DUCT RETROFIT DECISION GUIDE

Who: Heat pump installers | **Why:** Heat pumps may require more airflow than the existing system. Learn how to evaluate a duct system to ensure the heat pump will operate as intended.

A COMPREHENSIVE GUIDE DESIGNED TO ASSIST CONTRACTORS IN EVALUATING AND TESTING THE LONGEVITY AND COMPATIBILITY OF A DUCT SYSTEM WITH A HEAT PUMP SETUP

Poor ductwork is common in existing homes. This document details and guides the heat pump installer on how to make decisions on adjusting, reusing, or abandoning the existing ductwork. Leaky, outdated, or improper ducts lead to various problems, impacting efficiency, cost, comfort, and air quality. Heat pumps may require more airflow than the existing system to operate efficiently. To ensure optimal performance and customer satisfaction, evaluating, sizing, and testing ducts before installing a new system is crucial. The lifespan of ductwork varies (15-30 years), so it is important to evaluate and test if planning to reuse ductwork for a new HVAC system. This thorough approach guarantees proper function and customer comfort.

DECISION GUIDE

Acceptable for Use

- ✓ The ducts pass a visual evaluation
- ✓ The total external static pressure (TESP) is within the manufacturer's acceptable range
- ✓ Duct sizing meets the airflow requirements of the heat pump
- ✓ The duct system is reasonably balanced
- ✓ No leaks or compressions exist
- ✓ Return ducts are designed for heating AND cooling
- ✓ Ducts are insulated or in a conditioned space

Modify Existing Ducts

- ✓ Duct sizing can be adjusted to meet airflow requirements
- ✓ Ducts or grilles can be adjusted to balance the system
- ✓ Duct branches have compressions or leaks
- ✓ A return duct is needed for addition of heating or cooling
- ✓ Duct insulation has gaps or tears
- ✓ Registers blow air directly onto occupants.

Replace or Abandon if

- ✓ Ducts are in poor condition or deteriorating
- ✓ Duct size will not meet airflow requirements
- ✓ Ducts are uninsulated and in an unconditioned space

INTERVIEW THE HOMEOWNER

The homeowner may have knowledge or complaints that will lead to easy diagnoses and fixes of the duct system. Problems they are noticing with the existing system will likely carryover to the heat pump if left unaddressed. Ask about the age of the system, comfort from room to room, noise from ducts or registers, registers that blow too much or too little, filter clean/replace habits, maintenance habits, and any recent work or assessments.

EVALUATE THE DUCTS

Conducting a brief evaluation can detect early symptoms of a struggling or aging duct system requiring replacement, considering various performance-affecting factors. Collect lengths and sizes of duct plenums and branches while evaluating. Before completing any work, ask the homeowner if they are aware of the presence of any asbestos and conduct a check of insulation, duct, tape, and other possible asbestos containing materials.

1. Turn the HVAC system on and turn the fan settings to high.
2. Verify air is flowing from all registers. If no air can be sensed, the duct may be crushed, blocked, or disconnected.
3. Check the accessible ducts for visible gaps or tears in insulation.
   - Gaps in insulation allow for heat transfer to the unconditioned space around the duct.
   - Gaps may signify a larger issue as insulation may be blown off by air leaks in the ducting.
4. Trace each branch checking for compressed ducts and sharp bends or kinks.
   - Duct compressions of just 15% can increase pressure loss by 400-800% which greatly restricts airflow.
5. Check all joints and connections for air leakage. Use a smoke pencil to easily identify small leaks.
6. Duct leaks lead to imbalances, energy loss, and poor air quality; ENERGY STAR notes homes can lose 20-30% of conditioned air to leaks. Listen to each supply and return grille for noise or vibration.
7. Noise and vibration from ductwork could indicate interior deterioration, incorrect sizing, or inadequate securing, often caused by undersized ducts leading to loud or vibrating operation.
8. Check if the filters are excessively dirty and when they were last replaced.
9. If the ducts are found to be in acceptable condition, seal air leaks, fix minor bends, secure ducts, and clean the filters as necessary.

TEST THE DUCTWORK | STATIC PRESSURE

Ducted HVAC units depend on duct airflow for proper air distribution, with total external static pressure (TESP) as a key health indicator; employ a manometer to measure static pressure and test TESP, and filter pressure drop.

