs must be justified by the WXEOR audit.

11000 Diagnostic Testing Procedures

11100 Blower Door Testing

11110 Introduction

The use of a blower door as a weatherization tool is very important. It can be used to determine the pre- and post-weatherization dwelling leakage rates, giving the crew an accurate idea of the effectiveness of their air sealing efforts. In addition, the blower door is used for zone pressure testing and duct leakage testing.

Because the blower door is such an important weatherization tool, it is very important that it be setup and used properly at each weatherization job. The **depressurization** blower door test is preferred for North Dakota Weatherization because it takes less time to perform than a pressurization test and it is the standard test used in the low-income weatherization program across the U.S.

The blower door testing procedures below assume the use of The Energy Conservatory (TEC) Minneapolis Blower Door, Model 3, with the companion TEC analog magnehelic gauges or the TEC digital manometer, Model DG-3.

11120 Preparation for Blower Door Test

1. Subgrantees should maintain accurate calibration of blower doors and related equipment. This includes:
   a. Blower door fan.
      i. There should be no physical damage to the fan.
      ii. The flow sensor on the Minneapolis Blower Door, Model 3, is the white ring which is permanently attached to the end of the motor opposite the fan blade. It is perhaps the most critical part of your Blower Door fan. Make sure the sensor is in its proper position, not damaged, that the connected hose is in good condition, and that the four holes in the sensor are not obstructed or blocked.
   b. If there is a problem with the fan or the flow sensor, contact the manufacturer before further use.
   c. Magnehelic gauges (round with needle indicators) should be calibrated once every five years by the manufacturer.
   d. Digital pressure gauges should be calibrated annually by the manufacturer.
   e. For detailed maintenance recommendations for equipment manufactured by The Energy Conservatory, go to http://www.energyconservatory.com/manuals.html and download Maintenance Tips.

2. Deactivate all vented combustion-type appliances before depressurizing the structure by turning the thermostat down or the appliance off.
3. Prevent the ashes of wood/coal burning units from entering the living space by closing/sealing doors and dampers or by cleaning out or covering the ashes.
4. Inspect the 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.
5. Close all prime windows, self-storing storm windows (if possible), sky lights, and exterior doors and latch them, as they normally would be found during the winter.
6. Open all livable areas to the interior of the structure, even if the occupants close them off during the winter.
7. Close basement doors during test unless one or more of the following conditions is present:
   a. The basement is used as a living area.
   b. The client leaves the basement door open during the winter or there is no basement door.
   c. The air returns do not connect directly to the furnace.
8. Set up the blower door unit in a favorable location in an area free from obstructions and wind interference.

11130 Blower Door Test, Depressurization (normal)

1. Set the blower door up in an exterior door with the least number of obstacles within 3 feet of the blower door fan. If the doorway leads to an enclosed area, make sure the space is open to the outdoors. Do not set up in a door facing the wind if an acceptable alternative exists.
2. Install the frame and panel securely into the doorframe, making sure that there are no gaps between any of the components or between the components and the doorframe
3. Set the fan into the panel/frame assembly, making sure that the panel opening fits snugly around the fan. Install the fan so that the flow ring assembly (or low flow plate) is facing toward the inside of the house. Set up the fan in a level or nearly level position.
4. Set up the gauges in a vertical position if using the magnehelic or digital gauges.
5. Make sure the variable speed control is in the off position. Plug the fan electric cord into a safe and fully functional electrical outlet.
6. Insert the tube from the house pressure gauge into the hole in the door panel. Make sure that the end of the hose is not in front of the

fan outlet or positioned so that it is exposed to windy conditions. Leave the fan pressure gauge tube end inside the house (not connected to the fan). Ensure that the fabric cover or all the rings and the center plug are on the fan.

a. If you are using the magnehelic gauges, zero all three of them.

b. If you are using a digital manometer, record the background pressure reading. This reading is usually a result of stack pressure. When you depressurize the house with the blower door, make sure to bring the house to a pressure that is 50 Pascals less than this background pressure. For example, if the background pressure is -3 Pascals, depressurize the house to -53 Pascals. If the background pressure is -5 Pascals, depressurize the house to -55 Pascals. Install the open end of the fan pressure gauge tube onto the blower door fan pressure tap.

7. Perform a one-point test by depressurizing to -50 Pascals house pressure or the highest house pressure if unable to reach -50 Pascals. Use the flow rings or low-flow plate if the fan pressure is less than 20 Pascals. If wind seems to be affecting test results, take several one-point tests and average the results.

8. Calculate the CFM_{50} of the dwelling by using the markings on the magnehelic gauges, digital gauges, ZipTest Pro™ software in the TI-86 calculator, or the blower door tables.

11140 Blower Door Test, Pressurization

1. Use the pressurization blower door test method only if a solid fuel heating unit or a drip-pot, oil burning space heater is in operation, or for some other reason approved by the North Dakota weatherization program.

2. Install the door panel and hang the gauge assembly, as it normally would be installed.

3. Attach a tube to the lower tap of the house pressure gauge and run the other end of the tube through the hole in the upper part of the door panel making sure it is away from the fan outlet. See the digital manometer instructions for the proper hose connection for house pressurization.

4. Leave the fan pressure tube "Tee" attached to the gauges and fan, as it normally would be for a depressurization test.

5. Attach an extra "Tee" to the upper taps of the fan pressure gauge and run the other end of the tube to the outside of the house, somewhere away from any fan turbulence.

6. Install the fan with the flow rings/low-flow plate attaches should be facing the outdoors. The fan tube and the extra tube will run outside between the fan housing and the elastic collar. The fan speed control must remain on the inside of the door panel.

7. Level and stabilize the fan as necessary.
8. Do not change the fan directional switch from its normal (forward) position.
9. Zero the gauges according to the blower door manual.
10. Perform a one-point test by pressurizing to -50 Pascals house pressure or the highest house pressure if unable to reach -50 Pascals. Use the flow rings or low-flow plate if the fan pressure is less than 20 Pascals. If wind seems to be affecting test results, take several one-point tests and average the results.
11. Calculate the CFM_{50} of the dwelling by using the markings on the magnehelic gauges, digital gauges, ZipTest Pro™ software in the TI-86 calculator, or the blower door tables.

11200 Blower Door Guided Air Sealing

11210 Pre-Guideline and Guideline Air Sealing

Air sealing work on dwellings is of three categories:

1. *Pre-guideline air sealing.* Examples include replacing window glass where glass is missing and sealing gross holes in the building envelope. There is little question that sealing or repairing these gross holes in the dwelling envelope will be cost-effective.
   a. Prior to any work done on the dwelling, an “as-is” blower door test should be performed as a means of finding these gross holes. This test will indicate whether pre-guideline air sealing is required in order to perform a more representative blower door test.
2. *Guideline air sealing.* This is air sealing completed with the guidance of the Weatherization Cost-Effective Guidelines (WCEG). WCEG must be used on all blower door guided air sealing. The WCEG program of the ZipTest Pro™ software package for the TI-86 calculator. This type of air sealing work is usually cost-effective only up to a point. Once that point is reached, air sealing work on a dwelling should cease.

11300 Weatherization Cost-Effective Guidelines

11310 Introduction

This procedure must be used for *guideline air sealing*, as defined in Section 11200, just above. If the procedure is used correctly, it indicates whether the crew should continue or stop air sealing. The crew only needs to enter the correct information into the Weatherization Cost-Effective Guidelines (WCEG) program of the ZipTest Pro™ software package for the TI-86 calculator.

11320 Procedure

1. Prior to any blower door guided air sealing using the Cost-Effective Guidelines (CEG) program:
   a. Complete all required *Pre-guideline air sealing* as defined in Section 11200, just above.
   b. Complete all key juncture air sealing and insulation installation.
2. Use of the CEG program:
   a. After completing the above, if dwelling CFM_{50} is more than 200 percent of the calculated Building Tightness Limit (BTL), do more air sealing *before* using Cost-Effective Guideline (CEG) program.
   b. If dwelling CFM_{50} is from 125 percent to 199 percent of BTL, use CEG program for air sealing guidance.
   c. If dwelling CFM_{50} is from 125 percent to 199 percent of BTL, do not quit air sealing until performing zone pressure diagnostics testing in appropriate areas, even if CEG program indicates to stop air sealing.
   d. If CFM_{50} is more than 150 percent of BTL, the CEG limit has not been reached, and it is the end of the day, the air sealing work shall not be considered complete. In such a case, the dwelling must be considered in-progress and the crew must return for more air sealing. However, if the dwelling CFM_{50} is less than 150 percent of BTL at the end of the work day, air sealing may be considered completed.
   e. If all leakage tests have been performed and the CEG program indicates that air sealing should stop, stop air sealing.

11400 Building Tightness Limit Procedures and Calculation

11410 Introduction

The purpose of the Building Tightness Limit (BTL) calculation is to ensure that the dwelling complies with the ASHRAE Standard 62-1999, *Standard for Acceptable Indoor Air Quality*. This Standard requires at least 15 CFM of fresh outdoor air per person **and** 0.35 air changes per hour per dwelling unit.

The BTL is expressed as a CFM_{50} value; making is easy to determine whether the dwelling is tighter or looser than the BTL with a blower door test.

11420 General Procedure

1. Use the ZipTest Pro™ software loaded in the TI-86 calculator or the WXEOR audit to determine the BTL for each dwelling. Each dwelling requires a separate calculation.
2. Calculate the BTL before weatherization work begins. The BTL is a CFM_{50} estimate that is used as an air sealing guideline, that is, if the

dwelling is tightened to a CFM_{50} value that is less than the BTL, the building will not comply with ASHRAE 62-1999 unless continuously operating mechanical ventilation is installed.

Table 11-1

BTL Procedure Inputs/Outputs	
Input Data	***Output Values***
Climate zone	BTL CFM_{50}
Building square feet	Lawrence Berkeley number
Occupants (min. of 5)	
Building stories	
Building exposure	
Ceiling height	
Based on ZipTest Pro™ software	

11430 Calculation Procedures

1. Enter the input data into the BTL program of the ZipTest Pro™ software package. The required input data are listed in Table 11-1. The ZipTest Pro™ software program BTL will guide you when you are entering the data. Under no circumstance should combustion appliances be included in the BTL procedure for any reason. Refer to the ZipTest Pro™ software instructions for examples.
   a. Climate zone: Most of North Dakota is climate zone 1. The southwestern corner of the state is climate zone 2. Refer to the ZipTest Pro™ software instruction manual for the climate zone map.
   b. Building square feet: This is the occupied square feet of the dwelling. If the basement is finished and/or used as living space, include it in your whole house blower door test (door to basement open) and include the basement in the BTL square feet calculation.
   c. Occupants: The minimum number of occupants you are allowed to enter is five. As a guide, count the number of bedrooms and add one. If this is less than five, enter five.
   d. Stories: The exposed number of stories of the dwelling. Basements below grade should not be counted. The choices are 1, 1.5, 2, and 3 stories.
   e. Exposure: The choices here are “shielded”, “normal” and “exposed”. This entry has to do with the degree to which the dwelling is exposed to wind. Shielded is for buildings with significant blockage from the wind (trees or other buildings), normal is for buildings in a typical suburban setting (obstructions to the wind around the building, but not dense), and exposed is for buildings with very little wind blockage (meadow setting, lake-side, etc.).
   f. Ceiling height: Sometimes the program will ask you to enter the average ceiling height. If the program prompts you for this, enter a

value that will give a good approximation of the volume of the dwelling when the program multiplies the ceiling height by the building square feet that you already entered.

2. Try not to tighten the dwelling to a level below the BTL CFM_{50}. If the dwelling is tighter than the BTL CFM_{50} before weatherization or if weatherization makes the dwelling tighter than the BTL CFM_{50}, use the BTLa procedure that is part of the BTL1 program in the ZipTest Pro™ software. Exception: In some cases dwellings need continuously operating ventilation even though they are looser than the BTL. Examples include houses with difficult moisture problems. In such cases, install ventilation if it will help mitigate the moisture or other air quality problems.

   a. To properly size the exhaust ventilation, use the BTLa procedure that is part of the BTL1 program in the ZipTest Pro™ software package. This procedure will calculate the required CFM of a continuously operating exhaust fan. The input and output data for this procedure are listed in Table 11-2. Please refer to the ZipTest Pro™ software instruction manual for detailed instructions and examples.

      Note: The following sizing procedure is not appropriate for balanced ventilation systems, that is, mechanically driven exhaust and supply air.

      i. House CFM_{50}: The house CFM_{50} after all weatherization work has been completed.

      ii. Flow exponent: Enter the default value, 0.65.

      iii. Weather factor: For Bismarck and surrounding area, enter 0.99. For Fargo and surrounding area, enter 1.10. There are no other weather factor values available for North Dakota.

      iv. House square footage: This is the occupied square feet of the dwelling. If the basement is finished and/or used as living space, include it in your whole house blower door test (door to basement open) and include the basement as part of this square feet calculation.

Table 11-2

BTLa Procedure Inputs/Outputs	
Input Data	***Output Values***
a. House CFM_{50}	1. Effective leakage area (ELA), in^2
b. Flow exponent (0.65 default)	2. Equivalent leakage area, in^2
c. Weather factor	3. Estimated natural CFM
d. House square footage	4. Estimated natural ACH
e. House volume	5. Natural CFM/occupant
f. Building height	6. ELA minimum
g. Story height	7. CFM minimum
h. Occupant count (bedrooms + 1)	8. Exhaust ventilation CFM
	9. CFM_{50} limit
Based on ZipTest Pro™ software	

v. House volume: This is the occupied and conditioned volume of the dwelling. If the basement is finished and/or used as living space, include it in your whole house blower door test (door to basement open) and include the basement as part of this square feet calculation.

vi. Building height: This is the building height above grade in units of feet. For buildings with uneven above grade heights – walk-out basements, etc. – use the average height of the building

vii. Story height: This is the height, in feet, of one story of the building.

viii. Occupant count: For a particular dwelling, use the same number of occupants for the BTLa procedure that were used for the BTL procedure. The minimum should be five.

ix. After all the input values are entered, the output values as listed in Table 11-2 will be displayed. The required exhaust ventilation CFM is displayed as number 8. Please note that the value for number 9, CFM_{50} limit, is likely to be slightly different from the CFM_{50} limit calculated by the BTL procedure.

x. Once the CFM requirement for the exhaust ventilation is determined, refer to page 23 for fan selection and control.

11500 Depressurization Tightness Limit (DTL)

11510 Introduction

If the dwelling has conventionally vented combustion appliances, the Depressurization Tightness Limit (DTL) must be calculated before weatherization work begins.

The DTL calculation establishes a CFM_{50} minimum, below which the backdrafting of conventionally vented combustion appliances is likely to occur. This limit provides a guideline for air sealing activities.

The use of the DTL should never be used as a substitute for performing the worst-case draft test procedure.

The DTL is independent of the BTL; each must be calculated independently and the greater of the two for a particular dwelling must be used as the Overall Tightness Limit (OTL).

11520 Calculation Procedure

1. Use the DTL program in the ZipTest Pro™ software package loaded in the TI-86 calculator to calculate the dwelling DTL.
   a. In the ZipTest Pro™ software package, select the program “DTL”.
   b. Select a solution for “CFM_{50}”.
   c. Enter the total and actual CFM exhaust rate for all the exhausting appliances in the dwelling. You should include any appliances that are not yet installed, but will be during your weatherization work. For example, include the CFM exhaust rate of an electric or gas dryer that is not vented to the outdoors now, but will be vented as part of your weatherization work. Refer Table 11-3 to for guidance.

Table 11-3

Exhaust Appliance Nominal CFM	
Appliance	***CFM Nominal***
Bathroom exhaust fan	50
Kitchen range hood	100
Kitchen wall fan	250
Kitchen down-vent fan (Jenn-Air)	300 - 600
Dryer	180
Central vacuum	150
Fireplace	200 - 400
Note: Actual CFM might be significantly less than nominal – or rated – CFM.	

   d. Select and enter the appropriate building depressurization limit based on Table 11-4. If more than one appliance is located in a CAZ, use the lowest magnitude building depressurization limit for the existing CAZ appliances (for example, -2 Pascals is a lower magnitude than -5 Pascals).

Table 11-4

Building Depressurization Limits for Various Appliance Types (Used to calculate the Depressurization Tightness Limit)	
Appliance Type	***Building Depressurization Limit, Pascals***
Water heater only, atmospheric gas	-2
Water heater and atmospheric furnace	-5
Furnace or boiler, gas atmospheric or fan assist., Category I	-5
Oil or gas unit with power burner	-5
Induced draft appliance (fan at point of exit at wall)	-5
Direct-vent appliances	-10

e. Enter the appropriate flow exponent for the house. If you do not know the actual flow exponent, enter the default value, 0.65.

f. The ZipTest Pro™ software calculates the CFM_{50} tightening limit for combustion safety, the Depressurization Tightness Limit. Use this as a low limit to house tightening. For example, if the DTL is 1600 CFM_{50}, instruct the crew not to tighten to below 1600 CMF50.

Remember, the DTL is a pre-weatherization guideline only, it must never be used to replace the worst-case draft test procedure

11600 Overall Tightness Limit (OTL)

The Overall Tightness Limit (OTL) is simply the larger of the Building Tightness Limit (BTL) and the Depressurization Tightness Limit (DTL). Crews should do their best not to tighten below the OTL.

However, there are circumstances when a crew will tighten below the OTL, either knowingly or unknowingly. This might happen when:

1. Adding insulation, especially to walls, lowers the whole house CFM_{50} by a large increment, making the house tighter than either the BTL or the DTL. Walls must always be fully insulated, even if the crew knows that the building will become “too tight”.
2. Indoor air quality problems warrant the tightening of the building to below one of these limits, for example, air sealing a wall between a house and an attached garage lowers the CFM_{50} to a value less than the BTL or DTL.

Table 11-5 gives an example of the function these tightening limits play in the pre- and post-weatherization process. If air sealing makes the house tighter than the BTL or the DTL, make sure that the procedures are followed under the Building Tightness Limit and the Depressurization Tightness Limit procedures included in these standards.

Table 11-5

Use of Tightness Limit Procedures (BTL, DTL, and OTL) for North Dakota Weatherization Determination of Overall Tightness Limit		
Pre-Weatherization Activity	***Example Values***	***Notes***
1. Blower door test	2200 CFM_{50}	expressed as CFM_{50}
2. Building tightness limit (BTL)	1300 CFM_{50}	The higher of values 2 and 3 is used as the house overall tightness limit (OTL)
3. Depressurization tightness limit (DTL)	1100 CFM_{50}	
4. Determine OTL	1300 CFM_{50}	
Post-Weatherization Activity		
5. Blower door test	1050 CFM_{50}	expressed as CFM_{50}
6. If whole house CFM_{50} is below building tightness limit, install continuously operating exhaust ventilation	Install 40 CFM exhaust fan	
7. If whole house CFM_{50} is below depressurization tightness limit, mitigate possible draft problem.		Worst-case draft test will validate.
8. Perform worst-case draft test. Correct any draft problems. Check for venting code violations.		This must always be done if non-sealed (not direct-vent) combustion appliances operate in the dwelling.

11700 Worst-Case Draft Testing

11710 Introduction

The purpose of worst-case draft testing is to ensure the proper venting of all vented combustion devices in a dwelling. This testing must always be done after all other weatherization work has been completed. In site-built houses with ductwork in a combustion appliance zone, it should also be done before weatherization work begins.

The procedure for worst-case draft testing measures the difference in pressure between outside and inside the house at the combustion device in the combustion appliance zone (CAZ) and verifies adequate vent system draft at all conventionally vented combustion appliances. If more than one vented combustion appliances are located in different areas of the house, a test must be performed for each area.

In addition, before weatherization work begins, the Depressurization Tightness Limit (DTL) should be calculated when conditions warrant. The DTL is a CFM_{50} estimate that is used as an air sealing guideline, that is, if the dwelling is tightened to a CFM_{50} value that is less than the DTL, backdrafting is likely to occur. The DTL must never be used as a substitute for worst-case draft testing.

11720 Dwellings Requiring Testing

Worst-case draft testing must be done:

1. After all other work has been fully completed in all units weatherized (this is a health and safety requirement);
2. Before weatherization work begins in site-built houses with ductwork located in a combustion appliance zone (this is a diagnostics test to determine if leaky ductwork in the CAZ is affecting CAZ pressures).

The following are exceptions to the first requirement, above:

1. If the house or mobile home is all-electric with no combustion appliances, woodstoves or fireplaces, or has combustion appliances that are all sealed combustion (direct vent), a worst-case draft test does not have to be performed.
2. In apartments with no combustion appliances other than unvented or direct-vent combustion appliances, a worst-case draft test does not have to be performed.

11730 Test Procedure

Worst-case is defined as the configuration of the house that results in the greatest negative pressure *in the combustion appliance zone*.

1. Consideration must be given to the following:
   a. The types and locations of the heating systems.
   b. The location and strength of all exhausting equipment (bath fans, dryers, kitchen exhaust devices, etc.).
   c. The location of wood stoves, fireplaces and water heaters.
   d. The volume of the area where the combustion devices are located.
   e. The location of the forced-air system returns.
2. Place the building in the wintertime condition with all windows and exterior doors closed. If it is not practical to close or install existing storm windows, latch or lock primary window units. If the blower door is setup, make sure the fan is closed off.
3. Record the outdoor temperature on the Worst-Case Draft Test form for this test (refer to page 111). Other information should also be recorded on this form during the test procedure.
4. Deactivate all combustion appliances by turning them off or setting the control to pilot.
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. Adjust the pressure gauge to 15 Pascals if using a magnehelic gauge *when no hoses are connected to the pressure taps*. If using a digital manometer, no adjustment is needed.

