Building with Ducts in Conditioned Spaces

New Tradition Homes
Photo by David Hales, WSU

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*How to bring your ducts in from the cold*

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Introduction

In the early days of central heating, a large furnace was typically located in a basement near the center of the building. Hot air rose naturally into each room. As the room air cooled, it fell naturally into large ducts that returned it to the furnace. When blowers were added to furnaces it increased the flexibility of forced air systems. These blowers had two unfortunate side effects. First, they pressurized the ductwork leading to a significant potential for conditioned air to leak out. Second, it encouraged duct locations outside the house. Today, a typical house has a furnace located in the garage with ducts running through attics and crawlspaces. This configuration can lose between 10 and 15% percent of the heat in the ducts as conditioned air flows from the furnace (or heat pump) to the registers. This can typically transform a 90% efficient gas furnace into a 75% efficient one.

Air leakage from ducts is only half the problem, since ducts often run through unheated attics and crawlspaces, exposing them to extreme temperatures. These unconditioned spaces exist outside the “thermal boundary” of the house. To make matters worse, ducts typically have only R8 insulation, giving them about twice the heat loss rate of a typical exterior wall. Since it requires a considerable amount of energy to heat or cool air inside ducts, it seems unwise to circulate this air through areas that quickly steal that energy.

Designing and building homes where ducts are located inside the thermal boundary can reduce heating and cooling costs, increase energy efficiency and improve occupant comfort. If skillfully done, it can also reduce construction cost. In Chapter 9 of the Systems Handbook, the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) says, “For maximum energy efficiency, ductwork and equipment should be installed in the conditioned space.” The purpose of this guide is to help designers, architects, general contractors and sub-contractors work together to do just that.

Residential construction tends to be fragmented, so that each trade works independently. Even in conventional houses, this leads to conflicts. Bringing ducts inside from the cold requires much more coordination and communication than normally occurs on construction sites today. That is why this training material places a very strong emphasis on planning and communication.
Thermal Boundary

There is an important concept that you need to understand before getting specific about ways to bring ducts inside. Every house has a “thermal boundary” that separates “inside” from “outside” from the standpoint of heating and cooling. This thermal boundary has two parts: insulation and a rigid surface that prevents air movement. The air barrier is a rigid material, such as gypsum board, oriented strand board (OSB), plywood, pressed paperboard, sheet metal or rigid insulation. Joints between sheets and any holes in the air barrier material must be sealed with tape, caulk or expanding foam. The insulation must touch the air barrier. The amount of insulation must be consistent throughout the building. For example, if the walls of the house are R21, then all walls should achieve that level. If the attic is R49, then all ceilings must be R49. Continuity and consistency are the hallmarks of a good thermal boundary.

Deciding what is inside isn’t as straightforward as it might seem. An attic above an insulated ceiling is ventilated and is definitely outside the thermal boundary. In winter, attic temperature can be nearly as cold as outside, and in summer attics are often much hotter than outside. A ventilated crawlspace and a garage are also enclosed spaces that are actually outside the thermal envelope. In fact, a typical forced air system is almost all outside. While it true that these areas can be tempered, they are seldom close to the temperature of the indoors.

The situation can be especially problematic for air conditioning. In most houses, return duct runs through attics, which can easily range from between 100 and 140 degrees F in summer. Exposing the R8 ductwork to these extreme temperatures makes air-conditioning equipment run harder, use more energy and generate comfort complaints. It’s no wonder that many builders in cooling-dominated climates, such as Arizona and New Mexico, were early adopters of the ducts inside approach. It is now common to see forced air systems entirely within conditioned spaces in these hot climates. While cooling requirements are not very high in the Pacific Northwest, air conditioners and heat pumps are becoming common. Installing ducts inside increases efficiency and customer satisfaction.
In heating mode, ducts running outside the thermal boundary are also a problem. In northern climates, the heating season lasts far longer and leads to more fuel consumption than the cooling season. When temperatures drop to near or below freezing, even crawlspaces and garages can get cold. If you think of conventional crawlspaces and garages as being moderate, keep in mind that the temperature is elevated considerably by heat loss from ducts and the furnace. Heat that was paid for to heat conditioned space is now escaping.

**Consumer Benefits**

Many consumers will not immediately understand the reasons for bringing ducts inside. You can help them by explaining these points.

- Why connect a highly efficient heating system to a poorly designed and installed duct system that immediately cuts overall system efficiency by 10 to 15 percent? The impact is even greater during extreme weather, when heating systems strain to maintain comfort. Explain the idea of the home’s thermal boundary. The air inside ducts is conditioned indoor air. Why circulate this air -- that has been heated or cooled at considerable cost -- through the outdoors? Running a duct through the attic is like running it out the window and into the next room.

- Ducts in attics and crawlspaces are “out of sight, out of mind” and are the biggest source of serious problems. They can become disconnected. They can get in the way of workers who crush or puncture them. They also provide inviting nests for insects, rodents, and other critters.

- Placing ducts inside means that extra care goes into planning and installation. The result is a better HVAC system overall.

- Duct installers who are standing up in dry, well-lit conditions will do a better job than installers lying on their backs, in the dark, with dust falling in their eyes. It’s only natural that better working conditions lead to higher quality installations.

- Return duct leaks are under negative pressure (suction) and pull air into them. So furnace cabinets in garages and return ducts that pass through attic spaces draw pollutants from these areas into the house.

- Energy efficient homes have superior insulation, better windows and fewer drafts. They don’t need to compensate for extreme heat loss by washing the exterior walls with warm air. They are inherently more comfortable, which puts less demand on the HVAC system. Under these conditions, it’s acceptable to have registers on interior walls or ceilings.

**Approaches to Building with Ducts Inside**

There are two general concepts for keeping ducts inside. One is to find a place for duct runs within the existing thermal boundary. The second is to extend the thermal boundary around the ducts. Which are you--an “innie” or an “outie”?
While there are many different ways to build homes with ducts inside, this guide will describe six approaches. Of course, there can be variations on each theme and most house designs will combine approaches. You may choose one approach when you are designing from scratch and a different approach if you are modifying an existing design. Feel free to use your creativity to expand and evolve these ideas.

1) Dropped soffits
2) Inverted soffits
3) Conditioned attics
4) Insulated attic trusses
5) Open web floor trusses
6) Conditioned basements

For the purposes of this discussion, “ducts inside” will be defined as a house having the furnace or air handler and ninety-five percent of the duct length within the thermal envelope. This allows some flexibility to accommodate specific situations where a short excursion into unconditioned space is unavoidable. Ducts not connected directly to the forced air system are exempt. This means transfer (jump) ducts used for zonal pressure relief can run through unconditioned spaces. However, the techniques described below would certainly apply to pressure relief as well. Certifications with energy efficiency standards, such as ENERGY STAR®, Energy Trust of Oregon’s New Homes Program, Built Green®, LEED® for Homes, and Earth Advantage® may have their own specific definitions and requirements. Please consult those programs for more details.

Basic Principles

These ideas apply to all six approaches. Specific guidance for each approach appears later.

