Tech Note:

Ducting for Central-Ducted ASHPs or GSHPs

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Table of Contents

1.0 Purpose

This Tech Note is intended to help homeowners and coaches work with installers to re-use or adapt existing air ducting for heat distribution by heat pumps. It applies to homes that already have ducting for heat distribution from fossil-fuel heating systems and/or cooling via central air conditioning. This ducting is often suitable for re-use with a central ducted air-source heat pump (ASHP) or ground-source heat pump (GSHP). It is seldom cost-effective to add ducting throughout a home that does not already have it. However, a transition to using an ASHP or GSHP for heating may require ducting modifications.

Heat-pump installers should assess the sizing, air tightness, cleanliness, and insulation of existing ducting and propose itemized solutions for any needed mitigations. Each of these concerns is discussed a separate subsection.

Additional topics that are covered are listed in the Table of Contents.

1.1 References

The following references are cited multiple times in this note with the abbreviations R1, etc. Links to other references are just included in the text.

R1: *HVAC Duct Design: Manual D, Fittings, Friction Rate, Pressure Loss, & Static Pressure*, a 40-min. video. The first few minutes are most relevant to this Tech Note, the rest delves into details of duct design.

R2: *The Honest Book of Home Energy $avings*, a book published in pdf format by HEET.org that covers energy-saving home improvements specifically for New England homes, and includes a 7-page section on Duct Testing and Sealing and other useful energy saving techniques.

R3: *5 Factors for Ventilation: How to Plan a Healthy Home*, a 13-min. video.

2.0 Re-Using Existing Ducting

2.1 Sizing

Duct sizing, or cross-sectional area, is likely to be a concern when transitioning to a heat pump because heat pumps deliver air at cooler temperatures than fossil-fuel furnaces. Typical problems caused by improperly sized ducts are described in https://www.aztilac.com/why-the-hvac-duct-sizing-rule-of-thumb-matters:

> *If your ducts are too small, it can cause an increase in the static pressure. Not only will the system be noisier, but your air conditioner will also need to work extra hard to reach the desired temperature. As a result, your unit will run longer which can significantly increase your energy expenditure …, you'll also experience a noticeable decrease in airflow….and run into problems maintaining your equipment and a comfortable temperature. The lack of airflow will also harm your HVAC unit and significantly decrease its lifespan.*

A recent blog by a NYC-based HVAC company titled *Ductwork Sizing & Other Mistakes That Hinder Your HVAC Comfort* emphasizes the importance of proper duct sizing. It makes some key points about duct sizing:

- *Ductwork sizing that's too small is one of the most common HVAC installation mistakes*
- *The right ductwork sizing for your space can't be determined without a detailed load calculation. An HVAC professional will calculate the requirements for each zone or room to ensure consistent comfort, using a tool called ACCA Manual D*
- *The type of HVAC system you have also affects the ductwork sizing required. For example, heat pump systems and air purifiers require more air flow and often need larger ducts*

Ducts originally designed for heating-only use may be too small for a central ducted ASHP or GSHP, while those originally designed for both heating and cooling (even if A/C was never installed) are more likely to be adequate. Custom homes built around the 1970's are more likely to have larger ducts than those in developments. Only a few ASHPs (*e.g.* Bosch BOVA/B™) are compatible with small-diameter, high-velocity (*e.g.* UNICO™) duct systems, but high-velocity systems may decrease efficiency and increase noise compared to larger ducts. In some cases, return ducts are undersized, insufficient in number, or poorly located while supply ducts are adequate.

According to a 2005 discussion on HVAC-Talk, titled *Can ducts be too big?*, very large ducts in older homes are probably usable. HVAC professionals who responded said:

- *Larger ducts reduce the velocity of the air.*
- *Ducts should be sized as needed for proper volume and velocity for the system installed.*
- *Manual D provides an 'optimal' solution which minimizes the duct sizes. A smaller diameter distribution system is slightly less expensive and sometimes significantly easier to install. But there's no reason to downsize an already-installed duct system just because it's larger than optimal!*
- *Oversized ducts, too low of a static, can usually be fixed by adding dampers, to increase the static and redirect the airflow, as needed.*

Reference R1 goes into detail on duct design using Manual D; it also mentions that oversized ducts usually do not cause problems.

When duct systems are re-used, the balancing of air flow among rooms does not usually need to be completely re-done, but small adjustments may be needed, depending on the ducting modifications needed to connect to the new heat pump.

