

HOUSING ENERGY- EFFICIENCY INSPECTION FIELD MANUAL

CONTENTS

PREFACE	2
ACKNOWLEDGMENTS	2
DISCLAIMER	2
REFERENCES	2
OBJECTIVE	3
INFILTRATION INSPECTION	4
FOUNDATION AND FLOOR INSULATION	5
WALL INSULATION	5
ATTIC INSULATION	6
INFILTRATION AND VAPOR BARRIERS	7
WINDOWS AND DOORS	8
INFILTRATION TESTING	8
DUCT INSPECTION	9
DUCT TESTING	10
GAS-FIRED FURNACES AND BOILERS	11
HEAT PUMPS AND AIR CONDITIONERS	12
WATER HEATING	12
APPLIANCES, LIGHTING, AND VENTILATION FANS . . .	13
APPENDIX A	
ENERGY-EFFICIENCY CHECKLIST	14

HOUSING ENERGY-EFFICIENCY INSPECTION FIELD MANUAL

By Mark P. Ternes and Sherry E. Livengood, Oak Ridge National Laboratory

PREFACE

This field manual provides guidance on energy-efficiency-related materials and installation standards for field inspections of military family housing. The manual references procedures, standards, and general information found in the two companion guides listed in the References (p. 4) and the Proposed Rule 10 CFR Part 435, Energy Efficiency Code for New Federal Residential Buildings. The construction inspector on new construction, revitalization, and retrofit projects for military family housing is responsible for verifying that specified energy-efficiency measures are correctly installed according to contract drawings and specifications. The inspector must be thoroughly familiar with the project's drawings and specifications and be prepared to perform the inspections and oversight of specified tests. The inspector's role is essential to achieving energy efficiency in military family housing. Improperly installed energy-efficient materials and equipment will fail to achieve optimal energy savings. The two companion guides may be used to obtain further information on energy-efficiency measures and procedures.

ACKNOWLEDGMENTS

This manual was prepared for the following offices:

Air Force Program Management Offices
Army Program Management Offices
Headquarters United States Air Force
U.S. Army Installation Management
Office of The Civil Engineer
Facilities and Housing Directorate
Housing Division
Army Housing Division
DSN 227-0157 Facility Programs Branch
(703) 697-0157 DSN 328-8936
Air Force Civil Engineer Support Agency
U.S. Army Center for Public Works
Civil Engineer Technical Support
Mechanical and Energy Division
DSN 523-6361 DSN 656-6111
(904) 265-6361 (703) 806-6111
(703) 428-8936

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process

disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States. The guidelines presented in this manual are recommendations only and do not supersede any applicable energy conservation, building code, or other military requirements. The reader is responsible for determining the applicable requirements and implementing the program in compliance with these requirements.

REFERENCES

M. P. Ternes, R. L. Wendt, J. O. Kolb, and S. Scully, Design Guide for Military Family Housing: Energy-Efficient Revitalization and New Construction (Design Guide), prepared for the Headquarters United States Air Force, Office of The Civil Engineer, Housing Division, and the Air Force Civil Engineer Support Agency, Civil Engineer Technical Support, by Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 1996.

R. L. Wendt, M. P. Ternes, L. A. O'Leary, P. I. Berkowitz, E. M. Carrol, S. M. Harmelink, and L. V. Hasterok, Retrofit Guide for Military Family Housing: Energy-Efficient Weatherization and Improvements (Retrofit Guide), prepared for the Headquarters United States Air Force, Office of The Civil Engineer, Housing Division; the Air Force Civil Engineer Support Agency, Civil Engineer Technical Support; and the U.S. Army Installation Management, Facilities and Housing Directorate, Army Housing Division, Facility Programs Branch, by Oak Ridge National Laboratory, Oak Ridge, Tennessee, January 1997.

OBJECTIVE

The objective of this manual is to identify the important energy-efficiency features that an inspector should examine during field inspection of military family housing and to define a correct or standard-of-practice installation for the inspector. The manual was designed specifically for use on construction projects that followed the guidance provided in the Design Guide listed in the References, although the manual is a useful reference in conducting energy inspections for projects developed following the Retrofit Guide (see References) or for any other housing construction project. The manual also incorporates requirements made by the Proposed Rule 10 CFR Part 435, Energy Efficiency Code for New Federal Residential Buildings.

Contract drawings and specifications are the final authority on construction requirements. The appendix at the end of this manual is a checklist for recording energy-efficiency inspections.

INFILTRATION INSPECTION

In new detached housing units or in detached units for which revitalization entails gutting throughout, contract specifications should require infiltration performance testing to verify that the contractor met specified infiltration performance criteria (see INFILTRATION TESTING). For all units that do not require performance testing, visual inspections must be performed to verify that approved materials for minimizing infiltration were used and were installed according to required procedures.

Infiltration inspections must be performed during two phases of house construction in order to observe the installation of all sealing materials: (1) during and after framing but before insulation and drywall are installed, and (2) after drywall is installed. Inspections before insulation and drywall are installed are critical because these materials cover infiltration leakage sites and make them difficult to detect visually.

Appendix D of the Design Guide provides examples and discussion of significant leakage sites and general information about envelope air leakage.

All joints, openings, and penetrations should be sealed with appropriate materials. The inspector must first identify the infiltration reduction materials and procedures specified in the construction plans. Visual inspections should focus on whether these specifications are met as well as on whether installation of materials is according to standard practice. Some inspection items include sealing in the following areas using caulk, foam, or other materials, as specified. Before drywall is installed:

- between the bottom wall plate and subflooring using caulk or felt pads (Fig. A)
- the inside edge of the bottom wall plate (Fig. A)
- behind and around bathtubs before setting the bathtubs, using plastic or other sheet goods (Figs. B and E)
- windows and doors into rough openings using backer rod (Fig. E)
- wiring and plumbing penetrations at the top and bottom wall plates, ceilings, and floors (Fig. E)

After drywall is installed:

- bathtub drain penetrations using foam and/or rigid boards (Fig. B)
- plumbing pipes, medicine cabinets, and electrical boxes (e.g., receptacles, switches, lights, and circuit breaker box) to drywall (Fig. E)
- bathroom ventilation fan to drywall (Fig. E)
- attic bypasses and chases (e.g., duct and flue chases, open partition walls, and dropped-ceiling soffits, especially in hallways and for kitchen cabinets) (Fig. C)
- around the perimeter of attic access hatches or pull-down stairs, with weatherstripping (Fig. D)
- exterior penetrations (e.g., porch light fixtures, outside outlets, and phone and electric service holes) (Fig. C)
- floors of second-story overhangs or second-story floors that are over porches, garages, and other unconditioned areas (Fig. F)

FOUNDATION AND FLOOR INSULATION

The inspector must determine the type and amount (R-value) of insulation specified in the construction plans. Insulation materials should be inspected upon delivery to determine that they are the type and amount that were approved for use. Insulation materials should be stored according to the manufacturer's recommendations to prevent moisture damage. Section 4.2.4 of the Design Guide discusses installation techniques for foundation and floor insulation, especially insulation of crawl space or basement walls.

