

Measure Guideline: Air Sealing Mechanical Closets in Slab-On-Grade Homes

Bruce Dickson
IBACOS, Inc.

February 2012

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Prepared by:

Bruce Dickson

IBACOS, Inc.

2214 Liberty Avenue

Pittsburgh, Pennsylvania 15222

Technical Monitor: Michael Gestwick

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Contents

List of Figures	iv
List of Tables	v
Definitions.....	vi
Executive Summary	1
1 Strategies Covered in this Measure Guide	3
1.1 Audience for this Measure Guide	3
1.2 Industry Relevance for this Measure Guide.....	3
2 Common Practice and Inherent Risk Issues	3
2.1 Indoor Air Quality.....	4
2.2 Building and Equipment Durability.....	5
2.3 Occupant Comfort and Energy Efficiency.....	5
3 Air Sealing a Total Equipment Replacement.....	6
3.1 Procedure	7
4 Air Sealing the Existing Equipment and Mechanical Closet.....	14
5 Verification Testing	19
6 Selection Criteria for Maximum Energy Efficiency	20
6.1 Performance	20
6.2 System Interactions.....	20
6.3 Cost Effectiveness.....	20
6.4 Codes and Standards	21
7 Efficiency, Homeowner Awareness and Education.....	21
8 Conclusion	21
References	22

List of Figures

Figure 1. Typical space conditioning strategies in existing slab on grade homes.....	2
Figure 2a. Leakage paths into the system.....	5
Figure 2b. Cut away view.	6
Figure 3a. Closet with air handler and support shelf removed.	7
Figure 3b. Install air barrier product (gypsum board) on interior framing.....	8
Figure 4. Install the properly-sized and sealed ductboard plenum box.....	9
Figure 5a. Air handler installed on the prefabricated metal stand over the return air plenum.....	10
Figure 5b. Seal the return plenum to the air handler.	11
Figure 6a. Interior view - Air seal around the plenum and any penetrations through the ceiling. ...	12
Figure 6b. Exterior view of sealing around supply plenum at ceiling.	13
Figure 7a. Air leakage pathways.	14
Figure 7b. Interior view.....	15
Figure 8a. Install appropriate blocking in any open stud cavities at the support shelf.	16
Figure 8b. Make repairs at the ceiling lid to enable good sealing between components.	17
Figure 9a. Seal all joints and seams in framing and sheathing.	18
Figure 9b. Interior view showing sealing at the supply plenum.	19

** Unless otherwise noted, all figures were created by IBACOS.*

List of Tables

No table entries found.

Definitions

Air Barrier	A material or structural element that inhibits air flow into and out of a building's envelope or shell.
Air Handler	A device used to circulate heated or cooled air throughout the space of a home.
Backdrafting	The flow of air down a flue/chimney and into a house caused by low indoor air pressure that can occur when using several fans or fireplaces and/or if the house is very tight.
Blower Door	A calibrated fan that is used to measure the airtightness level of building envelopes and to diagnose and demonstrate air leakage problems. (Source: The Energy Conservatory)
Bulkhead/Dropped Soffit	Boxed in area constructed to hang down from a ceiling to house beams, ductwork, or plumbing systems.
Caulking	A material used to seal areas of potential air leakage into or out of a building envelope.
Condensate	The liquid resulting when water vapor contacts a cool surface; also the liquid resulting when a vaporized working fluid (such as a refrigerant) is cooled or depressurized.
Condensation	The process by which water in air changes from a vapor to a liquid due to a change in temperature or pressure; occurs when water vapor reaches its dew point (condensation point); also used to express the existence of liquid water on a surface.
Conditioned Space	The interior space of a building that is heated or cooled.
Dehumidify	The process of removing moisture from air.
Efficiency	The ratio of output divided by input. (Source: Residential Energy John Krigger and Chris Dorsi)
Energy Retrofit	The process of improving the overall energy efficiency and comfort level of a structure through upgrades to the thermal envelope and mechanical systems.
Expanding Spray Foam	Polyurethane or polyisocyanurate foam material that is used to seal cracks and holes to prevent air passage and provide insulation.

Latent Cooling Load	The amount of energy used to remove moisture in the air, including from outside air infiltration and from indoor sources such as occupants, plants, cooking, showering, etc.
Return Air Plenum	Ducting or constructed space that is designed to direct air from the living space into the air handler to be conditioned and re-distributed to the home.
Smoke Pencil	A non-toxic smoke generator used to detect drafts and air leaks in a home.
Static Pressure	The air pressure within a duct system during operation that results from duct type, layout, fan capacity and other associated restrictions (balancing dampers, turning vanes, filters, etc.).
Unconditioned Space	The spaces within a home that do not have any heating or cooling.

Executive Summary

With rising utility costs, homeowners are considering upgrades to increase energy efficiency while maintaining, or even increasing the level of comfort in the home. These upgrades can be as extensive as a whole house energy retrofit, where improvements are made to the air tightness and insulation levels of the thermal envelope and mechanical systems are removed and replaced; or, as minimal as a single component upgrade such as new windows or new appliances.

In many areas of the country, a slab-on-grade ranch style home is often constructed with an unconditioned attic that is insulated at the ceiling level and vented with soffit and ridge vents. The space conditioning system in this type of home is typically located in the unconditioned attic or in a centrally located utility closet within the living space of the home. In either scenario, the supply air ductwork is routed throughout the attic space, delivering conditioned air to individual rooms through the ceiling. The return air for these systems is fed to the air handler from either a single, central source or from ductwork that is routed from various rooms in the home. Air handlers that are located in attics draw return air from the living space through a return grille or grilles that have been cut through and installed in the ceiling plane. If the air handler is installed in a closet within the living space, it is typically an upflow unit that takes return air from beneath the air handler and distributes the conditioned air through supply ductwork that is routed throughout the attic. Normally, the cutout for the supply plenum that passes through the ceiling to reach the attic space is cut out in very rough fashion and not sealed well or is chinked with fiberglass. Chinking the gap with fiberglass or mineral wool is not an effective air barrier between the closet and unconditioned attic. Large gaps to the attic and any air leakage paths from the closet to the return plenum allows the operating air handler to draw hot, humid attic air into the conditioning system. Properly sealing all gaps between the supply plenum that penetrates the ceiling and all potential air leakage pathways from the closet space to the return plenum with expanding spray foam or caulking will improve the overall efficiency of the equipment and possibly comfort conditions within the home.

Definition: Energy Retrofit - The process of improving the overall energy efficiency and comfort level of a structure through upgrades to the thermal envelope and mechanical systems.

Definition: Unconditioned Space - The spaces within a home that do not have any heating or cooling.

Definition: Conditioned Space - The interior space of a building that is heated or cooled.