9. Set up pressure hoses so that the pressure differential from CAZ with reference to the outdoors can be easily measured.
10. With the interior doors 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 value.
11. Turn on all exhaust devices (except whole-house exhaust fan) and record the pressure in the CAZ. The pressure created in the CAZ from the operation of these exhaust fans is the difference between this value and the Baseline Pressure measured in step 10, above. *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 while combustion appliances are operating could be very hazardous.*
12. If the house contains a furnace, activate the blower. Record the pressure reading in the CAZ with reference to the outdoors. Caution: If the only way to activate the blower is to fire the furnace, extreme caution must be used due to the potential of combustion backdrafting or flame rollout.
13. Close interior doors and measure the pressure difference between the main body of the house and the room you are closing off when standing on the main-body side of the door with your pressure gauge. If this pressure is negative, leave this door open. If this pressure is positive, close this door.
14. Close the door to the CAZ (this is often the basement door). If closing this door results in a negative pressure in the CAZ with reference to the outdoors of a greater magnitude (for example, from a -2 to a -4), leave this door closed. If closing this door decreases the magnitude of the pressure (for example, from a -4 to a -3), leave this door open.
15. Determine whether the furnace air handler fan contributes to depressurization. This is done by turning the air handler fan off and then on again while watching the CAZ pressure with reference to outdoors.
16. Record the worst-case depressurization, that is, the most negative pressure in the CAZ with reference to outdoors.
17. Under these worst-case conditions, fire the combustion appliance and determine if the appliance is drafting properly after two minutes.
18. Under these worst-case conditions, fire the combustion appliance and measure its draft. After two minutes, the draft should comply with the draft values in
19. Table 11-6 or Table 11-7. If an acceptable draft is not obtained, the draft problem must be corrected, even it the CAZ pressure is within normal range.

20. If more than one appliance is located in the zone, fire the combustion appliance with the lowest Btu output first. Measure the draft at the appliance. The draft for atmospheric gas appliances or power oil burners should comply with the appropriate
21. Table 11-6 or Table 11-7. Shut down the appliance. Fire all remaining appliances, one at a time, in order of output (smaller to larger), testing each one for draft. If the appliances vent into the same chimney or vent connector, test each one individually. If the appliances vent into different chimneys or vents, test with each successive unit running. All appliances must achieve acceptable draft within two minutes of firing.
22. If draft is unacceptable, correct the problem with one of the following (listed in order of preference):
    a. Check for vent system blockage and correct if found,
    b. Increase CAZ air volume by connecting CAZ to other conditioned areas (see NFPA 54),
    c. Duct outdoor air directly to the combustion supply air port of burner(s), or
    d. Increase CAZ air volume by connecting CAZ to outdoors (see NFPA).
23. If the dwelling has other combustion appliance zones, repeat the sequence of activating exhaust equipment, door closure, furnace blower activation, and recording pressure readings.
24. When all worst-case draft testing has been completed, turn off all exhaust equipment and return doors and combustion appliances to their normal settings.

Table 11-6

Atmospheric Gas Appliances Only Acceptable Draft Test Readings for Various Outdoor Temperature Ranges					
°F	<20	21-40	41-60	61-80	>80
Pascals	-5	-4	-3	-2	-1
Water Column inches	-.02	-.016	-.012	-.008	-.004

Table 11-7

Power Oil Burners Acceptable Draft Readings Overfire and at Breech	
Draft Reading Location	***Acceptable Draft***
Overfire Draft	-0.02 inches or -5 Pascals
Vent Connector or Breech	-0.04 to -0.06 or -10 to -15 Pascals

11800 Room-to-Room Pressure Testing

11810 Air Handler Pressure Balance Testing for Site-Built Homes

11811 Introduction

This test procedure is performed only in dwellings with air handlers. Room-to-room pressure(s) should be measured in all rooms with forced air heating return or supply ducts and operable doors, after all weatherization installations have been completed. The procedure indicates the magnitude of:

1. Duct leakage to the outdoors, either through supply or return ducts.
2. Imbalances of air distribution resulting from closed interior doors. These closed doors can act as dampers to the free flow of air within the conditioned space of the dwelling.
3. Imbalances of air distribution resulting from airflow differences between the supply side and return side of the ductwork, for example, a restricted return truck.

11812 Test Procedure

1. Set house up in winter operating mode.
2. Run a pressure hose from the main body of the house to the outdoors.
3. Set up a magnehelic gauge zeroed at 15 Pa or a digital pressure gauge in the main body of the house.
4. Record any pressure difference between the main body of the dwelling and the outdoors. This is the reference background pressure.
   a. A reference background pressure might be due to stack-effect air leakage (especially if it is cold outdoors) or wind.
5. Turn on the air handler and measure the pressure of the main body of the house with reference to the outdoors.
   a. If the pressure difference between the main body and the outdoors is different with the air handler on than with the air handler off, there is probably some duct leakage to the outdoors
      i. Either from the return side of the system (the pressure difference of the dwelling with reference to outdoors will move toward positive when the air handler is activated), or
      ii. From the supply side of the system (the pressure difference of the dwelling with reference to outdoors will move toward negative when the air handler is activated).
6. Close all interior doors.

7. Repeat the pressure measurement from the main body of the house with reference to the outdoors.
   a. If this pressure is different than it was when all the interior doors were open, the interior doors are acting as dampers to the air distribution system. This can cause thermal discomfort and stuffiness in the room and it can increase the air leakage of the dwelling when the air handler is running.
8. Take the pressure gauge, being careful to level and zero on 15 Pa when using a magnehelic gauge, and 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. Make sure that registers and grilles are not blocked, even though they appear open. Provide pressure relief to any room with readings greater than 3 Pascals by:
   b. Opening the door slightly while measuring the pressure difference across the door. Open the door until the pressure difference is less than 3 Pascals and measure the square inches of opening. This is the number of square inches:
      i. The door must be undercut (this usually works well in mobile homes).
      ii. A direct grille, offset grilles, or jump duct must be to properly relief the pressure imbalance caused by the distribution system when the door is closed.
9. Turn off air handler and return house to the condition it was in before testing began.

11900 Duct Leakage Testing

11910 Introduction

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

Ductwork leakage can take place 1) within the confines of the conditioned envelope of the building or 2) to and from the outdoors.

Leakage to or from the outdoors wastes 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.

On the other hand, although duct leakage within the conditioned envelope usually does not have a significant energy impact, it might impose a hazard to occupant health by causing poor indoor air quality or backdrafting of combustion

appliances. These potential problems are addressed on site by an IAQ appraisal and by performing the worst-case draft test (refer to page 111).

Pressure pan and duct blower testing must be done in some dwellings to determine if ducts are leaking to a significant degree to or from the outdoors.

11920 Duct Leakage Standards

The following standards shall be followed for mobile homes (including double-wide mobile homes) and site-built homes, including manufactured housing.

11921 Mobile Homes

1. If there is a belly return system in the mobile home, convert it to a living-space return system (refer to Section 7700 on page 79).
2. For a living-space return system, if the sum of the pressure pan readings is 3 Pascal or less:[2]
   a. Visually check furnace-plenum joint and repair and seal with mastic, if necessary, and
   b. Visually check all boots and repair and seal with mastic, if necessary.
3. For a living-space return system, if the sum of the pressure pan readings is between 3 and 5 Pascals:
   a. Visually check all boots and repair and seal with mastic, if necessary.
   b. Visually check any crossover ducts and repair and seal with mastic, if necessary. Make sure these ducts are supported properly.
   c. Visually check furnace-plenum joint and repair and seal with mastic, if necessary, and
   d. Goal: Reduce the sum of pressure pan readings to 3 Pascals or less.
4. For a living-space return system, if the sum of the pressure pan readings is greater than 5 Pascals:
   a. Repair and seal as in 3 above, and
   b. Perform duct blower test and implement duct-blower guided duct repair and sealing. Refer to page 121, Duct Blower Testing.
   c. Goal: Reduce duct leakage to the outdoors, as measured with a duct blower and blower door, to10 percent of conditioned floor area.

11922 Site-Built Homes, Including Manufactured Housing

1. For ducts located in unconditioned spaces:

[2] The pressure pan readings must be adjusted for house/zone pressure differences. See Pressure Pan Multipliers chart and test on page 120 for instructions.

a. If possible, convert the unconditioned space where the ducts are located to a conditioned space, making sure the air and thermal barriers are installed effectively.
    i. Demonstrate the effectiveness of this weatherization work by performing a house-to-zone pressure and flow test (if possible) before and after converting the unconditioned space to a conditioned space.
    ii. Always repair disconnected ducts in the space.
    iii. It is preferred to seal the shell of the space rather than sealing the duct joints.
b. If the unconditioned space is impossible to convert to a conditioned space or it is determined impractical to convert to a conditioned space:
    i. Use a duct blower to determine the duct leakage to the outdoors. Examples of these types of unconditioned spaces include crawlspaces, unconditioned basements, attics, attached or tuck-under garages, and exterior walls.
    ii. Repair, seal with mastic, and thermally insulate ducts in unconditioned spaces to at least an R-8.
    iii. Goal: Reduce duct leakage to the outdoors, as measured with a duct blower and blower door, to 10 percent of conditioned floor area.

2. For ducts located in conditioned spaces, such as a basement or crawlspace:
    a. Perform a house-to-zone pressure and flow test (if conditions warrant) to determine if the space in question is conditioned in terms of its shell air barrier. The house-to-zone pressure should be 20 Pascals or less.
    b. Visually inspect the conditioned space to ensure that the shell is properly insulated.
    c. If it is determined that weatherization work should be done to the shell of the conditioned space housing the ducts, perform a house-to-zone pressure and flow test (if possible) before and after the work to quantify the effectiveness of the work.
        i. Always repair disconnected ducts in the space.
        ii. Sealing the shell of the space rather than sealing the duct joints is preferred.
        iii. Goal: The house-to-zone pressure should be 20 Pascals or less.

11930 Pressure Pan Testing Procedures[3]

11931 Introduction

Pressure pan testing helps find ductwork leaks or disconnections that are connected to outdoor air. 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.

11932 Test Procedure

1. Install the blower door for a depressurization test. Make sure the dwelling is set up for winter conditions.
2. Open all interior doors, including the door to the basement if the basement is considered conditioned space (heating system, water heater, washer or dryer located there and it is determined that the basement is part of the conditioned envelope),
3. Make sure the furnace burner and air handler is off and will not start during the testing. Remove the furnace filter and ensure that all registers, grilles, and balancing dampers are fully open.[4]
   a. Exception: When performing pressure pan testing in a mobile home, block the filter opening by covering the filter with a plastic bag and reinserting the filter with the bag over it. This blocks the filter opening and results in more accurate pressure pan testing. When the testing is completed, make sure to remove the plastic bag from around the filter.
4. Temporarily seal outside combustion air inlets or ventilation system connections that are directly connected to the duct system. These connections will show up as large leaks if not sealed prior to testing. 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.
5. Open attics, crawl spaces, garages, and other unconditioned spaces to the outdoor air as much as possible. If the basement is being treated as an unconditioned space, open it to the outdoor air.
6. Only one person at a time should be taking pressure pan readings. Having 2 registers in different parts of the duct covered by a pressure pan at the same time can affect readings.
7. Depressurize the dwelling to -50 Pascals with the blower door.

[3] This section is primarily based on *Using a Pressure Pan to Diagnose Duct* Leakage by The Energy Conservatory, March 2002. This document is available on the Internet at www.energyconservatory.com/manuals.html. When you get to this page, find “Pressure Pan User Manual”.
[4] 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.

8. Make sure the pressure pan is properly connected to the manometer. The proper connection should be reading the space under the pressure pan with reference to the main dwelling pressure.
9. Place the pressure pan completely over each register and grille in conditioned areas.
   a. If a register or grille is larger than the pressure pan, cover the oversized portion of the register or grille with tape while the reading is recorded.
   b. If access to a register or grille is difficult, for example at a kitchen counter kick space, cover the entire opening with tape and insert the pressure probe through the tape (near the center of the taped opening) while the reading is recorded.
   c. 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. Once you have taken the pressure pan reading, remove the seal before proceeding to the next register.

Table 11-8

Pressure Pan Multipliers	
House/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

10. Record the pressure pan readings before and after duct sealing activities to get an idea of sealing effectiveness. It will sometimes be useful to record readings during duct sealing. Always start your measurements using the blower door as a reference point and work clockwise around the dwelling.
    a. If an unconditioned space is not well connected to the outdoors (e.g. unvented crawlspaces or unvented attics) or has 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:
       i. With the dwelling at -50 Pascals, measure the pressure difference between the main dwelling and the unconditioned space in question. (For example, the house to zone pressure is 10 Pascals and the pressure pan reading is 2.0 Pascals).
       ii. Multiply the pressure pan reading by the multiplier in Table 11-8 to get the corrected and true reading. (For example, multiply the pressure pan reading of 2.0 Pascals by the

multiplier of “5”, resulting in a pressure pan reading of 10 Pascals).

11. 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 your pressure pan tests with the house at the highest achievable pressure. In this case, you will need to interpret your pressure pan readings carefully. Compare the measured pressure pan reading with the maximum possible reading.
12. Record the pre- and post-weatherization readings on the Diagnostic Field Form.

11940 Duct Blower Testing for Leakage to Outdoors

11941 Introduction

This required duct blower test requires measurement of duct air leakage to the outdoors, not total duct leakage (to outdoors and indoors).

During this test procedure a blower door fan will be used to pressurize the building to the test pressure, while the duct blower system is used to pressurize the duct system to the same pressure as the building. Because the duct system and the inside of the dwelling will be at the same pressure, there will be no leakage between the ducts and the dwelling during the test.

The blower door fan should be set up to blow air into the building for pressurization. Airflow through the blower door does not need to be measured during this test. Because of this, the blower door fan can either be set up in the pressurization test mode, or it can be set up in the standard depressurization test mode, with the fan direction switch reversed to blow air into the dwelling. Refer to your blower door manual for complete instructions.

For residential duct systems, generally is recommend as the test pressure. This pressure has been adopted by the majority of residential duct testing programs in the U.S. because 25 Pascals represents a typical operating pressure seen in many residential systems.

The instructions below assume the use of The Energy Conservatory Digital Manometer, Model DG-3, and the Minneapolis Duct Blaster™.

11942 Test Procedure

1. Close all exterior doors and windows.
2. Open all interior doors.
3. Open doors to heated or conditioned spaces. Close doors to all unconditioned spaces.
4. Install blower door properly.

5. Shut down solid-fuel appliances before activating blower door or duct blower.
6. Adjust the HVAC system controls so that the air handler fan will not turn on during the duct blower test.
7. Temporarily seal off all supply and return registers, except any central return grille being used to connect the duct blower system to the duct system.
8. Temporarily seal off all combustion air and ventilation air inlets that are directly connected to the duct system.
9. Turn off all exhaust fans, vented dryers, and room air conditioners.
10. Turn off all vented combustion appliances if there is a possibility that the space containing the appliance will be depressurized during the duct blower test.
11. Remove all filters from the duct system and air handler cabinet. If the duct blower will be installed at a central return grille, remove the filter from that grille.
12. If ducts run through unconditioned spaces such as attics, garages or crawlspaces, open vents, access panels, or doors between these spaces and the outdoors to eliminate pressure changes during the test procedure. This should also be done if the duct blower fan will be installed in an unconditioned space, for example, connected to an air handler in a garage or crawlspace.
13. On the blower door, connect the outdoor building pressure tube to the bottom tap on the 60 Pascal magnehelic gauge. The other end of this tubing should either be run to the outdoors, or to the unconditioned zone which contains the majority of the ductwork.
14. Install the duct blower at the furnace or at a large return grille.
15. Decide on the ring configuration for the duct blower.
16. Connect the digital manometer correctly:
    a. Connect a pressure hose between a register and the input tap on side “A” of the digital pressure gauge. Connect another pressure hose from the reference tap on side “A” to the interior of the dwelling. This means that if you are in the garage, the crawl space, or in the attic, you will need a pressure hose running under a door back to the interior of the house.
    b. Connect a red hose to the top tap on channel “B”. The other end of this hose is connected to the duct blower flow ring.
17. Pressurize the house with the blower door to the test pressure, 25 Pascals. Leave the blower door fan running.
18. Make sure the digital pressure gauge is set on channel “A”.
19. Set up the digital gauge properly.
    a. Turn the mode selection knob to time select and select “1 second”.

b. Turn the mode selection knob to fan select and select “8”. Choose “8-0” for no duct blower rings, “8-1” for one ring, and so on.

c. Turn the mode selection to pressure.

20. Turn on the duct blower and pressurize the ducts until the gauge reads zero, that is, the pressure between the duct system and the dwelling is zero. Leave the duct blower running.
21. Re-check the building pressure at the blower door and adjust if necessary.
22. Re-check the duct blower system and adjust if necessary.
23. On the DG-3 digital manometer, connected to the duct blower fan, turn the channel knob to “B” and turn the mode switch to “Flow”. The gauge will now display the air flow through the duct blower fan in cubic feet per minute at 25 Pascals (CFM_{25}). This fan flow is the measured duct leakage to the outdoors at the test pressure of 25 Pascals. This CFM_{25} flow can also be determined by reading fan pressure from Channel B and converting that pressure reading to flow by using the Duct Blaster™ Flow Conversion Table in the Duct Blaster™ instruction manual.
24. Check to make sure you have set the DG-3 correctly.
25. It is a good idea to move the register pressure hose to other registers. If the dwelling-to-duct pressure does not remain close to zero, there are probably significant duct leaks. Inspect and repair any obvious duct disconnects before continuing.
26. When the duct sealing and duct blower testing are completed, shut down and remove the blower door and duct blower.

The final worst-case draft test should be performed after the duct testing and duct sealing is completed.

111000 Zone Pressure Diagnostics (ZPD) Testing

111010 Introduction

Zone pressure diagnostics testing is performed to answer some fundamental questions: where is the functioning air barrier and where should it be located? These test procedures can also be used to measure the size of the leakage paths to various house zones. Leaking air often takes a path that moves through two surfaces with a cavity or zone between. These zones can include attics, basements, garages, knee-wall areas, or attached porch roofs.

ZPD procedures require the measurement of *pressure differences* across air barriers, like the pressure difference between the house and the zone (attic, for example), while the house is depressurized by a blower door to –50 Pascals. The procedures also require the determination of *flows* across air barriers. These flows can be calculated with the steps of the ZPD procedures and a computer or

a programmed calculator. Once these flows are calculated, an estimate of the square inches of leakage through an air barrier can be easily determined.

These procedures can be used with primary and secondary zones. Primary zones are zones to which you have access, such as basements or attics. This access allows you to open a temporary hole or door between the zone and the dwelling or the zone and the outdoors. For primary zones, ZPD can be conducted for reasons of:

1. Air leakage/energy loss concerns. If after initial tightening of large leaks the house still has significant, but not obvious, air leakage, performing ZPD can help identify whether leaks are in the attic floor, the house walls, or through the basement or crawlspace walls.
2. Indoor Air Quality concerns. Examples include air movement from attached or tuck-under garages into a living area and moisture or soil gas movement from a crawlspace into the dwelling.
3. Attic with potential or actual moisture-related problems. This might be the case if:
   a. The attic has obvious moisture problems,
   b. The dwelling has evidence of high winter relative humidity or significant sources of uncontrollable moisture are evident, or
   c. Ice dams are a concern.

Secondary zones are zones to which you have no access, such as porch roofs. This lack of access prevents you from creating a temporary hole between the zone and the dwelling or the zone and the outdoors. Because of this, you cannot determine the flow between secondary zone and the dwelling or outdoors. If you are able to insert a pressure hose into the zone, you can measure the pressure difference between the zone and the dwelling or outdoors.

