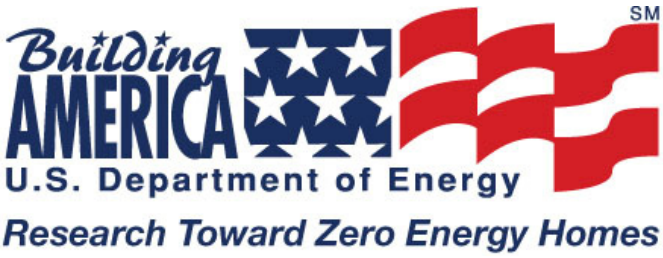



# PUBLICATION OF RECOMMENDATIONS FOR 30-40% PERFORMANCE LEVELS IN COLD CLIMATES

TASK ORDER KAAX-3-33410-07

DELIVERABLE NUMBER 07.E.4

PREPARED FOR:
MIDWEST RESEARCH INSTITUTE,
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION,
1617 COLE BOULEVARD,
GOLDEN, CO
80401-3393

PREPARED BY
IBACOS, INC.
2214 LIBERTY AVENUE
PITTSBURGH, PA 15222-4502
TEL: (412) 765-3664 / FAX: (412) 765-3738
CONTACT: RACHEL MAY

DATE: NOVEMBER 4, 2005

*Publication of Recommendations for 30-40% Performance Levels in Cold Climates*
*KAAX-3-33410-07.E.4*
*November 4, 2005*

# Building America Program
## Overview

The Building America Program is an industry-driven, cost-shared program sponsored by the U.S. Department of Energy (DOE) through the National Renewable Energy Laboratory for applying systems engineering approaches that accelerate the development and adoption of innovative building processes and technologies. The goal of the program is to produce energy-efficient, environmentally sensitive, affordable and adaptable residences on a community scale.

The Building America teams bring together all segments of the housing industry (designers, builders, developers, financial institutions, material suppliers and equipment manufacturers). These industry groups have traditionally worked independently of one another, slowing development and adoption of new technologies. By working together using a systems engineering approach, decisions previously made independently can quickly be made with consideration for the entire design, manufacturing and construction process, thereby increasing quality and performance without increasing cost.

In 1993, Building America's first phase established a partnership between DOE and the IBACOS (Integrated Building and Construction Solutions) consortium. These reports are in partial fulfillment of Innovative Building Technologies, Advanced Systems Development and Testing—a program between IBACOS and the National Renewable Energy Laboratory Division of Midwest Research Institute.

# Contents



This report was authored and reviewed by IBACOS:

Authored by: Duncan Prahl, Nathan Yost, Peter Yost
Reviewed by: Duncan Prahl

# Abstract

## Abstract

### Abstract

Integrating higher performance into a builder's operations is a multi-faceted process. One aspect includes integrating higher performance requirements and activities into the builder's scopes of work, to enable them to communicate what the trade contractors actually need to do in order to achieve the builder's overall goal of a high performance house. This report represents a first step in documenting the trade activities needed to achieve the high performance aspects of Building America houses into a scope of work program for builders.

### Keywords

Building America
High performance
Energy efficient
Scope of work

# Executive Summary

## Executive Summary

**Deliverable Description**

In collaboration with the Building America partners, the subcontractor shall also publish a report to provide builders with specific field recommendations for achieving 30-40% energy-saving levels in Cold climate (in accordance with the 2005 Research Milestones). This report shall be based on the latest available research results and shall address the practical and economic aspects of the energy-saving measures.

**Task Description**

The final report offering recommendations for achieving the specified energy-saving performance levels shall be sent to the NREL Technical Monitor for review and approval prior to submitting for publication.

**Publication**

IBACOS proposes publishing this report on the Building America website in Microsoft Word format, for use by builders as a tool to help them achieve higher performance levels associated with *Building America Residential System Research Results: Achieving 30% Whole House Energy Savings Level in Cold Climates* and *Building America Best Practices Series: Volume 3 Builders and Buyers Handbook for Improving New Home Efficiency, Comfort, and Durability in the Cold and Very Cold Climates.*

## Scopes of Work

In order to turn building science recommendations into actual practice by the builders, a vital tool is the scope of work. The scope of work is part of the legal contract between the builder and the trade contractors, and spells out specifically what must be done by the trade contractor to achieve the desired result. All too often, IBACOS has found that much of the building science application associated with Building America projects gets transferred within a builders organization and to the trades by "word of mouth" through an internal champion and on-site training, but this rarely gets formally documented. IBACOS wishes to thank Building America partner Ideal Homes for their contribution to this project.

The scopes of work in Appendix A are a first step in creating a set of operational tools that builders can use to physically and contractually integrate higher performance into their houses, by giving them mechanisms to hold their trade contractors accountable for their work. These documents are meant to supplement a more comprehensive set of scopes of work and contract documents that a builders should already have in place. This report delivers language and checklists for scopes of work that primarily address those areas related to the application of construction practices and design strategies associated with the findings reported in the *Building America Residential System Research Results: Achieving 30% Whole House Energy Savings Level in Cold Climates*. If builders do not have a scope of work program in place, these documents are designed to integrate with Linda Haas Davenport's *The Scopes of Work Program: Procedures and Standards to Increase Quality* (2001). In addition, references are made to the numerous details developed as part of the Building America Program, including those in the *EEBA Builders Guide to Cold Climates* and the *EEBA Water Management Guide*.

# Appendix

## Appendix A

High Performance Home Scopes of Work

1. Introduction and Overview
2. Standards and Description of Work
3. Foundation
4. Framing
5. Windows
6. Drainage Plane
7. Air Sealing and Insulation
8. HVAC

## References

BIRA, BSC, CARB, FSEC, IBACOS, NREL. REL/TP-550-38783. Building America Residential System Research Results: Achieving 30% Whole House Energy Savings Level in the Cold Climate Prepared under Task No(s). BET5.8004. October 2005

Davenport, Linda Haas "The Scopes of Work Program: Procedures and Standards to Increase Quality" Washington DC: Home Builders Press®. 2001

Lstiburek, Joseph. "Builders Guide to Cold Climates." Westford, MA: Building Science Press. 2004

Lstiburek, Joseph. "EEBA Water Management Guide." Westford, MA: Building Science Press. 2004

National Renewable Energy Lab. NREL/TP-550-38309. Building America Best Practices Series: Volume 3 Builders and Buyers Handbook for Improving New Home Efficiency, Comfort, and Durability in the Cold and Very Cold Climates. August 2005

# *Trade Contractor* Standards and Description of Work Performance

*The Company*'s Terms and Conditions are by reference a part of all Scope of Work requirements. *The Company*'s Construction Documents including Construction Drawings and Specifications, these "*Trade Contractor* Standards and Description of Work Performance" and the "*Trade Contractor* Requirements and Checklists" are included by reference as a description of the Work to be performed by *The Trade Contractor* and are by reference a part of the agreement between *The Company* and *The Trade Contractor*.

## Construction Requirements

Generally speaking, the work of *Trade Contractor* and their employees is expected to be performed in a good and workmanlike manner. Workmanlike quality is defined as workmanship which meets or exceeds those criteria indicated in applicable building codes, *The Company's* specific performance requirements, NAHB's Residential Construction Performance Guidelines, and manufacturer specifications, using materials and installation methods identified in the construction documents (plans and specifications) and the *Trade Contractor* Requirements and Checklists. The quality of *The Trade Contractor*'s installation is expected to support the quality of the builder's design and specified materials.

## Code Requirements

All jobs shall conform to those standards stipulated in the building code, mechanical code, plumbing code and electrical code applicable in the local jurisdiction. "Code" means the minimum standard that will achieve an occupancy permit. It does not necessarily mean "quality" or "high performance."

If any high performance requirements pertaining to the *Trade Contractor's* Work are in conflict with either the local building code or local code official interpretation of the local building code, it is the responsibility of the *Trade Contractor* to notify *The Company* of any conflict as soon as the *Trade Contractor* becomes aware of any such conflict.

## High Performance Requirements

High Performance Requirements address the major damage functions that affect materials and buildings: heat, water, radiation (ultraviolet) and biological organisms (which frequently require liquid water). Reducing the risk of damage by these forces is accomplished principally by controlling the following flows across the building enclosure: energy (thermal and ultraviolet radiation), air (heat and moisture), water (liquid, capillary and vapor) and insects and other pests.

The High Performance Requirements for each *Trade Contractor's* Work make explicit the general premise that quality and high performance are linked—one cannot be achieved without the other. While

a worker could successfully satisfy the requirements in the scopes without understanding the objective or the rational, an informed worker is more likely to satisfy the intent of the requirements and is definitely more likely to devise alternative solutions that may be as or more effective, as easy or easier to accomplish, and as or less expensive.

Trade Contractor-specific High Performance Requirements are contained in the Introduction of the *Trade Contractor* Requirements and Checklists for each *Trade Contractor*.

## General Requirements

The general requirements refer to the specific manufacturer's instructions or requirements or a specific trade organization's requirements for performance or installation practices. *The Trade Contractor* shall notify *The Company (Superintendent)* if a discrepancy is identified between the manufacturer's requirements and *The Company's* specific requirements.

All installations are the responsibility of *The Trade Contractor*. It is also the responsibility of *The Trade Contractor* to:

1. Ensure that each of their installation employees has read and understands the *Trade Contractor* Requirements and Checklists.
2. Designate a *Trade Contractor* supervisory representative to complete and sign the Pre-Work Inspection and the Post-Work Inspection Checklists contained in *Trade Contractor* Requirements and Checklists.

Completed Pre-Work Inspection and Post-Work Inspection Checklists must be and kept on file at *The Trade Contractor's* office.

## Interaction with Other Trades

Construction is a process that involves sequential work performed by a variety of subcontractors. *The Trade Contractor* must understand that his Work does not occur in isolation; rather it must integrate with Work that precedes and follows his Work. Each contractor must therefore preserve the integrity of the prior Work performed by other contractors. *The Trade Contractor* understands the importance of the continuity of drainage planes, air barriers, and thermal barriers and will train their employees to protect these systems or repair them if they are compromised during their course of their Work. The *Trade Contractor* Requirements and Checklists expresses trade interaction concerns and items in the Introduction as well as throughout the Requirements, associated Details, and Checklists, but particularly in the Pre-Work Inspection Checklist. The Pre-Work Inspection Checklist in *Trade Contractor* Requirements and Checklists establishes the status of these systems before *The Trade Contractor* begins work while the Post-Work Inspection Check List in *Trade Contractor* Requirements and Checklists verifies their status at the conclusion of *The Trade Contractor's* work.

## General Comments

1. *The Company* considers our *Trade Contractor*s to be experts at producing a high-quality job. But everyone on our construction team—staff, *Trade Contractor*s, and suppliers—recognizes the importance of providing quality in both the product and service areas while on our jobsites and in the homes of our purchasers.

2. Since we work as a team, poor quality or service from any of us reflects unfavorably on all of us. An exceptional level of product quality and highly effective service can help us all to increase our business and grow.

3. *The Company*'s definition of quality construction also requires that every job be completed correctly the first time. When this does not occur it costs both of us additional money, imposes on the purchaser, and hurts our reputations as quality builders. That is why, in situations where construction was not completed in a quality manner, prompt corrective action is required to remedy specific deficiencies.

4. In the following information the term 'Site Superintendent' refers to any *Company* representative with authority to perform the specified task. The term *Trade Contractor* means *The Trade Contractor's* organization or any representative who is assigned the authority to perform the specified task.

## Detailed Job Requirements

1. A new set of plans is required for each house. Plans are subject to changes and modifications. It is the responsibility of *The Trade Contractor* to have the new plans before beginning work. Plans should be picked up at the job trailer from the Site Superintendent, or provided to the *Trade Contractor's* installation crews by the *Trade Contractor*. Any errors that occur from using an incorrect set of plans will be corrected by *The Trade Contractor* at no cost to *The Company*.

2. Purchase orders shall be transmitted to *The Trade Contractor from The Company's* office and shall be provided in ample time for *The Trade Contractor* to have the correct materials on hand prior to starting the Work.