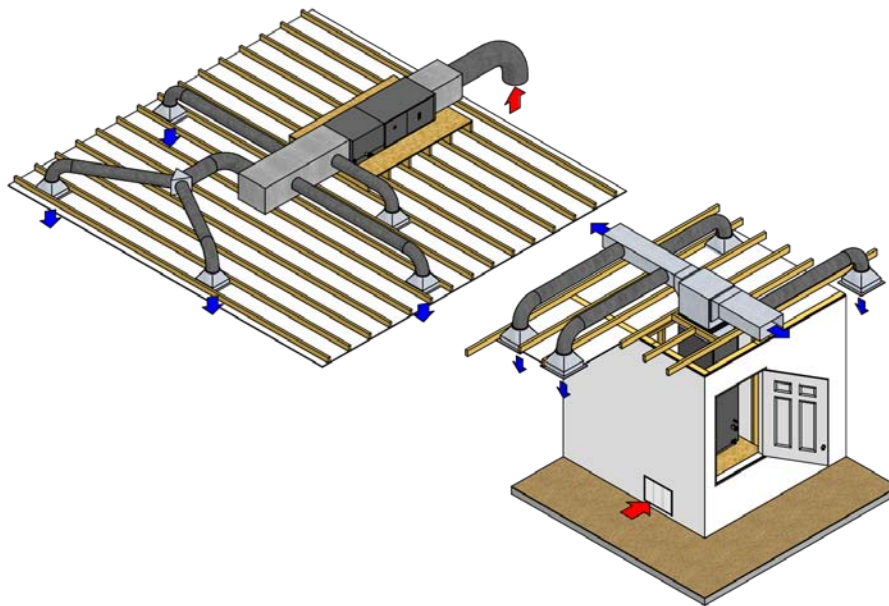


Figure 1. Typical space conditioning strategies in existing slab on grade homes.

Due to extreme temperatures in the attic, equipment and ductwork located there do not perform as efficiently as they would in conditioned space. A home designed to achieve Building America performance goals of energy savings would typically bring all equipment and ducts inside the conditioned enclosure.

However, while ductwork located within the conditioned living space versus the attic space is more energy efficient and installing it in conditioned space is very possible, most retrofit projects do not present ideal conditions for this type of strategy. During a retrofit, installing the ductwork within the living space is impractical in many instances, often requiring the retrofit contractor to insulate the attic roof deck, which can be costly, or lowering the ceiling by adding many bulkheads (dropped soffits) throughout the house to accommodate the ductwork.

Definition:

Bulkhead/Dropped Soffit - Boxed in area constructed to hang down from a ceiling to house beam, ductwork, or plumbing systems.

1 Strategies Covered in this Measure Guide

This measure guide covers two fundamental retrofit strategies for air sealing around air handling systems that are located within the living space in an enclosed closet. It includes the design and installation details necessary to effectively seal the air handler closet and central return system to maximize the efficiency and safety of the space conditioning system. This guide will discuss and demonstrate best practice methods associated with the air sealing of a mechanical closet where all of the equipment is removed and being replaced, and a closet where the equipment is to remain and existing conditions are sealed.

1.1 Audience for this Measure Guide

The audiences who will benefit most from this measure guide include the homeowner, the retrofit contractor, the mechanical contractor, and the equipment manufacturer.

1.2 Industry Relevance for this Measure Guide

The market demand for improved comfort, indoor air quality, and energy efficiency has increased. As energy costs rise, homeowners are becoming less tolerant of the loss of comfort and energy efficiency due to poor design and installation methods and are looking for ways to improve the performance and comfort of their homes.

2 Common Practice and Inherent Risk Issues

In a home where the air handler is located in a mechanical closet within the living space, it is not uncommon for the return air box or plenum area beneath the unit to be constructed of open framing, where no air barrier product (typically gypsum wallboard) has been applied against the studs. In some cases, this open framing may extend all the way to the attic. Without any air barrier on the interior of the closet, air is free to move within the wall cavities and potentially travel to and from any adjacent unconditioned spaces. If these conditions exist, in almost all circumstances the air will be drawn into the air handler if the air has already been drawn into the closet space. In addition, the ceiling plane above the air handler may or may not have an air barrier “lid” installed. If there is a lid, often the cutout for the supply plenum, which passes through the ceiling to reach the attic space, is cut out in very rough fashion and left unsealed. This allows the free movement of attic air into the mechanical closet and vice versa.

Definition: Return Air Plenum - Ducting or pre-constructed space that is designed to direct air from the living space into the air handler to be conditioned and re-distributed to the home.

If these inadequate, yet common practices exist in the home, there are potential risk issues that could affect the occupants of the house in terms of poor indoor air quality, building and equipment durability problems, occupant comfort, equipment inefficiency, and reduced system performance. Through these open building cavities and unsealed areas, hot, humid air is readily drawn down through the mechanical closet and delivered to the air handler from the open return plenum. This undesirable air within the system can make the air handler work longer or harder to remove the negative effects; or worse yet, this air passes through the system and is mixed with the conditioned air and distributed throughout the house.

2.1 Indoor Air Quality

A leaky mechanical closet with a bottom-feed return air system can draw unwanted air from the attic and building cavities into the duct system. This air may contain pollutants, such as dirt, dust, mold, and other allergens as well as unwanted moisture. If the air handler (furnace) is a gas-fired, natural-draft vented (B-vent) furnace, there is a high risk of backdrafting, or drawing exhaust gases back down the flue by the surrounding negative pressure from the leaky return. Backdrafting can lead to unhealthy exhaust gases being drawn into the living space of the house.

To ensure combustion safety and reduce health risks due to backdrafting, the following life-safety strategies are critically important if the home has a gas-fired, natural-draft vented (B-vent) furnace. The first and best strategy is to replace any natural draft appliances with sealed combustion, direct vent furnaces, or all electric heat pumps. This equipment does not backdraft. If a naturally vented (B-vent) furnace is installed and not being replaced, a thorough inspection by a qualified mechanical contractor should be completed to ensure proper venting and combustion air sourcing before proceeding with the retrofit. If existing natural draft-vented appliances (B-vent) will not be replaced, then it is critical to confirm that the home has a combustion air source that meets or exceeds the International Mechanical Code requirements for combustion air from the indoors, and is fitted with carbon monoxide alarms complying with UL 2034 in close proximity to the combustion appliances and outside each separate sleeping area in the immediate vicinity of the bedrooms. The 2006 International Mechanical Code ‘(IMC, 2006)’ requirements are below:

Definition: Backdrafting - The flow of air down a flue/chimney and into a house caused by low indoor air pressure that can occur when using several fans or fireplaces and/or if the house is very tight.