111020 Test Procedures

1. Use the ZipTest Pro™ software package loaded in the TI-86 calculator for these tests unless instructed otherwise.
2. Perform the whole house blower door test before doing any zone pressure diagnostics (ZPD) testing.
   a. If you cannot reach a house pressure difference of 50 Pascals and/or there are obvious large leaks, repair large leaks before any ZPD testing. You must be able to reach a house pressure difference of 50 Pascals in order to do ZPD testing, both before and after you create a temporary hole for the add-a-hole test.

b. If the whole house CFM_{50} is less than the Building Tightness Limit CFM_{50} and the attic is well vented, do not perform any ZPD testing.[5]

3. Identify zone types. ZPD can be done on all primary zones including attics, crawlspaces, basements, and attached or tuck-under garages. ZPD can also be done on some secondary zones such as porch roofs and cantilevers where sealing off from the house is anticipated.
4. For primary zone ZPD testing, perform the add-a-hole test using the ZipTest Pro™ software loaded into the TI-86 calculator. Follow these steps:
   a. Set up the blower door for building depressurization.
   b. With the digital manometer, run a pressure hose from the lower tap on channel A to the zone you are testing (try to use a blue hose). Run another pressure hose from the lower tap on channel B to the outdoors (try to use a green hose).
   c. Depressurize the building to –50 Pascals, using the digital manometer set on channel B.
   d. Adjust the top 60 Pascal gauge on the magnehelic gauge set to 50 Pascals so that it corresponds with the pressure reading on the digital manometer. By doing this, you are ensuring that one gauge will agree with the other during the testing.
   e. On the digital manometer, switch to channel A.
   f. Measure, record and enter the pressure from the building to the zone (BLD/ZONE ΔP1);[6]
   g. On the digital manometer, move the pressure hose (green) from the lower tap on channel B to the upper tap on channel A. Make sure the channel switch is set to channel A.
   h. Measure, record and enter the pressure from the zone to the outdoors (ZONE/OUT ΔP1);
   i. Determine where a temporary hole will be created, either between the building and the zone (B/Z) or between the zone and the outdoors (Z/O).
   j. Enter the location of the created hole in the ZipTest Pro™ software, either in the building-to-zone air barrier (B/Z) or in the zone-to-outdoor barrier (Z/O);

[5] On the other hand, if the attic is not vented to the outdoors, the roof might be serving as the primary air barrier. In this case, when the attic is vented, the whole house CFM_{50} might increase to a value significantly greater than the Building Tightness Limit CFM_{50}. Therefore, in situations like this, ZPD testing should be done in the attic.

[6] The terms inside the parenthesis in this section are actual names used in the ZipTest Pro™ software program.

k. Measure, record and enter the size of the added temporary hole, in square inches. It is best to lower the barrier ΔP1 in which the hole is added by 15 or more Pascals.

l. Make certain that the house to outdoor pressure is brought back up to 50 Pascals when the temporary hole is open.

m. On the digital manometer, move the pressure hose (green) from the top tap on channel A to the bottom tap on channel B.

n. With the temporary hole open and the building to outdoor pressure difference at 50 Pascals, measure, record and enter the pressure from the building to the zone (BLD/ZONE ΔP2);

o. On the digital manometer, move the pressure hose (green) from the lower tap on channel B to the upper tap on channel A. Make sure the gauge channel switch is set to channel A.

p. With the temporary hole open and the building to outdoor pressure difference at 50 Pascals, measure, record and enter the pressure from the zone to the outdoors (ZONE/OUT ΔP2);

q. With all the input data entered in the calculator, press enter for the calculation of the answers.

r. Record the three answers, the building-to-zone (BLD/ZONE) CFM_{50}, the zone-to-outdoor (ZONE/OUT) CFM_{50}, and the total path (TOTAL PATH) CFM_{50}. Dividing the first two numbers by ten gives an approximation of the square inches of leakage in the respective air barriers.

s. Based on the ZPD results, air seal as necessary.

t. During or after air sealing, perform add-a-hole ZPD to determine the effectiveness of the weatherization work.

5. For secondary zone testing:

a. It is not necessary – or possible – to perform an add-a-hole test; only pressure testing is required. Therefore, use of the ZipTest Pro™ software is not necessary.

b. If the house/zone pressure is equal to or greater than 35 Pascals, it is not necessary to also take a pressure reading during or after air sealing work.

c. If the house/zone pressure is less than 35 Pascals, continue to track progress by pressure testing during and then after air sealing work.

111100 Gas Range Testing

111110 Introduction

1. The purpose of this protocol is to guide the field analyst through a systematic procedure of gas range testing. This protocol is intended to

determine whether a gas range oven bake burner is emitting unacceptable levels of carbon monoxide.

2. The burner limit for this protocol for carbon monoxide emissions is ppm CO air-free[7] for oven bake burners. Oven broil burners are not required to be tested.
3. This method covers residential grade floor-mounted gas ranges, drop-in range top burners, and built-in ovens only. If drop-in range top burners or built-in ovens are encountered, follow the appropriate sections of this protocol for these appliances. This protocol is not intended for use with 1) outdoor gas grilles, 2) ovens in catalytic cleaning mode, or 3) ovens vented into flues or chimneys.
4. This protocol is not intended to determine whether gas ranges operate acceptably during misuse, such as using a range for space heating.
5. Accurately measuring CO emissions in the field is difficult due to the complex nature of combustion and dilution airflow patterns. Use of this protocol can increase the accuracy of measurements to, perhaps, +30 percent. This means that the protocol will sometimes result in false failures and false passes.
6. Because there is a broad variety of gas ranges in the field, there is the possibility that range characteristics not addressed in this protocol will be encountered. When problems are discovered that are beyond the scope of this protocol, it is important that the field analyst use his or her good judgment when deciding whether to pass or fail a burner or range.

111120 Inspection and Client Education

111121 A. Gas Range Inspection

1. Range top inspection:
    a. Inspect the range top burner area for cleanliness. If the burners or burner area are dirty enough to adversely impact the combustion process, inform the client that the range should be cleaned to reduce the possibility of unacceptable emissions.
    b. Inspect the burners for proper alignment and seating.
    c. All cooking vessel support grates should 1) be in place, 2) fit properly in the burner well, and 3) be in one piece with no broken parts.
    d. 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

[7] CO air-free is a CO as-measured reading that has been adjusted (normalized) with corresponding O_2 percentage readings from the same combustion gas sample. CO air-free is usually expressed as a parts-per-million (ppm) value, but it is actually an emission rate, not a percentage.

e. 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).

f. Ignite each burner for at least 30 seconds to inspect its flame for color and noise.

   i. 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.

   ii. You should be able to hear the gas/flame flow in a quiet kitchen. The sound should not be load or irregular.

2. Oven area inspection:

   a. Inspect the oven for cleanliness. If the burners or oven area are dirty enough to adversely impact the combustion process, inform the client that the range should be cleaned to reduce the possibility of unacceptable emissions. Do not test for CO emissions until the problem is corrected.

   b. 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.

   c. 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 by the owner.

   d. 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.

   e. If the range also has a broil burner at the top of the oven compartment, check its flame for proper size and color.

f. Inspect the oven compartment and under the oven compartment for any other defects that could lead to unacceptable CO emissions.

g. 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.

3. Inspect gas range installation for code compliance. Refer to the latest edition of the National Fuel Gas Code (NFPA 54), section 6.15: Household Cooking Appliances.

4. Verify that the range is set up for the supply gas. When a gas range is setup for natural gas but has propane piped to it, dangerous over-firing of the burners results. Although this is not a common occurrence, each range should be checked. Natural gas piped to a range setup for propane is not as hazardous because it results in under-firing.

    a. If a range is setup for natural gas but has propane piped to it, it will be over-firing, probably creating unacceptable levels of CO. A gas range in this condition must not be used until the problem is corrected. Symptoms of this problem include noisy flames, yellow flames, large flames rising above the cooking vessel support grates on the range top burners, carbon (smoke) emissions, or unacceptable carbon monoxide emissions.

    b. If a range is setup for propane but has natural gas piped to it, it will be under-firing. In this case, the client might complain of the long period required to boil water or the amount of time required for baking. This condition is usually not hazardous, but it should be corrected.

    c. Methods for verifying supply gas type and range setup:

        i. Client interview:

            1. Ask client about the history of the gas range. Is it new? Is it a recently acquired used range? If so, do they know where it was obtained? The client's answers might indicate the gas for which the range was setup at its last location.
            2. Ask client if they have noticed any flame irregularities. Flames too big, yellow, or noisy? Flames very small, cooking or baking taking too long?

        ii. Flame inspection:

            1. Range top burner flames should appear normal on the high setting, in size, color, and sound. If the flames appear over-fired or under-fired, it is likely that there is a setup/gas supply mismatch.

        iii. Determine gas type piped to gas range:

1. Ask client. Verify by checking for natural gas meter or propane tank and corresponding piping to the appliance.

d. If it is determined that the range setup gas does not match the supply gas, the client must not use the range until the mismatch is corrected.

5. Check for flexible 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 1) not brass, 2) is not a two-piece connector, and 3) 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.
6. 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.
7. If the gas range fails any of these items above or if the field analyst believes, for any reason beyond the scope of this protocol, that the range burners or the oven bake burner are emitting unacceptable levels of carbon monoxide, inform client of the dangers and suggest that they have the range repaired or replaced.

111122 Client Education

Educating the client is a very important. Always take the time to explain the following to the client:

1. The holes in the oven bottom must never be blocked with aluminum foil or anything else. Blockage of the vent holes can also occur from storing too much in the broiler or drawer area under the bake oven. Blockage of the oven bottom vent holes can result in unacceptable carbon monoxide emissions.
2. Do not use the range top burners or the oven burner(s) as a space heater. Use of a gas range for space heating is against the manufacturer's recommendations; gas ranges are not designed for such use.
3. Client should consider installing a CO alarm in the house according to the alarm manufacture's instructions.
4. Have the range checked and tuned once every two years by a technician with an instrument capable of measuring carbon monoxide. This checkup and tuning should include:
    a. Testing of range gas pressure.

b. 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.

5. The oven should be kept clean at all times. There is evidence that dirty ovens emit more CO than clean ovens.
6. 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.

111130 Measurement of Emissions

111131 Safety During the Test Period

1. While performing the emissions testing, monitor CO concentrations in the kitchen. Shut down the burner(s), discontinue testing, and open windows and/or doors if indoor air concentrations rise above 35 ppm.

111132 Oven Bake Burner Testing

1. Read and fully understand all instrument manufacture's instructions before using the instrument.
2. Test the oven bake burner only.[8] If the oven has a separate broil burner, do not test it.
    a. The natural flow of combustion gases upward from the oven and out of the oven vent must not be disrupted during the emissions testing process.
    b. Clear the oven of all pots, pans, or other objects.
    c. Clear area below oven of all objects.
    d. Leave oven shelves in place.
    e. If the vent holes on the oven bottom are blocked with foil, catch pans, or anything else, ask the client to remove the blockage.
    f. Ignite the burner, with the temperature setting at 350°F. The oven burner may not ignite immediately; this is normal for some electronic ignition systems. Bake burners with standing pilots usually ignite faster.
    g. Start timing device.
    h. Insert the probe of the emission measurement instrument into the oven vent sleeve at the back of the range top. Make sure the open

[8] Broil burners are not to be tested because 1) they are not used as often as bake burners; 2) when they are used, they are not on as long as bake burners; and 3) not all ovens have separate broil burners.

end of the instrument probe is fully inserted into the oven vent opening at its center. Do not allow dilution air to mix with the sampled combustion by-products. Ensure that grease or other buildup does not inadvertently block the probe tip.

i. After beginning the oven test, do not open the oven door. If the oven door is opened after the testing period begins, wait at least five minutes or to the end of the fifteen-minute warm up time, whichever is longer, before taking emissions readings.

j. It is not necessary to turn on the emissions measurement instrument at the beginning of the warm up; it may be turned on at a later time, but must be ready to take readings after fifteen minutes of oven warm up time.

k. Zero the instrument (Bacharach Fyrite Pro) according to the manufacturer's recommendations and prepare it for the test.

l. After fifteen minutes of burner warm-up, watch the emission measurement instrument for the minimum and then maximum CO ppm values. The corresponding CO air-free must be calculated and averaged for these minimum and maximum CO ppm readings. The step-by-step details:

    i. After fifteen minutes of warm up, watch for the minimum CO ppm value (not the minimum CO air-free value).

    ii. Record this minimum CO ppm value and the corresponding O_2 percentage (if your instrument automatically calculates CO air-free, record this value at the minimum CO ppm value).

    iii. Continue to watch the instrument until you detect the next maximum CO ppm value.

    iv. Record this maximum value and the corresponding O_2 percentage (if your instrument automatically calculates CO air-free, record this value at the maximum CO ppm value).

    v. Use the printing function on the emissions analyzer, if available.

m. Calculate the CO air-free emission rates for the minimum and maximum CO ppm readings from the following equation. Some emissions measurement instruments calculate CO air-free automatically.[9] If this is the case, this equation need not be used.[10]

[9] Instruments that calculate $CO_{air\text{-}free}$ automatically do so with an integral computer chip. The instrument reads CO and O_2 and then calculates $CO_{air\text{-}free}$ with the use of Equation 1, above. These instruments will not calculate $CO_{air\text{-}free}$ automatically if the O_2 percentage is high, for example, Bacharach equipment will not calculate $CO_{air\text{-}free}$ if the O_2 percentage is above 16; Testo equipment will not calculate $CO_{air\text{-}free}$ if the O_2 percentage is above 20.

i. For natural gas and propane:

$$CO_{air-free} = \left(\frac{20.9}{20.9 - O_2} \right) x\ CO_{ppm}$$

Where:
$CO_{air\text{-}free}$ = carbon monoxide, air-free
CO_{ppm} = as-measured carbon monoxide, ppm
O_2 = oxygen in combustion gas, percentage

n. Average the CO air-free emission rates for the minimum and maximum CO ppm readings.

o. Averaged CO air-free must be 800 ppm or less, averaged from the CO air-free values corresponding to the CO ppm minimum and maximum occurring after fifteen minutes of warm-up, with oven set to 350°F.

p. Determine whether the burner passes or fails the limit.

   i. If a failed burner can be adjusted in a way that reduces the CO emissions to below those set by the levels of this standard, then the range passes the protocol after the field analyst retests the range to ensure that the burner(s) now passes limits of the protocol.

   ii. If the failed burner(s) cannot be tuned or replaced to pass the protocol levels or the gas range construction does not allow for adjustment or parts replacement, the gas range should be replaced.

      1. If the field analyst believes, for reasons beyond the scope of this protocol, that a range burner(s) or the oven bake burner are emitting unacceptable levels of carbon monoxide, inform client of the dangers and suggest that they have the range repaired or replaced.

[10] The following equations may be used for natural gas and propane if the analyst has collected carbon monoxide and carbon dioxide readings.

For natural gas: $CO_{air-free} = \left(\frac{12.2}{CO_2} \right) x\ CO_{ppm}$

For propane: $CO_{air-free} = \left(\frac{14}{CO_2} \right) x\ CO_{ppm}$

Where CO_2 = carbon dioxide in combustion gas, percentage.

111200 Electricity Efficiency Measures

111210 Refrigerator Replacement and Testing

111211 Introduction

1. Refrigerators will be judged by their estimated annual kWhr usage. The kWhr usage will be estimated by:
    a. KWh/yr usage data from the AHAM[11] data base, based on brand and model,
    b. KWh/yr usage estimate based on refrigerator age or characteristics.
    c. KWh/yr estimates from actual metering of the refrigerator with the Brultech ECM-1200 device.
2. The basis for replacing a refrigerator or not is its Savings-to-Investment Ratio (SIR) value. If the SIR value for replacement for a refrigerator is 1.00 or greater, the refrigerator should be replaced. Calculation of the SIR is done with the AREFR Equation Nugget in the "Solver" section of the TI-86 calculator. In order to perform this calculation, the following values are needed:
    a. KWh/yr for existing refrigerator (kWhyrOld).[12] This is estimated from 1.a., 1.b., or 1.c, above.
    b. Annual Average Ambient Temperature (AAAT). This is your estimate of the annual average air temperature surrounding the refrigerator. This only needs to be estimated if the refrigerator is being metered with the Brultech ECM-1200.
    c. Present Ambient Temperature (PAT). This is the measured temperature around the refrigerator during the metering process. Again, this only needs to be estimated if the refrigerator is being metered with the Brultech ECM-1200.
    d. KWh/yr consumption of the replacement (new) refrigerator (kWhyrNew).
    e. The electricity cost per KWh (CostkWh), in units of dollars. For example, 6 cents would be entered as ".06".
    f. The cost of the replacement refrigerator (CostNew). This amount must include refrigerator cost, any delivery charge, installation costs, and disposal of the old unit.

[11] American Home Appliance Manufacturers.
[12] The terms in parenthesis in this section are the variable names in the AREFR Equation Nugget that is part of the ZipTest Pro software package loaded into the TI-86 calculator.

111212 Testing Procedure

1. Estimate the kWh/yr for the existing refrigerator. Use one of the three methods below for this estimation.
   a. KWh/yr usage data from the AHAM data base.
      i. Identify the make and model number of the refrigerator. Find the brand, model and annual electrical consumption in a reliable AHAM listing of refrigerators. If appropriate, multiply the annual kWh/yr consumption estimate listed by the degradation multiplier listed in Table 11-9.

Table 11-9

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

   b. KWh/yr usage estimate based on refrigerator age or characteristics.
      i. Some refrigerators will not be considered for replacement. They will not require AHAM data estimates, metering, or calculation of the replacement SIR. These include:
         1. Refrigerators that where manufactured after 1993. However, if you have good reason to believe the unit is not operating as it should, metering is a good idea.
      ii. Some refrigerators will be replaced without metering. If the kWh/yr estimates can be found in the AHAM data, use these values for (adjusted for age efficiency degradation with above table) for the calculation of the replacement SIR. If these refrigerators cannot be found in the AHAM data, do not meter them; use the estimated kWh/yr consumption listed in parenthesis after each type below for the calculation of the replacement SIR. The refrigerators that fall into this category are:
         2. Units manufactured before 1973 (1,700 kWh/yr).
         3. Units manufactured from 1973 to 1980, including pre-1980 side-by-side harvest gold or avocado green with auto-defrost (1300 kWh/yr).
         4. Units manufactured from 1981 to 1984 (1050 kWh/yr).
         5. Units manufactured from 1985 to 1988 (1000 kWh/yr).
         6. Units manufactured from 1989 to 1990 (900 kWh/yr).
         7. Units that run continuously (2000 kWh/yr).
   c. KWh/yr estimates from actual metering of the refrigerator with the Brultech ECM-1200 device.
      i. Plan the energy analysis, entry interview, and overall visit to facilitate connecting metering equipment promptly. **Leave**

the Brultech ECM-1200 meter in place for at least two hours. The longer the metering time, the more accurate the projected annual kWh estimate will be.

ii. Open the refrigerator/freezer door(s) in order to:

1. Place the indoor/outdoor recording thermometer near the back wall of the freezer compartment (make sure it is not in contact with any frozen food) and place the main body of your thermometer on a counter near the refrigerator or freezer. Make sure that you reset the thermometer before placing the remote bulb. After three to five minutes, record the remote bulb temperature of the freezer and the ambient temperature of the main thermometer. Now reset the thermometer again. The remote bulb in the freezer during your metering will indicate whether the refrigerator is in defrost mode when you begin your metering or whether it enters defrost mode during metering. Recording the temperature near the refrigerator in the kitchen with the main thermometer will help you determine the PAT (see below).
2. Determine and record the control setting in the fresh-food compartment of refrigerators,
3. Determine and record the control setting in the freezer compartment,
4. Determine if the unit has an anti-sweat feature; if so, turn it off for your metering, and
5. Make sure the contents in the unit are secure so that if you must move the unit, you will not upset any of the contents.

iii. If it is necessary to move the refrigerator/freezer to attach your meter or to check or clean the coils, be careful of the floor material. Carry a sturdy rug with you to help slide the unit in and out without damage to the floor (a piece of 2 x 4 four feet long will often be useful as a lever for lifting and moving). If the unit cannot be moved or moving it would potentially cause damage to the floor, document the reason why no measurement was taken and move on to other audit procedures.

iv. Listen for the refrigerator/freezer compressor before you unplug the electrical cord to attach your meter (a typical refrigerator compressor runs 25 – 50% of the time). If you must unplug it during compressor operation to connect your meter, wait about five minutes before plugging it back in to avoid experiencing compressor safety switch failure (or, go

ahead and “test” the restart protection, assuming that if the switch is ready to fail, the unit is a candidate for replacement).

v. Complete the installation of the Brultech ECM-1200. Follow the separate instructions for the use of the Brultech ECM-1200 meter.

vi. Make sure to reset the ECM-1200 before you start reading the electrical consumption.

vii. Check the initial Watt reading on your meter just after you connect it. Here are some Watt consumption ranges that will give you a hint of where the refrigerator is in its cooling/defrost cycle:

6. 10 – 40 Watts if door is open (light bulb) and/or anti-sweat heaters are on.
7. 250 – 400 Watts (steady-state) if compressor is running.
8. 400 – 1000 Watts if defrost cycle is operating. There is the possibility that you will meter during defrost time of an automatic defrost unit. Defrosters typically draw 400 Watts or more and can dramatically increase the temperature in the freezer during operation. These defrost times typically occur at the end of 16 – 40 hours of compressor run-time and last for 10 – 14 minutes. During the defrost time, freezer temperatures can be well above freezing for more than 30 minutes. If you find that you have encountered defrost-run time during your metering, reset the meter to eliminate the defrost-time effect. It is estimated that defrost-run time increases the annual consumption by 8 – 10 percent.

viii. Record the temperature around the outside of the unit, the present ambient temperature (PAT). If the unit is in a nook or air flow is obstructed around it, try to get a reading on all sides.

ix. Survey the area for sources of heat that are likely to influence refrigerator/freezer energy use during the year. Influencing items include adjacent ranges, wood stoves, solar gain from adjacent windows, and heat distribution terminal devices. Ask the occupants about the room temperature during the year. The purpose of this quick survey is to guide your client education comments and to

help you determine the average annual ambient temperature (AAAT).[13]

x. For the use of the Brultech EMC-1200 meter, follow these guidelines:

9. Brultech ECM-1200 settings. To determine the kWh per year with the Brultech ECM-1200, set the electric rate to $0.12 for manual defrost or to $0.13 for automatic defrost (page 24 in ECM-1200 manual) and set the projection period to 30 days (page 25 in ECM-1200 manual, Rate). [14]
10. Reading the projected kWh/yr. With these settings, when you read the cost of projected energy (page 33 in ECM-1200 manual, Cost of Projection of Energy), just read the number without the decimal point—this is the projected kWh/yr consumption. For example, read $13.86 as 1,386 kWh/yr of projected energy use.

xi. After you have completed your metering, remove you meter and all attachments. Plug the refrigerator back into the original outlet. If necessary, move the refrigerator/freezer back to its original location.

xii. Use the AREFR equation in the ZipTest Pro™ software package loaded in the TI-86 calculator. Enter the required input values to get the resulting Savings-to-Investment Ratio (SIR). If the SIR is one or greater, replace the refrigerator. If the SIR is less than one, do not replace.