Building design – Many building designers never really think about duct design. They draw a box in the garage, and leave the details up to the HVAC contractor. To make ducts inside the new normal, this practice will have to change. If a project is to include ducts inside, the first step must be taken by the designer. Using the specific information below, a designer and general contractor must choose an approach and apply it to the plans. An HVAC (mechanical) plan should become a standard part of the plan set. Since duct sizes are directly related to heating and cooling loads, careful sizing calculations can keep duct sizes as small as possible. The more efficient the building shell, the smaller the ducts need to be. Proper duct sizing will make it much easier for find paths for duct runs.

The HVAC plan should show the furnace location, duct paths, and associated framing in both plan and section views. The HVAC contractor should add a mechanical plan to the plan set with full specifications including design heat load, duct sizes, grille types, etc. The designer and HVAC contractor should consult with each other to be sure their work is compatible. The plans are not only a definitive legal description of the project, they are an essential communication tool used by entire project team.

Furnace location – Most ducts inside approaches will be easier if you find a central location for the furnace or air handler. This could be a utility room or even a closet. This location gives ready access to dropped soffits, lowered ceilings, vertical chases and other structural spaces within the thermal boundary. The key concern with an interior location is noise. You must select quiet equipment, install sound insulation
around the mechanical room and place a solid-core door on it. A central location also reduces the length of duct runs which can reduce installation cost and improve air flow.

Undoubtedly, space will be tight when the furnace is moved inside. Be sure the location you choose has adequate room for the equipment and allowable clearances. Air-conditioning coils and drain pans may require additional height. Access for filter changes and other maintenance must be maintained. Don’t forget to install the condensate drain leading to an indoor trapped drain. A drain pan is necessary, too. Consult the code for clearance to combustible surfaces.

Since the furnace in a conventional home is almost always in the garage, many builders find it tempting to keep it there and build an insulated room around it. This works, but it does create several potential issues. First, the duct runs must be able to enter the rest of the house without crossing the thermal boundary. A typical garage installation uses a downdraft furnace. It sits on a base can that has been set into the garage slab. This obviously violates the ducts inside idea. One solution that can be used without changing the foundation plan is to extend the floor framing into the garage so that the base can sits on top of the framed floor and enters the house without reaching into the crawlspace. If vertical space is tight, an insulated floor for the furnace room can be made by laying R10 rigid insulation on the floor and covering it with exterior grade sheathing. The wall that separates the furnace room from the house should be treated as an interior wall and remain uninsulated. If insulation is desired to reduce noise, a pressure relief path connected to the house can be added. This can be a transfer grille through the wall or a short transfer duct.

While a room in the garage isn’t the best location, it allows builders to get the benefits of ducts inside with current house designs. It’s a good transition to the more elegant solution of designing homes from the ground up with the entire system inside the thermal boundary.
Duct design – In typical homes, duct systems are not actually designed. The time and expense of a custom design is seldom supported by the prices paid. However, moving to ducts inside will require careful design of duct systems. Several factors drive this need for accurate duct design.

- Houses designed with ducts inside tend to be designed more energy efficient overall. They usually have higher insulation levels, better windows and considerably less air leakage. HVAC contractors should be sure to use an accurate thermal envelope description for the house, rather than assuming code-level characteristics or, even worse, software default values.
- Duct runs should be substantially shorter, which should reduce static pressure. Be sure to account for tighter turns, which can drive static pressure up, instead of down.
- Ducts need to fit into smaller spaces. Accurate design can allow smaller diameters or different duct profiles (e.g., rectangular vs. round) that might reduce the size of soffits, floor trusses and other framing accommodations.
- Supply registers can be located high on interior walls, rather than at the perimeter. Remember, these houses have much improved thermal shells. Careful attention to the face velocity at the supply boots and proper selection of registers or diffusers can throw air to the exterior and achieve good mixing. Use ACCA Manual T to select grilles. It’s not likely that the typical stamped metal grille will be the best choice. Again, ASHRAE agrees, “Many new buildings have well-insulated envelopes or sufficient thermal integrity so that supply registers do not have to be located next to exterior walls. Placing registers in interior walls can reduce duct surface area by 50% or more, with similar reductions in leakage and conductive losses.” This approach may not be best for every house, and if it is used grilles must be carefully selected for proper throw and mixing.
- Return ducts are best kept short. The return could be a 90-degree sweep to an adjacent wall. There could be no duct at all, only a direct return on the furnace cabinet with a louvered door on the mechanical room. Of course, returns make noise, so be sure to consider return duct material and length, return grille location and other noise factors.

Duct design is an important factor in maintaining comfort and performance. This step will be absolutely essential, at least until contractors recalibrate their rules of thumb for 21st Century homes.

Duct sealing – All joints in ductwork must be sealed with mastic paste. Flex duct may be attached to metal components with mechanical straps as long as the approved tool is used to tighten the strap. While it’s true that any duct leakage would spill into conditioned space, you still want to deliver as much air as possible to the intended location. In addition, leaks affect pressure in building cavities, which would increase building leakage and possibly cause water vapor condensation problems. So, it’s necessary to seal the ducts even when they are inside. Technically speaking, duct insulation is not required for ducts inside conditioned space. However, there may be reason to consider insulated ducts. If condensation on ducts is an issue in your climate, R4 insulation would generally prevent it. Plus, insulated ducts will allow less heat loss and deliver conditioned air to its destination at something closer to the proper temperature. Best of all, R4 flex duct costs little, if anything, more than uninsulated flex duct.

Thermal boundary – All chases, soffits and other accommodations for ducts must be located inside the thermal boundary. Three subcontractors are primarily responsible for maintaining the thermal boundary: framers, insulators and drywallers. To create an effective thermal boundary in a wall, build a six-sided box and place
insulation so it touches all sides. This means each wall cavity is enclosed by studs, plates and rigid material on the inside and outside. That description fits a typical exterior wall. Sheet material must be rigid, such as gypsum board, OSB (1/4-inch thick is enough), plywood, pressed paperboard (ThermoPly or equivalent), sheet metal or rigid insulation. Flexible material, such as housewrap, is not recommended.

Think of it this way—you should never see insulation material in a vertical assembly from the inside or outside. It should always be covered. In a horizontal assembly, such as a ceiling or floor, you should never see insulation from the inside of the building. It has been a common practice to cover insulation in hidden cavities with foil-scrim-kraft (FSK) paper. FSK doesn’t provide a true barrier to air leakage nor a sufficient resistance to wind loading and building pressure fluctuations. Standing inside the building, you should never see FSK paper. It should be replaced with a rigid sheet material. (For more details on thermal boundary installation and materials, see the ENERGY STAR Thermal Bypass Checklist in the Appendix.)