Warning: If there are naturally vented (B-vent) appliances located in the closet that are not going to be replaced a professional mechanical contractor should be hired to conduct a thorough inspection of all venting and make up air strategies. Any issues must be corrected before proceeding with the retrofit.

702.1 All air from indoors. Combustion and dilution air shall be permitted to be obtained entirely from the indoors in buildings that are not of unusually tight construction. In buildings of unusually tight construction, combustion air shall be obtained from the outdoors in accordance with Section 703, 705, 706 or 707.

702.2 Air from the same room or space. The room or space containing fuel burning appliances shall be in unconfined space as defined in Section 202.

702.3 Air from adjacent spaces. Where the volume of the room in which the fuel-burning appliances are located does not comply with Section 702.2, additional inside combustion and dilution air shall be obtained by opening the room to adjacent spaces so that the combined volume of all communicating spaces meets the volumetric requirement of Section 702.2. Openings connecting the spaces shall comply with Sections 702.3.1 and 702.3.2.

702.3.1 Number and location of openings. Two openings shall be provided, one within 1 foot (305 mm) of the ceiling of the room and one within 1 foot (305 mm) of the floor.

702.3.2 Size of openings. The net free area of each opening, calculated in accordance with Section 708, shall be a minimum of 1 square inch per 1,000 Btu/h (2201 mm²/kW) of input rating of the fuel burning appliances drawing combustion and dilution air from the communicating spaces and shall not be less than 100 square inches (64516 mm²).

2.2 Building and Equipment Durability

In a poorly sealed or unsealed mechanical closet, the air handler will have the potential to draw warm, moist air from the attic space and through the building cavities from outside. Drawing warm, moist air from the attic will generate more condensate on the air conditioning coil, which will have to be removed by a condensate pump and then drained. If the pump or drain fails, the result will be leaks or clogs, increasing the risk of water damage. In addition, this moist attic air will tend to increase the relative humidity within the home and may lead to condensation related issues on building surfaces.

2.3 Occupant Comfort and Energy Efficiency

In slab-on-grade homes during the cooling season, the conditioned living space of the home will typically be maintained between 68°–72°F degrees, while attic temperatures may exceed 110°F degrees. When the mechanical closet is not sealed well and there is a lot of air transfer between the attic space and closet, there is great potential for the system to draw warm, moist air from the attic and building cavities into the air handler (see Figures 2a and 2b). Drawing warm, moist air into the system will increase the latent cooling load of the system and require the air handler to work much harder to cool and dehumidify the air being delivered to the living space.

Definition: Dehumidify -
The process of removing
moisture from air.

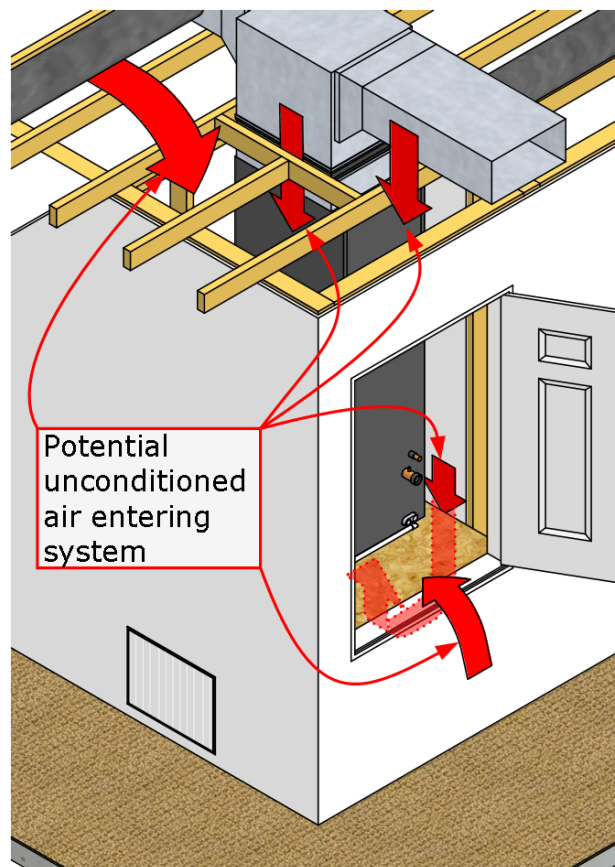


Figure 2a. Leakage paths into the system.

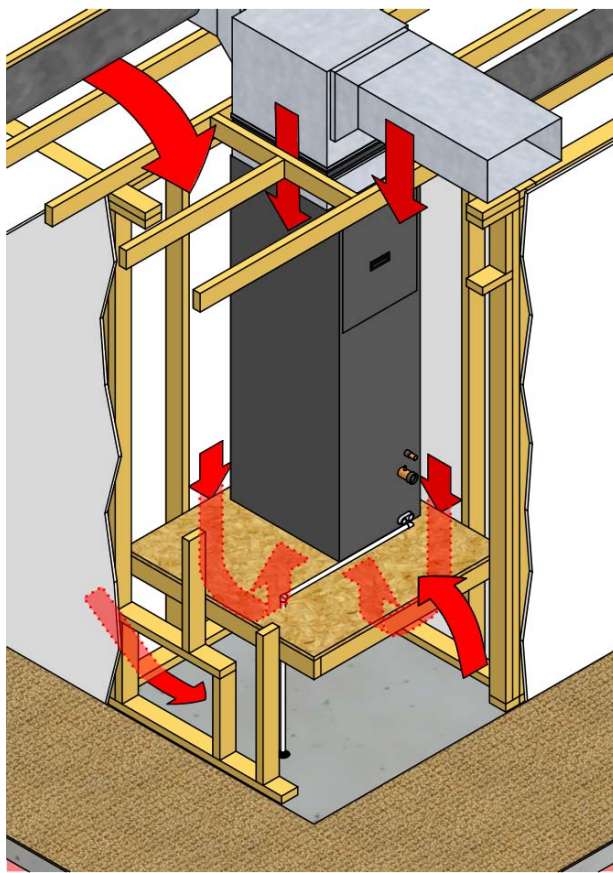


Figure 2b. Cut away view.

Homeowners will have higher utility bills due to the increased latent cooling load placed on the system. Homeowners may also experience reduced comfort due to the higher temperature of air from the attic entering the living space. In addition, the air handler may not sufficiently remove moisture from the living space, increasing indoor humidity and further decreasing homeowner comfort.

Definition: Latent Cooling Load - The amount of energy used to remove moisture in the air, including from outside air infiltration and from indoor sources such as occupants, plants, cooking, showering, etc.