111213 Replacement Guidelines

1. Fill out the work order and have the customer sign it. The work order includes customer information, space measurements, specifications for removing the existing unit, and instructions for installing the new refrigerator.
2. The size of the replacement refrigerator should be determined by the estimator. Talk with the client(s) regarding the need for a smaller or larger size. Their needs might have changed over time because of additional children or children leaving home. Try to specify a replacement of the same or a smaller size.
3. In most cases, replacing a side-by-side unit with another side-by-side unit shall 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:

[13] Each one degree difference between AAAT and PAT contributes to approximately a 2.5 percent difference in energy consumption during your metering period.
[14] Studies have shown that the automatic defrost cycle increases annual steady-state kWh by 8 - 10 percent. Increasing the electric rate from $0.12 to $0.13 is an increase of 8.3 percent.

a. A member of the household is confined to a wheelchair,
b. A member of the household has a handicap that makes it difficult to use a top-freezer model, or
c. Space limitations dictate the use of a side-by-side (less door-swing space required).

4. All replacement refrigerators shall be white in color.
5. 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.
6. Engage in client education, whether or not refrigerator(s) and/or freezer(s) are being replaced.
7. Control settings in new refrigerators should be set to "2" by the vendor, or according to the manufacturer's recommendation. The client should be advised during client education that the settings of new refrigerators should be kept at 2, or at the manufacturer's recommended setting.
8. Any refrigerator supplier must properly dispose of existing appliance(s) and provide documentation of delivery and of proper disposal to the subgrantee.

111220 Compact Fluorescent Bulb Replacement

111221 Introduction

Many new compact fluorescent light bulbs (CFLs) meet the stringent criteria of ENERGY STAR for long life, start time, energy savings, color, and brightness. These new CFLs provide high quality, warm light without the flickering or humming of older fluorescent bulbs.

Advanced technology enables CFLs to use 75 percent less energy than a standard incandescent bulb and last up to 10 times longer. This means that over the life of one CFL, a client can avoid replacing up to 13 incandescent bulbs.

Table 11-10

CFL/Incandescent Equivalency Chart	
CFL (Watts)	***Incandescent (Watts)***
14	40
20	60
25	75
32	100
50	150

ENERGY STAR CFLs emit the same amount of light as standard bulbs, but have lower Wattage ratings because they use less energy. Use this equivalency chart when replacing standard incandescent bulbs. Notice that in Table 11-10 the Wattage of an efficient CFL is about 1/3 that of a typical incandescent, for a given level of light output.

111222 Replacement Procedure

1. Collect the following information:

a. Cost of electricity in dollars and cents per kWh
b. Hours of use for each existing lamp
c. Proposed wattage of each new lamp
d. Cost of each new lamp

2. Select the appropriate table for the wattage of the old lamp. For those lamps with wattage between the listed wattages, select the table of the next lowest usage.
    a. Select the wattage that matches the proposed replacement (CFL Watts). For those readings that fall between the listed wattages, select the next highest reading from the table.
    b. Select the row corresponding to the daily usage (Hours on per day) for the lamp.
    c. Follow that row across to the column closest to the electric rate (energy cost in cents per kWh) of the utility serving the house.
    d. The dollars listed in the table represent the threshold cost of a replacement unit with a savings-to-investment ratio (SIR) of 1. All replacements that cost less than the cost listed in the table have an SIR greater than 1 and may be replaced. All replacements that cost more than the cost listed in the table have an SIR less than 1 and may not be replaced.
3. Leave all replaced incandescent bulbs with the client and explain that they should only be used in fixtures or lamps that are used for short periods each day.

50/15

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 50 Watt Incandescent

CFL Watts 15

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$2.30	$3.45	$4.60	$5.75	$6.90	$8.05
$0.025	$2.88	$4.31	$5.75	$7.19	$8.63	$10.07
$0.030	$3.45	$5.18	$6.90	$8.63	$10.35	$12.08
$0.035	$4.03	$6.04	$8.05	$10.07	$12.08	$14.09
$0.040	$4.60	$6.90	$9.20	$11.50	$13.81	$16.11
$0.045	$5.18	$7.77	$10.35	$12.94	$15.53	$18.12
$0.050	$5.75	$8.63	$11.50	$14.38	$17.26	$20.13
$0.055	$6.33	$9.49	$12.66	$15.82	$18.98	$22.15
$0.060	$6.90	$10.35	$13.81	$17.26	$20.71	$24.16
$0.065	$7.48	$11.22	$14.96	$18.70	$22.43	$26.17
$0.070	$8.05	$12.08	$16.11	$20.13	$24.16	$28.19
$0.075	$8.63	$12.94	$17.26	$21.57	$25.89	$30.20
$0.080	$9.20	$13.81	$18.41	$23.01	$27.61	$32.21
$0.085	$9.78	$14.67	$19.56	$24.45	$29.34	$34.23
$0.090	$10.35	$15.53	$20.71	$25.89	$31.06	$36.24
$0.095	$10.93	$16.39	$21.86	$27.32	$32.79	$38.25
$0.100	$11.50	$17.26	$23.01	$28.76	$34.51	$40.27
$0.105	$12.08	$18.12	$24.16	$30.20	$36.24	$42.28
$0.110	$12.66	$18.98	$25.31	$31.64	$37.97	$44.29
$0.115	$13.23	$19.85	$26.46	$33.08	$39.69	$46.31
$0.120	$13.81	$20.71	$27.61	$34.51	$41.42	$48.32
$0.125	$14.38	$21.57	$28.76	$35.95	$43.14	$50.33
$0.130	$14.96	$22.43	$29.91	$37.39	$44.87	$52.35
$0.135	$15.53	$23.30	$31.06	$38.83	$46.59	$54.36
$0.140	$16.11	$24.16	$32.21	$40.27	$48.32	$56.37

50/18

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 50 Watt Incandescent

CFL Watts 18

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$2.10	$3.16	$4.21	$5.26	$6.31	$7.36
$0.025	$2.63	$3.94	$5.26	$6.57	$7.89	$9.20
$0.030	$3.16	$4.73	$6.31	$7.89	$9.47	$11.04
$0.035	$3.68	$5.52	$7.36	$9.20	$11.04	$12.89
$0.040	$4.21	$6.31	$8.41	$10.52	$12.62	$14.73
$0.045	$4.73	$7.10	$9.47	$11.83	$14.20	$16.57
$0.050	$5.26	$7.89	$10.52	$13.15	$15.78	$18.41
$0.055	$5.79	$8.68	$11.57	$14.46	$17.36	$20.25
$0.060	$6.31	$9.47	$12.62	$15.78	$18.93	$22.09
$0.065	$6.84	$10.26	$13.67	$17.09	$20.51	$23.93
$0.070	$7.36	$11.04	$14.73	$18.41	$22.09	$25.77
$0.075	$7.89	$11.83	$15.78	$19.72	$23.67	$27.61
$0.080	$8.41	$12.62	$16.83	$21.04	$25.24	$29.45
$0.085	$8.94	$13.41	$17.88	$22.35	$26.82	$31.29
$0.090	$9.47	$14.20	$18.93	$23.67	$28.40	$33.13
$0.095	$9.99	$14.99	$19.99	$24.98	$29.98	$34.97
$0.100	$10.52	$15.78	$21.04	$26.30	$31.56	$36.81
$0.105	$11.04	$16.57	$22.09	$27.61	$33.13	$38.66
$0.110	$11.57	$17.36	$23.14	$28.93	$34.71	$40.50
$0.115	$12.10	$18.14	$24.19	$30.24	$36.29	$42.34
$0.120	$12.62	$18.93	$25.24	$31.56	$37.87	$44.18
$0.125	$13.15	$19.72	$26.30	$32.87	$39.44	$46.02
$0.130	$13.67	$20.51	$27.35	$34.19	$41.02	$47.86
$0.135	$14.20	$21.30	$28.40	$35.50	$42.60	$49.70
$0.140	$14.73	$22.09	$29.45	$36.81	$44.18	$51.54

50/20

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 50 Watt Incandescent

CFL Watts 20

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$1.97	$2.96	$3.94	$4.93	$5.92	$6.90
$0.025	$2.47	$3.70	$4.93	$6.16	$7.40	$8.63
$0.030	$2.96	$4.44	$5.92	$7.40	$8.88	$10.35
$0.035	$3.45	$5.18	$6.90	$8.63	$10.35	$12.08
$0.040	$3.94	$5.92	$7.89	$9.86	$11.83	$13.81
$0.045	$4.44	$6.66	$8.88	$11.09	$13.31	$15.53
$0.050	$4.93	$7.40	$9.86	$12.33	$14.79	$17.26
$0.055	$5.42	$8.14	$10.85	$13.56	$16.27	$18.98
$0.060	$5.92	$8.88	$11.83	$14.79	$17.75	$20.71
$0.065	$6.41	$9.61	$12.82	$16.02	$19.23	$22.43
$0.070	$6.90	$10.35	$13.81	$17.26	$20.71	$24.16
$0.075	$7.40	$11.09	$14.79	$18.49	$22.19	$25.89
$0.080	$7.89	$11.83	$15.78	$19.72	$23.67	$27.61
$0.085	$8.38	$12.57	$16.76	$20.95	$25.15	$29.34
$0.090	$8.88	$13.31	$17.75	$22.19	$26.63	$31.06
$0.095	$9.37	$14.05	$18.74	$23.42	$28.10	$32.79
$0.100	$9.86	$14.79	$19.72	$24.65	$29.58	$34.51
$0.105	$10.35	$15.53	$20.71	$25.89	$31.06	$36.24
$0.110	$10.85	$16.27	$21.69	$27.12	$32.54	$37.97
$0.115	$11.34	$17.01	$22.68	$28.35	$34.02	$39.69
$0.120	$11.83	$17.75	$23.67	$29.58	$35.50	$41.42
$0.125	$12.33	$18.49	$24.65	$30.82	$36.98	$43.14
$0.130	$12.82	$19.23	$25.64	$32.05	$38.46	$44.87
$0.135	$13.31	$19.97	$26.63	$33.28	$39.94	$46.59
$0.140	$13.81	$20.71	$27.61	$34.51	$41.42	$48.32

50/23

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 50 Watt Incandescent

CFL Watts 23

Fuel Cost per KWh

Hours On Per Day ----------►	**2**	**3**	**4**	**5**	**6**	**7**
$0.020	$1.78	$2.66	$3.55	$4.44	$5.33	$6.21
$0.025	$2.22	$3.33	$4.44	$5.55	$6.66	$7.77
$0.030	$2.66	$3.99	$5.33	$6.66	$7.99	$9.32
$0.035	$3.11	$4.66	$6.21	$7.77	$9.32	$10.87
$0.040	$3.55	$5.33	$7.10	$8.88	$10.65	$12.43
$0.045	$3.99	$5.99	$7.99	$9.98	$11.98	$13.98
$0.050	$4.44	$6.66	$8.88	$11.09	$13.31	$15.53
$0.055	$4.88	$7.32	$9.76	$12.20	$14.64	$17.08
$0.060	$5.33	$7.99	$10.65	$13.31	$15.98	$18.64
$0.065	$5.77	$8.***65***	$11.54	$14.42	$17.31	$20.19
$0.070	$6.21	$9.32	$12.43	$15.53	$18.64	$21.74
$0.075	$6.66	$9.98	$13.31	$16.64	$19.97	$23.30
$0.080	$7.10	$10.65	$14.20	$17.75	$21.30	$24.85
$0.085	$7.54	$11.32	$15.09	$18.86	$22.63	$26.40
$0.090	$7.99	$11.98	$15.98	$19.97	$23.96	$27.96
$0.095	$8.43	$12.65	$16.86	$21.08	$25.29	$29.51
$0.100	$8.88	$13.31	$17.75	$22.19	$26.63	$31.06
$0.105	$9.32	$13.98	$18.64	$23.30	$27.96	$32.62
$0.110	$9.76	$14.64	$19.53	$24.41	$29.29	$34.17
$0.115	$10.21	$15.31	$20.41	$25.52	$30.62	$35.72
$0.120	$10.65	$15.98	$21.30	$26.63	$31.95	$37.28
$0.125	$11.09	$16.64	$22.19	$27.73	$33.28	$38.83
$0.130	$11.54	$17.31	$23.08	$28.84	$34.61	$40.38
$0.135	$11.98	$17.97	$23.96	$29.95	$35.94	$41.93
$0.140	$12.43	$18.64	$24.85	$31.06	$37.28	$43.49

50/27

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 50 Watt Incandescent

CFL Watts 27

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$1.51	$2.27	$3.02	$3.78	$4.54	$5.29
$0.025	$1.89	$2.84	$3.78	$4.73	$5.67	$6.62
$0.030	$2.27	$3.40	$4.54	$5.67	$6.80	$7.94
$0.035	$2.65	$3.97	$5.29	$6.62	$7.94	$9.26
$0.040	$3.02	$4.54	$6.05	$7.56	$9.07	$10.58
$0.045	$3.40	$5.10	$6.80	$8.51	$10.21	$11.91
$0.050	$3.78	$5.67	$7.56	$9.45	$11.34	$13.23
$0.055	$4.16	$6.24	$8.32	$10.40	$12.47	$14.55
$0.060	$4.54	$6.80	$9.07	$11.34	$13.61	$15.88
$0.065	$4.91	$7.37	$9.83	$12.29	$14.74	$17.20
$0.070	$5.29	$7.94	$10.58	$13.23	$15.88	$18.52
$0.075	$5.67	$8.51	$11.34	$14.18	$17.01	$19.85
$0.080	$6.05	$9.07	$12.10	$15.12	$18.14	$21.17
$0.085	$6.43	$9.64	$12.85	$16.07	$19.28	$22.49
$0.090	$6.80	$10.21	$13.61	$17.01	$20.41	$23.81
$0.095	$7.18	$10.77	$14.36	$17.96	$21.55	$25.14
$0.100	$7.56	$11.34	$15.12	$18.90	$22.68	$26.46
$0.105	$7.94	$11.91	$15.88	$19.85	$23.81	$27.78
$0.110	$8.32	$12.47	$16.63	$20.79	$24.95	$29.11
$0.115	$8.69	$13.04	$17.39	$21.74	$26.08	$30.43
$0.120	$9.07	$13.61	$18.14	$22.68	$27.22	$31.75
$0.125	$9.45	$14.18	$18.90	$23.63	$28.35	$33.08
$0.130	$9.83	$14.74	$19.66	$24.57	$29.48	$34.40
$0.135	$10.21	$15.31	$20.41	$25.52	$30.62	$35.72
$0.140	$10.58	$15.88	$21.17	$26.46	$31.75	$37.04

60/15

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 60 Watt Incandescent

CFL Watts 15

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$2.96	$4.44	$5.92	$7.40	$8.88	$10.35
$0.025	$3.70	$5.55	$7.40	$9.24	$11.09	$12.94
$0.030	$4.44	$6.66	$8.88	$11.09	$13.31	$15.53
$0.035	$5.18	$7.77	$10.35	$12.94	$15.53	$18.12
$0.040	$5.92	$8.88	$11.83	$14.79	$17.75	$20.71
$0.045	$6.66	$9.98	$13.31	$16.64	$19.97	$23.30
$0.050	$7.40	$11.09	$14.79	$18.49	$22.19	$25.89
$0.055	$8.14	$12.20	$16.27	$20.34	$24.41	$28.47
$0.060	$8.88	$13.31	$17.75	$22.19	$26.63	$31.06
$0.065	$9.61	$14.42	$19.23	$24.04	$28.84	$33.65
$0.070	$10.35	$15.53	$20.71	$25.89	$31.06	$36.24
$0.075	$11.09	$16.64	$22.19	$27.73	$33.28	$38.83
$0.080	$11.83	$17.75	$23.67	$29.58	$35.50	$41.42
$0.085	$12.57	$18.86	$25.15	$31.43	$37.72	$44.01
$0.090	$13.31	$19.97	$26.63	$33.28	$39.94	$46.59
$0.095	$14.05	$21.08	$28.10	$35.13	$42.16	$49.18
$0.100	$14.79	$22.19	$29.58	$36.98	$44.38	$51.77
$0.105	$15.53	$23.30	$31.06	$38.83	$46.59	$54.36
$0.110	$16.27	$24.41	$32.54	$40.68	$48.81	$56.95
$0.115	$17.01	$25.52	$34.02	$42.53	$51.03	$59.54
$0.120	$17.75	$26.63	$35.50	$44.38	$53.25	$62.13
$0.125	$18.49	$27.73	$36.98	$46.22	$55.47	$64.71
$0.130	$19.23	$28.84	$38.46	$48.07	$57.69	$67.30
$0.135	$19.97	$29.95	$39.94	$49.92	$59.91	$69.89
$0.140	$20.71	$31.06	$41.42	$51.77	$62.13	$72.48

60/18

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 60 Watt Incandescent

CFL Watts 18

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$2.76	$4.14	$5.52	$6.90	$8.28	$9.66
$0.025	$3.45	$5.18	$6.90	$8.63	$10.35	$12.08
$0.030	$4.14	$6.21	$8.28	$10.35	$12.43	$14.50
$0.035	$4.83	$7.25	$9.66	$12.08	$14.50	$16.91
$0.040	$5.52	$8.28	$11.04	$13.81	$16.57	$19.33
$0.045	$6.21	$9.32	$12.43	$15.53	$18.64	$21.74
$0.050	$6.90	$10.35	$13.81	$17.26	$20.71	$24.16
$0.055	$7.59	$11.39	$15.19	$18.98	$22.78	$26.58
$0.060	$8.28	$12.43	$16.57	$20.71	$24.85	$28.99
$0.065	$8.97	$13.46	$17.95	$22.43	$26.92	$31.41
$0.070	$9.66	$14.50	$19.33	$24.16	$28.99	$33.82
$0.075	$10.35	$15.53	$20.71	$25.89	$31.06	$36.24
$0.080	$11.04	$16.57	$22.09	$27.61	$33.13	$38.66
$0.085	$11.73	$17.60	$23.47	$29.34	$35.20	$41.07
$0.090	$12.43	$18.64	$24.85	$31.06	$37.28	$43.49
$0.095	$13.12	$19.67	$26.23	$32.79	$39.35	$45.90
$0.100	$13.81	$20.71	$27.61	$34.51	$41.42	$48.32
$0.105	$14.50	$21.74	$28.99	$36.24	$43.49	$50.74
$0.110	$15.19	$22.78	$30.37	$37.97	$45.56	$53.15
$0.115	$15.88	$23.81	$31.75	$39.69	$47.63	$55.57
$0.120	$16.57	$24.85	$33.13	$41.42	$49.70	$57.98
$0.125	$17.26	$25.89	$34.51	$43.14	$51.77	$60.40
$0.130	$17.95	$26.92	$35.89	$44.87	$53.84	$62.82
$0.135	$18.64	$27.96	$37.28	$46.59	$55.91	$65.23
$0.140	$19.33	$28.99	$38.66	$48.32	$57.98	$67.65

60/20

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 60 Watt Incandescent

CFL Watts 20

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$2.63	$3.94	$5.26	$6.57	$7.89	$9.20
$0.025	$3.29	$4.93	$6.57	$8.22	$9.86	$11.50
$0.030	$3.94	$5.92	$7.89	$9.86	$11.83	$13.81
$0.035	$4.60	$6.90	$9.20	$11.50	$13.81	$16.11
$0.040	$5.26	$7.89	$10.52	$13.15	$15.78	$18.41
$0.045	$5.92	$8.88	$11.83	$14.79	$17.75	$20.71
$0.050	$6.57	$9.86	$13.15	$16.44	$19.72	$23.01
$0.055	$7.23	$10.85	$14.46	$18.08	$21.69	$25.31
$0.060	$7.89	$11.83	$15.78	$19.72	$23.67	$27.61
$0.065	$8.55	$12.82	$17.09	$21.37	$25.64	$29.91
$0.070	$9.20	$13.81	$18.41	$23.01	$27.61	$32.21
$0.075	$9.86	$14.79	$19.72	$24.65	$29.58	$34.51
$0.080	$10.52	$15.78	$21.04	$26.30	$31.56	$36.81
$0.085	$11.18	$16.76	$22.35	$27.94	$33.53	$39.12
$0.090	$11.83	$17.75	$23.67	$29.58	$35.50	$41.42
$0.095	$12.49	$18.74	$24.98	$31.23	$37.47	$43.72
$0.100	$13.15	$19.72	$26.30	$32.87	$39.44	$46.02
$0.105	$13.81	$20.71	$27.61	$34.51	$41.42	$48.32
$0.110	$14.46	$21.69	$28.93	$36.16	$43.39	$50.62
$0.115	$15.12	$22.68	$30.24	$37.80	$45.36	$52.92
$0.120	$15.78	$23.67	$31.56	$39.44	$47.33	$55.22
$0.125	$16.44	$24.65	$32.87	$41.09	$49.31	$57.52
$0.130	$17.09	$25.64	$34.19	$42.73	$51.28	$59.82
$0.135	$17.75	$26.63	$35.50	$44.38	$53.25	$62.13
$0.140	$18.41	$27.61	$36.81	$46.02	$55.22	$64.43