A visual inspection of foundation and floor insulation should be performed to verify that:

- the correct type of insulation was installed
- the correct amount of insulation was installed (the R-value should be identified on the insulation, or certification of R-value should be posted at the work site)
- the insulation was installed in the specified locations
- the insulation was installed according to specifications and manufacturer's instructions
- coverage of the insulation was complete:
- insulation of slab-on-grade foundations should be flush with the top of the slab
- floors of second-story overhangs or second-story floors that are over porches, garages, and other unconditioned areas must be insulated (Fig. F)

If batt insulation is installed under floors, the inspector should also verify that:

- batts were cut to fit around wiring, piping, and plumbing to prevent overcompression and incomplete coverage
- batts were installed flush against floor joists and framing members (Fig. G)
- insulation supports (support wires, chicken wire, etc.) were correctly installed. Supports should not overcompress floor insulation and should keep the batts flush against the subfloor. Support rods should be placed every 12 to 18 inches (Fig. G).
- the vapor barrier (if present) is flush against the floor (for cold climate)

A contractor insulating a crawl space should also have:

- placed a vapor barrier (6 mil plastic cover minimum) on the crawl space floor after application of termite protection
- overlapped the foundation with the vapor barrier
- overlapped vapor barrier joints

WALL INSULATION

The inspector must determine the type and amount (R-value) of insulation specified for installation in the construction plans. Insulation materials should be inspected upon delivery to determine that they are the type and amount that were approved for use. Insulation materials should be stored according to the manufacturers recommendations to prevent moisture damage.

A visual inspection of wall insulation should be performed to verify that:

- the correct type of insulation was installed
- the correct amount of insulation was installed. The R-value should be identified on the insulation, or certification of the R-value should be posted at the work site.

If blown-in insulation was used, the inspector should count the bags used at each housing unit to ensure that the quantity specified was installed.

- the insulation was installed in the specified locations
- the insulation was installed according to specifications and manufacturer's instructions
- coverage of the insulation was complete
- insulation was installed around windows and doors, at corners where exterior walls meet, at tees where interior walls meet exterior walls, and at other framing junctions which often have hidden pockets where insulation can be easily overlooked
- insulation was installed in walls next to unconditioned areas (e.g., garages, mechanical rooms, storage rooms, or garbage areas)
- insulation was installed in exterior walls behind tubs (Fig. H)
- rigid insulation (if specified) was installed between inside and outside headers over doors and windows (Fig. E)

For walls in which batt insulation was installed, the inspector should also verify that:

- batts were not overcompressed during installation
- correct lengths were used (Fig. I)
- batts that have the facing placed toward the inside of the housing unit (typical of cold climates) were stapled to the front of the studs rather than the side (Fig. I). (Many contractors prefer stapling batts to the side of the stud because it makes drywall installation easier, but stapling to the front of the stud compresses the batts less and increases the effectiveness of the insulation.)
- the insulation was cut to fit closely around piping and wiring rather than compressing the insulation around them (Fig. I)

ATTIC INSULATION

The inspector must determine the type and amount (R-value) of insulation specified for installation in the construction plans. Insulation materials should be inspected upon delivery to determine that they are the type and amount that were approved for use. Insulation materials should be stored according to the manufacturer's recommendations to prevent moisture damage.

An inspection of attic (ceiling) insulation should be performed to verify that:

- the correct type of insulation was installed
- the correct amount of insulation was installed (the R-value should be identified on the insulation or certification of the R-value should be posted at the work site)
- the insulation was installed in the specified locations
- the insulation was installed according to specifications and manufacturer's instructions
- coverage of the insulation was complete
- attic access hatches were insulated (Fig. J)

Inspectors should be careful not to cause undue compression of insulation during inspection.

If blown-in insulation was used, the inspector should count the bags used at each housing unit to ensure that the quantity specified was installed. For blown-in insulation, certificates must be posted at the site stating initial installed thickness, settled thickness, coverage area, and number of bags installed. The inspector should verify that depth sticks were used and properly installed. Depth sticks show that insulation was adequate and even. They should be affixed to joists or trusses, accurately measure distance from the attic floor, and face the attic access hatch. If depth sticks were not used, the inspector should measure the specified thickness from the attic floor to ensure that the correct amount of insulation was installed. (As an alternative to post-installation measurement of insulation depths, the inspector can mark the vertical truss members in several locations prior to installation of attic insulation. When insulation is installed, the inspector can verify that the marks were covered.) The inspector should also verify the following if blown-in insulation was used:

- The contractor blocked around flue pipes, recessed lights, exhaust fans, whole-house fans, electrical junction boxes, and chimneys (Fig. K). Attic equipment is usually labeled with proper clearances for blocking.
- Soffit dams and rafter baffles were installed prior to the insulation installation to prevent insulation from blocking soffit vents (Fig. L).

If batt insulation was used, the inspector should verify that:

- insulation fits flush against framing members
- the contractor used rafter baffles
- the contractor has installed insulation to cover the outside walls without overcompressing the insulation or covering soffit vents
- the contractor has placed the vapor barrier backing (if present) against the attic floor (for heating climates)

If new insulation was added to existing insulation, the inspector should verify that the contractor did not install a vapor barrier between the existing and the new insulation.

INFILTRATION AND VAPOR BARRIERS

If a vapor retarder (e.g., kraft paper facing on batts or polyethylene sheeting) is specified, the inspector should verify that it is installed where shown on drawings or where specified. In northern climates, vapor barriers are typically installed on the warm-in-winter side of insulation.

If installation of polyethylene sheeting at the inside face of the studs was specified, the inspector should verify that (Fig. M):

- the polyethylene covered the entire interior surface of the outside walls
- the polyethylene was sealed with a continuous bead of adhesive caulk at the top and bottom plates, around windows, and around pipe and wiring penetrations
- joints overlapped over one stud cavity and were caulked or taped at the overlap
- all rips and tears were repaired with tape

If specifications call for housewrap to be installed underneath the exterior finish, verify that (Fig. N):

- housewrap covered the entire wall surface, starting below the bottom wall plate and extending up to cover the top plate
- the edges of the housewrap were sealed with a continuous bead of caulk or tape approved by the housewrap manufacturer at the top and bottom plates and at all openings
- plastic-capped nails were used to mechanically hold the housewrap to the house
- all joints were overlapped and caulked or taped with housewrap tape
- diagonals were cut at windows, doors, and other openings, with triangular pieces folded inside the opening and sealed with approved tape or caulk
- all cuts and openings in the housewrap were sealed

WINDOWS AND DOORS

The inspector should check the following items to ensure correct installation of all new doors and windows:

- rough window and door openings were sized correctly for the new window or door units
- installed windows and doors matched windows and doors specified in the construction plans (check the U-value and infiltration rate of windows to see that they are less than or equal to the specified maximum values)
- windows and doors were installed according to manufacturer's instructions and specifications in the construction plans
- thresholds were installed on all doors and adjusted correctly
- the contractor applied caulk or sealant between the threshold and the floor
- the contractor installed weatherstripping correctly if weatherstripping was not applied at the factory

INFILTRATION TESTING

If infiltration testing is required in the construction specifications, the inspector should make sure that the contractor performs the tests correctly and that test results indicate that infiltration is below specified rates. Typically, testing will be required in new-detached housing units, in detached units for which revitalization entails gutting throughout, or in some other special instances. For units that do not require performance testing, only visual inspections must be performed (see INFILTRATION INSPECTION).