**Noise** – Locating furnaces inside could possibly create a problem with noise from the equipment and from air flow through ducts. To combat noise, use as many of these ideas as possible:

- Locate the furnace away from bedrooms and other areas where noise would be most annoying.
- Choose high quality equipment. Sealed combustion furnaces that are greater than 90% efficient have sealed burners which reduce noise. Variable speed blower motors may reduce the amount of time that high velocity air and serious vibration are present.
- Mount the furnace on vibration pads.
- Fill all building cavities adjacent to living spaces with sound insulation. High Sound Transmission Class (STC) methods, such as drywall attached to RC channel or two layers of drywall, may be warranted in extreme cases.
- Install a solid core or insulated door on the mechanical room or closet.
- Select proper grilles for required air flow (as well as good throw and mixing characteristics). It’s unlikely that the standard stamped metal floor register will be the right choice. There are a number of diffuser types available that are designed for better mixing and throw than provided by standard registers.
- Size ducts correctly.
- Avoid “cross talk” in the duct system that occurs when supply branches attach to a supply trunk directly across from each other.
- Use insulated flex duct for the last few feet of supply branches.
- Use insulated flex duct for returns. At least one 90-degree bend in the return will reduce noise. (It will also increase air flow resistance, so don’t add too many bends.)

It may not be necessary to use all these methods, but it makes sense to use as many as you find practical.

**Backdrafting** - Air leaks in the furnace cabinet, attached plenums and ducts could depressurize the mechanical space and cause flue gases from naturally-aspirated water heaters to spill into the space. From there, the flue gases could be drawn into the furnace and delivered into the living spaces. Several methods can be used to reduce the risk of this happening. Install a pressure relief path, such as a transfer duct or a through-the-wall grille that connects the furnace room with other conditioned spaces. Install a sealed combustion water heater that draws combustion air directly from outside the building. Never install a naturally-aspirated (B-vent) water heater in a small mechanical closet with an air handler.

**Pre-design meeting** – Conventional construction relies on tradespeople staying out of each other’s way as much as possible. Conflicts certainly arise, but are rare enough that this “wide berth” approach has become a
comfortable norm. *This conventional approach will not work with a ducts inside project.* Careful coordination is required throughout the project. This coordination should begin with a pre-design meeting among the key players, including: general contractor, designer, HVAC contractor, truss supplier, framer, drywall installer and insulator. During this meeting, it is essential that HVAC details be decided and recorded on the building plans. These details include:

- the locations or all duct runs and registers
- duct sizes
- necessary framing details
- air barrier location and material
- air sealing details, including sealant and locations
- location of all recessed lights and ceiling fans

These plans must be followed strictly so that each piece of the puzzle can fit. If problems arise that require adjustments, these changes must be discussed and agreed to by everyone involved. (If stock plans are used, this becomes a pre-construction meeting to decide how the plans will be modified.)

Guidelines for Trades

There are many approaches for moving ducts inside. No matter which approach you choose, there are several guidelines that your project team should adopt to help you succeed. These guidelines apply to all approaches.

**Designer/Architect:**

- Think about the best overall ducts inside approach and choose the one that best suits the current design. If necessary, you can combine approaches.
- Identify a central location for the furnace or air handler. Keep in mind the necessary connections, including combustion air supply and vent, fresh air ventilation duct and controls, and condensate drain. Be sure to maintain clearances required by code and access for maintenance.
- Anticipate ramifications of design changes. For example, adding additional floor depth might affect the dimensions of the stairway.
- Allow enough space for the required duct size and consult the HVAC contractor if necessary.
- Identify each duct run. Consult the HVAC contractor for duct sizes and register locations. Pay special attention to areas with vaulted ceilings, stairways, large beams and interior shear walls that may pose obstacles to ducts. Specify all these details on an HVAC plan in plan and in section view.
- Locate recessed lights, ceiling fans and other potential obstacles on the plan.
- Participate in a pre-design meeting with the project team to identify and solve potential issues.

**General Contractor:**

- Require the designer and all trades to attend a pre-design meeting to discuss the ducts inside approach and everyone’s responsibilities.
- Work closely with the designer and HVAC contractor to choose the best ducts inside approach as well as identify potential problems and solutions.
- Ensure accessibility to all furnace components for maintenance and repair, such as filters, access panels, controls, etc.
• Ensure there is adequate space around the furnace or air handler to meet the minimum clearance requirements in the code.

Framer:
• Review the location of the thermal boundary. Identify areas where additional sheet material must be installed to maintain a continuous air barrier. These include soffits, chases, etc.
• Coordinate with insulator about what sheet material will be used and who supplies it.
• Identify the locations of duct runs and the method that will be used to enclose them.
• Contact the HVAC contractor or designer with questions or concerns about duct sizes or other issues.
• If the furnace is located in the living space, install solid core door on the room where the furnace is located.
• Participate in a pre-design meeting with the project team to identify and solve potential issues.

Drywall Installer:
• Review the location of the thermal boundary.
• Participate in a pre-design meeting with the project team to identify and solve potential issues.

HVAC Contractor:
• Size the heating equipment and design the ductwork taking into account the smaller heat load and shorter duct runs of the particular design. Duct design is especially important to establish the smallest effective duct diameter for each run. This makes it easier to accommodate duct runs in interior chases and soffits. Of course, proper air flow should always be first priority.
• Consider noise levels when selecting air handlers, because the equipment will be located near living spaces. Select quiet equipment.
• Always install sealed combustion equipment with proper venting to the outside.
• Because the thermal envelope has been improved over past construction practices, it is generally not necessary to wash exterior surfaces with conditioned air. Most ducts will not need to extend all the way to the building perimeter.
• Select supply grilles with adequate throw to reach exterior surfaces and achieve good mixing with room air. This will generally not be the typical stamped metal floor register.
• Use fire-rated caulk and seal all gaps where ducts penetrate the thermal boundary.
• Avoid locating duct joints near obstacles that will interfere with fastening and sealing sections, such as above interior walls or behind waste pipes.
• Seal all ducts with mastic paste.
• Connect the fresh air duct and damper to the return duct near the grille.
• Participate in a pre-design meeting with the project team to identify and solve potential issues.

Insulator:
• Review the building plan to identify the building’s thermal boundary and the location of all ductwork inside the boundary.
• Identify areas where additional sheet material must be installed to maintain a continuous air barrier. These include soffits, chases, etc. (See the ENERGY STAR Thermal Bypass Checklist.)
• Coordinate with framer about what sheet material will be used and who supplies it.
• Seal all joints around soffits and chases. Seal electrical and plumbing penetrations.
• Be sure that the insulation value around soffits and chases is the same as the rest of that building component (walls, ceiling, floor).
• Place sound insulation around the room where the furnace is located, if requested.
• Participate in a pre-design meeting with the project team to identify and solve potential issues.

**Plumber:**
• Be sure that a condensate drain is installed at the furnace location.
• Insulate PEX pipe near ducts.
• Coordinate the location of major plumbing runs and gas pipe with HVAC contractor.
• Participate in a pre-design meeting with the project team to identify and solve potential issues.

**Electrician**
• Identify where ducts are to be located to avoid conflicts with all wiring and fixtures. This is especially important with recessed lights, ceiling fans and thick wires.
• Participate in a pre-design meeting with the project team to identify and solve potential issues.
Dropped Ceilings and Soffits

**Application:** This approach is appropriate for single-story homes with 9- or 10-foot plate heights. It is also useful in two-story designs and for branch ducts in a house that may use a different approach.