60/23

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 60 Watt Incandescent

CFL Watts 23

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$2.43	$3.65	$4.86	$6.08	$7.30	$8.51
$0.025	$3.04	$4.56	$6.08	$7.60	$9.12	$10.64
$0.030	$3.65	$5.47	$7.30	$9.12	$10.95	$12.77
$0.035	$4.26	$6.39	$8.51	$10.64	$12.77	$14.90
$0.040	$4.86	$7.30	$9.73	$12.16	$14.59	$17.03
$0.045	$5.47	$8.21	$10.95	$13.68	$16.42	$19.16
$0.050	$6.08	$9.12	$12.16	$15.20	$18.24	$21.28
$0.055	$6.69	$10.03	$13.38	$16.72	$20.07	$23.41
$0.060	$7.30	$10.95	$14.59	$18.24	$21.89	$25.54
$0.065	$7.91	$11.86	$15.81	$19.76	$23.72	$27.67
$0.070	$8.51	$12.77	$17.03	$21.28	$25.54	$29.80
$0.075	$9.12	$13.68	$18.24	$22.80	$27.36	$31.93
$0.080	$9.73	$14.59	$19.46	$24.32	$29.19	$34.05
$0.085	$10.34	$15.51	$20.68	$25.84	$31.01	$36.18
$0.090	$10.95	$16.42	$21.89	$27.36	$32.84	$38.31
$0.095	$11.55	$17.33	$23.11	$28.88	$34.66	$40.44
$0.100	$12.16	$18.24	$24.32	$30.41	$36.49	$42.57
$0.105	$12.77	$19.16	$25.54	$31.93	$38.31	$44.70
$0.110	$13.38	$20.07	$26.76	$33.45	$40.13	$46.82
$0.115	$13.99	$20.98	$27.97	$34.97	$41.96	$48.95
$0.120	$14.59	$21.89	$29.19	$36.49	$43.78	$51.08
$0.125	$15.20	$22.80	$30.41	$38.01	$45.61	$53.21
$0.130	$15.81	$23.72	$31.62	$39.53	$47.43	$55.34
$0.135	$16.42	$24.63	$32.84	$41.05	$49.26	$57.47
$0.140	$17.03	$25.54	$34.05	$42.57	$51.08	$59.59

60/27

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 60 Watt Incandescent

CFL Watts 27

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$2.17	$3.25	$4.34	$5.42	$6.51	$7.59
$0.025	$2.71	$4.07	$5.42	$6.78	$8.14	$9.49
$0.030	$3.25	$4.88	$6.51	$8.14	$9.76	$11.39
$0.035	$3.80	$5.69	$7.59	$9.49	$11.39	$13.29
$0.040	$4.34	$6.51	$8.68	$10.85	$13.02	$15.19
$0.045	$4.88	$7.32	$9.76	$12.20	$14.64	$17.08
$0.050	$5.42	$8.14	$10.85	$13.56	$16.27	$18.98
$0.055	$5.97	$8.95	$11.93	$14.91	$17.90	$20.88
$0.060	$6.51	$9.76	$13.02	$16.27	$19.53	$22.78
$0.065	$7.05	$10.58	$14.10	$17.63	$21.15	$24.68
$0.070	$7.59	$11.39	$15.19	$18.98	$22.78	$26.58
$0.075	$8.14	$12.20	$16.27	$20.34	$24.41	$28.47
$0.080	$8.68	$13.02	$17.36	$21.69	$26.03	$30.37
$0.085	$9.22	$13.83	$18.44	$23.05	$27.66	$32.27
$0.090	$9.76	$14.64	$19.53	$24.41	$29.29	$34.17
$0.095	$10.30	$15.46	$20.61	$25.76	$30.91	$36.07
$0.100	$10.85	$16.27	$21.69	$27.12	$32.54	$37.97
$0.105	$11.39	$17.08	$22.78	$28.47	$34.17	$39.86
$0.110	$11.93	$17.90	$23.86	$29.83	$35.80	$41.76
$0.115	$12.47	$18.71	$24.95	$31.19	$37.42	$43.66
$0.120	$13.02	$19.53	$26.03	$32.54	$39.05	$45.56
$0.125	$13.56	$20.34	$27.12	$33.90	$40.68	$47.46
$0.130	$14.10	$21.15	$28.20	$35.25	$42.30	$49.35
$0.135	$14.64	$21.97	$29.29	$36.61	$43.93	$51.25
$0.140	$15.19	$22.78	$30.37	$37.97	$45.56	$53.15

75/15

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 75 Watt Incandescent

CFL Watts 15

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$3.94	$5.92	$7.89	$9.86	$11.83	$13.81
$0.025	$4.93	$7.40	$9.86	$12.33	$14.79	$17.26
$0.030	$5.92	$8.88	$11.83	$14.79	$17.75	$20.71
$0.035	$6.90	$10.35	$13.81	$17.26	$20.71	$24.16
$0.040	$7.89	$11.83	$15.78	$19.72	$23.67	$27.61
$0.045	$8.88	$13.31	$17.75	$22.19	$26.63	$31.06
$0.050	$9.86	$14.79	$19.72	$24.65	$29.58	$34.51
$0.055	$10.85	$16.27	$21.69	$27.12	$32.54	$37.97
$0.060	$11.83	$17.75	$23.67	$29.58	$35.50	$41.42
$0.065	$12.82	$19.23	$25.64	$32.05	$38.46	$44.87
$0.070	$13.81	$20.71	$27.61	$34.51	$41.42	$48.32
$0.075	$14.79	$22.19	$29.58	$36.98	$44.38	$51.77
$0.080	$15.78	$23.67	$31.56	$39.44	$47.33	$55.22
$0.085	$16.76	$25.15	$33.53	$41.91	$50.29	$58.67
$0.090	$17.75	$26.63	$35.50	$44.38	$53.25	$62.13
$0.095	$18.74	$28.10	$37.47	$46.84	$56.21	$65.58
$0.100	$19.72	$29.58	$39.44	$49.31	$59.17	$69.03
$0.105	$20.71	$31.06	$41.42	$51.77	$62.13	$72.48
$0.110	$21.69	$32.54	$43.39	$54.24	$65.08	$75.93
$0.115	$22.68	$34.02	$45.36	$56.70	$68.04	$79.38
$0.120	$23.67	$35.50	$47.33	$59.17	$71.00	$82.83
$0.125	$24.65	$36.98	$49.31	$61.63	$73.96	$86.28
$0.130	$25.64	$38.46	$51.28	$64.10	$76.92	$89.74
$0.135	$26.63	$39.94	$53.25	$66.56	$79.88	$93.19
$0.140	$27.61	$41.42	$55.22	$69.03	$82.83	$96.64

75/18

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 75 Watt Incandescent

CFL Watts 18

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$3.75	$5.62	$7.49	$9.37	$11.24	$13.12
$0.025	$4.68	$7.03	$9.37	$11.71	$14.05	$16.39
$0.030	$5.62	$8.43	$11.24	$14.05	$16.86	$19.67
$0.035	$6.56	$9.84	$13.12	$16.39	$19.67	$22.95
$0.040	$7.49	$11.24	$14.99	$18.74	$22.48	$26.23
$0.045	$8.43	$12.65	$16.86	$21.08	$25.29	$29.51
$0.050	$9.37	$14.05	$18.74	$23.42	$28.10	$32.79
$0.055	$10.30	$15.46	$20.61	$25.76	$30.91	$36.07
$0.060	$11.24	$16.86	$22.48	$28.10	$33.73	$39.35
$0.065	$12.18	$18.27	$24.36	$30.45	$36.54	$42.62
$0.070	$13.12	$19.67	$26.23	$32.79	$39.35	$45.90
$0.075	$14.05	$21.08	$28.10	$35.13	$42.16	$49.18
$0.080	$14.99	$22.48	$29.98	$37.47	$44.97	$52.46
$0.085	$15.93	$23.89	$31.85	$39.81	$47.78	$55.74
$0.090	$16.86	$25.29	$33.73	$42.16	$50.59	$59.02
$0.095	$17.80	$26.70	$35.60	$44.50	$53.40	$62.30
$0.100	$18.74	$28.10	$37.47	$46.84	$56.21	$65.58
$0.105	$19.67	$29.51	$39.35	$49.18	$59.02	$68.86
$0.110	$20.61	$30.91	$41.22	$51.52	$61.83	$72.13
$0.115	$21.55	$32.32	$43.09	$53.87	$64.64	$75.41
$0.120	$22.48	$33.73	$44.97	$56.21	$67.45	$78.69
$0.125	$23.42	$35.13	$46.84	$58.55	$70.26	$81.97
$0.130	$24.36	$36.54	$48.71	$60.89	$73.07	$85.25
$0.135	$25.29	$37.94	$50.59	$63.23	$75.88	$88.53
$0.140	$26.23	$39.35	$52.46	$65.58	$78.69	$91.81

75/20

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 75 Watt Incandescent

CFL Watts 20

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$3.62	$5.42	$7.23	$9.04	$10.85	$12.66
$0.025	$4.52	$6.78	$9.04	$11.30	$13.56	$15.82
$0.030	$5.42	$8.14	$10.85	$13.56	$16.27	$18.98
$0.035	$6.33	$9.49	$12.66	$15.82	$18.98	$22.15
$0.040	$7.23	$10.85	$14.46	$18.08	$21.69	$25.31
$0.045	$8.14	$12.20	$16.27	$20.34	$24.41	$28.47
$0.050	$9.04	$13.56	$18.08	$22.60	$27.12	$31.64
$0.055	$9.94	$14.91	$19.89	$24.86	$29.83	$34.80
$0.060	$10.85	$16.27	$21.69	$27.12	$32.54	$37.97
$0.065	$11.75	$17.63	$23.50	$29.38	$35.25	$41.13
$0.070	$12.66	$18.98	$25.31	$31.64	$37.97	$44.29
$0.075	$13.56	$20.34	$27.12	$33.90	$40.68	$47.46
$0.080	$14.46	$21.69	$28.93	$36.16	$43.39	$50.62
$0.085	$15.37	$23.05	$30.73	$38.42	$46.10	$53.78
$0.090	$16.27	$24.41	$32.54	$40.68	$48.81	$56.95
$0.095	$17.17	$25.76	$34.35	$42.94	$51.52	$60.11
$0.100	$18.08	$27.12	$36.16	$45.20	$54.24	$63.28
$0.105	$18.98	$28.47	$37.97	$47.46	$56.95	$66.44
$0.110	$19.89	$29.83	$39.77	$49.72	$59.66	$69.60
$0.115	$20.79	$31.19	$41.58	$51.98	$62.37	$72.77
$0.120	$21.69	$32.54	$43.39	$54.24	$65.08	$75.93
$0.125	$22.60	$33.90	$45.20	$56.50	$67.80	$79.09
$0.130	$23.50	$35.25	$47.00	$58.76	$70.51	$82.26
$0.135	$24.41	$36.61	$48.81	$61.02	$73.22	$85.42
$0.140	$25.31	$37.97	$50.62	$63.28	$75.93	$88.59

75/23

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 75 Watt Incandescent

CFL Watts 23

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$3.42	$5.13	$6.84	$8.55	$10.26	$11.96
$0.025	$4.27	$6.41	$8.55	$10.68	$12.82	$14.96
$0.030	$5.13	$7.69	$10.26	$12.82	$15.38	$17.95
$0.035	$5.98	$8.97	$11.96	$14.96	$17.95	$20.94
$0.040	$6.84	$10.26	$13.67	$17.09	$20.51	$23.93
$0.045	$7.69	$11.54	$15.38	$19.23	$23.08	$26.92
$0.050	$8.55	$12.82	$17.09	$21.37	$25.64	$29.91
$0.055	$9.40	$14.10	$18.80	$23.50	$28.20	$32.90
$0.060	$10.26	$15.38	$20.51	$25.64	$30.77	$35.89
$0.065	$11.11	$16.67	$22.22	$27.78	$33.33	$38.89
$0.070	$11.96	$17.95	$23.93	$29.91	$35.89	$41.88
$0.075	$12.82	$19.23	$25.64	$32.05	$38.46	$44.87
$0.080	$13.67	$20.51	$27.35	$34.19	$41.02	$47.86
$0.085	$14.53	$21.79	$29.06	$36.32	$43.59	$50.85
$0.090	$15.38	$23.08	$30.77	$38.46	$46.15	$53.84
$0.095	$16.24	$24.36	$32.48	$40.59	$48.71	$56.83
$0.100	$17.09	$25.64	$34.19	$42.73	$51.28	$59.82
$0.105	$17.95	$26.92	$35.89	$44.87	$53.84	$62.82
$0.110	$18.80	$28.20	$37.60	$47.00	$56.41	$65.81
$0.115	$19.66	$29.48	$39.31	$49.14	$58.97	$68.80
$0.120	$20.51	$30.77	$41.02	$51.28	$61.53	$71.79
$0.125	$21.37	$32.05	$42.73	$53.41	$64.10	$74.78
$0.130	$22.22	$33.33	$44.44	$55.55	$66.66	$77.77
$0.135	$23.08	$34.61	$46.15	$57.69	$69.23	$80.76
$0.140	$23.93	$35.89	$47.86	$59.82	$71.79	$83.75

75/27

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 75 Watt Incandescent

CFL Watts 27

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$3.16	$4.73	$6.31	$7.89	$9.47	$11.04
$0.025	$3.94	$5.92	$7.89	$9.86	$11.83	$13.81
$0.030	$4.73	$7.10	$9.47	$11.83	$14.20	$16.57
$0.035	$5.52	$8.28	$11.04	$13.81	$16.57	$19.33
$0.040	$6.31	$9.47	$12.62	$15.78	$18.93	$22.09
$0.045	$7.10	$10.65	$14.20	$17.75	$21.30	$24.85
$0.050	$7.89	$11.83	$15.78	$19.72	$23.67	$27.61
$0.055	$8.68	$13.02	$17.36	$21.69	$26.03	$30.37
$0.060	$9.47	$14.20	$18.93	$23.67	$28.40	$33.13
$0.065	$10.26	$15.38	$20.51	$25.64	$30.77	$35.89
$0.070	$11.04	$16.57	$22.09	$27.61	$33.13	$38.66
$0.075	$11.83	$17.75	$23.67	$29.58	$35.50	$41.42
$0.080	$12.62	$18.93	$25.24	$31.56	$37.87	$44.18
$0.085	$13.41	$20.12	$26.82	$33.53	$40.23	$46.94
$0.090	$14.20	$21.30	$28.40	$35.50	$42.60	$49.70
$0.095	$14.99	$22.48	$29.98	$37.47	$44.97	$52.46
$0.100	$15.78	$23.67	$31.56	$39.44	$47.33	$55.22
$0.105	$16.57	$24.85	$33.13	$41.42	$49.70	$57.98
$0.110	$17.36	$26.03	$34.71	$43.39	$52.07	$60.74
$0.115	$18.14	$27.22	$36.29	$45.36	$54.43	$63.51
$0.120	$18.93	$28.40	$37.87	$47.33	$56.80	$66.27
$0.125	$19.72	$29.58	$39.44	$49.31	$59.17	$69.03
$0.130	$20.51	$30.77	$41.02	$51.28	$61.53	$71.79
$0.135	$21.30	$31.95	$42.60	$53.25	$63.90	$74.55
$0.140	$22.09	$33.13	$44.18	$55.22	$66.27	$77.31

90/15

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 90 Watt Incandescent

CFL Watts 15

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$4.93	$7.40	$9.86	$12.33	$14.79	$17.26
$0.025	$6.16	$9.24	$12.33	$15.41	$18.49	$21.57
$0.030	$7.40	$11.09	$14.79	$18.49	$22.19	$25.89
$0.035	$8.63	$12.94	$17.26	$21.57	$25.89	$30.20
$0.040	$9.86	$14.79	$19.72	$24.65	$29.58	$34.51
$0.045	$11.09	$16.64	$22.19	$27.73	$33.28	$38.83
$0.050	$12.33	$18.49	$24.65	$30.82	$36.98	$43.14
$0.055	$13.56	$20.34	$27.12	$33.90	$40.68	$47.46
$0.060	$14.79	$22.19	$29.58	$36.98	$44.38	$51.77
$0.065	$16.02	$24.04	$32.05	$40.06	$48.07	$56.09
$0.070	$17.26	$25.89	$34.51	$43.14	$51.77	$60.40
$0.075	$18.49	$27.73	$36.98	$46.22	$55.47	$64.71
$0.080	$19.72	$29.58	$39.44	$49.31	$59.17	$69.03
$0.085	$20.95	$31.43	$41.91	$52.39	$62.86	$73.34
$0.090	$22.19	$33.28	$44.38	$55.47	$66.56	$77.66
$0.095	$23.42	$35.13	$46.84	$58.55	$70.26	$81.97
$0.100	$24.65	$36.98	$49.31	$61.63	$73.96	$86.28
$0.105	$25.89	$38.83	$51.77	$64.71	$77.66	$90.60
$0.110	$27.12	$40.68	$54.24	$67.80	$81.35	$94.91
$0.115	$28.35	$42.53	$56.70	$70.88	$85.05	$99.23
$0.120	$29.58	$44.38	$59.17	$73.96	$88.75	$103.54
$0.125	$30.82	$46.22	$61.63	$77.04	$92.45	$107.86
$0.130	$32.05	$48.07	$64.10	$80.12	$96.15	$112.17
$0.135	$33.28	$49.92	$66.56	$83.20	$99.84	$116.48
$0.140	$34.51	$51.77	$69.03	$86.28	$103.54	$120.80

90/18

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 90 Watt Incandescent

CFL Watts 18

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$4.73	$7.10	$9.47	$11.83	$14.20	$16.57
$0.025	$5.92	$8.88	$11.83	$14.79	$17.75	$20.71
$0.030	$7.10	$10.65	$14.20	$17.75	$21.30	$24.85
$0.035	$8.28	$12.43	$16.57	$20.71	$24.85	$28.99
$0.040	$9.47	$14.20	$18.93	$23.67	$28.40	$33.13
$0.045	$10.65	$15.98	$21.30	$26.63	$31.95	$37.28
$0.050	$11.83	$17.75	$23.67	$29.58	$35.50	$41.42
$0.055	$13.02	$19.53	$26.03	$32.54	$39.05	$45.56
$0.060	$14.20	$21.30	$28.40	$35.50	$42.60	$49.70
$0.065	$15.38	$23.08	$30.77	$38.46	$46.15	$53.84
$0.070	$16.57	$24.85	$33.13	$41.42	$49.70	$57.98
$0.075	$17.75	$26.63	$35.50	$44.38	$53.25	$62.13
$0.080	$18.93	$28.40	$37.87	$47.33	$56.80	$66.27
$0.085	$20.12	$30.18	$40.23	$50.29	$60.35	$70.41
$0.090	$21.30	$31.95	$42.60	$53.25	$63.90	$74.55
$0.095	$22.48	$33.73	$44.97	$56.21	$67.45	$78.69
$0.100	$23.67	$35.50	$47.33	$59.17	$71.00	$82.83
$0.105	$24.85	$37.28	$49.70	$62.13	$74.55	$86.98
$0.110	$26.03	$39.05	$52.07	$65.08	$78.10	$91.12
$0.115	$27.22	$40.83	$54.43	$68.04	$81.65	$95.26
$0.120	$28.40	$42.60	$56.80	$71.00	$85.20	$99.40
$0.125	$29.58	$44.38	$59.17	$73.96	$88.75	$103.54
$0.130	$30.77	$46.15	$61.53	$76.92	$92.30	$107.68
$0.135	$31.95	$47.93	$63.90	$79.88	$95.85	$111.83
$0.140	$33.13	$49.70	$66.27	$82.83	$99.40	$115.97