2.2 Cleaning

With ducted systems growing in popularity, cleaning services are increasing available. For example, one provider that advertises on TV lately is Stanley Steemer™. But duct cleaning may not be necessary in most cases and in fact, may be detrimental, as explained in a2019 Washington Post story *Considering having your air ducts cleaned? Think again*:

> *...even if you have no special health concerns, cleaning your ducts may appeal to you at an intuitive level. After all, if your ducts are clean, all that air flowing out of your vents should come out clean, too, right? Well, actually, no. Although duct-cleaning operations may insist that duct cleaning is essential for your health, the evidence does not support their claims.*

The article cites an EPA report on duct cleaning, last updated on February 27, 2023.

The EPA report goes into considerable detail, including sections that suggest a path forward even when there is no single right answer yet. We recommend reading this report if you are considering duct cleaning.

2.3 Testing and Sealing

Leaky ductwork can result in significant energy loss and indoor air-quality problems. The air tightness of ducts is sufficiently important that duct leak testing is required for new construction by Massachusetts building code.

A blog titled *How to Check Your Ductwork for Leaks: 5 Simple Methods to Try* by installer PickHvac suggests

1. Look for obvious leaks, tears, or separations in the ductwork
2. Turn on your HVAC system to full power or strength
3. Check all the joints or elbows
4. Look for older duct tape on the ducts
5. Use a smoke pencil.

Reference R2 includes a 7-page section on Duct Testing and Sealing, and makes these key points:

- *This is a practical how-to guide that ranges from the do-it-yourself work to more advanced tasks that you might need a contractor to do. Most of these tasks cost less than $50 to do and have a 100% return on investment in a few months*

- *The air in your home cycles from your furnace through the supply ducts to your living space and then back through the return ducts in a giant circle. If there are gaps in those ducts, this circle doesn't work as well as it could, allowing heat to escape, and possibly pulling dusty or moldy basement air—or even carbon monoxide—into your living space. Closing up the gaps increases the efficiency of the mechanical system by up to 15%, and potentially improves the air quality of your home.*

Leaky return ducts in the attic can pull hot, humid summertime air, dust, and mold spores into the system, and leaky supply ducts can leak moist heated air into the attic, causing mold on the roof sheathing in the winter. There are several options for sealing exposed rigid ducts in a basement or attic. It is straightforward to seal them from the outside using 3M™ or equivalent metallic tape (NOT duct tape) or duct sealing mastic. This work can be DIY, if you are so inclined, or done by a contractor. After sealing, you can add insulation on the outside.

Services are available, some with cameras, to help find major duct leaks, including those that are inaccessible, *e.g.* behind finished walls. One testing method is called Duct Blaster™. It measures the amount of duct leakage inside and outside a home's thermal enclosure. With all vents temporarily blocked, the Duct Blaster is adjusted to pressurize the ducts to a standard test pressure (often 25 Pascals), then the amount of air passing through the Duct Blaster is the amount of duct air leakage. An installer who measures duct leakage with a Duct Blaster is performing a diagnostic test that can provide important information which can yield substantial benefits in terms of lowering operating cost, increasing comfort and improving indoor air quality, by identifying important duct system defects so they can be properly addressed. However, the Alliance is not aware of any installers who routinely use Duct Blaster before installation. One installer, one of the largest in Massachusetts, outsources duct blasting to a specialist when needed.

Some installers offer AeroSeal™, which seals from the inside and fixes leaks up to ½" diameter, even where the ducts are not readily accessible, e.g. in walls. Be sure to select a qualified AeroSeal contractor. We are aware of a case where the sealant was not properly applied, and damaged dampers in the ducting and the HVAC equipment. Be sure that the AeroSeal contractor and HVAC installer coordinate with each other to help avoid such issues.

2.4 Insulation

Poorly insulated ductwork can result in significant energy loss. From reference R2:

> *If your ducts and furnace are up in your unfinished attic, this work is even more critical to do because any escaping heat will rise out of your home without keeping you warm at all. Also, in this case you want to insulate the ducts as well as seal them, to make sure the air in them stays warm even if the attic is freezing.*

Reference R1, early in the video, notes that Rule #1 is to include all ducts within the conditioned space, especially attics where it gets very hot. Older prefabricated ducting (typically covered by black plastic sheeting) may have inadequate insulation with an R-value of only R-4, while best practice is a minimum of R-8 (usually covered by shiny silver Mylar) with a tight vapor barrier inside.