The contractor must verify that the units meet specified performance criteria (infiltration rates between minimum and maximum values) by conducting (or having a qualified blower door contractor conduct) specified testing procedures such as those described in Appendix C of the Design Guide. The inspector should know the specified testing procedures, observe the tests to see that they are performed according to the procedures, and verify that the units comply with the performance criteria (with minimum and maximum requirements).

The infiltration tests must be performed with the housing unit in a functionally complete condition (e.g., interior drywall completed, plumbing and electrical fixtures installed, windows hung, exterior doors installed, and ductwork installed). Temporary sealing of leakage sites to accommodate unfinished construction is forbidden.

Several key elements that an inspector should review during the infiltration test procedure include verifying that:

- the unit is functionally complete
- the house is properly prepared for testing
- no leakage sites are temporarily sealed
- the pressures and/or airflows indicated by the blower door gauges during testing are recorded properly on the measurement form and used in the analysis program (listed on the analysis printout)
- the flow exponent, the correlation coefficient, the percentage error in the flow data, and relative standard errors listed on the analysis printout (see Fig. O, for example) conform to the accuracy standards listed in the contract specifications or as indicated below
- the flow exponent (n) is greater than 0.5 and less than 1.0
- the correlation coefficient (r) is greater than 0.990
- the percentage error in the flow data at each pressure station is less than 5%
- the relative standard error of the estimated flow at 10 Pa is less than 10%
- the calculation of the natural air changes per hour is correct on the measurement form

If tests determine that the infiltration rate for a unit does not meet performance criteria, the contractor is required to make corrections and retest until acceptable rates are achieved (see Section 5.3 of the Design Guide).

DUCT INSPECTION

If ductwork is repaired and/or only portions of the system are to be replaced, deficiencies in the air distribution system and corrective sealing materials and procedures that require a visual inspection should have been specified. New air distribution systems require testing to verify that specified performance criteria are met (see DUCT TESTING).

The inspector should visually verify that the specified sealing materials were properly installed at the specified deficient locations (see Section 5.6 and Appendix F of the Design Guide).

Inspections should concentrate on verifying that:

- repairs were made with mastic and fiberglass tape or other approved material, not with fabric duct tape or tape with rubber-based adhesives
- return plenums were sealed (Fig. P)
- connections to the air handler and holes in the air handler were sealed (Fig. Q)
- connections of ducts to boots were sealed (Fig. R)
- duct boots were sealed to the floor or drywall (Fig. R)

If portions of new duct have been installed, the new ducts should also be inspected to confirm that:

- ducts were fastened together with mechanical fasteners
- all joints, boots, takeoffs, and collars were sealed with mastic and fiberglass tape or other approved material, not with fabric duct tape or tape with rubber-based adhesives (Figs. Q and R)
- flexduct was used only as branch connections to supply registers where space limitations and short-distance runs made installation of metal or fiberboard ducts prohibitively costly or difficult

- flexduct was installed with sufficient supports (at least every 5 feet)
- flexduct was installed with no sharp bends or kinks (bends should never exceed 90° and must have a radius greater than one diameter)
- flexduct was cut to the correct size
- the specified level of duct insulation (R-6 or better) was correctly installed

DUCT TESTING

New air distribution systems must meet specified performance criteria and receive a limited visual inspection. Repair and modification work of existing duct systems should only receive a thorough visual inspection (see DUCT INSPECTION).

The contractor must verify that the units meet the performance criteria (i.e., maximum air leakage of 150 cfm at 50 Pa) by conducting (or having a qualified subcontractor conduct) specified testing procedures such as those described in Appendix E of the Design Guide. The inspector should be familiar with the testing procedures, observe the tests to see that they are performed according to the procedures, and verify that the units comply with the performance criteria.

The air distribution tests must be performed after the duct system has been completely installed.

On sheet metal systems, it is easy to seal leaks found during testing if the testing is performed prior to insulating the ductwork. Key elements that the inspector must review during air distribution system testing include verifying that:

- the duct system is properly prepared for testing
- testing equipment (a duct blower) is set up according to the manufacturer's instructions
- pressures indicated by the (duct blower) gauges during testing are recorded properly on the measurement form
- the calculated airflow rate is consistent with the measured fan pressure and duct blower fan opening configuration

If tests determine that air distribution systems are not constructed within specified limits, the contractor is required to make corrections and retest until acceptable levels are met (see Section 5.7 of the Design Guide).

All new air distribution systems should also be inspected to confirm that:

- ducts were fastened together with mechanical fasteners
- all joints, boots, takeoffs, and collars were sealed with mastic and fiberglass tape or other approved material, not with fabric duct tape or tape with rubber-based adhesives (Figs. Q and R)
- flexduct was used only for branch connections to supply registers where space limitations and short-distance runs made installation of metal or fiberboard ducts prohibitively costly or difficult flexduct was installed with sufficient supports (at least every 5 feet)
- flexduct was installed with no sharp bends or kinks (bends should never exceed 90° and must have a radius greater than one diameter)
- flexduct was cut to the correct size
- the specified level of duct insulation (R-6 or better) was correctly installed

Section 5.6 and Appendix F of the Design Guide provide further information on these elements.

GAS-FIRED FURNACES AND BOILERS

The inspector should verify that new furnaces and boilers are identical to the specified equipment and that any ducted/piped combustion air supply (if installed) is properly labeled. The inspector should check to see that:

- the size of the equipment matches the specified level
- the efficiency of the equipment matches the specified level
- the required warning label for a ducted/piped combustion air supply is affixed and states: Warning: This pipe [duct, vent, etc.] has been installed to provide combustion air for an appliance that burns natural gas, propane gas, fuel oil, or any solid fuel. It should not be modified or obstructed in any way, without first consulting a qualified HVAC contractor or your local building department. Obstruction or improper modification may cause toxic combustion products to be drawn into the living space of the home.

Procedures for commissioning or tuning up new or existing equipment should have been specified for all new or revitalized housing units (see equipment manufacturer's installation instructions and Section 5.5 of the Design Guide). Prior to turnover of the housing units, the contractor must perform these procedures and document this work. The inspector should observe that the specified procedures were followed and retain copies of the documentation.

The inspector should verify that the following activities were completed:

- oxygen concentration and net stack temperature were measured at each burner, initial steady-state efficiency was calculated (on oil-fired systems, efficiency was adjusted for smoke number), and burner was adjusted to maximize steady-state efficiency
- for furnaces, circulation fan off-limit switches and high-limit switches were set in accordance with the manufacturer's requirements or contract specifications (90 to 95°F for off-limit switches and 200 to 250°F for high-limit switches) and the circulation fan on-limit switch was set at the lowest possible temperature setting that avoids cycling of the fan after the burner has shut off (usually 120 to 160°F)
- for boilers, system operating temperatures and high-limit switch settings were set to the manufacturer's standard recommended values
- the carbon monoxide level was measured in each burner after the burner had run continuously for 5 minutes, and the burner was adjusted if the reading was higher than 250 ppm
- carbon monoxide levels were measured in the living area, and if they exceeded 5 ppm, the leakage from the furnace or flue was repaired
- the exit temperature of supply air and the temperature rise across the heat exchanger were measured and were limited to within the specified acceptable ranges (maximum exit temperature usually 160°F and maximum temperature rise of usually 80°F)
- draft measurements were completed according to specified requirements, and it was demonstrated that adequate draft was present and spillage was minimized (usually 0.02 to 0.06 inches of water)

If a more thorough backdrafting test is specified, the inspector should make sure that the contractor performs the testing and that the installed equipment meets the specified requirements.