**Description:** Building cavities where ducts can run are created within the thermal envelope of the building. These cavities are surrounded by the building air barrier and full insulation. One good location for a dropped ceiling is a central hall adjacent to several bedrooms. The space above the ceiling allows easy access to each of the bedrooms. Soffits can also be built above upper cabinets, around the perimeter of a room to create a coffered look or as a design element to create a visual separation between two rooms.

One key element of this approach is the thermal boundary that separates the soffit space from the “outside”, which is usually the unconditioned attic. Joints between sheets and any holes in the air barrier material must be sealed with caulk or expanding foam. The insulation around the air barrier is installed to the same level as the rest of that component (for example, R-49 for ceilings and R-21 for walls).

You have two options for scheduling the installation of the air barrier.

1) **Using OSB**, framers can line the soffit during the rough framing stage of construction. HVAC installers then run ducts as they normally would. Because ducts don’t need to extend to the building perimeter, most of the branch ducts can be very short.

2) In some cases, you may decide to schedule drywall installation first, then frame the soffits, install ducts and have the drywall installers return to cover the bottom surface of the soffit. Drywall in the soffit can be installed at the same time that other “pre-drywall” jobs are done. For example, drywall behind the furnace is generally hung at a good time to also hang drywall in soffits.

**Advantages:**

+ Lower cost compared to some ducts inside approaches
+ No code issues
+ No increase in heating or cooling load
+ No increase in building height
+ Variable ceiling heights and coffered ceilings can add architectural interest

**Disadvantages:**

– Can be difficult to find a path for ducts around obstacles, such as stairs, beams, vaulted ceilings, etc.
– Scheduling of trades can be complicated. One or more trades may have to make additional visits to the site.
– Needs minimum ceiling height of 9 feet.
Key challenges:

- Delivering supply air to areas with vaulted ceilings.
- Scheduling trades.
- Coordinating more plumbing, electrical and ductwork in a small space.

Cost considerations:

- $ Additional framing material and sheet goods for lining soffits.
- $ Ducts can be shorter and may reduce cost. Heating system size can be reduced, which may reduce cost.

Keys to Success:

- Cap the soffit with rigid sheet material.
- Seal the rim joist adjacent to all soffits.
- Locate supply registers on interior walls when possible.
- Select grilles with adequate throw and mixing to reach exterior surfaces.

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**Project Team Member Guidelines**

All team members should participate in a pre-design meeting with the project team to identify and solve potential issues. Additional guidelines for each team member are outlined below:

**Designer:**

- Identify a central location for the air handler and soffits for duct runs.
- Allow proper clearances for mechanical equipment.
- Allow enough space for the required duct size and consult the HVAC contractor if necessary.
- Pay special attention to areas with stairways, vaulted ceilings, large beams and interior shear walls that may pose obstacles to ducts.
- Create an HVAC plan showing the exact location of ducts with section and plan views. Mark furnace condensate drain on plan.
- Locate recessed lights, ceiling fans and other potential obstacles on the plan to avoid conflicts.

**General Contractor:**

- Require the designer and all trades to attend a pre-design meeting to discuss the ducts inside approach and everyone’s responsibilities.
- Decide which trade (framer or drywaller) will install the air barrier to cap the soffit.
- Ensure accessibility to all furnace components for maintenance and repair, such as filters, access panels, controls, etc.
- Ensure there is adequate space around the furnace or air handler to meet the minimum clearance requirements in the code.
- Install solid core door on the room where the furnace is located.

**Framer:**

- Create soffit spaces according to the building plans.
- Line the surfaces of the soffit with a rigid sheet material, such as pressed paperboard, etc.

**Drywall Installer:**

- Review the thermal boundary and line soffits with drywall.

**HVAC Contractor:**

- Size the heating equipment and design the ductwork taking into account the smaller heat load and shorter duct runs.
- Consider noise levels when selecting furnaces and air handlers, because the equipment will be located near living spaces.
- Always install sealed combustion equipment with proper venting to the outside.
- Most ducts will not need to extend all the way to the building perimeter.
- Locate supply boots on interior walls when possible.
- Select supply grilles with adequate throw to reach exterior surfaces and achieve good mixing with air.
- Use fire-rated caulk to seal all gaps where ducts penetrate the air barrier material.
- Avoid locating ducts joints near obstacles that will interfere with fastening and sealing ducts.
- Seal all ducts with mastic paste.
- Connect the fresh air duct and damper to the return duct near the grille.

**Insulator:**

- Seal the joints between the sheets of rigid soffit liner, such as rigid insulation or pressed paperboard.
- When the soffit adjoins a rim joist, seal the rim with expanding foam.
- Seal all electrical and plumbing penetrations.
- Install insulation material around the soffit to match the R-value of the adjacent wall or ceiling.
- Place sound insulation around the room where the furnace is located.

**Plumber:**

- Insulate PEX pipe near ducts.
- Install condensate drain at the furnace location.
Inverted Soffits

Application: This approach is appropriate for single-story homes with plate heights as low as 7-1/2 feet. It is also useful for branch ducts in a house that may use a different approach for the trunk duct.

Description: Duct chases are created by extending the thermal envelope into the attic. These extensions are surrounded by the building air barrier and full insulation.

An inverted soffit would typically be located near the center line of the long axis of the floor plan, because it would serve as the main supply trunk. A central hallway is a good location, and if the plenum is wider than the hallway, supply ducts can drop directly into interior walls. This approach can also be used for laterals. Since the inverted soffit is invisible from the living space, it can run just about anywhere.

You can frame the inverted soffit on-site or purchase roof trusses with a square plenum already framed in place. The plenum is lined with a rigid sheet material such as OSB, pressed paperboard or drywall. The choice of lining material determines who will install it and what changes that tradesperson would have to make in the schedule. A drywall installer might have to make a special trip to hang drywall in the soffit itself several weeks before they would normally visit the house. Or, this may coincide with other “pre-drywall” tasks such as hanging the small section of wall adjacent to the furnace location. A framer would use OSB or paperboard to line the soffit. While this is a duty not normally assigned to a framer, it doesn’t require a change in scheduling.

Advantages:
+ Works with lower ceiling heights
+ Less likely to run into obstacles
+ No code issues
+ Doesn’t increase building height

Disadvantages:
− Slight increase in surface area and building volume, which would create a minor increase in heat loss from the building.
− Scheduling of trades can be complicated. One or more trades may have to make additional visits to the site.
Key challenges:
- Delivering supply air to areas with vaulted ceilings
- Tricky to seal the air barrier to the ceiling drywall

Cost considerations:
- $ Additional framing material and/or truss webs
- $ More sheet goods for lining soffits
- $ Additional work for framers or drywall hangers
- $ Reduced heating system size and shorter ducts may reduce cost

Keys to Success:
- ✓ Line the soffit with rigid sheet material
- ✓ Be sure the full insulation depth is achieved above the inverted soffit
- ✓ Locate supply registers on interior walls
- ✓ Select grilles or diffusers with adequate throw and mixing
- ✓ Choose quiet sealed combustion equipment

Project Team Member Guidelines

All team members should participate in a pre-design meeting with the project team to identify and solve potential issues. Additional guidelines for each team member are outlined below:

Designer:
- Identify a central location for the air handler and inverted soffits. Identify each duct path all the way to the register. Be aware of noise issues when locating the furnace.
- Specify the location of the plenum framing for the roof truss order.
- Allow proper clearances for mechanical equipment.
- Allow enough space for the required duct size and consult the HVAC contractor if necessary.
- Pay special attention to areas with vaulted ceilings, large beams and interior shear walls that may pose obstacles to ducts.
- Create an HVAC plan showing the exact location of ducts in plan and section views.
- Locate recessed lights, ceiling fans and other potential obstacles on the plan.
- Install solid core door on the room where the furnace is located.