2.5 Decommissioning Unsuitable Ducts

The HVAC installer should determine the suitability of existing ducting for use with a heat pump. If part or all of the ducting is unsuitable for the new heat-pump system, even with mitigation, explore whether some of the ducting can be used for ventilation, dehumidification, make-up air, etc. as suggested in R3.

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If it is decided that the ducts will serve no useful purpose, *e.g.* if being replaced by ductless mini-/multi-splits, it is good practice to minimize heat loss from the old ducts. This can be done by removing vent grilles and inserting insulation, then adding blocking panels well-sealed against the duct's inner surface. Vapor barriers should always be inside, to prevent condensation. Grilles can then be re-installed or replaced with blank cover panels. If it is necessary to recover space currently occupied by ducts, carpentry and plastering will be needed, a much more intrusive and expensive option. It is vitally important to block the bottom and top of any unused vertical ducts with building-codeapproved fire-resistant materials to prevent them from becoming a chimney in the event of a fire.

3.0 Additional Related Topics

3.1 Homes With Multiple Furnaces or Air Handlers

In New England, we encounter homes, especially larger ones, that have more than one furnace or air handler, but are still considered central ducted. Usually, there is one in the basement or first floor equipment room and a second in an attic, each including one or more zones. Some larger homes have more than two furnaces or air handlers.

Many single-level homes have only one HVAC system in the attic or basement. In some single-floor cases like ranch-style homes built on slabs, the unit that conditions the first floor is in the attic.

Locating a furnace or air handler in an attic leads to potential problems with heat loss from both ducting and HVAC equipment as noted in reference R1. Locating HVAC equipment and ducts in attics sometimes restricts maintenance access, especially if the attic entry is not walk-up, but via a trap door or pull-down stairway and sealing has been improved by adding an insulated access cover. Restricted attic access can lead to neglected service which, in turn, degrades performance and may lead to early failures.

3.2 Cold vs. Hot Roofs

Insulation and sealing of ductwork and air handlers in attics is particularly important in conventional cold-roof (*aka* vented) attics (having soffit vents, drip edge, gable vents, and/or ridge vents) where temperature differences can be great, and where moisture might condense on or in the ducts or equipment while cooling. Most of the homes that HeatSmart Alliance volunteer coaches encounter have cold-roof attics.

An alternative, increasingly used in new construction, is to implement a “hot roof”, where there is no attic venting, and insulation is added above or directly under and in contact with the roof deck. See, for example, https://akhouseproject.com/cold-roofs-vs-warm-roofs/. This approach encloses any attic ducts and equipment in conditioned space and has many times the R-value of the duct insulation. However, if the vapor barrier is not done correctly, problems like sheathing rot can occur, as summarized in https://www.trivalueconsultants.com/post/hot-roofs-the-benefits-pitfalls-and-mistakes

These references compare hot (unvented) vs. cold (vented) roofs, however they don’t fully concur, even on definitions. Our main point is that cold roofs may increase heat loss from attic ducts and air handlers, while hot roofs prevent that by locating ducts and associated HVAC equipment within the conditioned space.

Hot Roof Vs. Cold Roof: Which One Is Better? provides a good discussion on this topic.

Some homes have a combination of hot and cold roofs. For example, an addition or a partial cathedral ceiling may combine the two. In other cases, an insulated and sealed structure is added above and around the attic air handler, creating a small, conditioned space within the otherwise-unconditioned attic. This approach may mitigate some of the drawbacks of a purely hot or cold roof.

3.3 Adding Vertical Ductwork to Simplify GSHP Equipment

Homes with a separate air handler for the second floor usually have that air handler in the attic, with insulated horizontal ducts and ceiling registers (vents) for the 2nd floor rooms. Another air handler is typically in the basement, with ducts, and floor or wall vents, serving the first floor and possibly the basement. Each air handler has separate outdoor units (if ASHPs). For GSHP's, the attic air handler is typically connected to a unit (compressor and water-to-refrigerant heat exchanger) installed in the basement, a split system. The first floor is typically conditioned by a self-contained (packaged or non-split) GSHP also installed in the basement.

In a Hydro-Air system, each air handler has a hydronic coil heated by a single central boiler that serves the whole home. Some heat-pump installers replace these with air handlers having refrigerant-to-air heat exchangers. If fossil fuel is being retained as a backup, the replacement air handlers are usually also fitted with hydro-air coils. Ceiling registers on the second floor are not ideal for heating, while floor registers on the first floor are not ideal for cooling, yet many larger New England homes use this arrangement. Often, there are no supply or return ducts between floors, so installers of central GSHPs tend to propose separate replacement systems for each floor. But, according to several GSHP installers, if the heat load per floor is 3 tons or less (th minimum for most GSHPs), adding vertical ductwork between floors to eliminate the attic air handler and using a single, larger-capacity GSHP can be more cost-effective and energy-efficient solution. Adding zone control using duct dampers is a straightforward option. Dampers should be located where they can be checked and serviced.