3. Specific installation instructions, including associated Details, are supplied in *Trade Contractor* Requirements and Checklists.

4. Performance testing, when applicable (as detailed below), will be one method of testing the success of the installation.

5. Any items found during the final inspection that need correction shall be corrected before payment will be made.

## Performance Testing

1. When an appropriate test method exists to evaluate the performance of the installation, it will be detailed in this section. Testing protocols that may apply include 100% testing (every installation), random percentage (e.g. 1 in 7) or the reserved right to test any installation as determined by *The Company* or the *Site Superintendent*. Test protocols, and the definition of successful performance or the threshold for successful performance are detailed in the *Trade Contractor* Requirements and Checklists .

2. The definition of successful performance or the threshold for successful performance will also be detailed.

3. *The Trade Contractor* will be responsible for correcting the installation so that performance meets the stated threshold. The cost of corrective action is the responsibility of *The Trade Contractor*.

Inspection Checklist

1. The post-installation inspection checklist documents *The Trade Contractor's* compliance with the performance requirements that are explicitly detailed in *Trade Contractor* Requirements and Checklists. The Post-Inspection Checklist is contained in *Trade Contractor* Requirements and Checklists.

2. Inspection checklists are provided to document successful completion of the installation as included in *Trade Contractor* Requirements and Checklists. If the installation fails to meet the requirements specified in this Scope of Work or conform to the Finished Detail then *The Trade Contractor* must correct any deficiency found during any inspection at no cost to *The Company*. If the deficiency is discovered prior to payment, the deficiency must be successfully corrected before payment will be made.

3. Performance test results will be reported on the Post-Work Inspection Checklist. Note that there are times when the specific performance test cannot be performed until well AFTER the completion of the work, after completion of the checklist and even after the deficiency can be readily remedied by the responsible *Trade Contractor*. When this occurs, the *Trade Contractor* will take reasonable and practical measures to fix the performance failure, and develop a corrective action plan with the builder to identify the cause of the performance failure and how the *Trade Contractor* will meet the performance requirement in the future. It is conceivable that the deficiency for which the *Trade Contractor* is responsible will be worked out within the broader financial agreements and exchange between *The Company* and the *Trade Contractor*, rather than on the level of one particular home.

4. *The Trade Contractor* and the Site Superintendent must sign-off on all deficiencies attesting that the job is 100-percent complete and is correct per the job requirements found in this Scope of Work.

I _____ agent for _____

have read and fully understand the above Scope of Work and I hereby agree to perform all work in accordance with the above.

Date: _____ _____

Signed: *Trade Contractor* (or agent)

Date: _____ _____

For *The Company*

# Foundation Requirements and Checklists

**Foundation Requirements**
**1. Introduction – High Performance Foundation**

[NOTE: for the purposes of this scope of work, it is assumed that the foundation contractor is responsible for the foundation, system which includes strucutal footings, piers, slabs, and walls, the water management system including perimeter drainage and damproofing / waterproofing. To the extent that these activities are separately contracted by *The Company,* this Scope of Work should be split to focus on those work areas each *Trade Contractor* will be responsible for.]

High Performance is defined as superior energy efficiency, safety, comfort, and durability. Managing the flows of moisture and air with the same thoroughness as energy protects against the major damage functions a home faces— heat, water, radiation (ultraviolet) and biological organisms (frequently requiring liquid water).

The work of the *Foundation Trade Contractor* contributes to high performance in the following ways:

- Water management –
  - Installation of a capillary break between footings and foundation walls
  - Installation of a capillary break on the below-grade portions of exterior foundation walls
  - Installation of a capillary break between the soil and the concrete slab
  - Installation of a perimeter drain system along footings for basements and crawl spaces where the floor is below the exterior grade
  - Installation of a capillary break on both the above grade and below grade perimeter of slab on grade foundations
- Integrity and Continuity of the Thermal Barrier –
  - Installation of foundation insulation in a continuous manner
  - Installation of sub-slab insulation in a continuous manner
- Integrity and Continuity of the Air Barrier –
  - Installation of the concrete and foundation walls so that they can function as an air barrier. This is accomplished by providing control joints and expansion joints in the proper locations. These known areas of actual or potential cracks in the air barrier can then be properly sealed.
  - Installation of continuously sealed vapor barrier ground cover on the floor of a crawl space also provides an air barrier between the soil and air within the crawl space.
- Vapor management –
  - Installation of the polyethylene vapor barrier under concrete slab
  - Installation of the polyethylene vapor barrier/ground cover on the floor of a crawl space
  - Installation of dampproofing on the below ground sections of foundation walls

Construction is a process that involves sequential work performed by a variety of subcontractors. *The Foundation Trade Contractor's* work is generally followed by *The Framing Contractor, The Roofing Contractor, The Drainage Plane Contractor*, *The Window Trade Contractor*, *The Insulating Contractor* and later by *The HVAC Contractor* with these high performance implications:

- Air sealing must be accomplished between the top of foundation walls and the sill plate. Levelness and uniformity of the top of the foundation walls facilitate air sealing.

- Air sealing must be accomplished between rough openings for windows and doors. Dimensional accuracy and uniformity of these openings facilitate air sealing between the foundation wall and windows and doors.

Performance testing is often a key step along the path to high performance.

1. Water testing of the perimeter drainage system can determine the ability of the perimeter drainage system to transport water.

2. Successful performance is the free flow of water from any section of the perimeter drainage system to the opening to daylight or the sump pit.

*The Foundation Trade Contractor* will be responsible for correcting deficiencies in installation so that performance meets the requirements of *The Company* and high performance in these Scopes. The cost of corrective action is the responsibility of *The Foundation Trade Contractor*.

For more comprehensive information on the relationship between foundation installation and high performance homes, see the following resources:

- EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004)
- Building America Best Practices for Cold Climates
- Building America Houses That Work – Cold Climates

## 2. Detailed Installation Checklist

☐ **Pre-Work Inspection:** completed and signed by Site Superintendent and *The Foundation Trade Contractor*

**Foundations – Types – Check all that apply to this building**

☐ **Slab at Grade - Slab**
☐ **Basement – BSMT**
☐ **Crawl Space – interior grade below exterior grade – CS-BG**
☐ **Crawl Space – interior grade above exterior grade – CS-AG**

**Detailed Installation Checklist –**

☐ 1. Install capillary break on top surface of footing using specified material.

☐ 2. Install a minimum of 4 inches of crushed stone – 0.75 inch diameter, no fines. – under slabs and under ground covers in crawl spaces.

☐ 3. Install sub slab soil gas ventilation pipe – 4 inch perforated pipe, minimum total length of 6 feet, with central T-fitting that connects to the vertical solid pipe that will continue through the roof. Cap the short section of vertical pipe (minimum 6 inches above top of finished slab) to prevent concrete entering the pipe.

☐ 4. Install sub slab rigid insulation – extruded polystyrene, expanded polystyrene or high density mineral wool – on the crushed stone as specified in plans.

☐ 5. Install 0.75 inch rigid insulation as bond break between the foundation walls and the slab edge.

☐ 6. If a vapor retarder (polyethylene) is called for, it is installed on top of the rigid insulation in direct contact with the underside of the concrete slab.

☐ 7. For slabs with turned down edge, place the rigid insulation against the concrete form and place the polyethylene in footer trench and continue up to the top of the form. The polyethylene is placed interior to the rigid insulation so that the polyethylene will be in direct contact with the concrete. See Figure 1.

☐ 8. For slabs at grade with stem wall install rigid insulation along stem wall an under slab as called for in plans.

☐ 9. Control joints have been placed at the appropriate locations in all slabs.

☐ 10. Perimeter foundation drainage system installed along side the footings as shown in Figure 2.

☐ 11 Perimeter drainage system is connected to: (per plans or instructions from *The Company*)

- ☐ Daylight
- ☐ Interior drainage field and sump pit

☐ 12. Dampproofing installed on basement and crawl space walls to height of final grade.

☐ 13. Drainage board or free draining "backfill" installed per plans and specs.

## Figures

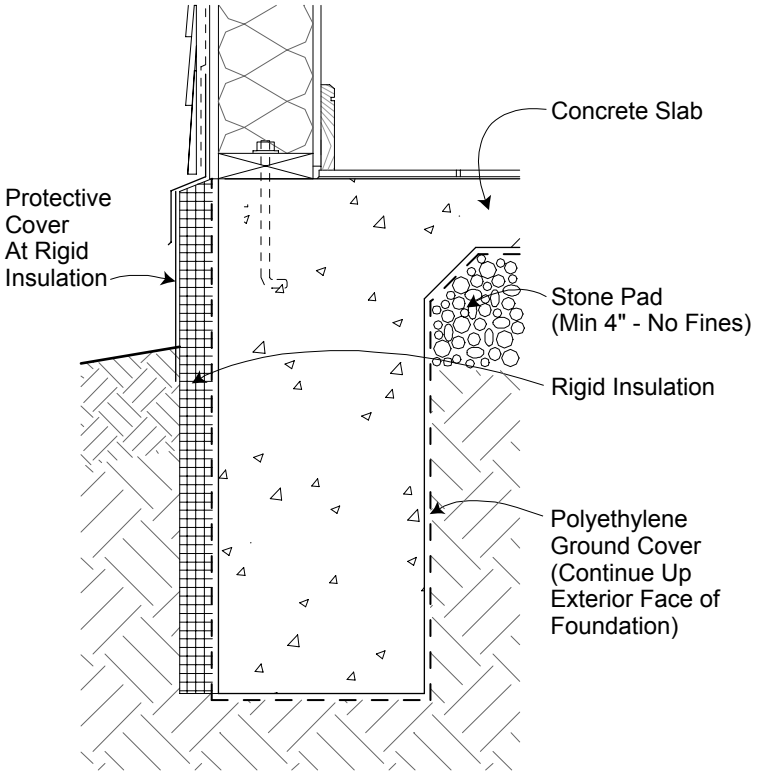



**Figure 1 – Slab at grade –polyethylene under turned down edge and rigid insulation along perimeter of slab foundation.**

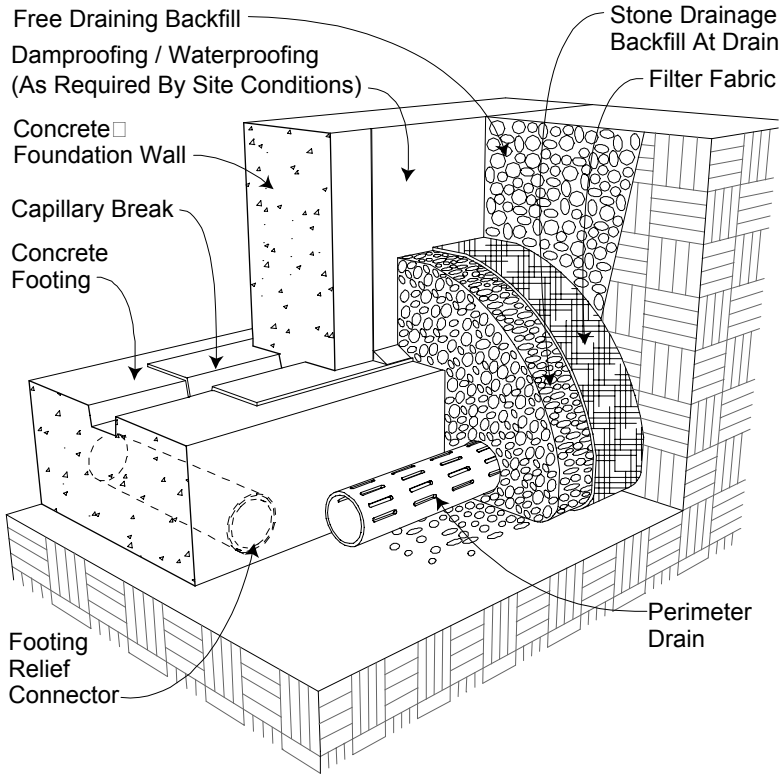



**Figure 2 – Perimeter Drainage System along Footer**

Refer to additional foundation details contained in the EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004), specifically Chapter 7, pages 181 through 232, and Chapter 10, pages 243 through 252.