Framer:
- Create soffit spaces according to the building plans. If roof trusses are used, be sure the trusses are installed so that the plenum lines up.
- Line the surfaces of the soffit with a rigid sheet material, such as OSB, pressed paperboard, etc.

Drywall Installer:
- Review the thermal boundary.
- Line soffits with air barrier.

HVAC Contractor:
- Size the heating equipment and design the ductwork taking into account the smaller heat load and shorter duct runs.
- Consider noise levels when selecting furnaces and air handlers, because the equipment will be located near living spaces.
- Always install sealed combustion equipment with proper combustion air supply ducting to the outside.
- Most supply ducts will not need to extend all the way to the building perimeter. Install supply registers on interior walls.
- Select supply grilles or diffusers with adequate throw and good mixing of room air.
- Use fire-rated caulk to seal all gaps where ducts penetrate the building air barrier.
• Avoid locating duct joints near obstacles that will interfere with fastening and sealing ducts.
• Seal all ducts with mastic paste.
• Connect the fresh air duct and damper to the return duct near the grille.

**Insulator:**
• Seal the joints between the sheets of rigid soffit liner.
• Seal all electrical and plumbing penetrations.

• Install insulation material around the soffit to match the R-value of the adjacent wall or ceiling.
• Place sound insulation around the room where the furnace is located.

**Plumber:**
• Insulate PEX pipe near ducts.
• Be sure that a condensate drain is installed at the furnace location.
Conditioned Attics

**Application:** This approach is most useful in single-story homes, because it allows easy access to every room. It could also be used for the upper story in multi-story homes.

**Description:** By locating the thermal boundary at the roof plane instead of the ceiling, a large area of useful space is created in the attic. Insulation, air barrier and vapor retarder are all attached to roof framing.

One common way to create a conditioned attic is with spray foam applied to the underside of the roof sheathing. Two types of spray foam are available, each with its own requirements. Low-density spray foam (0.5 pounds/cubic foot) has an insulating value of about R3.5-R4.0 per inch. It would require about 10 inches of low-density foam to make R38. Low-density foam is vapor permeable and requires a vapor retarder on the inside surface, which is most easily applied as a paint. High-density spray foam (2.0 pounds/cubic foot) has an insulating value of around R6.0 to R6.8 per inch, and would achieve an overall value of R38 with about a six-inch-thick application. While high-density spray foam does not require a vapor retarder it does need a fire-rated coating, which is again often applied in paint form.
Some manufacturers of composition shingles require ventilation below their products. When using spray foam, the roof deck is not ventilated, so the warranties of some composition shingles will be violated. There are a few shingle manufacturers that offer warranties for this situation. Proof of the warranty may be required by the code official. Other materials, such as steel and tile, do not have similar installation requirements. Both types of spray foam seal the attic well against air leaks. This creates a conditioned attic space for the furnace equipment, ducts, and ventilation devices as well as conditioned storage for family heirlooms. The main difference is the insulation thickness needed to achieve a desired R-value.

It would be possible to accomplish the same thing with blown-in insulation (fiberglass or cellulose), although a good deal of additional framing would be required to create cavities deep enough to hold full insulation (R38 to R60). A parallel chord roof truss or I-Joist roof framing could also create a cavity to hold insulation and provide nailing support for an air barrier attached to the bottom chord. Ventilation chutes (baffles) would be required to allow ventilation air to flow from the soffit vents to the ridge vent. The way the air barrier on the roof connects to the air barrier on the wall below will be tricky. One way to achieve this is to install solid blocking between the ceiling joists and then seal the blocking with expanding foam.
If the attic extends over a garage or other unconditioned space, a wall must be built to separate the conditioned attic. The wall must be fully insulated and air sealed just like other exterior walls in the house.
**Advantages:**

- Allows maximum flexibility in location of heating equipment, duct runs and registers.
- Works with any ceiling height.
- Completely avoids obstacles in single-story homes.
- Very low potential for trade scheduling conflicts.
- In Oregon, spray foam applied to the roof deck is specifically allowed by the state code.
- Doesn’t increase building height.

**Disadvantages:**

- Will not work in rooms with vaulted ceilings.
- Large increase in surface area and building volume, which would increase the building’s heat loss rate.
- However, the additional losses are considerably lower than the gains, so there is still a substantial overall benefit.
- Spray foam is generally much more expensive than other insulation materials.

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**Key challenges:**

- Cost of spray foam

**Cost considerations:**

- $ Additional cost of spray foam insulation.
- $ Reduced heating system size and shorter ducts might reduce cost.

**Keys to Success:**

- Select a roofing product that can be installed over an unvented attic while maintaining its warranty.
- Carefully compare the cost of low-density spray foam with a vapor retarder application against high-density spray foam with a fire-rated coating for the same R-value.
- Choose sealed combustion equipment that operates quietly. If the air handler is located in the attic, be sure to minimize noise and vibration.
All team members should participate in a pre-design meeting with the project team to identify and solve potential issues. Additional guidelines for each team member are outlined below:

**Designer:**
- Identify a central location for the air handler. Identify each duct path all the way to the register. Choose locations for duct runs that allow the space to serve as heated storage and for other uses. Be aware of noise issues when locating the furnace.
- Pay special attention to areas with vaulted ceilings that might pose obstacles to ducts.
- Carefully detail the way the air barrier on the roof connects to the air barrier on the walls.

**General Contractor:**
- Require the designer and all trades to attend a pre-design meeting to discuss the ducts inside approach and everyone’s responsibilities.
- Ensure the air sealing detail between the ceiling air barrier and the wall air barrier is continuous and durable.
- Ensure accessibility to all furnace components for maintenance and repair, such as filters, access panels, controls, etc.
- Ensure there is adequate space around the furnace or air handler to meet the minimum clearance requirements in the code.

**Framer:**
- Install parallel chord trusses or I-joists, if used.

**Drywall Installer:**
- Install drywall on rafters for I-Joist and parallel chord truss methods.

**HVAC Contractor:**
- Size the heating equipment and design the ductwork taking into account the smaller heat load and shorter duct runs.
- Select quiet furnace equipment.
- Always install sealed combustion equipment with proper combustion air supply ducting to the outside.
- Avoid locating ducts joints near obstacles that will interfere with fastening and sealing ducts.
- Seal all ducts with mastic paste.
- Connect the fresh air duct and damper to the return duct near the grille.

**Insulator:**
- If spray foam is used, be sure it is applied at the proper temperature and thickness to achieve the desired R-value.
- If blown-in insulation is used, be sure it is installed at the proper density.