3 Air Sealing a Total Equipment Replacement

In this first retrofit strategy, the homeowner will have the existing air handling system, which is located in a mechanical closet within the living space, removed and replaced with a more efficient unit into the same closet. This scenario also includes removal of the return air plenum that was located beneath the unit to ensure that a completely sealed system is reinstalled. If possible, it is best to plan for and install a full-size closet door to facilitate the installation and ease of maintenance of the new equipment.

3.1 Procedure

After removing the air handler and the shelf support, inspect the interior construction of the mechanical closet for sufficient air sealing (see Figure 3a). It will be necessary to sheathe any exposed wall or ceiling framing. The most convenient product for this purpose is gypsum wallboard, installed conventionally, and at a minimum with all seams and corners having the initial base coat of joint compound and taping.

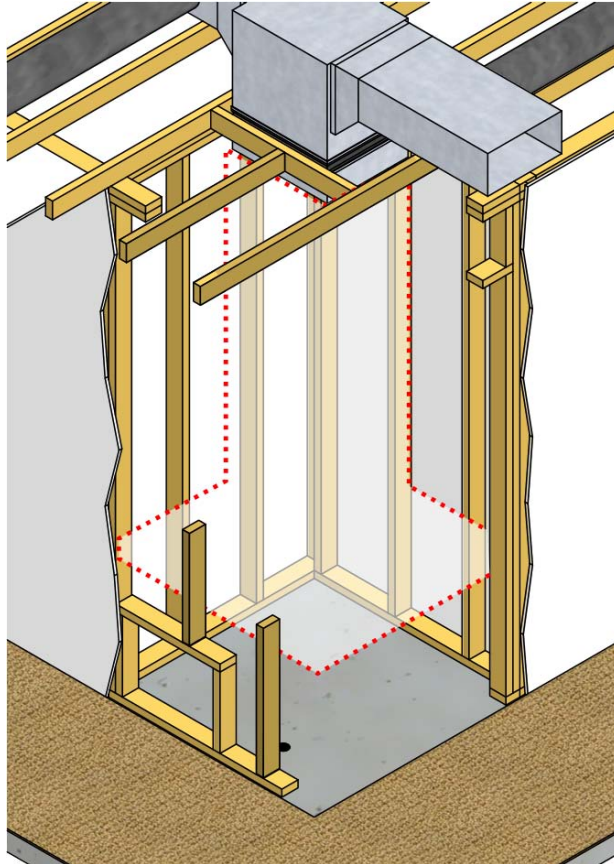


Figure 3a. Closet with air handler and support shelf removed.

In many cases, a small section of the existing supply plenum will still penetrate the ceiling plane in order to connect the new system to the existing supply ductwork in the attic, it is critical that the cutout surrounding the plenum is neat and sealable. If it is not, it will be necessary to add a new ceiling panel that is cut to fit neatly over the existing lid. When complete, the closet should take on the rough appearance of any other closet in the home (see Figure 3b). One coat of finishing on the joints and corners, as well as painting, is entirely cosmetic and can be left up to aesthetic preference.

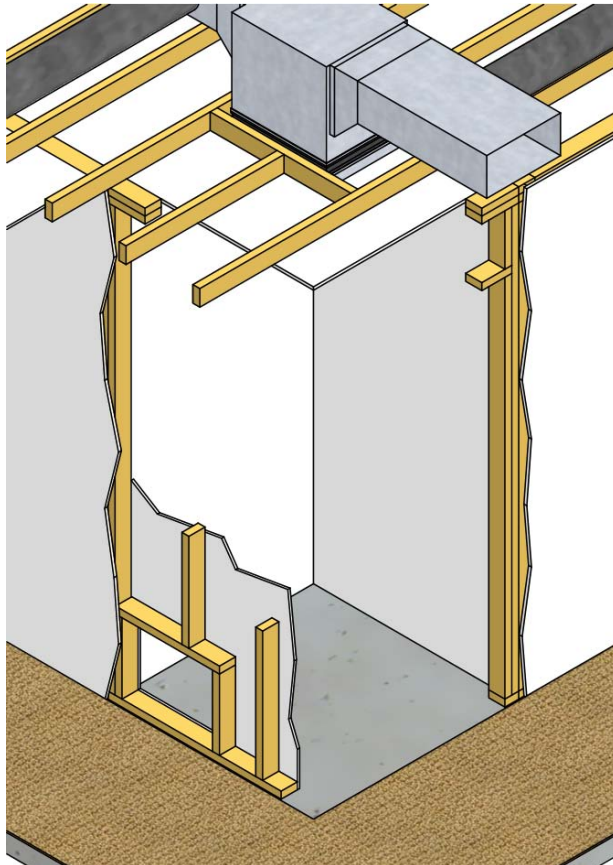


Figure 3b. Install air barrier product (gypsum board) on interior framing.

After the mechanical closet is completely air sealed, the mechanical contractor who is installing the new equipment will need to plan the air filtration strategy and construct a sealed return plenum box of the proper size. The best material for the plenum box is insulated fibrous duct board; because it is sound absorbent and easy to air seal (see Figure 4). Sealing all joints, seams and penetrations in the plenum with UL 181 rated foil tapes or approved mastics will ensure an airtight assembly. Fibrous duct construction should conform to the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Fibrous Glass Duct Construction Standards or the North America Insulation Manufacturers Association (NAIMA) Fibrous Glass Duct Construction Standards.

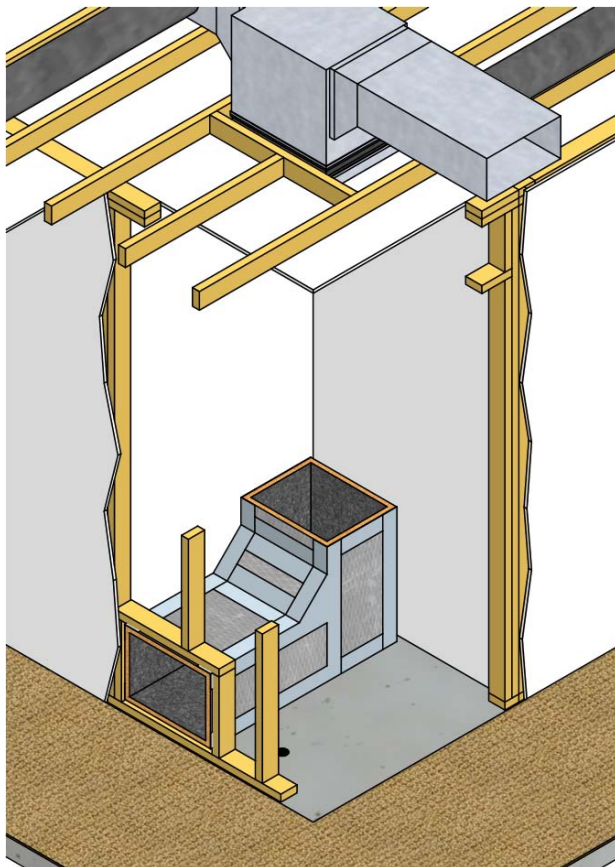


Figure 4. Install the properly-sized and sealed ductboard plenum box.