## Pre-Work Inspection Checklist

To be completed before the Trade Contractor starts work on the jobsite:

☐ 1. Construction is at the appropriate stage and conditions are acceptable for *The Foundation Contractor* to begin work.

☐ 2. Appropriate materials and equipment are onsite for work to be performed by *The Foundation Trade Contractor.*

☐ 4. *The Foundation Trade Contractor* has current plans. Record date of plans: [___/___/___]

☐ 5. *The Foundation Trade Contractor* has current *Company* specifications for foundation installations.

☐ 6. *The Foundation Trade Contractor* has reviewed and accepts all high performance items that appear in the Detailed Installation Checklist

Company Rep's Initials _____

Trade Contractor's Initials _____

**Post-Work Inspection Checklist:**

To be completed before Trade Contractor leaves jobsite:

- ☐ 1. The perimeter drainage system is installed.
- ☐ 2. The perimeter drainage system terminates to daylight or to the sump pit.
- ☐ 3. Dampproofing is present to final grade on crawl space and basement walls.
- ☐ 4. All site details match the Foundation Details.
- ☐ 5. No unapproved material substitutions have been made from *The Company* specs.
- ☐ 6. Crushed stone is to the proper depth is present on crawl space floors.
- ☐ 7. The soil gas ventilation pipe is present at the proper location, and marked so as not to be mistaken for a sewer connection.
- ☐ 8. Control joints are present at the correct locations in concrete slabs.
- ☐ 9. Water testing of the perimeter drainage system successfully demonstrated the ability of the drainage pipe to transport water daylight or to the sump pit.
- ☐ 10. The Trade Contractor installer checklist is completed and signed.

Company Rep's Initials _____

Trade Contractor's Initials _____

# Framing Requirements and Checklists

**Framing Requirements:**
**1. Introduction – High Performance Framing**

High Performance is defined as superior energy efficiency, safety, comfort, and durability. Managing the flows of moisture and air with the same thoroughness as energy protects against the major damage functions a home faces— heat, water, radiation (ultraviolet) and biological organisms (frequently requiring liquid water).

The work of the *Framing Trade Contractor* contributes to high performance in the following ways:

- Water management –
  - Capillary break installed between ALL bottom plates and concrete or masonry
  - Prompt installation of or enablement of prompt installation by a subsequent *Trade Contractor* of the roofing underlayment over sheathed roofs and weather-resistive barrier on walls
  - Installation of framing and sheathing materials not in excess of 19% moisture content and free of mold growth.
  - Installation of structural sheathing and insulating sheathing to prevent, to the greatest extent possible, water penetration into interior during construction, and if applicable as part of the final drainage plane strategy as determined by *The Company*.
- Integrity and Continuity of the Thermal Barrier –
  - Five-sided support for insulation in all framing cavities in the conditioned boundary for those areas to receive drywall by others. In concealed areas not to receive drywall as a finish material, *The Framing Contractor* shall coordinate with *The Supervisor* and *The Insulation Contractor* to assure that insulation is encapsulated on all six sides (see the Installation Checklist for details).
  - Efficient framing, such that two-by stock is used only where structurally necessary.
- Integrity and Continuity of the Air Barrier –
  - Air seal at all bottom plates on exterior walls
  - Install plywood or OSB structural sheathing with gaps as required by the manufacturer. Where insulated Sheathing is installed, butt panel joints tightly and tape joints (if applicable).
  - In concealed areas not to receive drywall as a finish material, the framing contractor shall coordinate with the site supervisor and insulation contractor to assure that insulation is installed and encapsulated on all six sides of frame wall cavities (see the Installation Checklist for details).
  - Installation of draft stops in areas that will not be accessible after completion of framing (see the Installation Checklist for details).
- Vapor management –
  - No substitutions of sheathing materials with performance properties (including water absorption and vapor permeability) different than the sheathing materials specified.

Construction is a process that involves sequential work performed by a variety of subcontractors. The *Framing Trade Contractor's* work is generally preceded by *The Foundation Trade Contractor*, with these high performance implications:

- Foundation insulation – protect this material and replace as necessary when damaged as the result of framing work.
- Foundation drainage system – protect this system and replace as necessary when damaged as the result of framing work.

*The Framing Trade Contractor's* work is generally followed by *The Roofing Contractor, The Drainage Plane Contractor*, *The Window Trade Contractor*, *The Insulating Contractor* and later by *The HVAC Contractor* with these high performance implications:

- Flashing and/or weather-resistive barriers installed in rough openings must accommodate integration with window and door unit flashings, particularly at the sill and head.
- Framing layout in high performance homes is done in coordination with HVAC layout of equipment and ducts—do NOT vary from the framing layout or add framing/blocking that could interfere with a high performance HVAC installation.
- Framing, sheathing and airflow retarder components (this last IF installed by the *Framing Trade Contractor*) must be properly installed to permit full insulation of building cavities in an airtight manner.

Performance testing is often a key step along the path to high performance. Infra-red thermal imaging and air leakage testing (blower door) can act as performance tests for efficient framing and draft stop details. These tests may be used by *The Company* to verify the contribution of the frame to the thermal and air barriers. Unfortunately these tests can generally be done only at a much later stage of construction when corrective action is quite costly. It is, therefore essential that these details be successfully executed. Successful performance is defined as the addition of no unnecessary framing materials in substitution of thermal insulation and the presence of draft stop materials in all problematic air sealing areas as shown on the framing plans and Details in SOW #2.

A critical component of high performance framing can be detailed framing layouts (See Figure 1 in the Installation Checklist). Detailed framing layouts can "codify" thermal and air barrier continuity and integration of framing with HVAC design and installation.

*The Framing Trade Contractor* will be responsible for correcting deficiencies in installation so that performance meets the requirements of *The Company* and high performance in these Scopes. The cost of corrective action is the responsibility of *The Framing Trade Contractor*.

For more comprehensive information on the relationship between framing and high performance homes, see the following resources:

- EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004)
- Building America Best Practices for Cold Climates
- Building America Houses That Work – Cold Climates

**2. Detailed Installation Requirements –**

☐ Pre-Work and Post –Work Inspection checklists will be completed and signed by Site Superintendent and *The Trade Contractor*

☐ 1. Install Capillary break (closed-cell foam sill sealer or rubber membrane) underneath carrying beams at foundation beam pockets.

☐ 2. Install a double layer closed-cell foam sill sealer as a capillary break and air seal underneath all bottom plates that rest on concrete or masonry and separate conditioned from unconditioned spaces, including vertical transitions at foundation steps.

☐ 3. Install capillary break (closed-cell foam sill sealer or rubber membrane) under interior wall partitions on concrete slabs

☐ 4. If a framing layout plan is provided by *The Company*, install all framing per the framing layout plan (See Example in Figure 1 below).

☐ 5. Use of structural lumber shall be limited to structural applications. This includes the following on walls that separate conditioned space from unconditioned space (See Figure 2 below):

- ☐ drywall stops at inside corners
- ☐ interior partition/exterior wall drywall stops
- ☐ minimized number of cripples
- ☐ minimized number of studs at rough openings
- ☐ 2- or 3-stud corners
- ☐ top plates (single)

☐ 6. All headers are load-tuned—they are sized to the specific load they will carry. Install headers only of the size and material as called out on the framing plans/specifications.

☐ 7. Install a capillary break at locations where wood based sheathing (i.e. plywood, OSB) runs past the framed wall and contacts concrete or masonry. The capillary break is installed between the sheathing and concrete or masonry.

☐ 8. All framing cavities that separate conditioned space from unconditioned space are to be framed to form a five-sided (top, bottom, two sides, and rear) cavity to contain the insulation and prevent air from moving through air permeable insulation products (see Figure 3 below). The sixth side of most of these cavities will be completed with the installation of with the interior gypsum board, or other air impermeable finish interior. Those cavities that will NOT be finished with and air impermeable interior sheathing shall be sheathed with thin-profile sheathing, plywood, OSB, gypsum board, or other air impermeable sheathing products by *The Framing Contractor*. These areas include, but are not necessarily limited to:

- ☐ a. tub surrounds on exterior walls
- ☐ b. soffits terminating on exterior walls
- ☐ c. framed fireplace/entertainment center/seat enclosures on exterior walls
- ☐ d. plumbing/electrical/HVAC chases at attic or exterior walls
- ☐ e. other architectural details that require framing on walls that will be insulated

☐ 9. All framing cavities that separate conditioned space from unconditioned space shall be sheathed on both sides of the stud cavity. If they are not sheathed as part of the building exterior, they are sheathed with a continuous, air sealed, air impermeable material to accomplish the five-

sided enclosure for cavity insulation containment (See Figure 4 below). This includes but is not limited to the following areas:

- ☐ a. attic knee walls
- ☐ b. ceiling height transition walls that abut attic space
- ☐ c. walls that abut unconditioned front entryways
- ☐ d. walls that abut future conditioned space

☐ 10. If required by *The Company*, rigid insulation of the thickness specified in the Specifications shall be installed as exterior sheathing and shall be installed on all walls that separate conditioned from unconditioned space.

- ☐ IF the rigid insulation is part of a continuous air barrier, then all seams in the rigid insulation are taped with material as specified by *The Company*.
- ☐ IF the rigid insulation is part of the drainage plane, than all vertical seams are taped and all horizontal seams are "z"-flashed with 18-inch wide polyethylene sheathing. That is, after each course of rigid insulation is installed, polyethylene strips are fastened 8 to 9 inches up the framing from the top edge of the rigid insulation, draping down so that as the next course of rigid insulation is installed, the poly flashing forms a weatherlapped joint.

☐ 11. Air seal band or rim joists by installing a continuous bead of construction adhesive between the mudsill or top plat and the perimeter band or rim joists, between the subfloor and the perimeter band or rim joists, and at all vertical butt joints in the perimeter band or rim joists.

☐ 12. Exterior sheathing material matches *The Company's* specifications. Alternate materials must be approved in writing by *The Company*.

☐ 13. Install all framing and framing accessory materials per manufacturer installation requirements. Any deviation from the manufacturer installation requirements must be approved by *The Company*.