**Plumber:**
- Insulate PEX pipe near ducts.
- Be sure that a condensate drain is installed at the furnace location.
Insulated Attic Trusses

**Application:** This approach is useful for single-story homes and the upper level of two-story homes.

**Description:** Attic trusses have been available from manufacturers for many years. Similar to an inverted truss, the Insulated Attic Truss approach extends the conditioned space into the attic. In this case, the space is large enough to locate the furnace and possibly other equipment. In designs with a steeply pitched roof, a space below the roof is carved out for storage and other purposes. In this case, the purpose is to house the heating system and all (or at least most) of the ducts. Because this space is conditioned it must have a complete and continuous thermal barrier in the walls and ceiling. Access to the equipment could be provided by a stairway or ladder.

The attic space might run the entire length of the building or could be centrally located and linked to inverted soffits or other chases that radiate around the building. Insulation on top of this space must provide the same insulating value as other ceilings, most likely R38 or R49. Likewise, the walls should be thermally identical to other exterior walls, including top and bottom plates and full insulation and a rigid backing on the back side of the attic walls. (See ENERGY STAR Thermal Bypass Checklist in the Appendix for details.)

**Advantages:**
- Works with lower ceiling heights
- Less likely to run into obstacles
- No code issues
- Doesn’t increase building height
- No additional scheduling issues

**Disadvantages:**
- Large increase in surface area and building volume, which would create a noticeable increase in heat loss from the building. However, the benefits of the ducts inside approach will outweigh the impact of the large building shell.
- The large attic knee walls create more surface area that must be backed with a rigid air barrier material.

**Key Challenges:**
- Backing the attic walls
- Blocking & air sealing the transition between attic walls and first floor ceiling.

**Cost Considerations:**
- $ Additional cost for trusses & sheet goods for backing the insulated attic walls.
- $ Additional operational cost for heating and cooling

**Keys to Success:**
- Carefully plan the location of the attic space and how it connects to duct runs beyond the attic room.
- Be sure the full insulation depth is achieved in the ceiling and walls of the attic room.
- Install top and bottom plates between trusses for attic walls, and blocking in ceiling joist cavities directly below the attic walls.
- Locate supply registers or diffusers on interior walls.
- Select grilles with adequate throw to reach exterior surfaces.
- Choose sealed combustion equipment that operates quietly.
All team members should participate in a pre-design meeting with the project team to identify and solve potential issues. Additional guidelines for each team member are outlined below:

**Designer:**
- Identify a central location for the air handler. Identify each duct path all the way to the register and detail the way the attic wall barrier connects to the ceiling air barrier below. Be aware of noise issues when locating the furnace.
- Specify the location of the attic trusses for the roof truss order.
- Create easy access for maintenance.
- Allow proper clearances for mechanical equipment.
- Allow enough space for the required duct size and consult the HVAC contractor if necessary.
- Draw an HVAC system in plan and section view, showing the exact location of ducts.

**General Contractor:**
- Require the designer and all trades to attend a pre-design meeting to discuss the ducts inside approach and everyone’s responsibilities.
- Ensure the blocking and air sealing detail between the attic wall air barrier and the downstairs ceiling air barrier is continuous and durable.
- Ensure accessibility to all furnace components for maintenance and repair, such as filters, access panels, controls, etc.
- Ensure there is adequate space around the furnace or air handler to meet the minimum clearance requirements in the code.

**Framer:**
- Locate the attic trusses and other framing elements according to the plan.
- Install top and bottom plates between trusses for attic walls, and blocking in ceiling joist cavities directly below the attic walls.
- Install rigid sheet material on the back (outside) of attic walls.
- Check the dimensions of the furnace room to be sure it is large enough for maintenance and repair of equipment, such as filters, access panels, controls, etc. Check with HVAC contractor about necessary clearances.

**Drywall Installer:**
- Hang drywall in attic.

**HVAC Contractor:**
- Size the heating equipment and design the ductwork taking into account the smaller heat load and shorter duct runs.
- Consider noise levels when selecting air handlers, because the equipment will be located near living spaces.
- Always install sealed combustion equipment with proper combustion air supply ducting to the outside.
- Most supply ducts will not need to extend all the way to the building perimeter.
- Select supply grilles or diffusers with adequate throw and good mixing with room air.
- Using fire-rated caulk, seal all gaps where ducts penetrate the building air barrier.
- Seal all ducts with mastic paste.
- Connect the fresh air duct and damper to the return duct near the grille.

**Insulator:**
- Seal all electrical and plumbing penetrations.
- Install insulation material in attic truss walls and ceiling to match the R-value in the rest of the house.
- Use expanding foam to seal ceiling blocking to ceiling below attic walls.

**Plumber:**
- Insulate PEX pipe near ducts.
- Be sure that a condensate drain is installed at the furnace location.
Open Web Floor Trusses

**Application:** This approach works only with two-story home designs.

**Description:** In two-story homes, the space between floors is already used to some extent to run ducts, pipes and wires. While ducts easily run between floor joists, it can be very difficult and sometimes impossible to run ducts across joists. Open web floor trusses can allow unrestricted access to rooms on the upper and lower floors.

The first decision you would need to make about open web floor trusses is how deep they should be. I-Joist floors are typically 12-inches deep. Unfortunately, this may not be adequate for the size of ducts required for the heating system. So, the first step would be to consult the HVAC contractor for the necessary duct sizes. HVAC contractors should do a full system design, which includes ACCA Manuals J, S and D, to answer this question. Consider using rectangular duct that offers the same cross-sectional area with less height.

Since systems are sometimes oversized, correct sizing calculation may result in smaller systems and duct work. Because higher insulation levels, more air-tight construction and more efficient windows can reduce heating and cooling loads significantly, duct sizes could be smaller than the contractor’s previous experience would lead him or her to install. Smaller duct diameter means less depth to the floor joists.

Increasing joist depth has several impacts. Most two-story buildings currently use 12-inch I-Joists. Builders who have installed open web trusses have often used 14 or 16-inch joists to accommodate larger ducts. Increasing joist depth would require additional siding and may affect other exterior details. Stair layout could also be affected by even a few inches difference in height. While stair height may be fairly easy to accommodate in a new plan, it can become tricky when modifying existing plans.
The metal connector plates of the trusses can be hazardous to flex duct. Pulling flex duct across a sharp edge can easily damage the duct. One way to eliminate this problem would be to ask the truss manufacturer to install vertical members in the trusses to create a special channel, called a duct chase. Manufacturers have great flexibility on where to place them, so they should be able to accommodate any duct distribution. Of course, the duct system must be carefully designed in advance to specify the locations and then the trusses must be installed correctly so the channels line up. Be sure to inform other trades not to block the chases with pipes, wires, or recessed lights.

The furnace can be located on the first or second floor. Most builders following this approach choose the second floor with a downdraft furnace. The base can is dropped into the joist bay in order to reduce the height of the furnace assembly. Because the furnace is now inside the home and above a living space, it’s necessary to protect against water damage from condensate generated by the furnace or cooling coil. The drain pan detail can be tricky to work out. A moisture sensor might be an acceptable alternative.
With the supply plenum already protruding into the joist space, it can be directly connected to a supply trunk. Branch ducts may be insulated flex duct to reduce noise. One consequence of this approach is that the space between floors is now extremely vulnerable to air leakage and vapor condensation. It’s essential to protect the entire rim joist. This can be done by covering the entire rim with high density spray foam, which combines the properties of insulation, air barrier and moisture barrier. Another common approach is to press fiberglass insulation into the joist bay, and then cut a square of rigid insulation (usually extruded polystyrene or foil-faced urethane) and fit it between joists so that it covers the fiberglass. Finally, caulk around the rigid insulation to prevent moisture-laden air from reaching the cold rim joist. Both methods will seal and protect the building.