The main return duct should be constructed with straight duct modules fabricated from flat sections of fibrous glass duct board. Joints, corners, and longitudinal seams need to be sealed using a UL 181 approved closure system as outlined in NAIMA'S Fibrous Glass Duct Construction Standards, 3rd edition (2002). One of the most effective and easiest to install methods for air filtration is to install a high performance filter that is designed to coordinate with the size of the return air grille. These types of filters do not require any additional ductwork at the unit and their location on the wall allows for easy homeowner maintenance.

Next, install the air handler on a prefabricated metal stand that straddles the return plenum (see Figure 5a).

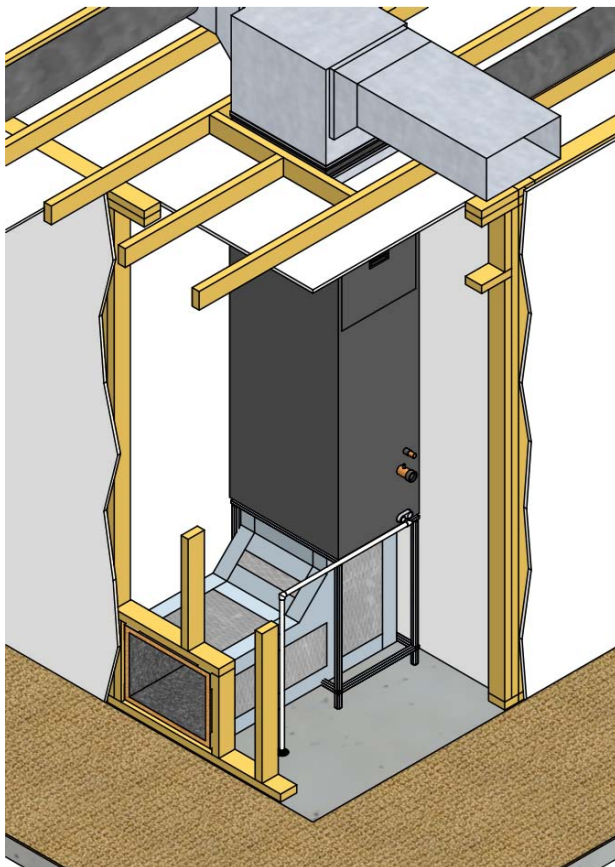


Figure 5a. Air handler installed on the prefabricated metal stand over the return air plenum.

This method of installation allows the return plenum to be easily connected and sealed to the air handler. It is critical that the connection between the return air opening on the base of the air handler is well sealed to the return plenum opening with approved foil tape or mastic (see Figure 5b). Additionally the same sealing practices must occur between the supply air ductwork and top of the unit connection. A thorough sealing job will complete the air-tight connection. An alternative to the metal stand method would be to construct a support shelf that fits neatly over the return plenum on which the air handler is installed. Make sure the front opening of the return plenum that faces the living space is sized to accept the grille and filter to deliver the designed return airflow with the air filter installed. Note: The grille should be sized to yield the designed airflow. If the grille is too small, it will lead to higher static pressures, decreased latent-load moisture removal, reduced occupant comfort and efficiency, and the potential for a whistling noise.

Definition: Static Pressure
– The air pressure within a duct system during operation that results from duct type, layout, fan capacity and other associated restrictions (eg balancing dampers, turning vanes, filters).

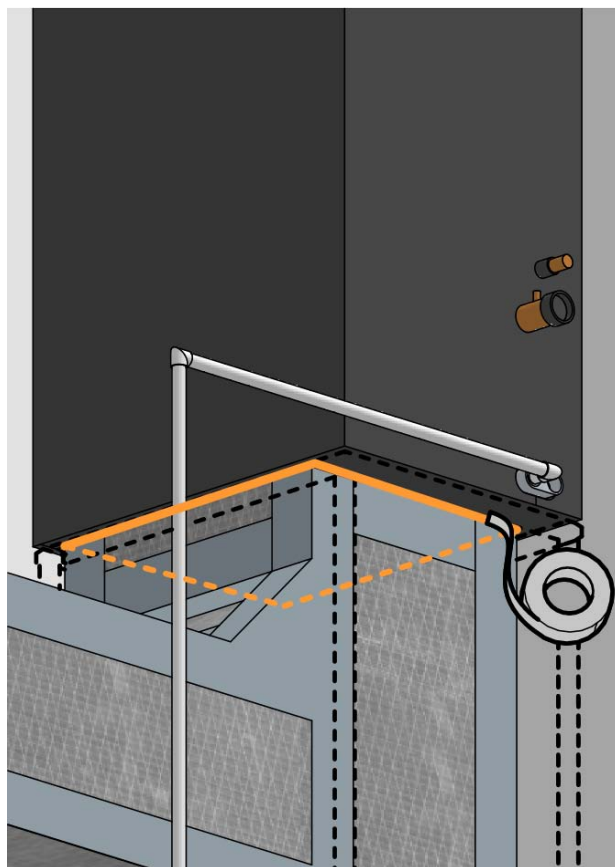


Figure 5b. Seal the return plenum to the air handler.

Following the installation of the return plenum and air handler, completely seal any gaps around the ceiling lid and duct box with spray foam (see Figures 6a and 6b). Proper sealing of any exhaust piping and wiring that may penetrate the ceiling plane should be done at this time. Make certain that all required safety shields and collars are installed on any naturally vented gas type furnaces (B-vent).

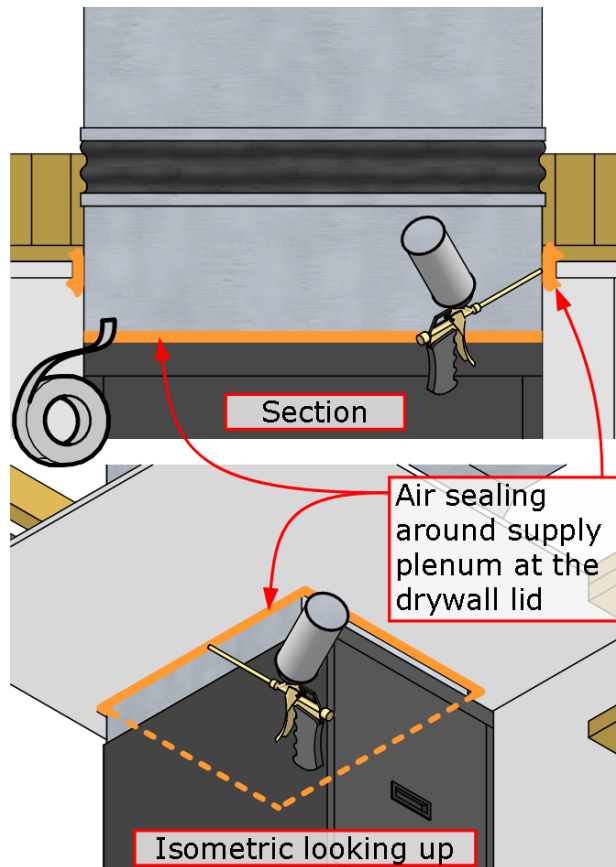


Figure 6a. Interior view - Air seal around the plenum and any penetrations through the ceiling.