90/20

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 90 Watt Incandescent

CFL Watts 20

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$4.60	$6.90	$9.20	$11.50	$13.81	$16.11
$0.025	$5.75	$8.63	$11.50	$14.38	$17.26	$20.13
$0.030	$6.90	$10.35	$13.81	$17.26	$20.71	$24.16
$0.035	$8.05	$12.08	$16.11	$20.13	$24.16	$28.19
$0.040	$9.20	$13.81	$18.41	$23.01	$27.61	$32.21
$0.045	$10.35	$15.53	$20.71	$25.89	$31.06	$36.24
$0.050	$11.50	$17.26	$23.01	$28.76	$34.51	$40.27
$0.055	$12.66	$18.98	$25.31	$31.64	$37.97	$44.29
$0.060	$13.81	$20.71	$27.61	$34.51	$41.42	$48.32
$0.065	$14.96	$22.43	$29.91	$37.39	$44.87	$52.35
$0.070	$16.11	$24.16	$32.21	$40.27	$48.32	$56.37
$0.075	$17.26	$25.89	$34.51	$43.14	$51.77	$60.40
$0.080	$18.41	$27.61	$36.81	$46.02	$55.22	$64.43
$0.085	$19.56	$29.34	$39.12	$48.89	$58.67	$68.45
$0.090	$20.71	$31.06	$41.42	$51.77	$62.13	$72.48
$0.095	$21.86	$32.79	$43.72	$54.65	$65.58	$76.51
$0.100	$23.01	$34.51	$46.02	$57.52	$69.03	$80.53
$0.105	$24.16	$36.24	$48.32	$60.40	$72.48	$84.56
$0.110	$25.31	$37.97	$50.62	$63.28	$75.93	$88.59
$0.115	$26.46	$39.69	$52.92	$66.15	$79.38	$92.61
$0.120	$27.61	$41.42	$55.22	$69.03	$82.83	$96.64
$0.125	$28.76	$43.14	$57.52	$71.90	$86.28	$100.67
$0.130	$29.91	$44.87	$59.82	$74.78	$89.74	$104.69
$0.135	$31.06	$46.59	$62.13	$77.66	$93.19	$108.72
$0.140	$32.21	$48.32	$64.43	$80.53	$96.64	$112.75

90/23

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 90 Watt Incandescent

CFL Watts 23

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$4.40	$6.61	$8.81	$11.01	$13.21	$15.42
$0.025	$5.51	$8.26	$11.01	$13.76	$16.52	$19.27
$0.030	$6.61	$9.91	$13.21	$16.52	$19.82	$23.12
$0.035	$7.71	$11.56	$15.42	$19.27	$23.12	$26.98
$0.040	$8.81	$13.21	$17.62	$22.02	$26.43	$30.83
$0.045	$9.91	$14.87	$19.82	$24.78	$29.73	$34.69
$0.050	$11.01	$16.52	$22.02	$27.53	$33.03	$38.54
$0.055	$12.11	$18.17	$24.23	$30.28	$36.34	$42.39
$0.060	$13.21	$19.82	$26.43	$33.03	$39.64	$46.25
$0.065	$14.32	$21.47	$28.63	$35.79	$42.95	$50.10
$0.070	$15.42	$23.12	$30.83	$38.54	$46.25	$53.96
$0.075	$16.52	$24.78	$33.03	$41.29	$49.55	$57.81
$0.080	$17.62	$26.43	$35.24	$44.05	$52.86	$61.66
$0.085	$18.72	$28.08	$37.44	$46.80	$56.16	$65.52
$0.090	$19.82	$29.73	$39.64	$49.55	$59.46	$69.37
$0.095	$20.92	$31.38	$41.84	$52.31	$62.77	$73.23
$0.100	$22.02	$33.03	$44.05	$55.06	$66.07	$77.08
$0.105	$23.12	$34.69	$46.25	$57.81	$69.37	$80.94
$0.110	$24.23	$36.34	$48.45	$60.56	$72.68	$84.79
$0.115	$25.33	$37.99	$50.65	$63.32	$75.98	$88.64
$0.120	$26.43	$39.64	$52.86	$66.07	$79.28	$92.50
$0.125	$27.53	$41.29	$55.06	$68.82	$82.59	$96.35
$0.130	$28.63	$42.95	$57.26	$71.58	$85.89	$100.21
$0.135	$29.73	$44.60	$59.46	$74.33	$89.19	$104.06
$0.140	$30.83	$46.25	$61.66	$77.08	$92.50	$107.91

90/27

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 90 Watt Incandescent

CFL Watts 27

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$4.14	$6.21	$8.28	$10.35	$12.43	$14.50
$0.025	$3.94	$5.92	$7.89	$9.86	$11.83	$13.81
$0.030	$4.73	$7.10	$9.47	$11.83	$14.20	$16.57
$0.035	$5.52	$8.28	$11.04	$13.81	$16.57	$19.33
$0.040	$6.31	$9.47	$12.62	$15.78	$18.93	$22.09
$0.045	$7.10	$10.65	$14.20	$17.75	$21.30	$24.85
$0.050	$7.89	$11.83	$15.78	$19.72	$23.67	$27.61
$0.055	$8.68	$13.02	$17.36	$21.69	$26.03	$30.37
$0.060	$12.43	$18.64	$24.85	$31.06	$37.28	$43.49
$0.065	$10.26	$15.38	$20.51	$25.64	$30.77	$35.89
$0.070	$11.04	$16.57	$22.09	$27.61	$33.13	$38.66
$0.075	$11.83	$17.75	$23.67	$29.58	$35.50	$41.42
$0.080	$12.62	$18.93	$25.24	$31.56	$37.87	$44.18
$0.085	$13.41	$20.12	$26.82	$33.53	$40.23	$46.94
$0.090	$14.20	$21.30	$28.40	$35.50	$42.60	$49.70
$0.095	$14.99	$22.48	$29.98	$37.47	$44.97	$52.46
$0.100	$15.78	$23.67	$31.56	$39.44	$47.33	$55.22
$0.105	$16.57	$24.85	$33.13	$41.42	$49.70	$57.98
$0.110	$17.36	$26.03	$34.71	$43.39	$52.07	$60.74
$0.115	$18.14	$27.22	$36.29	$45.36	$54.43	$63.51
$0.120	$18.93	$28.40	$37.87	$47.33	$56.80	$66.27
$0.125	$19.72	$29.58	$39.44	$49.31	$59.17	$69.03
$0.130	$20.51	$30.77	$41.02	$51.28	$61.53	$71.79
$0.135	$21.30	$31.95	$42.60	$53.25	$63.90	$74.55
$0.140	$22.09	$33.13	$44.18	$55.22	$66.27	$77.31

100/15

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 100 Watt Incandescent

CFL Watts 15

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$5.59	$8.38	$11.18	$13.97	$16.76	$19.56
$0.025	$6.98	$10.48	$13.97	$17.46	$20.95	$24.45
$0.030	$8.38	$12.57	$16.76	$20.95	$25.15	$29.34
$0.035	$9.78	$14.67	$19.56	$24.45	$29.34	$34.23
$0.040	$11.18	$16.76	$22.35	$27.94	$33.53	$39.12
$0.045	$12.57	$18.86	$25.15	$31.43	$37.72	$44.01
$0.050	$13.97	$20.95	$27.94	$34.92	$41.91	$48.89
$0.055	$15.37	$23.05	$30.73	$38.42	$46.10	$53.78
$0.060	$16.76	$25.15	$33.53	$41.91	$50.29	$58.67
$0.065	$18.16	$27.24	$36.32	$45.40	$54.48	$63.56
$0.070	$19.56	$29.34	$39.12	$48.89	$58.67	$68.45
$0.075	$20.95	$31.43	$41.91	$52.39	$62.86	$73.34
$0.080	$22.35	$33.53	$44.70	$55.88	$67.06	$78.23
$0.085	$23.75	$35.62	$47.50	$59.37	$71.25	$83.12
$0.090	$25.15	$37.72	$50.29	$62.86	$75.44	$88.01
$0.095	$26.54	$39.81	$53.09	$66.36	$79.63	$92.90
$0.100	$27.94	$41.91	$55.88	$69.85	$83.82	$97.79
$0.105	$29.34	$44.01	$58.67	$73.34	$88.01	$102.68
$0.110	$30.73	$46.10	$61.47	$76.83	$92.20	$107.57
$0.115	$32.13	$48.20	$64.26	$80.33	$96.39	$112.46
$0.120	$33.53	$50.29	$67.06	$83.82	$100.58	$117.35
$0.125	$34.92	$52.39	$69.85	$87.31	$104.77	$122.24
$0.130	$36.32	$54.48	$72.64	$90.80	$108.97	$127.13
$0.135	$37.72	$56.58	$75.44	$94.30	$113.16	$132.02
$0.140	$39.12	$58.67	$78.23	$97.79	$117.35	$136.91

100/18

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 100 Watt Incandescent

CFL Watts 18

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$5.39	$8.09	$10.78	$13.48	$16.17	$18.87
$0.025	$6.74	$10.11	$13.48	$16.85	$20.22	$23.58
$0.030	$8.09	$12.13	$16.17	$20.22	$24.26	$28.30
$0.035	$9.43	$14.15	$18.87	$23.58	$28.30	$33.02
$0.040	$10.78	$16.17	$21.56	$26.95	$32.34	$37.74
$0.045	$12.13	$18.19	$24.26	$30.32	$36.39	$42.45
$0.050	$13.48	$20.22	$26.95	$33.69	$40.43	$47.17
$0.055	$14.82	$22.24	$29.65	$37.06	$44.47	$51.89
$0.060	$16.17	$24.26	$32.34	$40.43	$48.52	$56.60
$0.065	$17.52	$26.28	$35.04	$43.80	$52.56	$61.32
$0.070	$18.87	$28.30	$37.74	$47.17	$56.60	$66.04
$0.075	$20.22	$30.32	$40.43	$50.54	$60.65	$70.75
$0.080	$21.56	$32.34	$43.13	$53.91	$64.69	$75.47
$0.085	$22.91	$34.37	$45.82	$57.28	$68.73	$80.19
$0.090	$24.26	$36.39	$48.52	$60.65	$72.78	$84.90
$0.095	$25.61	$38.41	$51.21	$64.02	$76.82	$89.62
$0.100	$26.95	$40.43	$53.91	$67.38	$80.86	$94.34
$0.105	$28.30	$42.45	$56.60	$70.75	$84.90	$99.06
$0.110	$29.65	$44.47	$59.30	$74.12	$88.95	$103.77
$0.115	$31.00	$46.50	$61.99	$77.49	$92.99	$108.49
$0.120	$32.34	$48.52	$64.69	$80.86	$97.03	$113.21
$0.125	$33.69	$50.54	$67.38	$84.23	$101.08	$117.92
$0.130	$35.04	$52.56	$70.08	$87.60	$105.12	$122.64
$0.135	$36.39	$54.58	$72.78	$90.97	$109.16	$127.36
$0.140	$37.74	$56.60	$75.47	$94.34	$113.21	$132.07

100/20

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 100 Watt Incandescent

CFL Watts 20

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$5.26	$7.89	$10.52	$13.15	$15.78	$18.41
$0.025	$6.57	$9.86	$13.15	$16.44	$19.72	$23.01
$0.030	$7.89	$11.83	$15.78	$19.72	$23.67	$27.61
$0.035	$9.20	$13.81	$18.41	$23.01	$27.61	$32.21
$0.040	$10.52	$15.78	$21.04	$26.30	$31.56	$36.81
$0.045	$11.83	$17.75	$23.67	$29.58	$35.50	$41.42
$0.050	$13.15	$19.72	$26.30	$32.87	$39.44	$46.02
$0.055	$14.46	$21.69	$28.93	$36.16	$43.39	$50.62
$0.060	$15.78	$23.67	$31.56	$39.44	$47.33	$55.22
$0.065	$17.09	$25.64	$34.19	$42.73	$51.28	$59.82
$0.070	$18.41	$27.61	$36.81	$46.02	$55.22	$64.43
$0.075	$19.72	$29.58	$39.44	$49.31	$59.17	$69.03
$0.080	$21.04	$31.56	$42.07	$52.59	$63.11	$73.63
$0.085	$22.35	$33.53	$44.70	$55.88	$67.06	$78.23
$0.090	$23.67	$35.50	$47.33	$59.17	$71.00	$82.83
$0.095	$24.98	$37.47	$49.96	$62.45	$74.94	$87.44
$0.100	$26.30	$39.44	$52.59	$65.74	$78.89	$92.04
$0.105	$27.61	$41.42	$55.22	$69.03	$82.83	$96.64
$0.110	$28.93	$43.39	$57.85	$72.31	$86.78	$101.24
$0.115	$30.24	$45.36	$60.48	$75.60	$90.72	$105.84
$0.120	$31.56	$47.33	$63.11	$78.89	$94.67	$110.44
$0.125	$32.87	$49.31	$65.74	$82.18	$98.61	$115.05
$0.130	$34.19	$51.28	$68.37	$85.46	$102.56	$119.65
$0.135	$35.50	$53.25	$71.00	$88.75	$106.50	$124.25
$0.140	$36.81	$55.22	$73.63	$92.04	$110.44	$128.85

100/23

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 100 Watt Incandescent

CFL Watts 23

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$5.06	$7.59	$10.12	$12.66	$15.19	$17.72
$0.025	$6.33	$9.49	$12.66	$15.82	$18.98	$22.15
$0.030	$7.59	$11.39	$15.19	$18.98	$22.78	$26.58
$0.035	$8.86	$13.29	$17.72	$22.15	$26.58	$31.01
$0.040	$10.12	$15.19	$20.25	$25.31	$30.37	$35.43
$0.045	$11.39	$17.08	$22.78	$28.47	$34.17	$39.86
$0.050	$12.66	$18.98	$25.31	$31.64	$37.97	$44.29
$0.055	$13.92	$20.88	$27.84	$34.80	$41.76	$48.72
$0.060	$15.19	$22.78	$30.37	$37.97	$45.56	$53.15
$0.065	$16.45	$24.68	$32.90	$41.13	$49.35	$57.58
$0.070	$17.72	$26.58	$35.43	$44.29	$53.15	$62.01
$0.075	$18.98	$28.47	$37.97	$47.46	$56.95	$66.44
$0.080	$20.25	$30.37	$40.50	$50.62	$60.74	$70.87
$0.085	$21.51	$32.27	$43.03	$53.78	$64.54	$75.30
$0.090	$22.78	$34.17	$45.56	$56.95	$68.34	$79.73
$0.095	$24.04	$36.07	$48.09	$60.11	$72.13	$84.16
$0.100	$25.31	$37.97	$50.62	$63.28	$75.93	$88.59
$0.105	$26.58	$39.86	$53.15	$66.44	$79.73	$93.02
$0.110	$27.84	$41.76	$55.68	$69.60	$83.52	$97.44
$0.115	$29.11	$43.66	$58.21	$72.77	$87.32	$101.87
$0.120	$30.37	$45.56	$60.74	$75.93	$91.12	$106.30
$0.125	$31.64	$47.46	$63.28	$79.09	$94.91	$110.73
$0.130	$32.90	$49.35	$65.81	$82.26	$98.71	$115.16
$0.135	$34.17	$51.25	$68.34	$85.42	$102.51	$119.59
$0.140	$35.43	$53.15	$70.87	$88.59	$106.30	$124.02

100/27

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 100 Watt Incandescent

CFL Watts 27

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$4.80	$7.20	$9.60	$12.00	$14.40	$16.80
$0.025	$6.00	$9.00	$12.00	$15.00	$18.00	$21.00
$0.030	$7.20	$10.80	$14.40	$18.00	$21.60	$25.20
$0.035	$8.40	$12.60	$16.80	$21.00	$25.20	$29.39
$0.040	$9.60	$14.40	$19.20	$24.00	$28.79	$33.59
$0.045	$10.80	$16.20	$21.60	$26.99	$32.39	$37.79
$0.050	$12.00	$18.00	$24.00	$29.99	$35.99	$41.99
$0.055	$13.20	$19.80	$26.39	$32.99	$39.59	$46.19
$0.060	$14.40	$21.60	$28.79	$35.99	$43.19	$50.39
$0.065	$15.60	$23.40	$31.19	$38.99	$46.79	$54.59
$0.070	$16.80	$25.20	$33.59	$41.99	$50.39	$58.79
$0.075	$18.00	$26.99	$35.99	$44.99	$53.99	$62.99
$0.080	$19.20	$28.79	$38.39	$47.99	$57.59	$67.19
$0.085	$20.40	$30.59	$40.79	$50.99	$61.19	$71.39
$0.090	$21.60	$32.39	$43.19	$53.99	$64.79	$75.59
$0.095	$22.80	$34.19	$45.59	$56.99	$68.39	$79.78
$0.100	$24.00	$35.99	$47.99	$59.99	$71.99	$83.98
$0.105	$25.20	$37.79	$50.39	$62.99	$75.59	$88.18
$0.110	$26.39	$39.59	$52.79	$65.99	$79.18	$92.38
$0.115	$27.59	$41.39	$55.19	$68.99	$82.78	$96.58
$0.120	$28.79	$43.19	$57.59	$71.99	$86.38	$100.78
$0.125	$29.99	$44.99	$59.99	$74.99	$89.98	$104.98
$0.130	$31.19	$46.79	$62.39	$77.99	$93.58	$109.18
$0.135	$32.39	$48.59	$64.79	$80.98	$97.18	$113.38
$0.140	$33.59	$50.39	$67.19	$83.98	$100.78	$117.58

150/15

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 150 Watt Incandescent

CFL Watts 15

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$8.88	$13.31	$17.75	$22.19	$26.63	$31.06
$0.025	$11.09	$16.64	$22.19	$27.73	$33.28	$38.83
$0.030	$13.31	$19.97	$26.63	$33.28	$39.94	$46.59
$0.035	$15.53	$23.30	$31.06	$38.83	$46.59	$54.36
$0.040	$17.75	$26.63	$35.50	$44.38	$53.25	$62.13
$0.045	$19.97	$29.95	$39.94	$49.92	$59.91	$69.89
$0.050	$22.19	$33.28	$44.38	$55.47	$66.56	$77.66
$0.055	$24.41	$36.61	$48.81	$61.02	$73.22	$85.42
$0.060	$26.63	$39.94	$53.25	$66.56	$79.88	$93.19
$0.065	$28.84	$43.27	$57.69	$72.11	$86.53	$100.95
$0.070	$31.06	$46.59	$62.13	$77.66	$93.19	$108.72
$0.075	$33.28	$49.92	$66.56	$83.20	$99.84	$116.48
$0.080	$35.50	$53.25	$71.00	$88.75	$106.50	$124.25
$0.085	$37.72	$56.58	$75.44	$94.30	$113.16	$132.02
$0.090	$39.94	$59.91	$79.88	$99.84	$119.81	$139.78
$0.095	$42.16	$63.23	$84.31	$105.39	$126.47	$147.55
$0.100	$44.38	$66.56	$88.75	$110.94	$133.13	$155.31
$0.105	$46.59	$69.89	$93.19	$116.48	$139.78	$163.08
$0.110	$48.81	$73.22	$97.63	$122.03	$146.44	$170.84
$0.115	$51.03	$76.55	$102.06	$127.58	$153.09	$178.61
$0.120	$53.25	$79.88	$106.50	$133.13	$159.75	$186.38
$0.125	$55.47	$83.20	$110.94	$138.67	$166.41	$194.14
$0.130	$57.69	$86.53	$115.38	$144.22	$173.06	$201.91
$0.135	$59.91	$89.86	$119.81	$149.77	$179.72	$209.67
$0.140	$62.13	$93.19	$124.25	$155.31	$186.38	$217.44

150/18

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 150 Watt Incandescent

CFL Watts 18

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$8.68	$13.02	$17.36	$21.69	$26.03	$30.37
$0.025	$10.85	$16.27	$21.69	$27.12	$32.54	$37.97
$0.030	$13.02	$19.53	$26.03	$32.54	$39.05	$45.56
$0.035	$15.19	$22.78	$30.37	$37.97	$45.56	$53.15
$0.040	$17.36	$26.03	$34.71	$43.39	$52.07	$60.74
$0.045	$19.53	$29.29	$39.05	$48.81	$58.58	$68.34
$0.050	$21.69	$32.54	$43.39	$54.24	$65.08	$75.93
$0.055	$23.86	$35.80	$47.73	$59.66	$71.59	$83.52
$0.060	$26.03	$39.05	$52.07	$65.08	$78.10	$91.12
$0.065	$28.20	$42.30	$56.41	$70.51	$84.61	$98.71
$0.070	$30.37	$45.56	$60.74	$75.93	$91.12	$106.30
$0.075	$32.54	$48.81	$65.08	$81.35	$97.63	$113.90
$0.080	$34.71	$52.07	$69.42	$86.78	$104.13	$121.49
$0.085	$36.88	$55.32	$73.76	$92.20	$110.64	$129.08
$0.090	$39.05	$58.58	$78.10	$97.63	$117.15	$136.68
$0.095	$41.22	$61.83	$82.44	$103.05	$123.66	$144.27
$0.100	$43.39	$65.08	$86.78	$108.47	$130.17	$151.86
$0.105	$45.56	$68.34	$91.12	$113.90	$136.68	$159.45
$0.110	$47.73	$71.59	$95.46	$119.32	$143.18	$167.05
$0.115	$49.90	$74.85	$99.79	$124.74	$149.69	$174.64
$0.120	$52.07	$78.10	$104.13	$130.17	$156.20	$182.23
$0.125	$54.24	$81.35	$108.47	$135.59	$162.71	$189.83
$0.130	$56.41	$84.61	$112.81	$141.01	$169.22	$197.42
$0.135	$58.58	$87.86	$117.15	$146.44	$175.73	$205.01
$0.140	$60.74	$91.12	$121.49	$151.86	$182.23	$212.61