Bonus rooms over unconditioned garages create special challenges for the open web truss approach. Because the truss web members interfere with batt insulation, only blown-in insulation should be allowed in exterior floors framed with open web trusses. Since the ducts are already running between floors, it’s logical to continue them into the insulated floor below the bonus room. Unfortunately, there isn’t enough vertical space for ducts and the full insulation thickness in the same joist cavity. It’s best to keep the duct out of the insulated floor. You may be able to run the duct up an interior wall and deliver air near the ceiling of the bonus room blowing out toward the exterior wall. With adequate velocity and the proper grille, this will keep the room comfortable. If you decide that it is necessary to run a duct to the exterior wall, then you will have to frame a soffit below the joist to hold the full insulation level (usually R38). High R-value rigid insulation could also be used in this location. In this situation, rectangular metal duct mounted close to the floor may be a good choice.

A very similar approach can be used with I-Joists. Most I-Joists can be drilled in the field with holes up to the full height of the web member. Check with the manufacturer for hole size and placement guidelines. Some manufacturers can cut holes to your requirements in the factory. Here again, designing the duct system in advance, documenting all these details on the building plans, and careful communications are essential for success.
Advantages:
+ Allows high degree of flexibility in location of heating equipment, duct runs and registers.
+ Works with any ceiling height.
+ Lower potential for trade schedule conflicts.

Disadvantages:
− Can increase stair height and require additional siding material.
− May raise overall building height by several inches.
− Requires careful location of plumbing and electrical (especially recessed lights).
− Insulation and sealing of the rim joist requires extra care.
− Additional cost of trusses.

Key challenges:
- Avoiding conflicts with plumbing and recessed lights.
- Creating a well-insulated and moisture-protected rim joist.
- Filling the floor cavity with blown-in insulation, instead of batts.
- Sealing the joist bays between the heated and unheated spaces.

Cost considerations:
$ Additional cost of trusses (if any), siding and exterior trim.
$ Plans with rooms over unheated spaces can be expensive to address.
$ Ducts can be shorter and may reduce cost. Heating system size can be reduced, which may reduce cost.

Keys to Success:
✓ Careful planning and communication.
✓ Proper drain pan for second-story furnaces.
All team members should participate in a pre-design meeting with the project team to identify and solve potential issues. Additional guidelines for each team member are outlined below:

**Designer:**
- Identify a central location for the air handler, supply plenum and trunk. Identify each duct path all the way to the register. Be aware of noise issues when locating the furnace.
- Pay special attention to furnace room details, such as clearances, access, drain pan, condensate drain and overall height.
- Specify the location of duct channel in the truss.
- Identify all potential obstructions in the joist space, especially recessed lights. Include them in the plans.
- Detail the method for sealing the rim joist.
- Specify blown-in insulation and full insulation depth for floors over unheated spaces.

**General Contractor:**
- Require the designer and all trades to attend a pre-design meeting to discuss the ducts inside approach and everyone’s responsibilities.
- Ensure proper air sealing and vapor retarder installation around rim joist.
- Ensure accessibility to all furnace components for maintenance and repair, such as filters, access panels, controls, etc.
- Ensure there is adequate space around the furnace or air handler to meet the minimum clearance requirements in the code.
- Be sure the framers know where the duct channel needs to be.

**Framer:**
- Be sure the duct chase (if there is one) lines up across all the trusses or joists.
- Check the dimensions of the furnace room to be sure it is large enough for maintenance and repair of equipment, such as filters, access panels, controls, etc. Check with HVAC contractor about necessary clearances.

**HVAC Contractor:**
- Size the heating equipment and design the ductwork taking into account the smaller heat load and shorter duct runs.
- Carefully consider the supply plenum as it fits into the joist space. Don’t forget to accommodate a drain pan and drain line.
- Select quiet furnace equipment.
- Always install sealed combustion equipment with proper combustion air supply ducting to the outside.
- Avoid locating ducts joints near obstacles that will interfere with fastening and sealing ducts.
- Seal all ducts with mastic paste.
- Connect the fresh air duct and damper to the return duct near the grille.

**Insulator:**
- Carefully insulate and air seal the rim joist, including those adjacent to unheated spaces, such as garages.
- Use blown-in insulation in floors over unheated spaces.

**Plumber:**
- Insulate PEX pipe near ducts.
- Be sure that a condensate drain is installed at the furnace location.

**Electrician**
- Be sure to know where ducts are to be located to avoid conflicts with electrical wiring and fixtures, especially with recessed lights and ceiling fans.
Conditioned Basements

**Application:** Single-story homes or the first level of multi-story homes.

**Description:** Since the dawn of central heating, furnaces have been located in basements. They offer direct access to the home’s entire first floor and provide ample space for mechanical equipment and ducts. If the basement is sealed and insulated just the same as the rest of the home, it is inside the thermal boundary. Conditioned basements must have these elements:

1. Wall insulation covered by a fire-rated surface
2. Concrete slab floor
3. Underslab insulation
4. Rim joist fully insulated and air sealed
5. Duct insulation is not required

Basements don’t require any special ventilation beyond that required for living spaces under the applicable code or energy efficiency program. They generally don’t require a dedicated source of supply air from the forced air system, since the furnace cabinet offers sufficient incidental heat.

Basements offer one special challenge not experienced by above-grade walls. They have no ability to dry outward, because the soil is always relatively warm and humid. For this reason, below-grade walls must always be built to allow water vapor to move into the conditioned space. Knowing the below-grade concrete wall will always be a source of moisture has two important implications for materials. Wood framing must never come into direct contact with the concrete and the wall’s interior vapor retarder should always be relatively “open” to vapor transmission. This is often called the ability to “dry to the inside.” Good choices for vapor retarder materials are vapor retarder paint or the asphalted kraft paper backing on insulation. Plastic vapor retarders should never be installed in below grade walls.
The rim joist of a conditioned basement must be insulated to the same R-value as the above-grade wall and fully air sealed.

It’s strongly recommended that fibrous insulation not be used in below grade walls. Instead, install rigid insulation that will not hold water.

These features apply to all basements inside the thermal boundary, including full basements, partial basements, daylight basements and “short” basements. A short basement is a conditioned space that may be only 3 to 5 feet tall. The short basement approach offers several advantages beyond a place to house HVAC equipment and ducts. Noise from mechanical equipment is minimized. It allows easy access for plumbing and technology maintenance and upgrades. The short basement offers warmer floor temperatures. Controlled ventilation to the outside may not be required, unless radon conditions at the site or building codes dictate it. The walls of short basements must always be insulated with rigid insulation instead of standard fibrous insulation. Short basements should also have insulation below the floor slab.
Advantages:
+ Underfloor duct runs are very conventional, requiring no changes by the HVAC contractor.
+ Works with any above grade wall height.
+ Lower potential for trade scheduling conflicts.