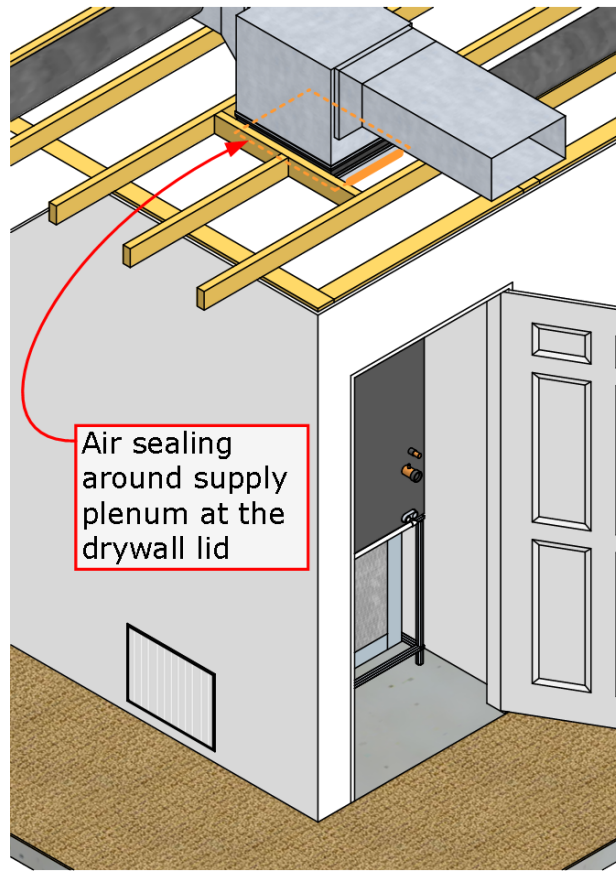


Figure 6b. Exterior view of sealing around supply plenum at ceiling.

This measure guide is intended to address the air sealing of the mechanical closet and associated equipment. Additional information related to further inspections and detailing of the remaining ductwork that is located in the attic space can be found in the following reference materials.

- Flexible Duct Performance & Installation Standards. (5th edition 2010) of the Air Diffusion Council
- An Introduction to Residential Duct Systems, <http://ducts.lbl.gov/>
- Air Seal and Insulate with ENERGY STAR, http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_sealing
- Guide to Attic Air Sealing – Identifying and Blocking Air Leakage Pathways Providing Airtight Closure, <http://www.buildingscience.com/documents/guides-and-manuals/gm-attic-air-sealing-guide>.

4 Air Sealing the Existing Equipment and Mechanical Closet

In this second retrofit strategy, the existing equipment will remain in place within the mechanical closet, and the mechanical closet, supply plenum penetration through the ceiling, and return air plenum will be air sealed. The objective of this retrofit is to eliminate, as best as possible, all leakage paths from the attic space into the closet and from the closet space to the return air plenum beneath the air handling unit. (see Figures 7a and 7b).

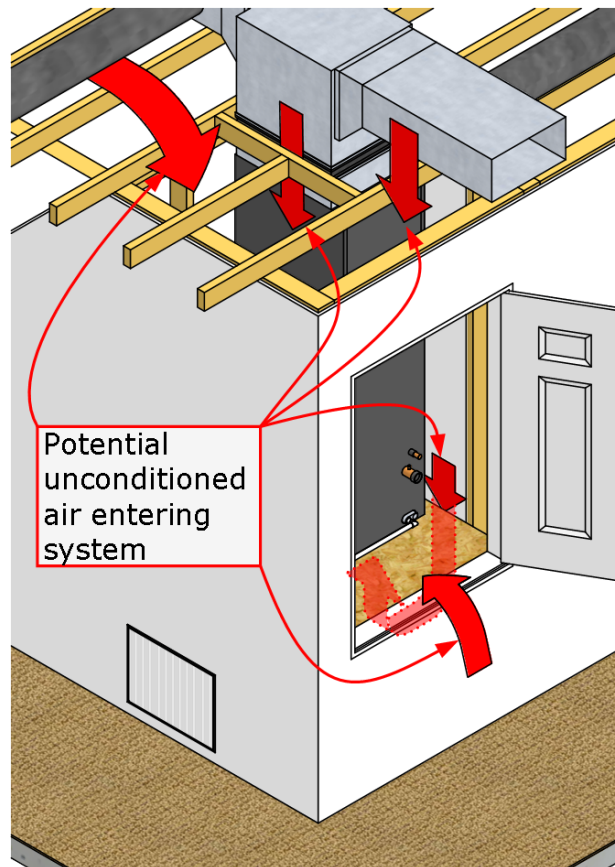


Figure 7a. Air leakage pathways.

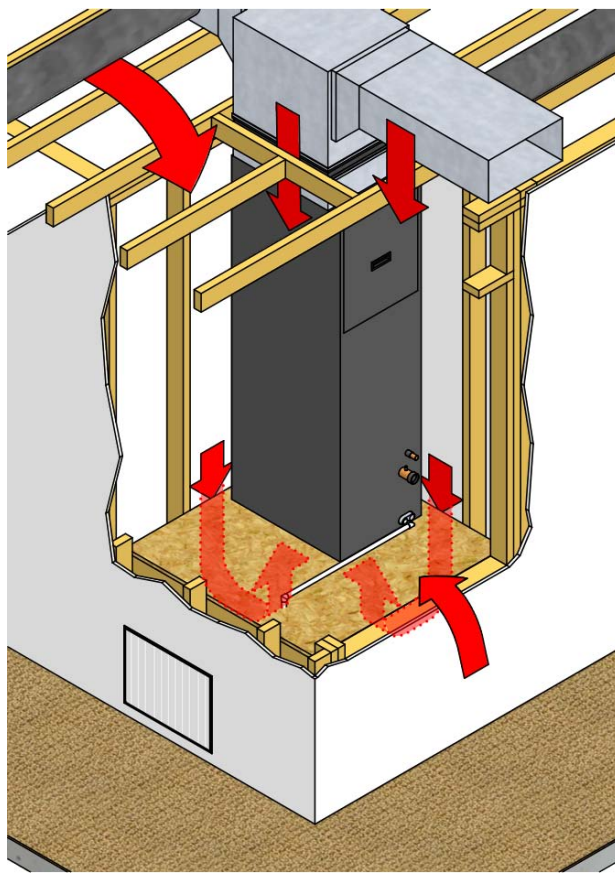


Figure 7b. Interior view.