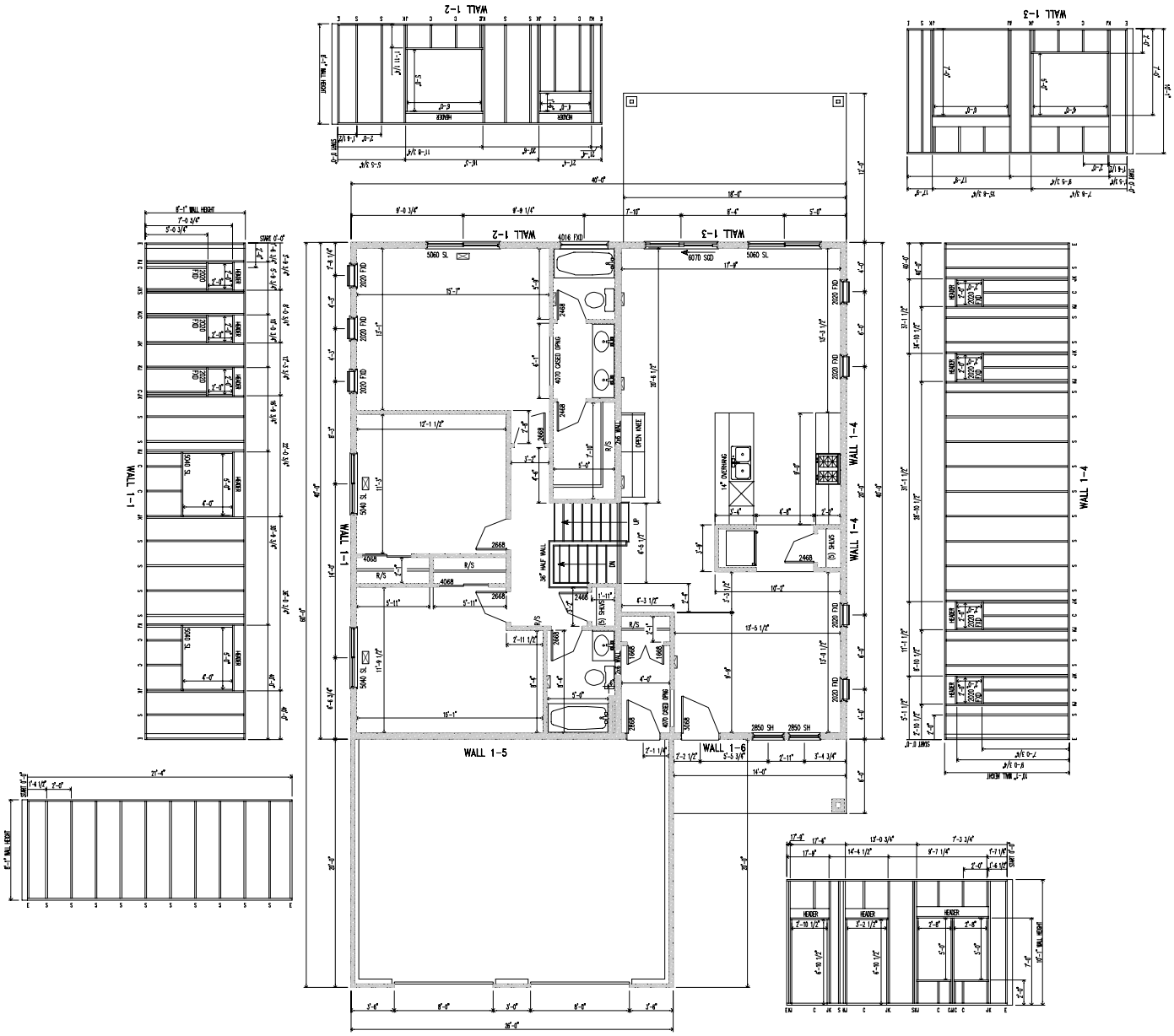
**NOTE**: If *The Company* includes roofing underlayment installation in the responsibilities of *The Framing Contractor*, see the Scopes of Work documents for *The Roofing Trade Contractor*.

**NOTE**: If *The Company* includes drainage plane installation in the responsibilities of *The Framing Contractor*, see the Scopes of Work documents for *The Drainage Plane Contractor*.

**NOTE**: If *The Company* includes window installation in the responsibilities of *The Framing Contractor*, see the Scopes of Work documents for *The Window Installation Contractor*.

**3. Details and Sequenced Drawings**

## Figure 1 – Framing Layout



## Figure 2. – Efficient Framing Details

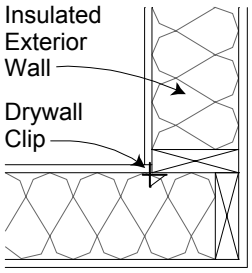



**Figure 2a - Drywall clip at interior corner**

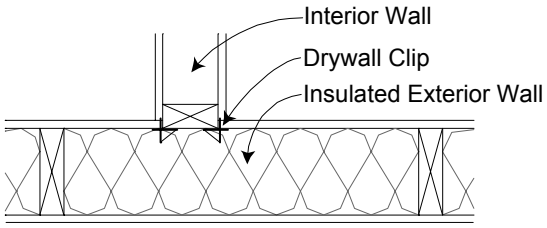



**Figure 2b - Drywall clips at interior partition.**

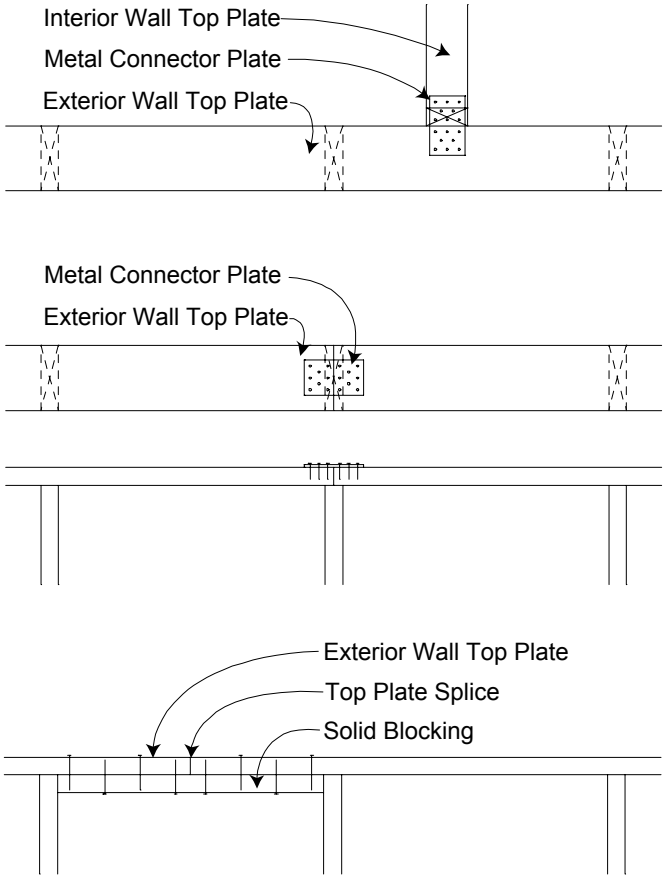



**Figure 2c - Methods for joining single top plates.**

Figure 3 – Draft Stopping Details – Group 1

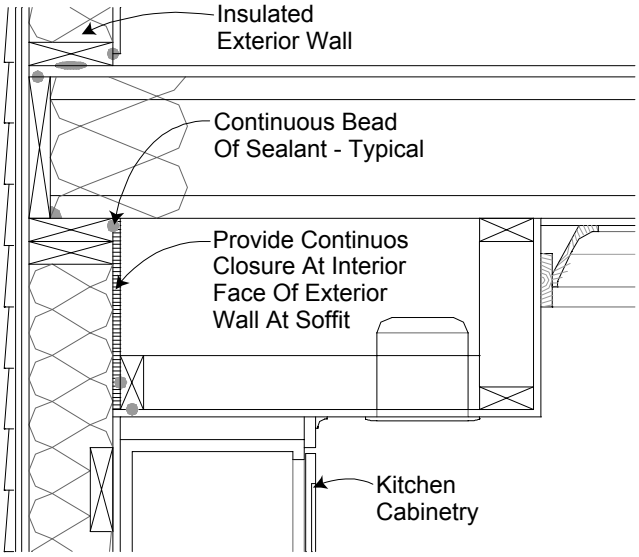



**Figure 3a - Draft stop behind soffit**

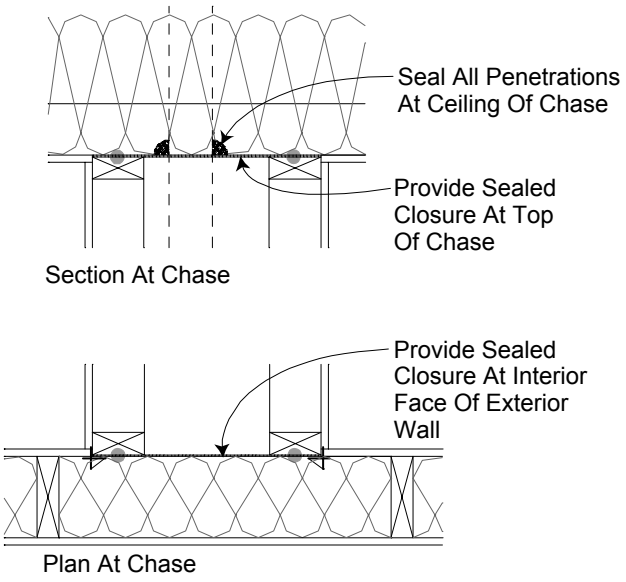



**Figure 3b - Draft stops: Upper drawing shows draft stop where chase meets attic and pipe continues into attic; Lower drawing shows draft stopping where chase meets exterior wall.**

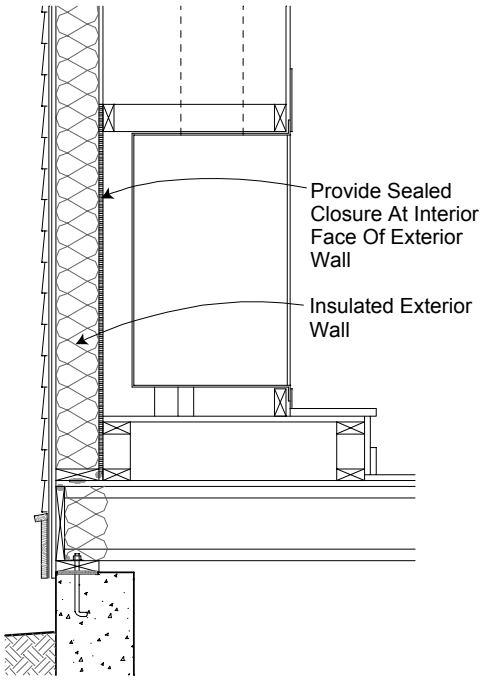



**Figure 3c - Draft stop behind fire place insert.**

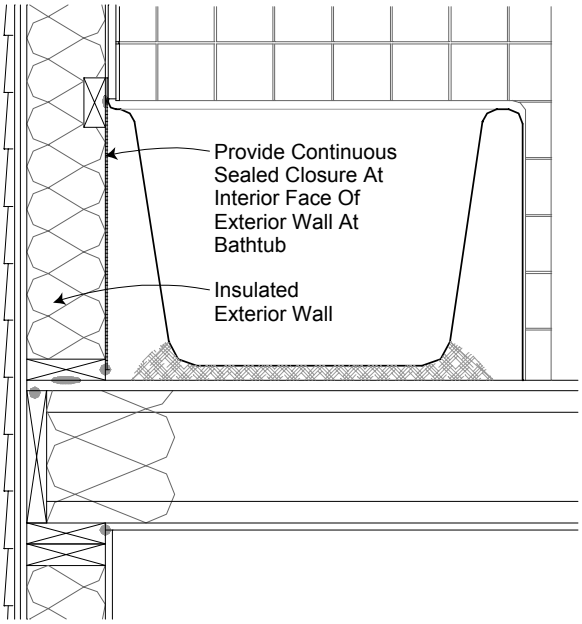



**Figure 3d - Draft stop behind bathtub.**

For additional framing details, refer the EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004), specifically Chapter 11, pages 253 through 272. Additional framing details can be found at http://www.buildingscience.com/housesthatwork/advancedframing/default.htm

**Pre-Work Inspection Checklist**

To be completed before the Trade Contractor starts work on the jobsite:

- ☐ 1. Construction is at the appropriate stage and conditions are acceptable for *The Trade Contractor* to begin work.
- ☐ 2. Measured moisture content of framing lumber does not exceed 19 %.
- ☐ 3. If available from *The Company*, HVAC equipment and duct layout and sizing have been reviewed for integration/compatibility with the framing plans.
- ☐ 4. Appropriate materials and equipment are onsite for work to be performed by *The Framing Trade Contractor.*
- ☐ 5. *The Framing Trade Contractor* has current plans. Sign off on date of plans: [___/___/___]
- ☐ 6. *The Framing Trade Contractor* has current *Company* specifications for all framing and framing accessories materials.
- ☐ 7. *The Framing Trade Contractor* has reviewed and accepts all High Performance Framing Requirements listed in the Introduction to Framing Requirements and Checklists.
- ☐ 8. *The Framing Trade Contractor* has reviewed and understands/accepts the Framing Requirements and Checklists including the associated details; in particular, five-sided or six-sided containment for all framing cavities that will be insulated.
- ☐ 9. *The Framing Trade Contractor* has reviewed and understands the HVAC duct layout and other mechanical system layouts, and has coordinated the framing layout with the *Supervisor* to ensure no conflicts with the work of *The Company's HVAC Trade Contractor*.