For ASHPs, indoor units are less expensive and available in smaller capacities, thus adding vertical ductwork is less common. The following table compares the relative merits of adding vertical ducts to eliminate HVAC equipment in an attic.

Benefits and Drawbacks of Adding Vertical Ducts in Two-Story Homes

Benefits	Drawbacks
• Reduced equipment and annual maintenance cost • Only one compressor and set of controls allows convenient whole-house remote monitoring and control • Better match to small heat loads, better efficiency • Eliminates concerns about neglecting to service the attic unit (such as air filter changes) • Avoids need for a split GSHP system, which would increase chance of refrigerant leaks (all ASHPs are inherently split systems)	• Zone dampers are needed when a 2nd zone is added and may be hard to access for adjustments. • Requires a roughly 2' x 4' vertical chase between floors. This may be in the back of an existing closet or by adding an insulated duct outdoors • Reduces some beneficial redundancy • Requires a larger-capacity heat pump to serve both floors

3.4 Vaulted Ceilings

Many larger homes have vaulted ceilings of two stories or more in height. Ceiling fans, especially with very high ceilings, may help avoid stratification and use little power to run slowly, particularly if high efficiency (CFM/watt) ceiling fans are specified. Ceiling fans can be considered part of the HVAC system, unless located outside over a deck or patio.

3.5 Air Filters

Filters are usually at least MERV-11, much bigger than those available in stores for forced-air heating systems and typically require changing every 2 or 3 months, or even less frequently if there are no pets in the home. The pressure drop across a filter is an important ducting design parameter, so a compatible replacement filter should be used. MERV 13 to 15 is preferred to minimize micro particles. Note that the air-handler static pressure, ducting system, and air filter back-pressure all must be accounted for in duct system design.

There are usually quantity discounts and sales that can reduce your costs for replacement filters. Some systems, *e.g.* Bryant Evolution Extreme ASHPs, prolong filter life by measuring pressure differences to present a "change the filter" reminder rather than simply measuring time. Reference R3 recommends filtering via pleated fabric as the best method to increase interior air quality.

3.6 Pros and Cons of Ducted vs. Ductless Systems

The preceding sections have focused on disadvantages (and mitigations) of ducting issues. However, ducted systems can have advantages over ductless mini- or multi-splits. Accessories like air filters/purifiers can be added and maintained in one place. Short-run "compact" ducted systems may also avoid issues with multi-splits causing overheating or cooling in smaller rooms. Aesthetics are better, both inside and out, especially for GSHPs, where there is nothing like an ASHP outdoor unit visible outside. If a MERV 13-15 filter is used, there is also a benefit of fresher air. Because air circulates among multiple rooms, particulates in the air can be removed by the filter.

A potential drawback of ductless ASHPs with an indoor unit serving just one room is vulnerability to lack of ventilation if the room's door is tightly closed, blocking air from the remainder of the house or zone that would be circulated in a ducted system. This is especially a concern for bedrooms, where harmful levels of CO_2 can accumulate overnight. Possible mitigations include leaving the door partly open, cutting the bottom of the door to increase the opening area, installing louvered panels in the door or walls, installing transfer fans (room-to-room), or house plants. Photosynthesis naturally replaces some CO_2 with oxygen as well as absorbing other pollutants like formaldehyde, as discussed in a 1989 NASA study for enclosed space, where you can't open windows. Some indoor plants are now being marketed based on their ability to purify air. See, for example, the video *Unbelievable Air Purifier: "These 2023 Bedroom Plants Release Oxygen!*. R3 also covers key aspects of ventilation.

HVAC Reality Check: Are Duct Systems Dumb or Essential?, an 11-min. video, covers the above-mentioned points and other advantages of ducted vs. ductless systems. This video and R3 also cover tight construction where ducts are used not only to distribute conditioned air (e.g. 600 CFM in the 3000 Ft2 example), but also for humidity control (350 CFM), ERV or HRV (150 CFM) make-up air (400 CFM), and sometimes radon. These systems should all be designed together in order to minimize redundant duct work.

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