HEAT PUMPS AND AIR CONDITIONERS

The inspector should verify that new heat pumps and air conditioners are identical to the specified equipment by checking to see that:

- the size of the equipment matches the specified level
- the efficiency of the equipment matches the specified level

Procedures for commissioning or tuning up new or existing equipment should have been specified for all new or revitalized housing units (see equipment manufacturer's installation instructions and Section 5.5 of the Design Guide). Prior to turnover of the housing units, the contractor must perform these procedures and document this work. The inspector should observe that the specified procedures were followed and retain copies of the documentation.

The inspector should verify that the following activities were completed:

- the airflow rate across the indoor coil was measured and established at 350 to 450 cfm per ton of cooling capacity
- the refrigerant charge was checked and adjusted based on superheat and subcooling measurements made with the system operating in the cooling mode (heat pumps adjusted in the winter should use the hot gas temperature method rather than the superheat and subcooling method)
- the air temperature difference across the indoor coil was 15 to 20°F when the system was operating in the cooling mode
- the outdoor unit of each system was located at least 2 feet away from decks, shrubs, landscaping, or other obstructions that could restrict airflow, plug heat exchanger surfaces, or promote recirculation

WATER HEATING

The inspector should verify for all new water heaters that:

- the water heater matches the specified size, efficiency, and fuel type
- the water heater was installed according to manufacturer's installation instructions
- the first 3 feet of hot water pipes above the hot water tank were insulated (Fig. S)
- the hot and cold water lines were connected to the correct tap on the tank
- heat traps were installed on the hot and cold water pipes (if heat traps were not an integral part of the tank) (Fig. S)
- the temperature on the water heater was set at 120 to 125°F (10°F lower than recommended in the Design Guide)
- the water heater was insulated (if specified) (Fig. S)
- a separate gas shutoff valve or electrical switch was installed

For other water-heating-related items, the inspector should verify that new sink faucets and shower heads limit the flow rate to specified levels. (Typically, flow rates should be less than 2.5 gpm for shower heads, 2.0 gpm for kitchen faucet aerators, and 1.5 gpm for other faucet aerators.)

APPLIANCES, LIGHTING, AND VENTILATION FANS

The inspector should verify that:

- the rated annual energy consumption labels on new appliances (refrigerators, dishwashers, etc.) match the rating on the approved equipment
- new lighting fixtures and bulbs are consistent with approved fixtures and bulbs (in most cases, new lighting fixtures should be required to be fluorescent)
- if new fluorescent fixtures and bulbs made for outdoor use were approved, these fixtures and bulbs were installed
- recessed lighting fixtures meet specifications
- recessed lighting fixtures were sealed (at factory or on-site) according to specifications to minimize air leakage from the conditioned space to the unconditioned ceiling cavity
- recessed lighting fixtures that have boxes built around them to seal them from the ceiling cavity maintain minimum specified clearance from combustible material
- automatic gravity dampers are working properly on ventilation fans in bathrooms and at clothes dryer vents (check before installation)

APPENDIX A ENERGY-EFFICIENCY CHECKLIST

The following pages are an energy-efficiency checklist that has been condensed from the previous sections of this field manual. The inspector is encouraged to photocopy a set of the following pages for each housing unit, carry the checklists into the field, and check off items as they are inspected. Checklist data may then be transferred into the inspector's logs or retained as permanent project records showing that energy-efficiency work was completed.

ENERGY-EFFICIENCY CHECKLIST

INFILTRATION INSPECTION

Before drywall is installed, seal:

- between bottom wall plate and subflooring
- inside edge of bottom wall plate
- behind and around bathtubs
- windows and doors at rough openings
- wiring and plumbing penetrations

After drywall is installed, seal:

- bathtub drain penetrations
- plumbing pipes, medicine cabinets, and electrical boxes
- bathroom ventilation fan to drywall
- attic bypasses and chases
- around the perimeter of attic accesses
- exterior penetrations
- floors of second-story overhangs or second-story floors over porches, garages, etc.

FOUNDATION AND FLOOR INSULATION

- correct type, amount, and location of insulation
- insulation installed according to specifications
- coverage of insulation complete:
 - slab-on-grade foundation insulation flush with top of slab
 - insulated floors of second-story overhangs or second-story floors over porches, garages, etc.
- batts cut to fit around wiring, piping, and plumbing
- batts flush against floor joists and framing members

ATTIC INSULATION

- correct type and amount of insulation
- insulation installed according to specifications
- coverage of insulation complete
- If blown-in insulation:*
 - blocked around flue pipes, recessed lights, exhaust fans, whole-house fans, electrical junction boxes, and chimneys
- soffit dams installed
- If batt insulation:*
 - insulation fits flush against framing members
 - rafter baffles used
 - insulation covers outside walls, is not overcompressed, and does not cover soffit vents
 - vapor barrier backing against attic floor (cold climates)

INFILTRATION AND VAPOR BARRIERS

- Vapor barrier installed in right location
- Polyethylene sheeting:*
 - polyethylene covers completely
 - polyethylene sealed with caulk at top and bottom plates, around windows, and around pipe and wiring penetrations
 - joints overlapped one stud cavity and caulked or taped
 - rips and tears repaired with tape
- Housewrap:*
 - housewrap covers entire wall surface
 - edges of housewrap sealed with caulk or tape
 - plastic capped nails used
 - joints overlapped and caulked or taped

- insulation supports correctly installed

FOUNDATION AND FLOOR INSULATION (cont.)

- vapor barrier completely covers crawl space floor, overlaps foundation, and joints overlapped

WALL INSULATION

- correct type, amount, and location of insulation
- insulation installed according to specifications
- coverage of insulation complete:
 - insulation installed around windows, doors, at corners where exterior walls meet, at tees where interior walls meet exterior walls, and at other framing junctions
 - insulation installed in walls next to unconditioned areas
 - insulation installed at exterior walls behind tubs
 - rigid insulation installed between inside and outside headers over doors and windows
- batts not overcompressed and correct lengths used
- batts stapled to front of studs
- insulation cut to fit closely around piping and wiring

INFILTRATION AND VAPOR BARRIERS (cont.)

- diagonals cut at openings, folded inside, and sealed
- cuts and openings in housewrap sealed

WINDOWS AND DOORS

- rough window and door openings sized correctly
- windows and doors match specifications
- installed according to manufacturer's instructions and specifications
- thresholds installed on doors and adjusted correctly
- caulk or sealant applied between threshold and floor
- weatherstripping installed correctly

INFILTRATION TESTING

- unit is functionally complete and prepared for testing with no leakage sites temporarily sealed
- pressures and/or airflows indicated by gauges during testing recorded properly and used in analysis program
- flow exponent, correlation coefficient, percentage error in flow data, and relative standard errors listed on analysis printout conform to accuracy standards in specification or as below:
 - flow exponent (n) ≥ 0.5 and ≤ 1.0
 - correlation coefficient (r) ≥ 0.990
 - % error in flow data at each pressure station $\leq 5\%$
 - relative standard error of estimated flow at 10 Pa $\leq 10\%$
 - calculation of natural air changes per hour correct

ENERGY-EFFICIENCY CHECKLIST (cont.)