Company Rep's Initials _____

Trade Contractor's Initials _____

**Post-Work Inspection Checklist:**

To be completed before Trade Contractor leaves jobsite:

- ☐ 1. If applicable, all site details match the *Company*'s Framing Layout Plans.
- ☐ 2. All capillary breaks to be installed by the *Framing Trade Contractor* as set forth in the Framing Requirements and associated Details are in place.
- ☐ 3. Any structural or insulating sheathing is free from damage (holes). Sheathing has been installed according to manufacturer's requirements, and is in accordance with Framing Standards and Description of Work Performance, Framing Requirements, and *Company* specifications.
- ☐ 4. All site details match the associated Details in the Framing Requirements.
- ☐ 5. All framing cavities that will receive drywall and separate conditioned space from unconditioned space have five-sided containment. All framing cavities that will not receive drywall and separate conditioned space from unconditioned space have been insulated and have six-sided containment.
- ☐ 6. All air sealing measures to be performed by the *Framing Trade Contractor* as set forth in the Framing Requirements and associated Details have been installed.
- ☐ 7. No unapproved framing material substitutions have been made from *The Company* specifications.

Company Rep's Initials _____

Trade Contractor's Initials _____

# Windows – Requirements and Checklists

**Window Installation Requirements:**
**1. Introduction – High Performance Window Installation**

High Performance is defined as superior energy efficiency, safety, comfort, and durability. Managing the flows of moisture and air with the same intensity as energy protects against the major damage functions a home faces— heat, water, radiation (ultraviolet) and biological organisms (frequently requiring liquid water).

The work of the *Window/Door Trade Contractor* contributes to high performance in the following way:

- Water Management – Proper integration of unit flashing, rough opening flashing, and the weather-resistive barrier create a continuous drainage plane keeping liquid water out of the wall assemblies and moving water off of the wall assemblies.

Construction is a process that involves sequential work performed by a variety of subcontractors. The *Window/Door Trade Contractor's* work is generally integrated with the work of the Drainage Plane Trade Contractor with these high performance considerations:

- The flashing systems and components of both the rough openings and the window/door units must properly integrate with the work of the *Drainage Plane Trade Contractor*, regardless of whether the window/door unit installation takes place before or after the work of the *Drainage Plane Trade Contractor*.

*The Window/Door Trade Contractor's* work is generally followed by the *Air Sealing/Insulation Trade Contractor* and the *Wall Cladding Contractor* with these high performance implications:

- The window/door units are adequately shimmed so that minimally-expanding foam insulation can be installed between the rough opening and the unit to contribute to both thermal and air barrier continuity.
- Depending upon the type of wall cladding, the window/door flashing system may need to be integrated with the wall cladding for proper water management.

Performance testing is often a key step along the path to high performance. Window/door installations may be tested for water management performance by spray rack or hose testing. This test would take place after the window/door installations have been integrated with the weather-resistive barrier but before the installation of cavity insulation. Successful test results are leak-free window or door installations.

*The Window/Door Trade Contractor* will be responsible for correcting deficiencies in installation so that performance meets the requirements of *The Company* and high performance in these Scopes. The cost of corrective action is the responsibility of *The Window/Door Trade Contractor*.

For more comprehensive information on the relationship between window/door installation and high performance homes, see the following resources:

- EEBA Water Management Guide (EEBA-WMG, 2004)
- EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004)
- Building America Best Practices for Cold Climates
- Building America Houses That Work – Cold Climates

**NOTE:** Because window installation can take place before or after the weather-resistive barrier (depending on a number of factors including variations in cladding), and because window installation is different when installed in conjunction with high performance rigid insulation exterior insulation, three different sets of detailed installation requirements follow:

**2a. Windows Installed AFTER the Weather-Resistive Barrier**
**2b. Windows Installed BEFORE the Weather-Resistive Barrier**
**2c. Windows Installed With Rigid Insulation Exterior Sheathing**

**2a. Detailed Installation Requirements – Windows Installed AFTER the Weather-Resistive Barrier**

☐ Pre-Work and Post –Work Inspection checklists will be completed and signed by Site Superintendent and *The Trade Contractor*

☐ 1. Use the specified windows, flashing and sealant.

☐ 2. Install window according to manufacturer's instructions flashing the opening and window using the detailed written instructions and drawings in this document

**Details and Sequence Drawings**

☐ 1. Insert backdam using material specified by *The Company*. (EEBA-WMG, 2004: Step 3, page 23)

☐ 2. Cut the house wrap drainage plane above the window; temporarily tape the house wrap above the window up and out of the way. (EEBA-WMG, 2004: Step 3, page 23)

☐ 3. Insert the 2 pieces of adhesive backed sill flashing. The vertical leg of the flashing must be at least 6 inches in length. The interior edge of the flashing must be on top of the back dam. (EEBA-WMG, 2004: Step 3, page 43, Alternate method, Step 4, page 23, and skip next step))

☐ 4. Install the corner patches of adhesive flashing. (EEBA-WMG, 2004: Step 4, page 43)

☐ 5. Install a continuous bead of sealant to the backside of the head and jamb flanges. (EEBA-WMG, 2004: Step 5, page 24)

☐ 6. Install window, level and attach according to manufacturer's instructions.

☐ 7. Install jamb flashings followed by head flashing. (EEBA-WMG, 2004: Step 7, page 25)

☐ 8. Remove tape and bring house wrap above window back to its original position and tape the heading flashing. (EEBA-WMG, 2004: Step 8, page 25)

Form will be signed by *The Trade Contractor* thereby indicating that all work has been completed in the manner specified within this Scope of Work.

**2b. Detailed Installation Requirements – Windows Installed <u>BEFORE</u> the Weather-Resistive Barrier**

☐ Pre-Work and Post –Work Inspection checklists will be completed and signed by Site Superintendent and *The Trade Contractor*

☐ 1. Use the specified windows, flashing and sealant.

☐ 2. Install window according to manufacturer's instructions flashing the opening and window using the detailed written instructions and drawings in this document

**Details and Sequence Drawings**

☐ 1. Insert backdam using material specified by *The Company*. (EEBA-WMG, 2004: Step 2, page 31)

☐ 2. Mechanically attach (or adhere by removing upper portion of release paper) the sill apron, using a piece of flashing, building paper or house wrap (as specified) so that the top edge of the strip is flush with the rough opening. The strip should extend 6 inches past each side of the rough opening. At least 3 inches at the bottom of this strip must be unattached so that a section of the drainage plane can be slipped under later. (EEBA-WMG, 2004: Step 3, page 32)

☐ 3. Insert the 2 pieces of adhesive backed sill flashing as shown in Sequence Drawing Set 2. The vertical leg of the flashing must be at least 6 inches in length. The interior edge of the flashing must be on top of the back dam. (EEBA-WMG, 2004: Step 4, page 32)

☐ 4. Install the corner patches of adhesive flashing (EEBA-WMG, 2004: Step 5, page 33)

☐ 5. Install the jamb flashings (EEBA-WMG, 2004: Step 6, page 33)

☐ 6. Install the short pieces of flashing under the bottom edge of the jamb flashings and over the sill apron

☐ 7. Install a continuous bead of sealant to the backside of the jamb and head flanges. (EEBA-WMG, 2004: Step 7, page 34)

☐ 8. Install window, level and attach according to manufacturer's instructions.

☐ 9. Install jamb flashings follow by head flashing as shown in Sequence Drawing Set 2. (EEBA-WMG, 2004: Step 8, page 34)

Form will be signed by *The Trade Contractor* thereby indicating that all work has been completed in the manner specified within this Scope of Work.

**2c. Detailed Installation Requirements – Windows Installed with Rigid Insulation as the Exterior Sheathing and Weather-Resistive Barrier**

☐ Pre-Work and Post –Work Inspection checklists will be completed and signed by Site Superintendent and *The Trade Contractor*

☐ 1. Use the specified windows, flashing and sealant.

☐ 2. Install window according to manufacturer's instructions flashing the opening and window using the detailed written instructions and drawings in this document

**Details and Sequence Drawings**

☐ 1. Insert backdam using material specified by *The Company*. (EEBA-WMG, 2004: Step 2, page 37)

☐ 2. Insert the 2 pieces of adhesive backed sill flashing as show. The vertical leg of the flashing must be at least 6 inches in length. The interior edge of the flashing must be on top of the back dam. (EEBA-WMG, 2004: Step 3, page 38)

☐ 3. Install the corner patches of adhesive flashing. (EEBA-WMG, 2004: Step 4, page 38)

☐ 4. Install the jamb flashings. (EEBA-WMG, 2004: Step 5 , page 39.)

☐ 5. Install a continuous bead of sealant to the backside of the jamb and head flanges.

☐ 6. Install window, level and attach according to manufacturer's instructions.

☐ 7. Install jamb flashings followed by head flashing. (EEBA-WMG, 2004: Steps 8 – 9, pages 40 – 41.)

☐ 8. Install a counter flashing over the head flashing as shown in Sequence Drawing Set 3. Use the specified material (polyethylene, house wrap or building paper) to create a weatherlapped drainage plane from the z-flashing at the horizontal joint in the sheathing above the window to the frame of the window. Use short sections of tape to hold this section of the drainage plane in place until the cladding is installed. (EEBA-WMG, 2004: pages 79.)

Form will be signed by *The Trade Contractor* thereby indicating that all work has been completed in the manner specified within this Scope of Work.

**Pre-Work Inspection Checklist**

To be completed before the *Trade Contractor* starts work on the jobsite:

- ☐ 1. Construction is at the appropriate stage and conditions are acceptable for the *Window/Door Trade Contractor* to begin work, particularly in terms of integrating the weather-resistive barrier and both rough opening and window unit flashing.
- ☐ 2. Exterior wall sheathing is cut flush to (is not proud of) the rough opening.
- ☐ 3. Appropriate materials and equipment are onsite for work to be performed by the *Window/Door Trade Contractor.*
- ☐ 4. *The Window/Door Trade Contractor* has current plans. Record date of plans: [___/___/___]
- ☐ 5. *The Window/Door Trade Contractor* has current *Company* specifications for all window and door materials.
- ☐ 6. *The Window/Door Trade Contractor* has reviewed and accepts all High Performance Window/Door Requirements listed in the Introduction to Windows – Requirements and Checklists.
- ☐ 7. *The Window/Door Trade Contractor* has reviewed and understands/accepts the Window/Door Detailed Installation Requirements and Checklists (2.a, 2.b, and 2.c), in particular, the importance of thermal and air barrier continuity.
- ☐ 8. Rough openings for windows and doors are within tolerances provided in the plans and as required for installation according to manufacturer's specifications and the installation requirements.

Company Rep's Initials _____

Trade Contractor's Initials _____

**Post-Work Inspection Checklist**

To be completed after the *Trade Contractor* has completed all work on the jobsite:

- ☐ 1. Window/Door unit installation accomplishes/will permit proper integration with the weather-resistive barrier.
- ☐ 2. Window/Door installation permits proper integration of wall cladding flashings.
- ☐ 3. Window/door units have not been damaged during installation (mitered corners, flanges, etc.).
- ☐ 4. All site details match the Detailed Installation Requirements.
- ☐ 5. No unapproved material substitutions have been made from *The Company* specifications.
- ☐ 6. Water testing cannot be conducted until both the window/door and weather-resistive barrier are installed. *The Window/Door Contractor* will be responsible for corrective action if subsequent water testing identifies water leakage to the interior that is the result of deficient window/door installation.

Company Rep's Initials _____

Trade Contractor's Initials _____

# Drainage Plane Requirements and Checklists

**Drainage Plane Requirements:**
**1. Introduction – High Performance Drainage Plane**

High Performance is defined as superior energy efficiency, safety, comfort, and durability. Managing the flows of moisture and air with the same thoroughness as energy protects against the major damage functions a home faces— heat, water, radiation (ultraviolet) and biological organisms (frequently requiring liquid water).

The work of the *Drainage Plane Trade Contractor* contributes to high performance in the following ways:

- Water management –
  - Provides a barrier to prevent rain water that penetrates the finished exterior cladding system, from entering the wall assembly or being introduced into window or door openings
  - Provides a pathway for liquid water that has penetrated the cladding system or accumulates due to daily or seasonal changes in thermal and humidity levels behind the cladding system to safely exit the exterior wall assembly
- Integrity and Continuity of the Thermal Barrier –
  - The drainage plane, when properly sealed, can also reduce airflow through the wall assembly, which improves the thermal performance of the cavity insulation
- Integrity and Continuity of the Air Barrier –
  - The drainage plane, when properly sealed, can function as an airflow retarder
- Vapor management –
  - The rate at which water vapor flows into and out of the wall assembly is based in part on the material properties of the drainage plane.