First, inspect the interior of the closet space for air leakage locations. Start with the closet ceiling. Any holes or gaps should be thoroughly sealed with either caulk, or expanding foam. Silicone or polyurethane caulks are best (most durable). If existing gaps are too wide (larger than $\frac{3}{4}$ "), it may be necessary to fit and seal additional sheathing products around the supply plenum (see Figures 8a and 8b). If there is exposed wall framing, inspect the top plates for penetrations into the attic, and seal them, as necessary. Inspect the air handler platform around the perimeter, where the platform is attached to the sidewalls. If necessary, install blocking to close any large framing voids—such as between studs—and then seal the blocking with caulk or spray foam. Inspect the base of the air handler unit where it rests upon the closet shelf, and seal the perimeter with caulking or expanding foam (see Figures 9a and 9b). If possible, and the opening at the return air grille is large enough for access, inspect the interior space of the under unit return plenum. In particular, look for any gaps or holes that may permit air leakage to other building components of the house. Sealing of these areas with expanding foam, mastic, or rated foil tapes will greatly improve the overall performance of the system.

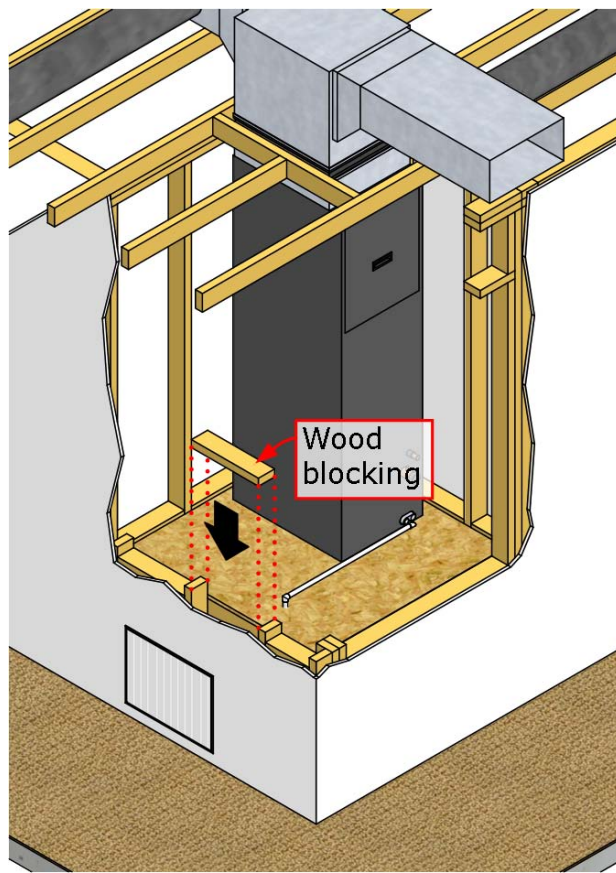


Figure 8a. Install appropriate blocking in any open stud cavities at the support shelf.

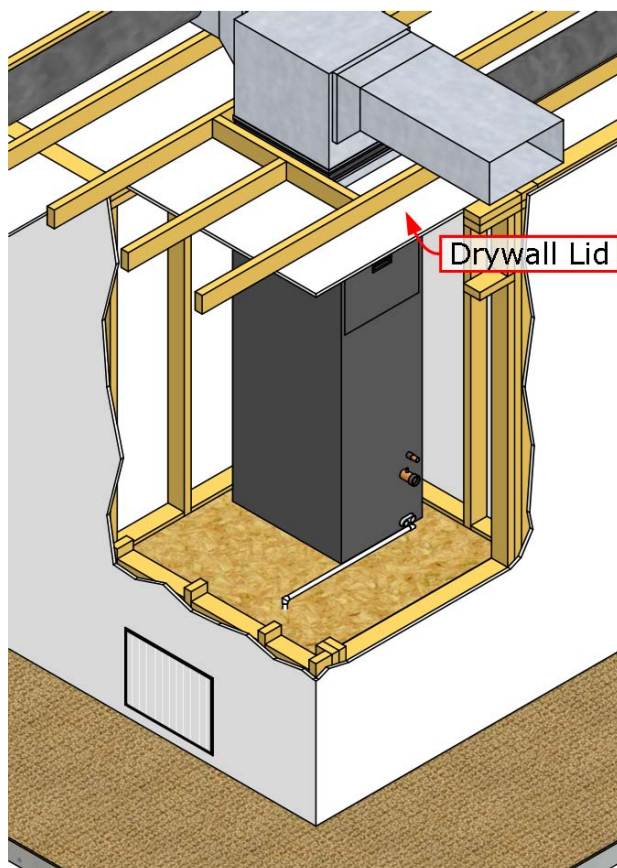


Figure 8b. Make repairs at the ceiling lid to enable good sealing between components.

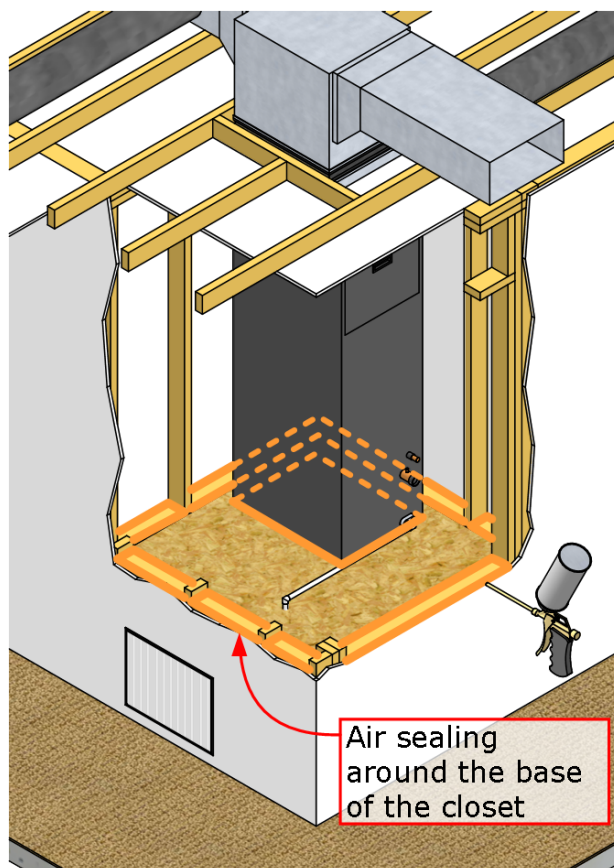


Figure 9a. Seal all joints and seams in framing and sheathing.