DUCT INSPECTION

- repairs made with mastic and fiberglass tape or other approved material, not fabric duct tape
- return plenums sealed
- connections to air handler and holes in air handler sealed
- connections of ducts to boots sealed
- duct boots sealed to floor or drywall

New ducts:

- ducts fastened together with mechanical fasteners
- joints, boots, takeoffs, and collars sealed with mastic or other approved material, not with fabric duct tape
- flexduct used only as branch connections to supply registers
- flexduct has sufficient supports
- flexduct has no sharp bends or kinks
- flexduct cut to correct size
- specified level of duct insulation installed

DUCT TESTING

- duct system properly prepared for testing
- testing equipment set up according to manufacturer's instructions
- pressures indicated by gauges during testing recorded properly on measurement form
- airflow rate constant with measured fan pressure and fan opening configuration of test equipment

GAS-FIRED FURNACES AND BOILERS (cont.)

- carbon monoxide levels measured in each burner after 5 min. continuous burn, and burner adjusted if readings are ≥ 250 ppm
- carbon monoxide levels measured in living area, and, if > 5 ppm, leakage repaired
- temperature rise across heat exchanger measured and was limited to specified acceptable range
- draft measurements completed, met specified requirements, and showed adequate draft present and spillage minimized

HEAT PUMPS AND AIR CONDITIONERS

- size and efficiency of equipment matches specifications
- Commissioning items:*
- airflow rate across indoor coil measured and established at 350 to 450 cfm per ton of cooling capacity
- refrigerant charge checked and adjusted based on superheat and subcooling measurements made with system operating in cooling mode
- air temperature difference across indoor coil was 15 to 20°F when system was operating in cooling mode
- outdoor unit of each system located at least 2 feet away from decks, shrubs, and landscaping

WATER HEATERS

- water heater matches specified size, efficiency, and fuel type
- water heater was installed according to manufacturer's installation instructions

DUCT TESTING (cont.)

New air distribution systems:

- ducts fastened together with mechanical fasteners
- joints, boots, takeoffs, and collars sealed with mastic or other approved material, not with fabric duct tape
- flexduct used only as branch connections to supply registers
- flexduct has sufficient supports
- flexduct has no sharp bends or kinks
- flexduct cut to correct size
- specified level of duct insulation installed

GAS-FIRED FURNACES AND BOILERS

- size and efficiency of equipment matches specifications
- required warning label affixed to ducted/piped combustion air supply
- Commissioning items:*
- oxygen concentration and net stack temperature measured at each burner, initial steady-state efficiency calculated, and burner adjusted to maximize steady-state efficiency
- for furnaces, circulation fan "off" limit switches and high-limit switches set to manufacturer's requirements or specifications, and circulation fan "on" limit switch set at lowest possible temperature setting that avoids cycling of fan after burner has shut off (usually 120 to 160°F)
- for boilers, system operating temperatures and high-limit switch settings set to the manufacturer's standard recommended values

WATER HEATERS (cont.)

- first 3 feet of hot water pipes insulated
- hot and cold water lines were connected to correct taps on tank
- heat traps installed on hot and cold water pipes
- temperature on water heater set at 120 to 125°F
- water heater insulated
- separate gas shutoff valve or electric switch installed
- sink faucets and shower heads limit flow rate to specified levels

APPLIANCES AND LIGHTING

- rated annual energy consumption labels on new appliances (refrigerators, dishwashers, etc.) match rating on approved equipment
- lighting fixtures and bulbs consistent with approved fixtures and bulbs
- fluorescent fixtures and bulbs made for outdoor use installed
- recessed lighting fixtures meet specifications and sealed and blocked correctly
- automatic gravity damper works properly on ventilation fans

House: Example
 Test Date: 10/31/97

Measured Data:
 Inside Temp: 85F
 Outside Temp: 95F

House (PA)	Fan (PA)	Ring (N.A.B)	Flow (CFM)
9.0	90	B	590
15.0	17	A	757
20.0	25	A	915
26.0	34	A	1064
30.0	41	A	1167
35.0	50	A	1286
39.5	57	A	1372
45.0	68	A	1496
49.5	80	A	1620
60.0	106	A	1860

Corrected Data:

House (PA)	Flow (CFM)	Error (%)
9.0	596	6.8
15.0	764	-0.3
20.0	923	0.5
26.0	1074	-1.0
30.0	1177	-0.8
35.0	1298	-0.8
39.5	1384	-2.0
45.0	1509	-1.6
49.5	1635	0.4
60.0	1877	2.1

Regression Results:

Corr Coeff = 0.9978
 C = 138.8233
 N = 0.6310

	House Pressure		
	4 PA	10 PA	50 PA
CFM	333	594	1639
STERR	3.4%	2.1%	0.7%

Leakage Areas:

Effective L.A. (LBL) = 94.39 SQ IN
 Equivalent L.A. (CAN) = 174.31 SQ IN

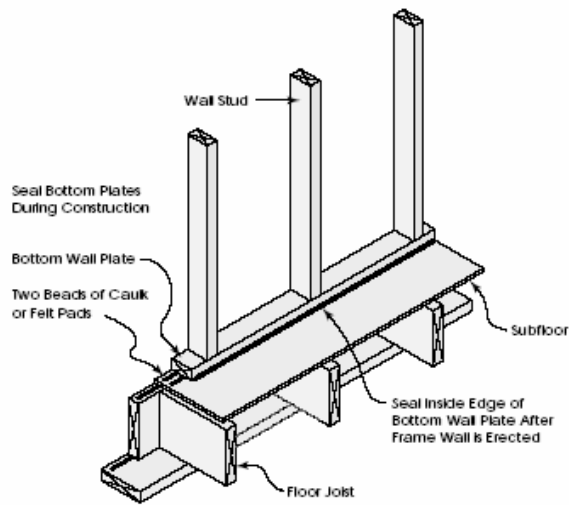


Figure A

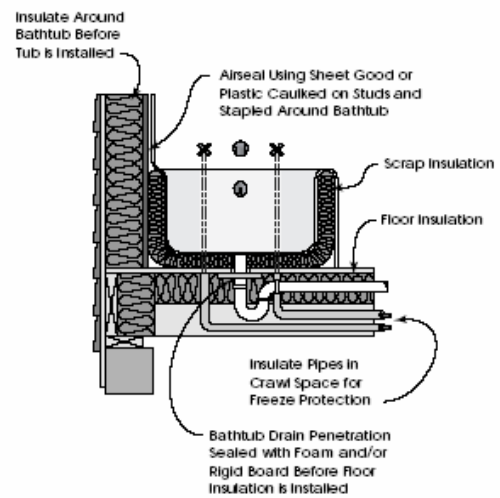


Figure B

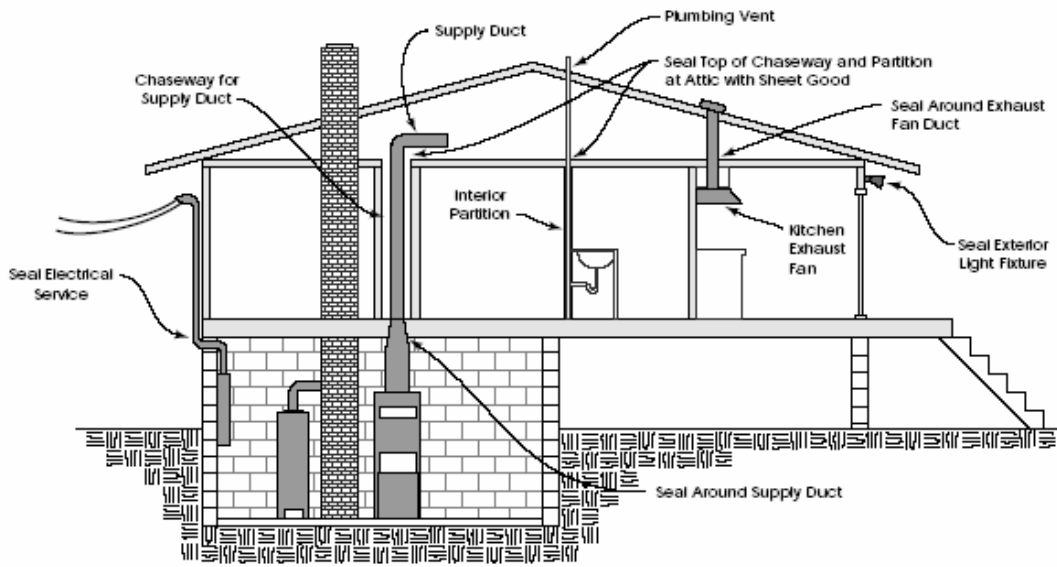


Figure C

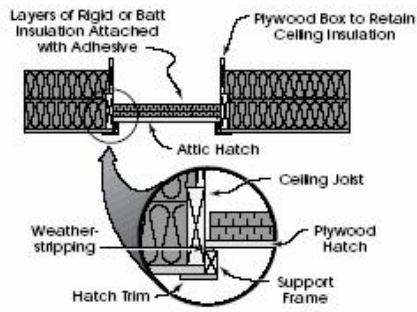


Figure D

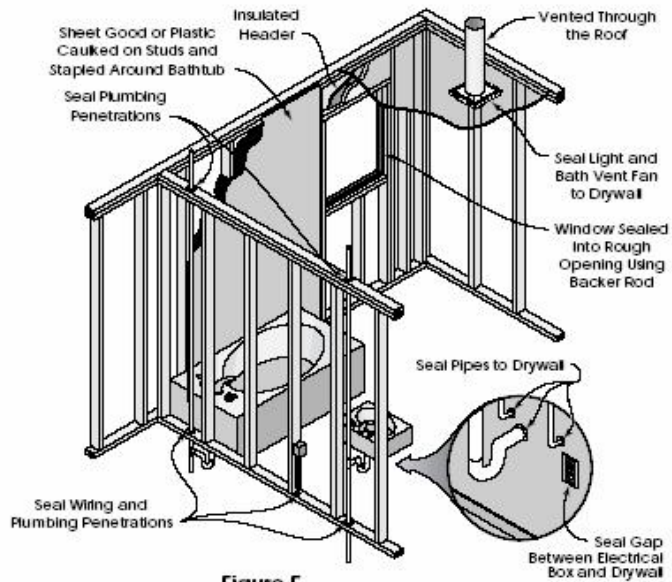


Figure E

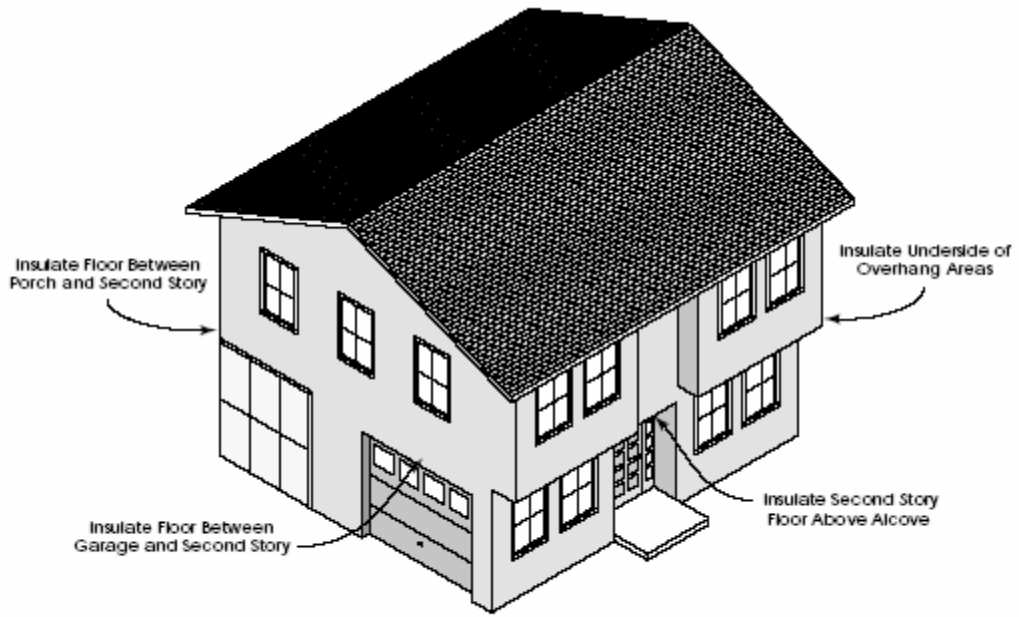


Figure F