Construction is a process that involves sequential work performed by a variety of subcontractors. The *Drainage Plane Trade Contractor's* work is generally preceded by *The Foundation Trade Contractor* and *The Framing Contractor* with these high performance implications:

- Foundation insulation – protect this material and replace as necessary when damaged as the result of framing work.
- Foundation drainage system – protect this system and replace as necessary when damaged as the result of framing work.
- Sheathing materials installed by *The Framing Contractor* are key elements of the airflow retarder and the thermal insulation – protect these components and replace or repair as necessary if damage during installation of the drainage plane.

*The Drainage Plane Trade Contractor's* work is generally followed by *The Window Trade Contractor*, *The Insulating Contractor* and later by *The HVAC Contractor* with these high performance implications:

- Flashing and/or weather-resistive barriers installed in rough window and door openings must integrate with window and door unit flashings, particularly at the sill and head.

- Flashings at roofs wall intersections and at penetrations through the wall (i.e. plumbing, electrical, vents, HVAC refrigerant lines, etc.) that are provided by other trades must be integrated with the drainage plane to keep water from entering the wall assembly.
- Framing, sheathing and airflow retarder components, IF installed by the *Drainage Plane Trade Contractor*, must be properly installed to permit full insulation of building cavities in an airtight manner.

Performance testing is often a key step along the path to high performance. Drainage plane installation may be tested for water management performance by spray rack or hose testing. This test would take place after the drainage plane has been integrated with the window/door installations but before the installation of cavity insulation. Successful test results are leak-free drainage plane installations.

*The Drainage Plane Trade Contractor* will be responsible for correcting deficiencies in installation so that performance meets the requirements of *The Company* and high performance in these Scopes. The cost of corrective action is the responsibility of *The Drainage Plane Trade Contractor*.

For more comprehensive information on the relationship between the drainage plane and high performance homes, see the following resources:

- EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004)
- EEBA Water Management Guide (EEBA-WMG June 2004)
- Building America Best Practices for Cold Climates
- Building America Houses That Work – Cold Climates

**2. Detailed Installation Requirements –**

**a. Drainage Plane <u>After</u> Window Installation**

☐ Pre-Work and Post –Work Inspection checklists will be completed and signed by Site Superintendent and *The Drainage Plane Trade Contractor*

☐ 1. Use the specified drainage plane material, fasteners and sealant or tape.

☐ 2. Install according to manufacturer's instructions.

☐ 3. Install drainage plane continuously from the bottom to the top of the assembly. (EEBA-WMG (June 2004): page 33).

☐ 4. Weather lap the drainage plane so that the bottom of upper sheets or sections extends over the top of the bottom sheet by a minimum of three inches for horizontal joints. Weather lap vertical joints by a minimum of six inches. Alternate lapping dimensions may be required based on specific manufacturer's installation instructions.

☐ 5. Below windows or other penetrations, the drainage plane is installed underneath (interior to) the bottom edge of the sill flashing (EEBA-WMG (June 2004): Step 9, page35.); the minimum over lap of the drainage plane material over the flashing at the head of the window is three inches (EEBA-WMG (June 2004): Step 12, page 36).

☐ 6. Above windows or other penetrations, the drainage plane material is installed over (exterior to) the top edge of the head flashing.

☐ 7. Flash all wall penetrations, including but not limited to those penetrations for wires, pipes and vents, with the flashing materials or blocks specified by *The Company*. (EEBA-WMG (June 2004): page 82).

☐ 8. Terminate the drainage plane at the correct location as shown on the details and sequenced drawings, providing a pathway for water to leave the assembly.

☐ 9. Lap the drainage plan over all flashings provided by the Roofing Trade Contractor, providing a pathway for water to leave the assembly (EEBA-WMG (June 2004): page 82 & 83)

**Details and Sequenced Drawings**

Refer to flashing and drainage plane installation details contained in EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004) and the EEBA Water Management Guide (June 2004).

## Pre-Work Inspection Checklist - Drainage Plane <u>After</u> Window Installation

To be completed before the Trade Contractor starts work on the jobsite:

- ☐ 1. Construction is at the appropriate stage and conditions are acceptable for *The Trade Contractor* to begin work.
- ☐ 2. Sheathing is installed and attached per Framing SOW.
- ☐ 3. Windows are installed and properly flashed.
- ☐ 3. Appropriate materials and equipment are onsite for work to be performed by *The Drainage Plane Trade Contractor.*
- ☐ 4. *The Drainage Plane Trade Contractor* has current plans. Date of plans: [___/___/___]
- ☐ 5. *The Drainage Plane Trade Contractor* has current *Company* specifications for all drainage plane and drainage plane accessories materials.
- ☐ 6. *The Drainage Plane Contractor* has reviewed and accepts all High Performance Drainage Plane Requirements listed in the Introduction to the Drainage Plane Requirements and Checklists.
- ☐ 7. *The Drainage Plane Trade Contractor* has reviewed and understands/accepts the Detailed Installation Requirements 2.a "Drainage Plane-**<u>After</u>** Windows Installation."

Company Rep's Initials _____

Trade Contractor's Initials _____

## Post-Work Inspection Checklist - Drainage Plane <u>After</u> Window Installation

To be completed before Trade Contractor leaves jobsite:

☐ 1. The drainage plane is installed in a weather lapped manner.

☐ 2. The drainage plane sections overlap a minimum of three inches for horizontal joints and six inches for vertical joints.

☐ 3. The manufacturers recommended or Company specified fasteners were used to attach the drainage plane.

☐ 4. Joints between sections of the drainage plane are properly taped (if called for in the Detailed Installation Requirements 2.a. "Drainage Plane After Windows Installation").

☐ 5. The drainage plane properly integrates with the flashing at windows, doors, roof wall intersections, and other penetrations:

☐ The drainage plane below windows, doors, and other penetrations is installed under (interior) to the bottom of the flashing.

☐ The drainage plane above windows, doors, roof wall intersections, and other penetrations is installed over (exterior) to the top of the flashing.

☐ 6. All site details match the Drainage Plane Details in the Drainage Plane Installation Checklist and Details – SOW #2.

☐ 7. No unapproved drainage plane material substitutions have been made from *The Company* specs.

☐ 8. The *Drainage Plane Trade Contractor* understands that final performance evaluation of the drainage plane may be dependent on performance tests (water testing) that *The Company* may conduct at any time in the construction process once the *Drainage Plane Trade Contractor's* work is complete.

Company Rep's Initials _____

Trade Contractor's Initials _____

**2. Detailed Installation Requirements –**

**b. Drainage Plane <u>Before</u> Window Installation**

☐ Pre-Work and Post –Work Inspection checklists will be completed and signed by Site Superintendent and *The Drainage Plane Trade Contractor*

☐ 1. Use the specified drainage plane material, fasteners and sealant or tape

☐ 2. Install according to manufacturer's instructions.

☐ 3. Install drainage plane continuously from the bottom to the top of the assembly.

☐ 4. Weather lap the drainage plane so that the bottom of upper sheets or sections extends over the top of the bottom sheet by a minimum of three inches for horizontal joints. Weather lap vertical joints by a minimum of six inches. Alternate lapping dimensions may be required based on specific manufacturers installation instructions.

☐ 5. Terminate the drainage plane at the correct location providing a pathway for water to leave the assembly.

☐ 6. Flash all wall penetrations, including but not limited to those penetrations for wires, pipes and vents, with the flashing materials or blocks specified by *The Company*.

☐ 7. Cut the drainage plane at openings for windows and doors, according to the Details and Sequenced Drawings, in preparation for the installation of windows and doors.

☐ 8. Lap the drainage plan over all flashings provided by the Roofing Trade Contractor, providing a pathway for water to leave the assembly (EEBA-WMG (June 2004): page 82 & 83)

Company Rep's Initials _____

Trade Contractor's Initials _____

**2.b. Details and Sequenced Drawings**

Refer to flashing and drainage plane installation details contained in EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004) and the EEBA Water Management Guide (June 2004).

## **Pre-Work Inspection Checklist - Drainage Plane <u>Before</u> Window Installation**

☐ 1. Construction is at the appropriate stage and conditions are acceptable for *The Trade Contractor* to begin work.

☐ 2. Sheathing is installed and attached per Framing SOW.

☐ 3. Appropriate materials and equipment are onsite for work to be performed by *The Drainage Plane Trade Contractor.*

☐ 4. *The Drainage Plane Trade Contractor* has current plans. Sign off on date of plans: [___/___/___]

☐ 5. *The Drainage Plane Trade Contractor* has current *Company* specifications for all drainage plane and drainage plane accessory materials.

☐ 7. *The Drainage Plane Contractor* has reviewed and accepts all High Performance Drainage Plane Requirements listed in the Introduction to the Drainage Plane Requirements and Checklists.

☐ 8. *The Drainage Plane Trade Contractor* has reviewed and understands/accepts the Detailed Installation Requirements 2.a "Drainage Plane-**<u>Before</u>** Windows Installation."

Company Rep's Initials _____

Trade Contractor's Initials _____

## **Post-Work Inspection Checklist - Drainage Plane Before Window Installation**

☐ 1. The drainage plane is installed in a weather lapped manner.

☐ 2. The drainage plane sections overlap a minimum of three inches for horizontal joints and six inches for vertical joints.

☐ 3. The manufacturers recommended or Company specified fasteners were used to attach the drainage plane.

☐ 4. Joints between sections of the drainage plane are properly taped (if called for in Detailed Installation Requirements 2.b.).

☐ 5. The drainage plane properly integrates with the flashing at roof wall intersections, and other penetrations:

☐ The drainage plane below penetrations is installed under (interior) to the bottom of the flashing.

☐ The drainage plane above roof wall intersections, and other penetrations is installed over (exterior) to the top of the flashing.

☐ 6. All site details match the Drainage Plane Details in the Drainage Plane Installation Checklist and Details 2.b. "Drainage Plane Before Window Installation."

☐ 7. No unapproved drainage plane material substitutions have been made from *The Company* specs.

☐ 8. The *Drainage Plane Trade Contractor* understands that final performance evaluation of the drainage plane may be dependent on performance tests (water testing) that *The Company* may conduct later in the construction process after windows and doors have been installed.

Company Rep's Initials _____

Trade Contractor's Initials _____

# Air Sealing/Insulation – Requirements and Checklists

**Air Sealing/Insulation Requirements:**
**1. Introduction – High Performance Air Sealing/Insulation**

High Performance is defined as superior energy efficiency, safety, comfort, and durability. Managing the flows of moisture and air with the same intensity as energy protects against the major damage functions a home faces— heat, water, radiation (ultraviolet) and biological organisms (frequently requiring liquid water).

The work of the *Air Sealing/Insulation Trade Contractor* contributes to high performance in the following ways:

- Integrity and Continuity of the Thermal Barrier –
  - Complete fill of all framing cavities in the conditioned boundary—no voids, no gaps
  - Focus on the largest and most common thermal bypasses
- Integrity and Continuity of the Air Barrier –
  - Continuous air sealing at plates and assembly transitions
  - Complete air sealing at penetrations
- Vapor management –
  - No substitutions of insulation materials with performance properties (including water absorption and vapor permeability) different than the materials specified by *The Company*.
  - Installation of draft stops in areas that will not be accessible after completion of framing (outside wall fireplaces, tub surrounds on outside walls, soffits terminating on outside walls, vertical chases, etc.)
  - The moisture performance of wall and roof assemblies is a function of the combined performance of all assembly components, not the performance of just the "vapor retarder" that is traditionally installed behind the interior sheathing (drywall). It is likely that your local code or your local code official's interpretation of the code may require the installation of a vapor retarder. Consideration should then be given to "smart" vapor retarders to manage vapor movement into and out of assemblies, based on local climate conditions.
  - No substitutions of materials with performance properties (including water absorption and vapor permeability) different than the sheathing materials specified.