150/20

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 150 Watt Incandescent

CFL Watts 20

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$8.55	$12.82	$17.09	$21.37	$25.64	$29.91
$0.025	$10.68	$16.02	$21.37	$26.71	$32.05	$37.39
$0.030	$12.82	$19.23	$25.64	$32.05	$38.46	$44.87
$0.035	$14.96	$22.43	$29.91	$37.39	$44.87	$52.35
$0.040	$17.09	$25.64	$34.19	$42.73	$51.28	$59.82
$0.045	$19.23	$28.84	$38.46	$48.07	$57.69	$67.30
$0.050	$21.37	$32.05	$42.73	$53.41	$64.10	$74.78
$0.055	$23.50	$35.25	$47.00	$58.76	$70.51	$82.26
$0.060	$25.64	$38.46	$51.28	$64.10	$76.92	$89.74
$0.065	$27.78	$41.66	$55.55	$69.44	$83.33	$97.21
$0.070	$29.91	$44.87	$59.82	$74.78	$89.74	$104.69
$0.075	$32.05	$48.07	$64.10	$80.12	$96.15	$112.17
$0.080	$34.19	$51.28	$68.37	$85.46	$102.56	$119.65
$0.085	$36.32	$54.48	$72.64	$90.80	$108.97	$127.13
$0.090	$38.46	$57.69	$76.92	$96.15	$115.38	$134.60
$0.095	$40.59	$60.89	$81.19	$101.49	$121.78	$142.08
$0.100	$42.73	$64.10	$85.46	$106.83	$128.19	$149.56
$0.105	$44.87	$67.30	$89.74	$112.17	$134.60	$157.04
$0.110	$47.00	$70.51	$94.01	$117.51	$141.01	$164.52
$0.115	$49.14	$73.71	$98.28	$122.85	$147.42	$171.99
$0.120	$51.28	$76.92	$102.56	$128.19	$153.83	$179.47
$0.125	$53.41	$80.12	$106.83	$133.54	$160.24	$186.95
$0.130	$55.55	$83.33	$111.10	$138.88	$166.65	$194.43
$0.135	$57.69	$86.53	$115.38	$144.22	$173.06	$201.91
$0.140	$59.82	$89.74	$119.65	$149.56	$179.47	$209.38

150/23

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 150 Watt Incandescent

CFL Watts 23

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$8.35	$12.52	$16.70	$20.87	$25.05	$29.22
$0.025	$10.44	$15.65	$20.87	$26.09	$31.31	$36.53
$0.030	$12.52	$18.79	$25.05	$31.31	$37.57	$43.83
$0.035	$14.61	$21.92	$29.22	$36.53	$43.83	$51.14
$0.040	$16.70	$25.05	$33.40	$41.75	$50.09	$58.44
$0.045	$18.79	$28.18	$37.57	$46.96	$56.36	$65.75
$0.050	$20.87	$31.31	$41.75	$52.18	$62.62	$73.05
$0.055	$22.96	$34.44	$45.92	$57.40	$68.88	$80.36
$0.060	$25.05	$37.57	$50.09	$62.62	$75.14	$87.67
$0.065	$27.13	$40.70	$54.27	$67.84	$81.40	$94.97
$0.070	$29.22	$43.83	$58.44	$73.05	$87.67	$102.28
$0.075	$31.31	$46.96	$62.62	$78.27	$93.93	$109.58
$0.080	$33.40	$50.09	$66.79	$83.49	$100.19	$116.89
$0.085	$35.48	$53.23	$70.97	$88.71	$106.45	$124.19
$0.090	$37.57	$56.36	$75.14	$93.93	$112.71	$131.50
$0.095	$39.66	$59.49	$79.32	$99.15	$118.97	$138.80
$0.100	$41.75	$62.62	$83.49	$104.36	$125.24	$146.11
$0.105	$43.83	$65.75	$87.67	$109.58	$131.50	$153.41
$0.110	$45.92	$68.88	$91.84	$114.80	$137.76	$160.72
$0.115	$48.01	$72.01	$96.01	$120.02	$144.02	$168.03
$0.120	$50.09	$75.14	$100.19	$125.24	$150.28	$175.33
$0.125	$52.18	$78.27	$104.36	$130.45	$156.55	$182.64
$0.130	$54.27	$81.40	$108.54	$135.67	$162.81	$189.94
$0.135	$56.36	$84.53	$112.71	$140.89	$169.07	$197.25
$0.140	$58.44	$87.67	$116.89	$146.11	$175.33	$204.55

150/27

Threshold Cost of a Replacement CFL (Yielding a Savings-to-Investment Ratio of 1)

Replacement of 150 Watt Incandescent

CFL Watts 27

Fuel Cost per KWh	Hours On Per Day ----------► 2	3	4	5	6	7
$0.020	$8.09	$12.13	$16.17	$20.22	$24.26	$28.30
$0.025	$10.11	$15.16	$20.22	$25.27	$30.32	$35.38
$0.030	$12.13	$18.19	$24.26	$30.32	$36.39	$42.45
$0.035	$14.15	$21.23	$28.30	$35.38	$42.45	$49.53
$0.040	$16.17	$24.26	$32.34	$40.43	$48.52	$56.60
$0.045	$18.19	$27.29	$36.39	$45.48	$54.58	$63.68
$0.050	$20.22	$30.32	$40.43	$50.54	$60.65	$70.75
$0.055	$22.24	$33.36	$44.47	$55.59	$66.71	$77.83
$0.060	$24.26	$36.39	$48.52	$60.65	$72.78	$84.90
$0.065	$26.28	$39.42	$52.56	$65.70	$78.84	$91.98
$0.070	$28.30	$42.45	$56.60	$70.75	$84.90	$99.06
$0.075	$30.32	$45.48	$60.65	$75.81	$90.97	$106.13
$0.080	$32.34	$48.52	$64.69	$80.86	$97.03	$113.21
$0.085	$34.37	$51.55	$68.73	$85.92	$103.10	$120.28
$0.090	$36.39	$54.58	$72.78	$90.97	$109.16	$127.36
$0.095	$38.41	$57.61	$76.82	$96.02	$115.23	$134.43
$0.100	$40.43	$60.65	$80.86	$101.08	$121.29	$141.51
$0.105	$42.45	$63.68	$84.90	$106.13	$127.36	$148.58
$0.110	$44.47	$66.71	$88.95	$111.18	$133.42	$155.66
$0.115	$46.50	$69.74	$92.99	$116.24	$139.49	$162.73
$0.120	$48.52	$72.78	$97.03	$121.29	$145.55	$169.81
$0.125	$50.54	$75.81	$101.08	$126.35	$151.61	$176.88
$0.130	$52.56	$78.84	$105.12	$131.40	$157.68	$183.96
$0.135	$54.58	$81.87	$109.16	$136.45	$163.74	$191.03
$0.140	$56.60	$84.90	$113.21	$141.51	$169.81	$198.11

12000 Glossary

- A -

Abatement – A measure or set of measures designed to permanently eliminate a hazard (i.e. lead based paint). Abatement strategies include removal of the hazardous materials, replacement of building components containing the hazardous material, enclosure or encapsulation. All of these strategies require proper preparation, cleanup, waste disposal post abatement clearance testing, and if applicable, record keeping and monitoring.

Absorption – Absorption is the process by which a substance can be readily taken into the body through the skin or membranes. The best defense is to have a protective barrier between the substance and the skin.

Air Changes per Hour at 50 Pascals (ACH_{50}) – The number of times that the complete volume of a home is exchanged for outside air in one hour when a blower door depressurizes or pressurizes the home to 50 Pa.

Air Changes per Hour natural (ACH_{nat}) – The number of times the indoor air is exchanged with the outdoor air in one hour under natural driving forces. It can be estimated with blower door use.

Air exchange – The process where indoor air is replaced with the outdoor air through air leakage and ventilation. One CFM out equals one CFM in.

Air-Free Carbon Monoxide – A method used to be able to compare CO readings with varying amounts of dilution air (oxygen) mixed in. The air-free method adjusts air content (oxygen) to zero.

Air handler – A steel cabinet containing a blower with cooling and/or heating coils connected to ducts, which circulates indoor air across the exchangers and into the living space.

Air infiltration barrier – A spun polymer sheet (for example, house wrap) that stops almost all the air traveling through a building cavity, while allowing moisture to pass through it.

Altitude Adjustment – When a gas appliance is installed more than 2000 feet above sea level, its input rating must be reduced by approximately four percent per 1000 feet above sea level.

AFUE – Annual Fuel Utilization Efficiency – A laboratory derived efficiency for heating appliances which accounts for chimney losses, jacket losses, and cycling losses, but not distribution losses or fan/pump energy.

AAMA – Architectural Aluminum Manufacturers' Association

Asbestos – A fibrous mineral with fireproof and insulation characteristics which may be shaped into a variety of building materials. Small, sharp asbestos fibers may cause damage to lungs if they are inhaled.

Ambient air – Air in the living space.

ANSI – American National Standards Institute, Inc.

ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

ASME – American Society of Mechanical Engineers

ASTM – American Society for Testing and Materials

Ampere – A unit of measurement that tells how much electricity flows through a conductor. It is like cubic feet per second to measure the flow of water. For example, a 1,200-watt, 120-volt hair dryer pulls 10 amperes of electric current (watts divided by volts).

Aquastat – A heating control that switches the burner or the circulator pump in a hydronic heating system.

Atmospheric appliances – A heating device that takes its combustion air from the surrounding room air. Also, know as open-combustion heater.

- B -

Backdrafting – Continuous spillage of combustion gases from a vented combustion appliance into the living space.

Backdraft damper – A damper, installed near a fan, that allows air to flow in only one direction and prevents reverse flow when the fan is off.

Backer rod – Polyethylene foam rope used as a backer for caulking.

Baffle – A plate or strip designed to retard or redirect the flow of flue gases.

Balance point – The outdoor temperature at which no heating is needed to maintain inside temperatures.

Ballast – A coil of wire or electronic device that provides a high starting voltage for a lamp and limits the current from flowing through it.

Balloon framing – A method of construction in which the vertical framing members (studs) are continuous pieces running the entire height of the wall.

Band joist – See Rim joist.

Barometric vent damper – a device installed in the heating unit vent system to control draft. Usually used on oil-fueled units or gas units with power burners.

Batt – A blanket of preformed insulation, generally 14.5" or 22.5" wide and varying in thickness from 3.5" to 9".

BDL – See Building Depressurization Limit.

Belly return – A configuration found in some mobile homes that uses the belly cavity as the return side of the distribution system.

Belt Tension (proper adjustment of) – Minimum of one-inch play per side. The belt should not slip on the pulleys.

Benefit-to-Cost Ratio (BCR) – See Savings-to-Investment Ratio (SIR).

Bimetal element – A metal spring, lever, or disc made of two dissimilar metals that expand and contract at different rates as the temperature around them changes. This movement operates a switch in the control circuit of a heating or cooling device.

Blocking – A building element or material used to prevent movement into or through building cavities.

Blow-down – Removing water from a boiler to remove sediment and suspended particulates.

Blower – The “squirrel-cage” fan in a furnace or air handler.

Blower door – A calibrated device to measure the air tightness of a building by pressurizing or depressurizing the building and measuring the flow through the fan.

Blown insulation – A loose-fill insulation that is blown into attics and building cavities using an insulation blowing machine.

Boot – A duct section that connects between a duct and a register, floor, or wall cavity or between round and square ducts.

Branch circuit – An electrical circuit used to power outlets and lights within a home.

Brightness – The luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed in that direction.

British Thermal Unit (Btu) – The quantity of heat required at sea level to raise the temperature of one pound of water one degree Fahrenheit.

BTL – Building Tightness Limit calculation procedure, expressed in units of CFM_{50}, based on the American Society of Heating, Refrigerating and Air-Conditioning Engineers Standard 62-1999, *Ventilation for Acceptable Indoor Air Quality*. This method was clearly explained in an article in *Home Energy* magazine (Tsongas 1993). The method closely follows the parameters set in ASHRAE 62-1999: For acceptable indoor air quality, 15 CFM per person (set minimum of five people) or 0.35 air changes per hour (ACH), whichever is greater, must be supplied by natural air leakage and/or continuously operating ventilation.

BTLa – Building Tightness Limit calculation procedure, expressed in units of CFM_{50}, that is more complex than the BTL method and is based on ASHRAE Standard 62, Standard 119 (*Air Leakage Performance for Detached Single-Family Residential Buildings*), and Standard136 (*A Method of Determining Air Change Rates in Detached Dwellings*). This method closely follows the parameters set in ASHRAE 62-1999: For acceptable indoor air quality, 15 CFM per person or 0.35 air changes per hour (ACH), whichever is greater, must be supplied by natural air leakage and/or continuously operating ventilation. However, the BTLa method uses different calculation methods – based on ASHRAE 119 and 136 – than the BTL method to arrive at the final tightness limits.

Btuh – British thermal units per hour.

Building cavities – The spaces inside walls, floors, and ceilings or between the interior and exterior sheeting.

Building Depressurization Limit (BDL) – BDL is a selected indoor negative pressure; expressed in Pascals, immediately around vented combustion appliances that use indoor air for combustion supply air. If a combustion appliance experiences a negative pressure of a greater magnitude than the BDL, it has the potential to backdraft, causing a hazardous condition for the occupants. The BDL for furnaces and boilers is often -5 Pascals and for stand-alone natural

draft water heaters, -2 Pascals. Field studies have been done to determine the negative pressure at which these appliances will begin to backdraft.

Building science – An involved perspective on buildings, using contemporary technology to analyze and solve problems dealing with design, construction, maintenance, safety, and energy efficiency of the buildings.

Building Tightness Limit – A general term for a house-tightening limit, expressed in units of CFM_{50}, used for ensuring adequate indoor air quality for the house occupants. Two building tightness limit procedures used in the North Dakota Weatherization Program are BTL and BTLa.

Burner – A device that facilitates the burning of a fossil fuel like gas or oil.

Bypass – An air leakage site that allows air to leak out of a building passing around the air barrier and insulation.

- C -

Carbon dioxide (CO_2) – A heavy, colorless, nonflammable gas formed by the oxidation of carbon, by combustion, and in respiration of plants and animals.

Carbon monoxide (CO) – An odorless, colorless, tasteless, and poisonous gas produced by incomplete combustion.

Caulking – A mastic compound for filling joints and cracks.

CAZ – See Combustion Appliance Zone.

Cellulose insulation – Insulation, packaged in bags for blowing, made from newspaper or wood waste and treated with a fire retardant.

Chimney – A building component designed for the sole purpose of assuring combustion by-products are exhausted to the exterior of the building.

Circuit breaker – A device that automatically disconnects an electrical circuit from electricity under a specified or abnormal condition of current flow.

Coefficient of Performance (COP) – A heat pump or air conditioner's output in Watt-hours of heat removed divided by Watt-hours of electrical input.

Coil – A snakelike piece of copper tubing surrounded by rows of aluminum fins that clamp tightly to the tubing to aid in heat transfer.

Cold Air Return (Return side): Ductwork through which house air is drawn for reheating during furnace cycle.

Color rendering index (CRI) – A measurement of a light source's ability to render colors the same as sunlight. CRI has a scale of 0 to 100.

Color temperature – A measurement of the warmness or coolness of a light source in the Kelvin temperature scale.

Combustible – Susceptible to combustion, inflammable, any substance that will burn.

Combustible Gas Leak Detector – A device for determining the presence and general location of combustible gases in the air.

Combustion – The act or process of burning. Oxygen, fuel and a spark must be present for combustion to occur.

Combustion air – Air required to chemically combine with a fuel during combustion to produce heat and flue gases, mainly carbon dioxide and water vapor.

Combustion analyzer – A device used to measure steady-state efficiency of combustion heating units.

Combustion appliance – Any appliance in which combustion occurs.

Combustion Appliance Zone (CAZ) – The closed space or area, which holds one or more combustion appliances.

Combustion chamber – The area inside a heating unit where combustion takes place.

Compact fluorescent light (CFL) – A small fluorescent light engineered to fit conventional incandescent fixtures.

Compressor – A motorized pump that compresses the gaseous refrigerant and sends it to the condenser where heat is released.

Condense – To change from a gaseous or vaporous state to a liquid or solid state by cooling or compression.

Condenser – The coil in an air conditioning system where the refrigerant condenses and releases heat, which is carried away by air moving across the coil.

Condensate – The liquid formed when a vapor is condensed.

Condensate receiver – A tank for catching returning condensate water from a steam heating system.

Conditioned Space – A heated or cooled area of a building. Conditioned space includes any area of a dwelling that is determined to be within the insulated envelope or shell.

Conductance – The quantity of heat, in Btu, that will flow through one square foot of material in one hour, when there is a one degree Fahrenheit temperature difference between both surfaces. Conductance values are given for a specific thickness of material, not per inch thickness.

Conduction – The transfer of heat energy through a material (solid, liquid or gas) by the motion of adjacent atoms and molecules without gross displacement of the particles.

Conductivity – The quantity of heat that will flow through one square foot of homogeneous material, one inch thick, in one hour, when there is a temperature difference of one degree Fahrenheit between its surfaces.

Confined space – A space with a volume of less than 50 cubic feet per 1,000 Btu per hour of the total input rating of all combustion appliances installed in that space.

Contractor – Any for-profit, not-for-profit, or government entity that provides services to the program under contract, not as a result of a grant of funds.

Control circuit – A circuit whose work is switching a power circuit or opening an automatic valve.

Convection – The transmission of heat by the actual movement of a fluid because of differences in temperature, density, etc.

Conventionally vented combustion appliance – Combustion appliances that are characterized by atmospheric burners or natural draft. Sealed or direct-vent appliances are not conventionally vented.

Cooling load – The maximum rate of heat removal required of an air conditioner when the outdoor temperature and humidity are at the highest expected level.

Cost-effective – Having an acceptable payback, return-on-investment, or savings-to-investment ratio.

Critical framing juncture – An intersection of framing members and envelope components that require special attention during prep and installation of insulation.

Cross section – A view of a building component drawn or imagined by cutting through the component.

CFM – Cubic Feet per Minute – A measurement of air movement in cubic feet past a certain point or through a certain structure per minute.

CFM_{50} – The number of cubic feet per minute of air flowing through the fan housing of a blower door when the house pressure is 50 Pa (0.2 inches of water column). This figure is the most common and accurate way of comparing the tightness of buildings that are tested using a blower door.

CFM_{nat} – The number of cubic feet of air flowing through a house from indoors to outdoors during typical, natural conditions. This figure can be roughly estimated using a blower door using the LBL (Lawrence Berkeley Labs) infiltration model.

- D -

Degree-days (DD) – A measure of the temperature element of climate produced by summing the temperature differences between the inside (65°F) and the daily average outside temperature for a one-year period.

Demand – The peak need for electrical energy. Some utilities levy a monthly charge for demand.

Density – The weight of a material divided by its volume, usually measured in pounds per cubic foot.

DOE - The United States Department of Energy.

Depressurize - To lower the pressure in an enclosed area with respect to a reference pressure.

Depressurization Tightness Limit (DTL) – A calculation procedure, expressed in units of CFM_{50}, performed to estimate the building tightness level at which combustion appliances might backdraft when the house is under conditions of worst-case depressurization. A BDL must be selected for the calculation of the DTL. The DTL sets a low limit for air sealing that may or may not be lower than the building tightness limit for the same house. Refer to Appendix C for a flow chart of this procedure.

Design temperature - A high or low temperature used for designing heating and cooling systems when calculating the building load.

Dilution air - Air that enters through the dilution device-an opening where the chimney joins to an atmospheric-draft combustion appliance.

Dilution device - A draft diverter, draft hood, or barometric draft control on an atmospheric-draft combustion appliance.

Direct-vent appliance - Appliances that are constructed and installed so that all combustion air is taken directly from and the flue gases are vented directly to the outside.

Distribution system - A system of pipes or ducts used to distribute energy.

DHW - Domestic Hot Water

Dormer - A framed structure projecting above a sloping roof surface, and normally containing a vertical window.

Draft diverter - A device built into an appliance or made a part of the vent connector for an appliance that is designed to: 1) provide for the ready escape of the flue gasses from the appliance in the event of no draft, backdraft, or stoppage beyond the draft hood, 2) prevent a backdraft from entering the appliance, and 3) neutralize the effect of stack action of the chimney or gas vent upon the operation of the appliance.

Drywall - Gypsum interior wallboard used to produce a smooth and level interior wall surface and to resist fire. Also called gypsum wallboard and sheetrock.

Dry bulb temperature - Normal ambient air temperature measured by a thermometer.

DTL – See Depressurization Tightness Limit.

Duct blower - A blower-door-like device used for testing duct leakiness and air flow.

Duct zone - A building space or cavity that contains heating or cooling ducts.

- E -

Eave - The part of a roof that projects beyond its supporting walls. See also soffit.

Efficiency - The ratio of output divided by input.

Efficacy - The number of lumens produced by a watt used for lighting a lamp. Used to describe lighting efficiency.

Electric service - The electric meter and main switch, usually located outside the building.

Emittance - The rate that a material emits radiant energy from its surface. Also called emissivity.

Encapsulation - Any covering or coating that acts as a barrier between the hazard (i.e. lead-based paint) and the environment, the durability of which relies on adhesion and the integrity of existing bonds between any existing layers (i.e. paint) and the substrate.

Enclosure - The use of rigid, durable construction materials that are mechanically fastened to the substrate to act as a barrier between the hazardous material (i.e. lead-based paint) and the environment.

Energy - A quantity of heat or work.

Energy audit - The process of identifying energy conservation opportunities in buildings.

Energy consumption - The conversion or transformation of potential energy into kinetic energy for heat, light, electricity, etc.