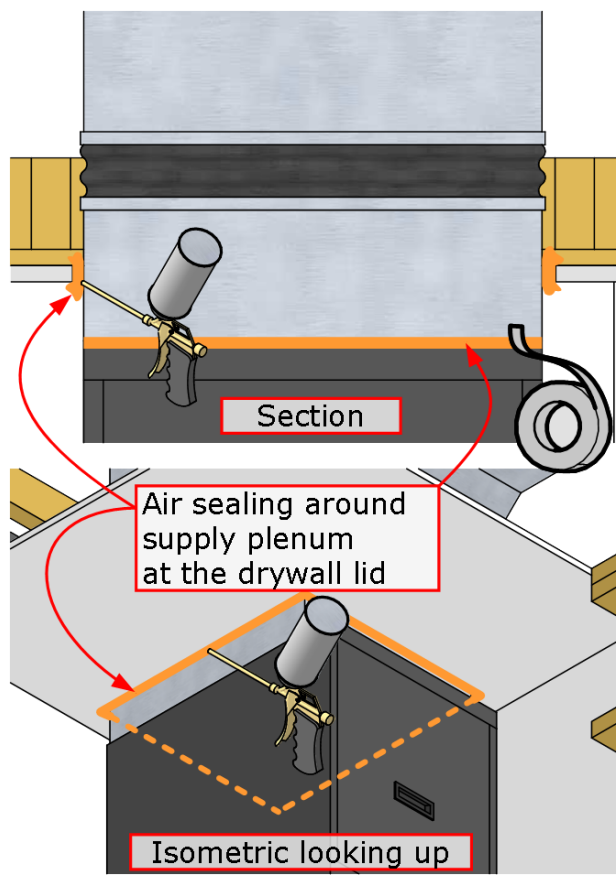


Figure 9b. Interior view showing sealing at the supply plenum.

5 Verification Testing

Diagnostic pressure testing of the house with a blower door, and diagnostic pressure testing of the ductwork will help to determine if the air sealing efforts have been effective or if further sealing is needed. These tests can help to identify the amount and location of air leakage, making it easier to complete the sealing process. If the air sealing of the mechanical closet and central return system is effective, a standard depressurization test with a blower door will not yield any air movement coming down through the chase way. The use of a smoke pencil or puffer is an effective tool to visualize and identify any air leaks for sealing. A duct leakage pressurization or depressurization test will also indicate the overall tightness of the space conditioning system, as well as whether the new return plenum box is airtight.

Definition: Blower Door
- A calibrated fan that is used to measure the airtightness level of building envelopes and to diagnose and demonstrate air leakage problems. (Source: The Energy Conservatory)

Smoke pencil - A non-toxic smoke generator used to detect drafts and air leaks in a home.

6 Selection Criteria for Maximum Energy Efficiency

6.1 Performance

- Increasing the air tightness of the mechanical closet and return air plenum will result in improved occupant comfort of the living space.
- HVAC system load reduction will be achieved by eliminating the addition of warm moist attic air into the system.
- HVAC system efficiency will be increased by ensuring and maintaining the designed amount of return air to the system.
- Noise reduction through the use of fibrous insulated ductwork for the return air plenum box.

6.2 System Interactions

- Improved air tightness of the thermal envelope.
- HVAC system load reduction, which in turn will reduce energy costs.
- Improved dehumidification of the interior air that will lead to better comfort for the homeowner.

6.3 Cost Effectiveness

Sealing the mechanical closet so that it does not have the ability to draw unintentional air from the attic or building cavities is one of the easiest and cost-effective solutions to improve the performance of the space conditioning system and provide better comfort to the living spaces of the home. In either scenario, the cost to make the sealing improvements would be minimal on both the labor involved and materials needed.

Estimated costs for the work effort and associated materials to conduct the first total replacement scenario for a standard 4' by 4' closet with an 8' ceiling height would be in the neighborhood of \$1,200.00 and would include costs for the demolition of the existing support shelf, hanging and taping of the gypsum wallboard, new fibrous ductboard return plenum and incidental caulking and foam. The second scenario, where existing equipment is to remain and the comprehensive air sealing of the closet will take place, will have an estimated cost of \$500.00 to install any necessary blocking and gypsum wallboard and to perform a thorough air seal with expanding foam and caulking.

In addition to the costs of the construction activities, there could be additional costs to conduct air leakage testing and mechanical system safety inspections. These costs vary on the complexity of the home but should generally fall into the \$300.00 range for testing and \$100.00 for the safety inspection.

Note: Costing is intended to provide a reference for the air sealing retrofit activities and are rough estimates. Costs will vary depending upon house type, complexity, location, and trade base.

6.4 Codes and Standards

The 2009 International Energy Conservation Code (IECC) and the 2009 International Residential Code (IRC) have several new mandatory requirements for air sealing in new construction and additions. These codes apply to new construction where adopted by local jurisdictions. In general, these requirements do not apply to retrofit projects unless the project adds living space to the building or changes the building's energy load. The existing, unaltered portions of the structure are not required to comply with all of the requirements of the 2009 IECC or IRC. However, Building America recommends implementing these requirements in existing portions of your home wherever they are applicable and your budget allows or health and safety concerns make them necessary.

The requirements regarding new buildings can be summarized in this section excerpted from IECC, Chapter 4, Section 402.4, Air Leakage (mandatory). Builders can see IECC 2009, Chapter 4 "Residential," and IRC 2009, Chapter 11 "Energy Efficiency," for more details.

7 Efficiency, Homeowner Awareness and Education

Informing and educating the homeowners to the importance of the purpose of the mechanical closet and all components is critical for long-term functionality of the space. It is best to instruct the homeowners that the mechanical closet is specifically to house the heating and cooling equipment for the home and that it is not an additional storage closet. In particular, chemicals and volatile organic compounds (such as found in paints, finishes, and cleaning supplies) should be stored away from the space conditioning equipment and ductwork.

The location of the air handler within the closet makes service and routine maintenance such as filter changes easily accomplished.

8 Conclusion

This air sealing measure guide represents one of the easier and cost-effective retrofit actions that a homeowner can either contract out to a retrofit contractor or implement themselves. Either way, air sealing and isolating the mechanical closet from the attic space and return air plenum will save energy, increase homeowner comfort, and minimize any building durability issues.

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