Construction is a process that involves sequential work performed by a variety of subcontractors. *The Air Sealing/Insulation Trade Contractor's* work is generally preceded by *The Framing Trade Contractor*, *The Plumbing Trade Contractor, The Electrical Trade Contractor, The HVAC Trade Contractor* and *The Window Installation Trade Contractor* with these high performance implications:

- Framed five-sided cavities to receive insulation – framing and exterior sheathing have created five-sided containment for all cavities requiring cavity insulation that will receive drywall to create a continuous thermal barrier.
- Cavities that are to receive thermal insulation in concealed locations that will not receive drywall (i.e. behind tubs and showers on exterior walls, chases, fireplaces, etc.) have been insulated and an air impermeable barrier has been installed to contain the insulation on all six sides.

- Plumbing/Electrical/HVAC – all plumbing/electrical/HVAC penetrations to the conditioned boundary have been made and are ready to be air sealed/insulated.
- Windows and Doors – All windows and doors have been installed and adequately shimmed to permit minimally-expanding spray foam air sealing of rough openings.

*The Air Sealing/Insulation Trade Contractor's* work is generally followed by *The Drywall Trade Contractor* with these high performance implications:

- All cavity insulation and air sealing details that will be rendered inaccessible by drywalling have been completed by *The Air Sealing/Insulation Trade Contractor*.
- An element of the continuous air barrier may be sealant applied to the backside of all drywall at the perimeter of all planes and penetrations (exterior wall outlets, for example). This arrangement must be confirmed with *The Company* and the *Drywall Trade Contractor*

Performance testing is often a key step along the path to high performance. Homes will be tested for building enclosure air leakage with a blower door test. Testing protocols that may apply include 100% testing (every installation), random percentage (e.g. 1 in 7) or the reserved right to test any installation as determined by *The Company* or the *Site Superintendent*. The Company reserves the right to further performance test the air sealing and insulation performance by infra-red thermal imaging of the building enclosure. Successful performance by *The Air Sealing/Insulation Trade Contractor* is determined by:

a. Building enclosure air leakage that does not exceed 0.25 CFM/square foot of building enclosure surface area at a 50 Pa air pressure differential.

b. Identification of no significant voids or air leakage upon qualitative infra-red thermal imaging of the building enclosure.

**NOTE**: "Smoke-testing" during the blower door test and infra-red thermal imaging can help to determine if failure to meet the performance test minimum is the result of *Air Sealing/Insulation Trade Contractor* deficiencies or damage to *The Air Sealing/Insulation Trade Contractor*'s work by subsequent trades. Each Trade Contractor agrees to stand by the determination of *The Company* and its performance tests in terms of responsibility for thermal performance.

**NOTE**: The EPA Energy Star program has identified 13 of the most common air leakage and thermal bypasses—they are listed here. For more information, see: http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Thermal_Bypass_Checklist.pdf.

For more comprehensive information on the relationship between air sealing/insulation and high performance homes, see the following resources:

- EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004)
- Building America Best Practices for Cold Climates
- Building America Houses That Work – Cold Climates
- RESNET Adopted Enhancements to the Mortgage Industry National Home Energy Rating Standards Chapter 3.B. 9. Insulation Installation

**2. Detailed Installation Requirements –**

☐ **Pre-Work Inspection:** completed and signed by Site Superintendent and *The Trade Contractor* (see Air Sealing/Insulation SOW #3, Trade Contractor & Site Supervisor Pre/Post Checklist)

**Detailed Installation Checklist –**

☐ 1. Install attic venting insulation baffles to ensure a continuous pathway for soffit-to-ridge attic ventilation and to prevent any wind that enters the soffit vents from blowing through the insulation material.

☐ 2. Air seal/insulate with the materials as specified by *The Company*.

☐ 3. Air seal at all the critical junctions in building enclosure assemblies (See Figure 1 below):

☐ mudsills ☐ bottom plates ☐ top plates

☐ 4. Air seal/insulate at all rim joists (See Figure 1 below).

☐ 5. Air seal/insulate at all applicable thermal bypasses (See Figure 2 below):

☐ shower/tub at exterior wall
☐ attic knee walls
☐ cantilevered floor
☐ flue shaft
☐ dropped ceiling/soffit
☐ staircase at exterior wall/attic
☐ whole-house fan attic penetration
☐ conditioned space over garage
☐ attic hatch
☐ duct shafts
☐ piping shaft/penetrations
☐ fireplace on exterior wall
☐ recessed lighting
☐ walls abutting enclosed but unconditioned space

☐ 6. All insulation is installed according to the requirements for Grade I insulation, as defined by the "RESNET Adopted Enhancements to the Mortgage Industry National Home Energy Rating Standards Chapter 3.B. 9. Insulation Installation:"

☐ 7. Confirm with *The Company* any air sealing details that are the express responsibility of trade contractors whose work follows that of the *Air Sealing/Insulation Trade Contractor* (*Drywall Trade Contractor*, etc.).

☐ 8. Confirm with *The Company* any material substitutions from *The Company*'s air sealing/insulation specifications **before** making any substitutions.

**Details and Sequenced Drawings**

Refer to air sealing and insulation details contained in the EEBA "Builder's Guide to Cold Climates" (sixth edition, Oct 2004), specifically Chapter 11, pages 274 through 311. Additional air sealing details can be found at http://www.buildingscience.com/housesthatwork/airsealing/default.htm

Form will be signed by *The Trade Contractor* thereby indicating that all work has been completed in the manner specified within this Scope of Work (SOW) document #2.

**Pre-Work Inspection Checklist**

To be completed before the Trade Contractor starts work on the jobsite:

- ☐ 1. Construction is at the appropriate stage and conditions are acceptable for *The Air Sealing/Insulation Contractor* to begin work.
- ☐ 2. All framing cavities that will receive cavity insulation have five-sided containment.
- ☐ 3. Roof framing/trusses accommodate [full height/no. of inches] installation of roof/ceiling insulation to the outside plane of the top-story exterior walls.
- ☐ 4. All plumbing/electrical/mechanical penetrations to the building enclosure have been made and are ready for air sealing/insulation.
- ☐ 5. Appropriate materials and equipment are onsite for work to be performed by *The Air Sealing/Insulation Trade Contractor.*
- ☐ 6. *The Air Sealing/Insulation Trade Contractor* has current plans. Record date of plans: [ ___/___/___ ]
- ☐ 7. *The Air Sealing/Insulation Trade Contractor* has current *Company* specifications for all air sealing and insulation materials.
- ☐ 8. *The Air Sealing/Insulation Trade Contractor* has reviewed and understands/accepts the Air Sealing/Insulation Installation Details and Checklist (SOW #2); in particular, the importance of thermal and air barrier continuity.
- ☐ 9. *The Air Sealing/Insulation Trade Contractor* has reviewed and accepts all high performance items that appear in the Air Sealing/Insulation Standards and Description of Work Performance (SOW #1).

Company Rep's Initials _____

Trade Contractor's Initials _____

**Post-Work Inspection Checklist:**

To be completed before Trade Contractor leaves jobsite:

☐ 1. Attic insulation baffles and insulation have been installed such that the pathway is the specified size allowing unobstructed air flow from soffit to ridge.

☐ 2. All insulation is installed according to the requirements for Grade I insulation, as defined by the "RESNET Adopted Enhancements to the Mortgage Industry National Home Energy Rating Standards Chapter 3.B. 9. Insulation Installation:"

☐ 3. All assembly transitions and thermal bypasses are air sealed and insulated for thermal and air barrier continuity.

☐ 4. Any insulating sheathing is free from damage (holes).

☐ 5. All site details match the Air Sealing/Insulation Details in the Air Sealing/Insulation Installation Details and Checklist (SOW #2).

☐ 6. No unapproved material substitutions have been made from *The Company* specs.

☐ 7. Trade Contractor understands that final performance evaluation of the air sealing/insulation is dependent on performance tests (blower door and thermal imaging) that *The Company* may conduct later in the construction process.

Company Rep's Initials _____

Trade Contractor's Initials _____

# Cold Climate HVAC – Requirements and Checklists

## HVAC Requirements:
## 1. Introduction – High Performance HVAC

High Performance is defined as superior energy efficiency, safety, comfort, and durability. Managing the flows of moisture and air with the same thoroughness as energy protects against the major damage functions a home faces— heat, water, radiation (ultraviolet) and biological organisms (which frequently require liquid water).

The work of the *HVAC Trade Contractor* contributes to high performance in the following ways:

- Water management – The HVAC contractor maintains the integrity of the drainage plane by flashing and/or sealing penetrations to the building enclosure made during installation of the HVAC system that are not included in the *Drainage Plane Contractor's* scope of work.
- Integrity and Continuity of the Air Barrier – The HVAC contractor maintains the integrity of the air barrier by air sealing penetrations to the building enclosure made during installation of the HVAC system that are not included in the *Air Sealing/Insulation Trade Contractor's* scope of work.
- Energy Efficiency –
  - System performance based on the appropriate application of ACCA Manuals J, S and D
  - Proper sizing of mechanical equipment, ducts, registers and grilles
  - Air sealing of all ducts and plenums and insulating any ducts not inside conditioned space
  - Commissioning HVAC component/systems
- Safety –
  - Combustion equipment specified and installed to avoid backdrafting and spillage of combustion by-products into the occupied space.
  - Outside air ventilation and exhaust systems designed, specified and installed per ASHRAE 62.2 – Ventilation and Acceptable Indoor Air Quality for Low-Rise Residential Buildings.
- Comfort –
  - HVAC system maintains operative temperatures and interior relative humidities within ranges as established in ASHRAE 55 – Thermal Comfort Conditions for Human Occupancy
  - HVAC system is designed, specified and installed to reduce velocity and pressure induced noise by properly orientating trunk lines, plenums, and returns; properly sizing ducts and register grilles; and installing acoustic lining where necessary.
- Vapor management – Proper sizing and charging of the cooling system help control interior moisture levels.

Construction is a process that involves sequential work performed by a variety of subcontractors. The *HVAC Trade Contractor's* work is preceded by *The Framing Trade Contractor* and perhaps some stages of the *Air Sealing/Insulation Trade Contractor*, with these high performance implications:

- Framing – constructed according to plans so that all ducts can be installed in their designed locations within the conditioned space.
- Air Sealing/Insulation – Air and thermal barrier continuity established by this Trade Contractor is maintained as the HVAC equipment and ducts are installed.

*The HVAC Trade Contractor's* work is generally followed by *Interior Finish Trade Contractors* and by finish work of *The Plumbing and Electrical Trade Contractors* with these high performance implications:

- Duct and duct sealing are not damaged by subsequent *Trade Contractors* or if damaged, repaired or replaced by the *HVAC Trade Contractor* via notification of the *Site Supervisor*.

Performance testing is often a key step along the path to high performance. HVAC performance tests include but are not necessarily limited to:

a. an air tightness test to measure the air tightness of the duct system
b. an air tightness test to measure the air tightness of the entire air distribution system (includes ducts and air handler, and may include associated mechanical ventilation ducts and equipment)
c. system air flow test (total and room testing),
d. room-to-room pressurization test.
e. refrigerant charge test
f. temperature rise across furnace heat exchanger

Successful performance is defined as:

g. Total system leakage no more than ten percent and duct leakage to the outside no more than five percent of the manufacturer's high speed air handler air flow.
h. Air flow at supply plenum is within ten percent of manufacturer rating; air flow to each room is within 10% of design airflows calculated using ACCA manual J, S &D.
i. With the air handler on high speed and interior and exterior doors closed, pressures across closed doors are less than or equal to 3 Pascals
j. Superheat method (fixed metering systems) – superheat temperature within 2°F of manufacturer recommendation/subcool method (thermal expansion valve systems) - subcool temperature within 2°F of manufacturer recommendation
k. temperature rise across furnace heat exchanger within manufacturers specifications

*The HVAC Trade Contractor* will be responsible for correcting deficiencies in installation so that performance meets the requirements of *The Company* and high performance in these Scopes. The cost of corrective action is the responsibility of *The HVAC Trade Contractor*.