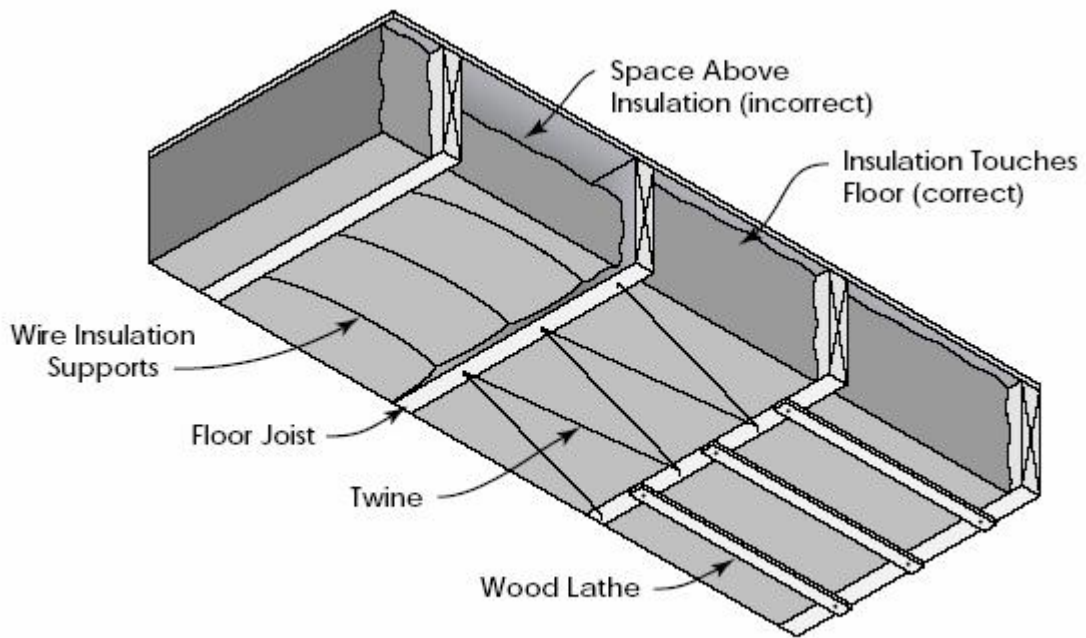


Figure G

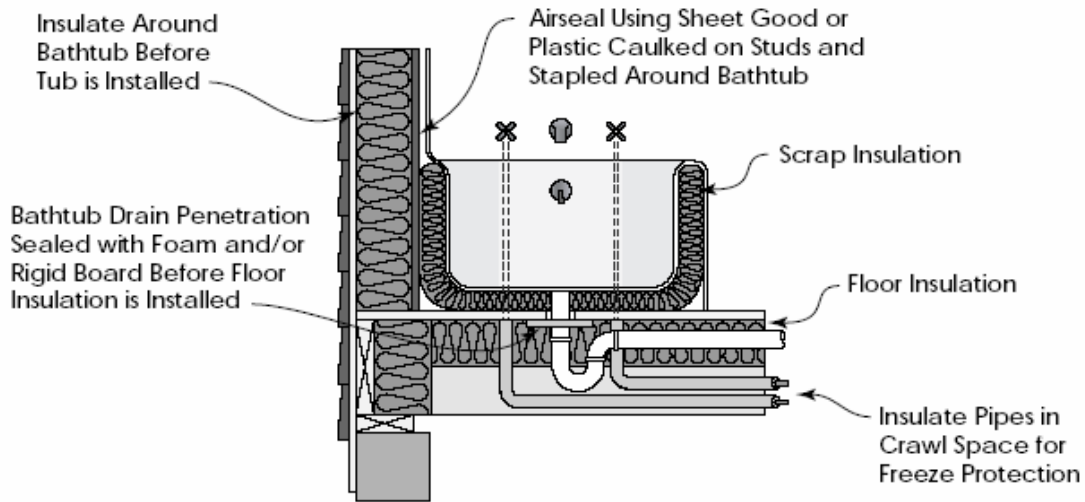


Figure H

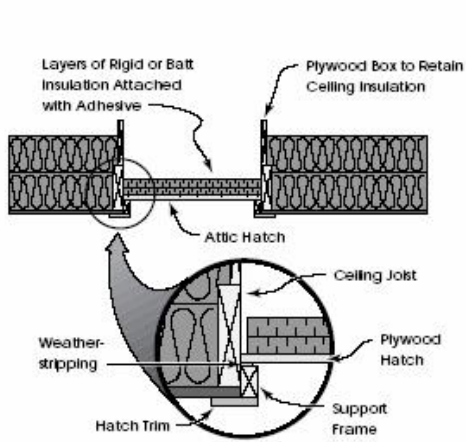


Figure J

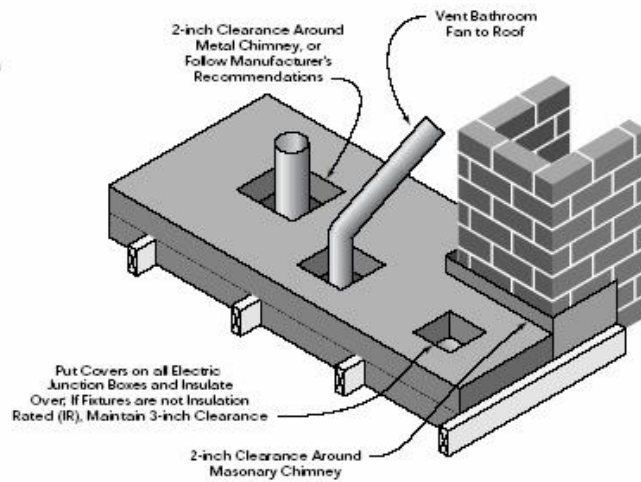


Figure K

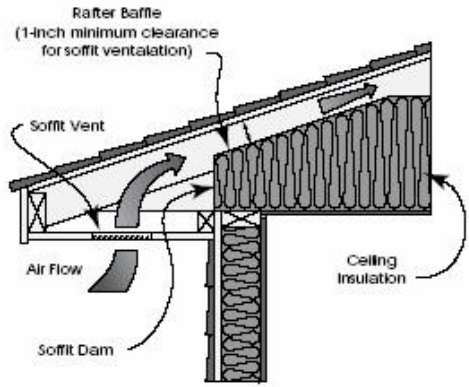
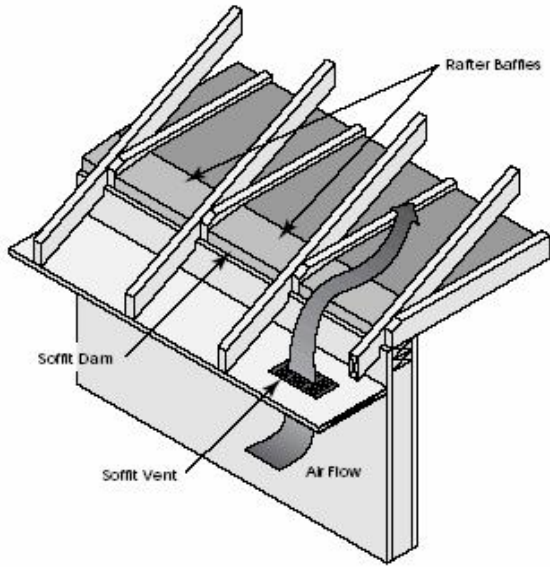


Figure L

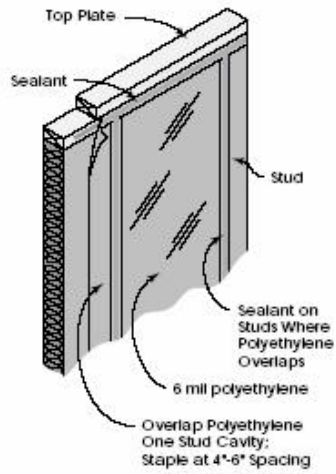
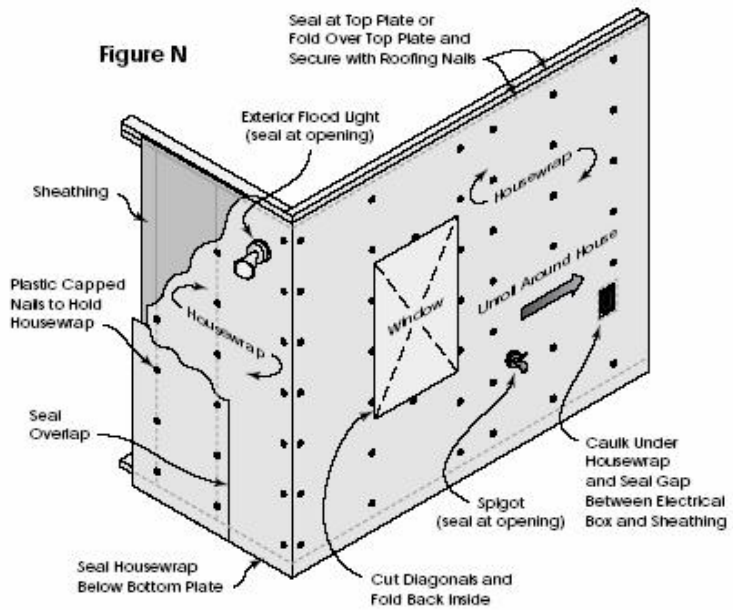