Energy efficiency - Term describing how efficiently a building component uses energy.

EEM - Energy efficiency measure.

Energy efficiency ratio (EER) - A measurement of energy efficiency for room air conditioners. The EER is computed by dividing cooling capacity, measured in British Thermal Units per hour (Btuh), by the watts of power. (See also Seasonal Energy Efficiency Rating - SEER)

Envelope - The building shell. The exterior walls, floor, and roof assembly of a building.

Environmentally sensitive - A person who is highly sensitive to pollutants, often because of overexposure, is said to be environmentally sensitive.

Evaporation - The process of being changed into a vapor or gas at a temperature usually below the boiling point. Evaporation is a cooling process.

Evaporative cooler - A device for cooling homes in dry climates that cools the incoming air through the evaporation of water.

Evaporator - The heat transfer coil of an air conditioner or heat pump that cools the surrounding air as the refrigerant inside the coil evaporates and absorbs heat.

Exacerbate - To aggravate or make worse.

Exfiltration - Air flowing out of a building from its conditioned space through the holes in the shell.

- F -

Fahrenheit - A temperature scale for which water boils at 212° and freezes at 32°.

Fan control - A bimetal thermostat that turns the furnace blower on and off as it senses the presence of heat.

Fan-off temperature - In a furnace, the supply air temperature at which the fan control shuts down the distribution blower.

Fan-on temperature - In a furnace, the supply air temperature at which the fan control activates the distribution blower.

Feeder wires - The wires connecting the electric meter and main switch with the main panel box indoors.

Fenestration - Window and door openings in a building's wall.

Fiberglass - A fibrous material made by spinning molten glass.

Fill tube - A plastic or metal tube used for its stiffness to blow insulation inside a building cavity and allows the insulation to be delivered at the extreme end of the cavity.

Fire stop - Framing member, usually installed horizontally between studs, designed to stop the spread of fire within a wall cavity.

Furring - Thin wood strips fastened to a wall or ceiling surface as a nailing base for finish materials.

Flame safety control - A control for avoiding fuel delivery in the event of no ignition.

Flammable/Inflammable - Combustible; readily set on fire.

Flashing - Waterproof material used to prevent leakage at intersections between the roof surface at walls or penetrations.

Floor joists - The framing members that support the floor.

Flue - A vent for combustion gases.

Foam board - Plastic foam insulation manufactured most commonly in 4' x 8' sheets in thicknesses of ½" to 3".

Foot-candle - A measure of light striking a surface.

Footing - The part of a foundation system that transfers the weight of the building to the ground.

Frost line - The maximum depth of the soil where water will freeze during the coldest weather.

- G -

Gable - The triangular section of an end wall formed by the pitch of the roof.

Gable roof - A roof shape that has a ridge at the center and slopes in two directions.

GAMA - Gas Appliance Manufacturers' Association

Gasket - Elastic strip that seals a joint between two materials.

General heat waste – Weatherization measures for which savings or savings-to-investment ratios (SIR) are difficult or impossible to calculate. Examples include all air sealing work, ductwork sealing and insulation, pipe insulation, and dryer vent kit installation. No SIR values are required for these measures.

Glazing - Glass installation. Pertaining to glass assemblies or windows.

Glazing compound - A flexible, putty-like material used to seal glass in its sash or frame.

Gypsum board - A common interior sheeting material for walls and ceilings made of gypsum rock powder packaged between two sheets of heavy building paper. Also called sheetrock, gyprock, or gypboard.

Ground Fault Circuit Interrupter (GFI or GFCI) - An electrical connection device that breaks a circuit if a short occurs. These are required for all exterior use of electrical equipment or when an electrical outlet is located near a water source.

- H -

Hazardous condition - A situation that is causing a danger to the client/crew/contractor that exists before, is created by, or is exacerbated by, weatherization. For example, a dwelling could have a moisture problem that is allowing biological hazards (molds, viruses, bacteria, etc.) to flourish. Another example would be allowing fiberglass to enter the living space due to improperly fastened or sealed ductwork.

Hazardous material - A particular substance that is considered a danger to the client/crew/contractor.

HHS - United States Department of Health and Human Services

Heat anticipator - A very small electric heater in a thermostat that causes the thermostat to turn off before room temperature reaches the thermostat setting, so that the house does not overheat from heat remaining in the furnace and distribution system after the burner shuts off.

Heat capacity - The quantity of heat required to produce a unit of temperature change.

Heat exchanger - The area in a heating unit that separates the combustion process from the distribution fluid, with the sole purpose of transferring heat from the combustion process to the distribution fluid.

Heat loss - The amount of heat escaping through the building shell during a specified period.

Heat pump - A type of heating/cooling unit, usually electric, that uses a refrigerant fluid to heat and cool a space.

Heat rise - In a furnace, the number of degrees of temperature increase that air is heated as it is blown over the heat exchanger. Heat rise equals air supply temperature minus air return temperature.

Heating degree day (HDD) - Each degree that the average daily temperature is below the base temperature (usually 65°F) constitutes one heating degree day.

Heating load - The maximum amount of heat needed by a building during the very coldest weather to maintain the designed inside temperature.

Heating seasonal performance factor (HSPF) - Rating for heat pumps describing how many Btus they transfer per kilowatt-hour of electricity consumed.

HVAC - Heating, Ventilating, Air-Conditioning

High limit - A bimetal thermostat that turns the heating element of a furnace off if it senses a dangerously high temperature.

Hip Roof - A roof that slants in four directions from a central peak.

Home energy index - The number of Btus of energy used by a home divided by its area of conditioned square feet and by the number of heating degree days during one year.

HVI - Home Ventilating Institute

WAP - Home Weatherization Assistance Program

House pressure - The difference in pressure between the inside and outside of the house.

HUD - United States Department of Housing and Urban Development

Humidistat - An automatic control that switches a fan, humidifier, or dehumidifier on and off based on the relative humidity at the control.

Humidity ratio - The absolute amount of air's humidity measured in pounds of water vapor per pound of dry air.

Hydronic - A heating system using hot water or steam as the heat-transfer fluid. A hot-water heating system (common usage).

- I -

Illumination - The light level measured on a horizontal plane in foot-candles.

Incandescent light - The common light bulb found in residential lamps and light fixtures and sold in stores everywhere that is known for its inefficiency.

IAQ - Indoor Air Quality

Infiltration - The uncontrolled movement of non-conditioned air into a conditioned air space.

Infrared - Pertaining to heat rays emitted by the sun or warm objects on earth.

Ingestion - Ingestion is the process by which a substance enters the body by swallowing through the mouth. The best defense is to wash your hands before eating or putting your fingers in your mouth, keeping hazardous materials out of

reach from small children, and guarding against splashing of hazardous materials into your mouth.

Inhalation - Inhalation is the process by which a substance is breathed into the body in the form of a gas, vapor, fume, mist, or dust. The best defense is to use a proper filter to remove these contaminants before they enter the body or to not create dust if possible.

Input rating - The designed capacity of an appliance usually specified in Btus or units of energy.

Insulating glass - Two or more glass panes spaced apart and sealed in a factory giving a higher R-value.

Insulation - A material used to retard heat transfer.

Intermittent ignition device (IID) - A device that lights the pilot light on a gas appliance when the control system calls for heat, thus saving the energy wasted by a standing pilot.

Internal gains - The heat generated by bathing, cooking, and operating appliances that must be removed during the summer to promote comfort or will reduce the heating demand in the winter.

Interstitial - Space between framing and other building components.

- J -

Joist - A horizontal wood framing member that supports a floor or ceiling.

Joule - A unit of energy. One thousand joules equals 1 Btu.

- K -

Kilowatt - One thousand watts. A unit of measurement of the amount of electricity needed to operate given equipment.

Kilowatt-hour - The most commonly used unit for measuring the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour.

Kinetic energy - Consisting of or depending on motion; distinguished from potential energy.

- L -

Lamp - A light bulb.

Latent heat - The amount of heat energy required to change the state of a substance from a solid to a liquid or from a liquid to a gas without changing the temperature of the substance.

Lath - A thin strip of wood or base of metal or gypsum board serving as a support for plaster.

Light quality - Good light quality is characterized by absence of glare and low brightness contrast.

Living space – A space in a dwelling that is lived in or regularly occupied. This space may be conditioned or unconditioned.

Low-water cutoff - A float-operated control for turning the burner off if a steam boiler is low on water.

Lumen - A unit of light output from a lamp.

Low-E - Short for low emissivity, which refers to the characteristic of a metallic glass coating to resist the flow of radiant heat.

- M -

Main panel box - The service box containing a main switch, and the fuses or circuit breakers located inside the home.

Make-up air - Air supplied to a space to replace exhausted air.

Manifold - A tube with one inlet and multiple outlets or multiple inlets and one outlet.

Manometer - A pressure differential gauge used for measuring gas and air pressures.

MHEA - Manufactured Housing Energy Audit, developed by DOE for WAP. Used to audit mobile homes.

Masonry - Construction of stone, brick, or concrete block.

Mastic - A thick creamy substance used to seal seams and cracks in building materials and especially useful on ductwork.

MSDS - Materials Safety Data Sheet

Metabolic process - Chemical and physiological activities in the human body.

Mitigate - To make less severe.

Mortar - A mixture of sand, water, and cement used to bond bricks, stones, or blocks together.

- N -

NBS - The National Bureau of Standards, Department of Commerce renamed the National Institute of Standards and Technology (NIST).

NEMA - National Electrical Manufacturers' Association

NEAT - National Energy AudiT, developed by DOE for WAP. Used to audit single-family and low-rise multi-family buildings.

NFPA - National Fire Protection Association.

NWMA - National Woodwork Manufacturers Association.

Net Free Vent Area (NFVA) - The area of a vent after that area has been adjusted for the restrictions caused by insect screen, louvers, and weather coverings. The free area is always less than the actual area.

Natural ventilation - Ventilation using only natural air movement, without fans or other mechanical devices.

Non-conditioned space - An area within the building envelope that is not heated or cooled and tends to be the same temperature as outside.

Nozzle - An orifice designed to change a liquid like oil into a mist to improve the combustion process.

- O -

O_2 - Oxygen.

Ohm - A unit of measure of electrical resistance. One volt can produce a current of one ampere through a resistance on one ohm.

Orifice - A hole in a gas pipe where gas exits the pipe to be mixed with air in a burner before combustion in a heating device. The size of the orifice will help determine the flow rate.

OTL – See Overall Tightness Limit.

Output capacity - The conversion rate of useful heat or work that a device produces after waste involved in the energy transfer is accounted for.

Overall Tightness Limit (OTL) – The OTL is expressed in units of $CFM_{50.}$ The OTL considers both the building tightness limit and the DTL. For example, if the building tightness limit is 1300 CFM_{50} and the DTL is 1400 CFM_{50}, the OTL for the house is 1400 CFM_{50}, satisfying both the building tightness limit and the DTL.

Oxygen Depletion Sensor (ODS) - A safety device for unvented (vent-free) combustion heaters that shuts off gas when oxygen is depleted.

- P -

Parts per million (ppm) - The unit commonly used to represent the degree of pollutant concentration where the concentrations are small.

Pascal (Pa) - A metric unit of measurement of air pressure. 2.5Pa = 0.01 inches of water column.

Payback period - The number of years that an investment in energy conservation will take to repay its cost in energy savings.

Perimeter Pull - A technique used in attics previously insulated with batt insulation. The batts are cut back 2 feet from the eaves and the area is insulated with blown insulation to ensure coverage over the outer wall top plate and to prevent wind washing of the insulation under the existing batts.

Perlite - A heat-expanded mineral used for insulation.

Perm - A measurement of how much water vapor a material will let pass through it per unit of time under a specified pressure difference.

Pilot Tube - A device for measuring fluid velocity. An instrument placed in a moving fluid and used along with a manometer to measure fluid velocity.

Plaster - A plastic mixture of sand, lime, and Portland cement spread over wood or metal lathe to form the interior surfaces of walls and ceilings.

Plate - A piece framing member installed horizontally to which the vertical studs in a wall frame are attached.

Plenum - The section of ductwork that connects the air handler to the main supply duct.

Plywood - Laminated wood sheeting with layers cross grained to each other.

Polyethylene - A plastic made by the polymerization of ethylene, used in making translucent, lightweight, and tough plastics, films, insulations, vapor retarders, air barriers, etc.

Polyisocyanurate - Plastic foam insulation sold in sheets, similar in composition to polyurethane.

Polystyrene insulation - rigid plastic foam insulation, usually white, blue, pink, or green in color.

Polyurethane - versatile plastic foam insulation, usually yellow in color.

Potential energy - Energy in a stored or packaged form.

Pressure - A force that encourages movement by virtue of a difference in some condition between two areas. High pressure moves to low pressure.

Pressure diagnostics - The practice of measuring pressures and flows in buildings to control air leakage, and to ensure adequate heating and cooling airflows and ventilation.

Pressure pan - A device used to block a duct register, while measuring the pressure behind it.

Pressure Relief Valve - A safety component required on a boiler and water heater, designed to relieve excess pressure buildup in the tank.

Pressuretrol - A control that turns a steam boiler's burner on and off as steam pressure changes.

Primary window - The main window installed on the outside wall. Not to be confused with a storm window.

Provider - Either a grantee or contractor.

- R -

R-value - A measurement of thermal resistance.

Radiant barrier - A foil sheet or coating designed to reflect radiant heat flow. Radiant barriers are not mass insulating materials.

Radiant temperature - The average temperature of objects in a home, including walls, ceiling, floor, furniture, and other objects.

Radiation - Heat energy that is transferred by electromagnetic or infrared light from one object to another. Radiant heat flow can travel through a vacuum and other transparent materials.

Radon - A radioactive gas that decomposes into radioactive particles.

Rafter - A beam that gives form and support to a roof.

Rated ventilation - A ventilation system that has been designed and installed under the guidelines established by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard for Acceptable Indoor Air Quality (Standard 62).

Reflectance - The ratio of lamination or radiant heat reflected from a given surface to the total light falling on it. Also called reflectivity.

Refrigerant - Any of various liquids that vaporize at a low temperature, used in mechanical refrigeration.

Register - A grille covering a duct supply outlet used to diffuse the airflow and sometimes control the flow.

Relative humidity - The percent of moisture present in the air compared to the maximum amount possible at that given temperature. Air that is saturated has 100% relative humidity.

Relay - An automatic, electrically operated switch.

Reset controller - Adjusts fluid temperature or pressure in a central heating system according to outdoor air temperature.

RCS - Residential Conservation Service Program

Resistance - The property of a material resisting the flow of electrical energy or heat energy.

Retrofit - An energy conservation measure that is applied to an existing building. Also means the action of improving the thermal performance or maintenance of a building.

Return air - Air circulating back to the furnace or central air conditioning unit from the house, to be heated or cooled and supplied back to the living area.

Rim joist - The outermost joist around the perimeter of the floor framing.

Rocking on the High Limit– Refers to the gas burner being shut down by the high limit switch on a furnace, instead of being properly activated by the fan-on/fan-off control.

Room air conditioner - A unitary air conditioner installed through a wall or window, which cools the room by removing heat from the room and releasing it outdoors.

- S -

Sash - A movable or stationary part of a window that frames a piece of glass.

Savings-to-Investment Ratio (SIR) – For an energy saving measure, the ratio of the savings over the investment (cost), including the discounting the investment value and escalation of fuel costs.

Sealed-combustion appliance - An appliance that draws combustion air from outdoors and has a sealed exhaust system. Also called a direct-vent appliance.

Seasonal energy efficiency ratio (SEER) - A measurement of energy efficiency for central air conditioners. The SEER is computed by dividing cooling capacity, measured in Btuh, by the Watts. (See also Energy Efficiency Rating.)

Sensible heat - The heat required to change the temperature of a material without changing its form.

Sequencer - A bimetal switch that turns on the elements of an electric furnace in sequence.

Service wires - The wires coming from the utility transformer to the service equipment of the building.

Sheathing - structural sheeting, attached on top of the framing, underneath siding and roofing of a building. Any building material used for covering a building surface.

Sheetrock - See drywall.

Shell - The building's exterior envelope—walls, floor, and roof of a building.

Shingle - A modular roofing component installed in overlapping rows.

Short circuit - A dangerous malfunction in an electrical circuit, where electricity is flowing through conductors and into the ground without going through an electric load, such as a light or motor.

Sill - The bottom of a window or doorframe.

Sill box - The area bounded by the rim joist, floor joists, sill plate, and floor.

Site-built home – Includes a house built on the site from building supplies or manufactured homes assembled on the site from pieces shipped to the site on flatbed trucks. Does not include mobile homes and double-wides.

Sling psychrometer - A device holding two thermometers, one wet bulb and one dry bulb, which is slung through the air to determine relative humidity.

Slope - The roof section of a knee wall attic with the roof and ceiling surfaces attached to the rafters.

Soffit - The underside of a roof overhang or a small lowered ceiling, as above cabinets or a bathtub.

Solar gain - Heat from the sun that is absorbed by a building.

Solenoid - A magnetic device that moves a switch or valve stem.

Space heating - Heating the living spaces of the home with a room heater or central heating system.

Spillage - Temporary flow of combustion gases from a dilution device.

Stack effect - The tendency for warm buoyant air to rise and leak out of the top of the house and be replaced by colder outside air entering from the bottom of the house.

Steady-state efficiency (SSE) - The efficiency of a heating appliance, after an initial start-up period and while the burner is operating, that measures how much heat crosses the heat exchanger. The steady-state efficiency is measured by a combustion analyzer.

Steam trap - An automatic valve that closes to trap steam in a radiator until it condenses.

Steam vent - A bimetal-operated air vent that allows air to leave steam piping and radiators, but closes when exposed to steam.

Stud - A vertical framing member used to build a wall.

Sub floor - The sheathing over the floor joists and under the flooring.

Supply air - Air that has been heated or cooled and is then moved through the ducts and out the supply registers of a home.

Suspended ceiling - Modular ceiling panels supported by a hanging frame.

- T -

Technical Waiver -

Therm - A unit of energy equivalent to 100,000 Btus or 29.3 kilowatt-hours.

Thermal break - A piece of relatively low conducting material between two high conducting materials installed to reduce heat flow through the assembly.

Thermal bridging - Rapid heat conduction resulting from direct contact between thermally conductive materials like metal and glass.

Thermal bypass - An indirect penetration that tends to reduce the effectiveness of insulation by allowing conditioned air to move out of a structure, or allowing unconditioned air to move in, depending on the exerted pressures.

Thermal conductance - A material’s ability to transmit heat; the inverse of the R-value.

Thermal resistance - Same as R-value, expressing ability to retard heat flow.

Thermocouple - A bimetal-junction electric generator used to control the safety valve of an automatic gas valve.

Thermostat - A device used to control a heating or cooling system to maintain a set temperature.

Transformer - A double coil of wire that reduces or increases voltage from a primary circuit to a secondary circuit.

Truss - A braced framework usually in the shape of a triangle to form and support a roof.

- U -

U-factor - The total heat transmission in Btus per square feet per hour with a 1°F temperature difference between the inside and the outside; the thermal conductance of a material.

Ultraviolet radiation - Light radiation having wavelengths beyond the violet end of the visible spectrum; high frequency light waves.

Underlayment - Sheeting installed to provide a smooth, sound base for a finish material.

UL - Underwriter's Laboratory

- V -

Vapor barrier - A material that retards the passage of water vapor.

Vapor diffusion - The flow of water vapor through a solid material.

Vapor retarder - A vapor barrier.

Vaporize - Change from a liquid to a gas.

Vent damper - An automatic damper powered by heat or electricity that closes the chimney while a heating device is off.

Ventilation - The movement of air through an area for removing moisture, air pollution, or unwanted heat.

Venting - The removal of combustion gases by a chimney.

Vermiculite - A heat-expanded mineral used for insulation.

Volt - A unit of electromotive force. It is the amount of force required to drive a steady current of one ampere through a resistance of one ohm. Electrical systems of most homes in the United States have 120 volt systems.

- W -

Watt (W) - A unit measure of electric power at a point in time, as capacity or demand. One Watt of power maintained over time is equal to one joule per second.

Watt-hour - One Watt of power extended for one hour. One thousandth of a kilowatt-hour

Weatherization - The process of reducing energy consumption and increasing comfort in buildings by improving energy efficiency of the building and maintaining health and safety.

Weatherstripping - Flexible gaskets, often mounted in rigid metal strips, for limiting air leakage.

Weep holes - Holes drilled for allowing water to drain out of an area in a building component where it may accumulate.

Wet bulb temperature - The temperature of a dampened thermometer of a sling psychrometer used to determine relative humidity.

Window films - Plastic films, coated with a metalized reflective surface that are adhered to window glass to reflect infrared rays from the sun.

Window frame - The sides, top, and sill of the window, which form a box around window sashes and other components.

Worst-Case Depressurization - A condition created when 1) all exhaust appliances (bathroom exhaust, kitchen exhaust, vented dryers, etc.) are operating, 2) the interior doors of a house are in a position that causes the greatest negative pressure in the CAZ, and 3) the furnace air handler is operating if such operation causes increased negative pressure in the CAZ.

Worst-Case Draft Test - A test which creates Worst-Case Depressurization in a Combustion Appliance Zone (CAZ). This test is used to determine if combustion appliances will vent properly under these worst-case conditions.