Disadvantages:
− Requires the use of rigid insulation materials for walls and ground insulation.
− Insulation and sealing of the rim joist requires extra care and materials.

Key challenges:
✓ Extra detailing of insulation and air sealing of the foundation wall.

Cost considerations:
$ Rigid insulation is more expensive than batt materials that would be used to insulate the framed floor.

Keys to Success:
✓ Insulating the below grade wall
✓ Insulating and air sealing the rim joist.

Project Team Member Guidelines

All team members should participate in a pre-design meeting with the project team to identify and solve potential issues. Additional guidelines for each team member are outlined below:

Designer:
• Create a heated space from the bottom of the lowest framing member, including beams, to the top of the floor slab that ranges from full ceiling height to no less than three feet.
• Identify a central location for the air handler, supply plenum and trunk in the basement. Identify the location of the return duct. Be aware of noise issues when locating the furnace.
• Detail rigid insulation under the floor slab.
• Detail wall insulation to prevent wetting and allow drying to the inside.

General Contractor:
• Require the designer and all trades to attend a pre-design meeting to discuss the ducts inside approach and everyone’s responsibilities.
• Ensure proper insulation and air sealing of the foundation wall all the way up to the subfloor.
• Ensure proper installation of rat slab.
• Ensure accessibility to all furnace components for maintenance and repair, such as filters, access panels, controls, etc.
• Ensure there is adequate space around the furnace or air handler to meet the minimum clearance requirements in the code.

HVAC Contractor:
• Size the heating equipment and design the ductwork taking into account the smaller heat load and shorter duct runs.
• Select quiet furnace equipment.
• Always install sealed combustion equipment with proper combustion air supply ducting to the outside.
• Avoid locating ducts joints near obstacles that will interfere with fastening and sealing ducts.
• Seal all ducts with mastic paste.

Insulator:
• Carefully insulate the below-grade wall with rigid insulation and air seal the rim joist.

Plumber:
• Insulate PEX pipe near ducts.
• Be sure that a condensate drain is installed at the furnace location.
References


# Appendix

## ENERGY STAR Qualified Homes

### Thermal Bypass Inspection Checklist

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<th>Home Address:</th>
<th>City:</th>
<th>State:</th>
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<td><strong>Inspection Guidelines</strong></td>
<td><strong>Corrections Needed</strong></td>
</tr>
<tr>
<td>1. Overall Air Barrier and Thermal Barrier Alignment</td>
<td><strong>Requirements:</strong> Insulator shall be installed in full contact with sealed interior and exterior air barrier except for alternate to interior air barrier under Item no. 2 (Walls Adjacent Exterior Walls or Unconditioned Spaces)</td>
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<tr>
<td></td>
<td><strong>All Climate Zones:</strong></td>
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<td></td>
<td>1.1 Overall Alignment Throughout Home</td>
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<td>1.2 Garage Band Joist Air Barrier (all bays adjoining conditioned space)</td>
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<td>1.3 Attic Eave Baffles Where Vents/Leakage Exist</td>
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<tr>
<td></td>
<td><strong>Only at Climate Zones 4 and Higher:</strong></td>
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<tr>
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<td>1.4 Slab-edge Insulation (A maximum of 25% of the slab edge may be uninsulated in Climate Zones 4 and 5)</td>
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<td><strong>Best Practices Encouraged, Not Req'd:</strong></td>
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<td></td>
<td>• Fully insulated wall aligned with air barrier at both interior and exterior, OR</td>
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<td></td>
<td>• Alternate for Climate Zones 1 thru 3, sealed exterior air barrier aligned with RESNET Grade 1 Insulation fully supported</td>
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<td></td>
<td>• Continuous top and bottom plates or sealed blocking</td>
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<tr>
<td></td>
<td><strong>2.1 Wall Behind Shower/Tub</strong></td>
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<td></td>
<td><strong>2.2 Wall Behind Fireplace</strong></td>
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<td></td>
<td><strong>2.3 Insulated Attic Slopes/Walls</strong></td>
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<td><strong>2.4 Attic Knee Walls</strong></td>
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<td></td>
<td><strong>2.5 Skylight Shaft Walls</strong></td>
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<td></td>
<td><strong>2.6 Wall Adjacent Porch Roof</strong></td>
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<td></td>
<td><strong>2.7 Staircase Walls</strong></td>
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<td></td>
<td><strong>2.8 Double Walls</strong></td>
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<tr>
<td>3. Floors between Conditioned and Exterior Spaces</td>
<td><strong>Requirements:</strong></td>
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<tr>
<td></td>
<td>• Air barrier is installed at any exposed fibrous insulation edges</td>
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<td></td>
<td>• Insulation is installed to maintain permanent contact with sub-floor above including necessary supports (e.g., staves for blankets, netting for blow-in)</td>
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<td></td>
<td>• Blanket insulation is verified to have no gaps, voids or compression</td>
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<td></td>
<td>• Blown-in insulation is verified to have proper density with firm packing</td>
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<td></td>
<td><strong>3.1 Insulated Floor Above Garage</strong></td>
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<td></td>
<td><strong>3.2 Cantilevered Floor</strong></td>
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<td>4. Shafts</td>
<td><strong>Requirements:</strong></td>
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<td></td>
<td>• Openings to unconditioned spaces are fully sealed with solid blocking or flashing and any remaining gaps are sealed with caulk or foam (provide fire-rated collars and caulking where required)</td>
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<td></td>
<td><strong>4.1 Duct Shaft</strong></td>
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<td></td>
<td><strong>4.2 Piping Shaft/Penetration</strong></td>
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<td></td>
<td><strong>4.3 Fire Shaft</strong></td>
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<tr>
<td>5. Attic/Ceiling Interface</td>
<td><strong>Requirements:</strong></td>
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<td></td>
<td>• All attic penetrations and dropped ceilings include a full interior air barrier aligned with insulation with any gaps fully sealed with caulk, foam or tape</td>
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<td></td>
<td>• Movable insulation fits snugly in opening and air barrier is fully gasketed</td>
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<td></td>
<td><strong>5.1 Attic Access Panel (fully gasketed and insulated)</strong></td>
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<td></td>
<td><strong>5.2 Attic Drop-down Stair (fully gasketed and insulated)</strong></td>
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<td><strong>5.3 Dropped Ceiling/Soft (full air barrier aligned with insulation)</strong></td>
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<td></td>
<td><strong>5.4 Recessed Lighting Fixtures (ICAT labeled and sealed to drywall)</strong></td>
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<td><strong>5.5 Whole-house Fan (insulated cover gasketed to the opening)</strong></td>
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<td>6. Common Walls Between Dwelling Units</td>
<td><strong>Requirements:</strong></td>
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<td></td>
<td>• Gap between drywall shaft wall (i.e., common wall) and the structural framing between units is fully sealed at all exterior boundary conditions</td>
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<tr>
<td></td>
<td><strong>6.1 Common Wall Between Dwelling Units</strong></td>
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