For more comprehensive information on the relationship between HVAC and high performance homes, see the following resources:

- EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004)
- Building America Best Practices for Cold Climates
- Building America Houses That Work – Cold Climates
- Air Conditioning Contractors of America (ACCA) Manual J, S and D

**2. Detailed Installation Requirements –**

☐ Pre-Work and Post –Work Inspection checklists will be completed and signed by Site Superintendent and *The Trade Contractor*

☐ 1. HVAC equipment is sized per the ACCA Manual J loads, using methodologies described in Manual S.

☐ 2. All HVAC delivery components installed per the sizing of ACCA Manual D and located per the duct layout plan (See Figure 1 for a sample duct layout plan):

☐ plenums ☐ trunks ☐ ducts ☐ registers ☐ grilles

☐ 3. All HVAC delivery components, including the air handler cabinet, have been sealed with mastic. Access panels have been sealed with foil faced UL181 tape after final commissioning.

☐ 4. All duct boots sealed with mastic to framing and/or subfloor.

☐ 5. All HVAC penetrations flashed for water management and sealed for air and thermal barrier continuity.

☐ 6. All exhaust fans are ducted to the outside.

☐ 7. The mechanical ventilation system installed per *The Company* specifications (See Figure 2 for a representative Central Fan-Integrated Supply (CFIS) system set-up).

☐ 8. Confirm with *The Company* any material or component substitutions from *The Company*'s HVAC specifications.

**Details and Sequenced Drawings**

**Figure 1. Sample Duct Layout**

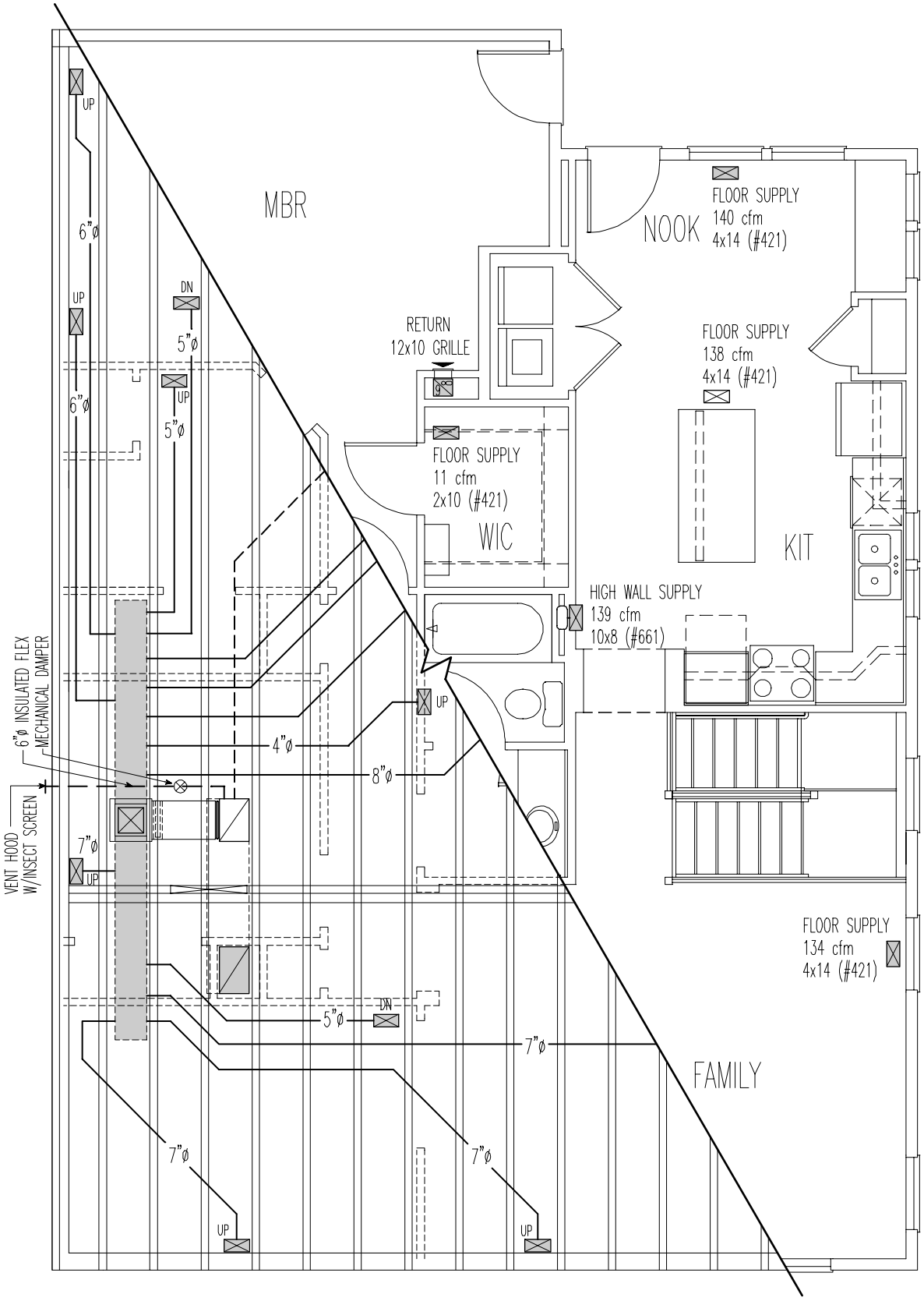
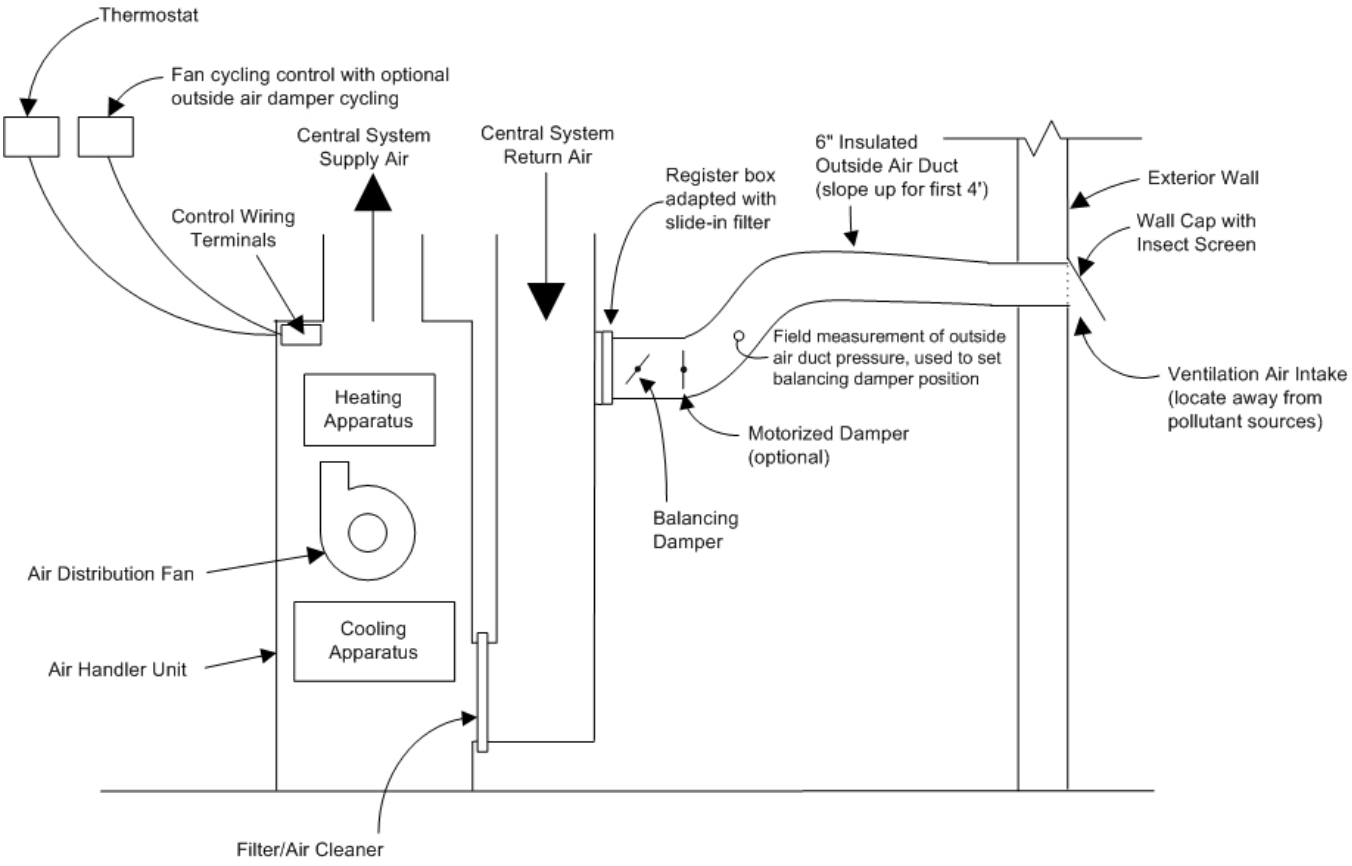


**Figure 2. Central Fan Integrated Supply Ventilation**




Refer to HVAC duct sealing details contained in the EEBA Builder's Guide to Cold Climates (sixth edition, Oct 2004), specifically Chapter 12, pages 328 through 330, and pages 337 through 341. Additional high performance HVAC design and installation guidance can be found at http://www.cee1.org/resid/rs-ac/hvac.php3.

Form will be signed by *The Trade Contractor* thereby indicating that all work has been completed in the manner specified within this Scope of Work (SOW) document #2.

**Pre-Work Inspection Checklist**

To be completed before the Trade Contractor starts work on the jobsite:

☐ 1. Construction is at the appropriate stage and conditions are acceptable for *The HVAC Contractor* to begin work.

☐ 2. The *HVAC Trade Contractor* has current plans. Record date of plans: [___/___/___]

☐ 3. The *HVAC Trade Contractor* has current *Company* specifications for all HVAC components and systems.

☐ 4. All duct boots sealed with mastic to framing and/or subfloor.

☐ 5. All HVAC penetrations flashed for water management and sealed for air and thermal barrier continuity.

☐ 6. All exhaust fans are ducted to the outside.

☐ 7. The *HVAC Trade Contractor* has completed or has received from *The Company* an integrated HVAC system layout and equipment specifications, designed according to ACCA Manual J, S & D. This layout includes room airflow requirements, duct and terminal locations, grille and register specifications, ventilation system layout and product specifications, and heating/cooling equipment specifications.

☐ 8. If available, the *HVAC Trade Contractor* has received and reviewed a detailed framing layout from The Company and has notified The Company of any conflicts between the detailed framing and ducts layouts.

☐ 9. The *HVAC Trade Contractor* has reviewed and accepts all high performance items that appear in the HVAC Standards and Description of Work Performance (SOW #1).

☐ 10. The *HVAC Trade Contractor* has reviewed and understands/accepts the HVAC Installation Details and Checklist (SOW #2).

Company Rep's Initials _____

Trade Contractor's Initials _____

**Post-Work Inspection Checklist:**

To be completed before Trade Contractor leaves jobsite:

☐ 1. All HVAC system components and equipment have been installed per *The Company*'s plans, specifications, and the plan-specific ACCA Manual J/S/D.

☐ 2. The following HVAC performance tests have been performed with successful results OR all deficiencies leading to the unsuccessful results have been corrected:

- ☐ Total system leakage: _[result]_ [passing threshold]
- ☐ Air flow at supply plenum: _[result]_ [passing threshold]
- ☐ Air flow at supply register(s): _[result]_ [passing threshold]
- ☐ System on/door closed pressure differential: _[result]_ [passing threshold]
- ☐ Superheat/subcool refrigerant charge test: _[result]_ [passing threshold]
- ☐ Furnace heat rise test test: _[result]_ [passing threshold]

☐ 3. All site details match the HVAC Details in the HVAC Installation Details and Checklist

Company Rep's Initials _____

Trade Contractor's Initials _____