Figure M

Figure N



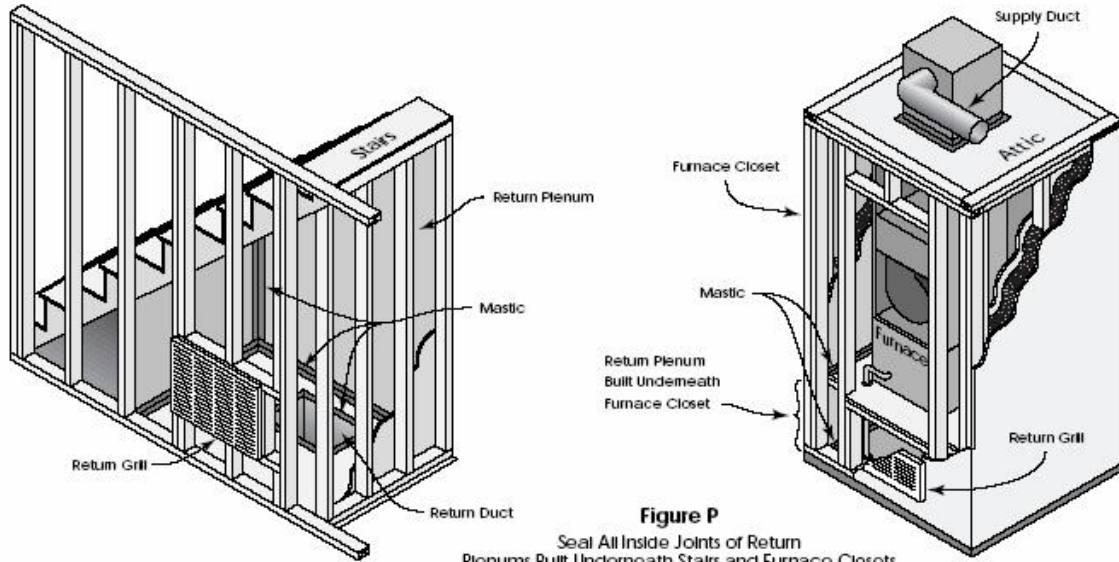


Figure P
 Seal All Inside Joints of Return Plenums Built Undemeath Stairs and Furnace Closets

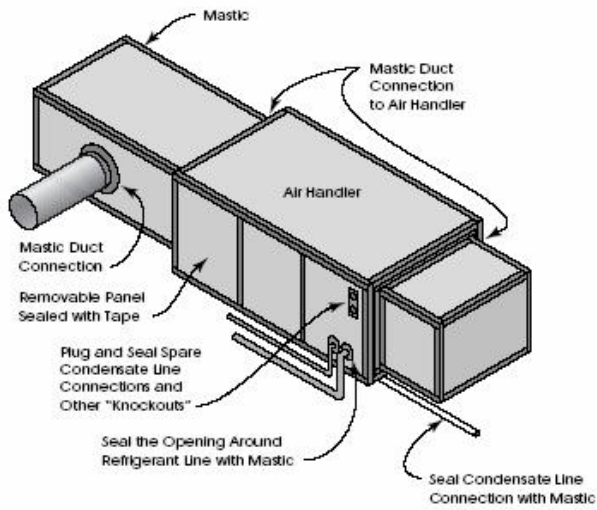


Figure Q

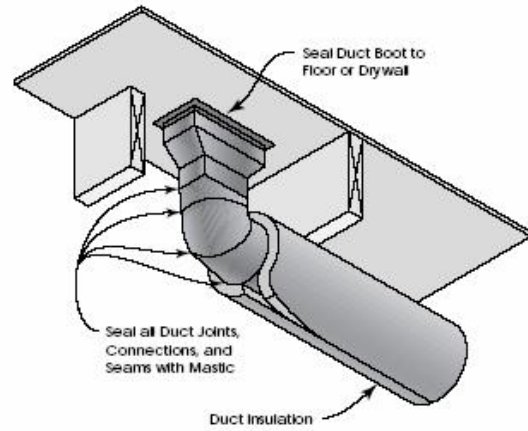


Figure R

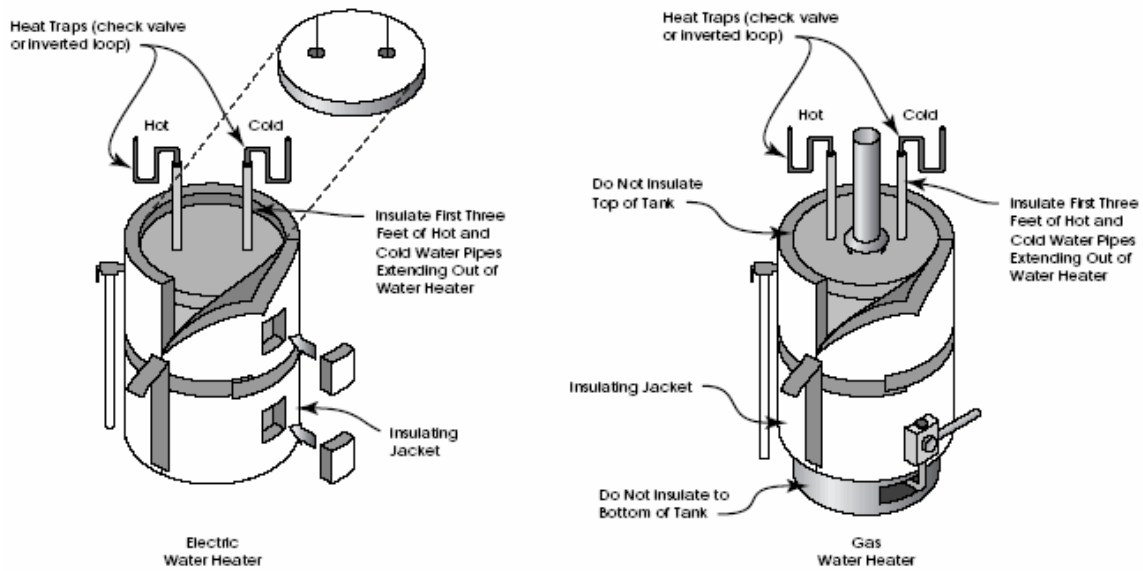


Figure 5