1. Plug your pressure probes into the digital manometer and turn it on
   - Attach your pressure hoses to each input point and then attach the static pressure probes to each hose.
   - If the manometer has a magnet on the back, place it on the furnace for easy access.
2. Insert probes
   - Insert the **channel A** probe into the air handler before the fan. Point the very end of your probe downward toward the airflow of the fan.
     - » Consult the user manual to locate measurement areas.
   - Put the **channel B** probe into the air handler after the fan. Point the end of the probe downward toward the airflow of the air handler.
     - » If there is not a hole after the fan, use a drill and a stepped-up drill bit to make a small hole near the coil. This will be situated in the middle section near the filter.
     - » Do not drill near or on top of the heat exchanger, or you could damage it.
3. Measure TESP
   - Add the numbers on the manometer display to get a reading for the TESP in inches of water column.
   - If one of the numbers is negative, treat it like a positive when you add your numbers together.
   - Check the manufacturer recommended TESP for the model installed. Compare the measured value to this value.
   - High TESP has various causes. The most common cause is a dirty or incorrectly situated filter. Measure the filter pressure to help diagnose.
4. Measure filter pressure
   - Insert the probes around the filter to test the area for pressure.
   - Place channel A probe above the filter and channel B probe below the filter in the test port that is already there. Check the channel B probe on the manometer to see what it is reading.
   - Change the filter if the filter pressure is higher than 0.1 inches (0.25 cm), and then test it again to see if your TESP went down.

VERIFY DUCT SIZING

Proper duct sizing and design involve understanding dimensions, lengths, and materials. While challenging in the field, conducting an ACCA Manual D is crucial during new installations or when integrating a new air handler to guarantee accurate sizing and design. Checking duct capacity and balancing can assist in identifying necessary modifications, yet they don't substitute for Manual D or testing in confirming precise duct replacement requirements.

CHECK THE DUCT CAPACITY

For a swift evaluation of the ducts system's adequacy for the new air handler, consult the National Comfort Institute's sizing tables, which provide estimated duct capacities. If inadequacies arise, consider upsizing or adding extra branches or plenums, though these values serve as an initial check and not a definitive sizing solution.

When sizing for a heat pump, the ducts should be sized to the larger of the heating and cooling loads, also called the design load.

1. **How much air is the duct system supposed to handle?**
   - Check the heat pump manufacturer specifications and use the listed value, usually 350-400 CFM per ton is minimum for a heat pump.
   - A heat pump may require more airflow than the existing system. Ducts that are too small may result in inefficiencies, poor comfort, or noise.

2. **Are the supply trunks able to handle the airflow?**
   - List the sizes of all supply plenums coming from the air handler.
   - Use the airflow table to sum the capacity of all supply plenums.
   - Confirm this number is larger than the required airflow found in step 1.

3. **Are the supply branches able to handle the airflow?**
   - Repeat step 2 for the supply branches coming from the supply plenum.
   - Confirm the supply branch capacity is larger than the required airflow found in step 1.

4. **Are the return ducts able to handle the airflow?**
   - Repeat step 2 for the return ducts.
   - Confirm the return duct capacity is larger than the required airflow found in step 1.

5. **Does the duct system behave as expected?**
   - Confirm the calculations by turning the system on high and testing the CFM at each register.
   - If the airflow at any register is lower than expected when compared to the table or other similar ducts, the duct may be too small, compressed, misshapen, or deteriorating.
   - Higher airflow than expected may result in discomfort from noisy airflow or the feel of air blowing harshly into populated areas.

VERIFY THE DUCT BALANCING

Duct balancing ensures even heating and cooling distribution throughout the home avoiding discomfort, energy waste, and temperature imbalances. A properly balanced system will provide the correct ratio of heating or cooling to each room. While minor adjustments can be made with dampers, installing a new heat pump allows comprehensive system balancing. To balance the system, a Manual J should be completed and the zonal loads should be known.

The simplest way to check the balance of a duct system is to measure the airflow exiting the registers.

1. With the existing system fan on high, use an anemometer or balancing hood to measure the airflow in CFM at each register.
2. Sum all registers in a single room to get the total airflow into the room.
3. Then, divide the room's airflow by its design load to get the room's balancing ratio (CFM/BTU).
4. Calculate the balancing ratio for all rooms conditioned by the duct system and compare.
5. If any room's balancing ratio is much less than the average, the area likely needs larger or additional ducts.
6. If any room's balancing ratio is much greater than the average, the area likely needs a smaller duct.

Perform Manual D calculations to size ducts for proper airflow matching room heating/cooling loads, verify changes, and balance the system for consistent home-wide heating and cooling from the heat pump.

IMPACTS OF IMPROPER DUCT SIZING

1. Substantially undersized ducts can lead to noise issues where the static pressure is so high that rectangular portions of the duct run may pop out, creating a larger bang sound when operating (known in the industry as "oil canning"), then settle back in when the system stops. This is particularly common with return ducts.
2. Ducts that are long, contain excessive bends, or have high friction materials present excessive friction (exceeding max friction rate of 0.1 Wg/100ft). Excessive friction causes high friction loss which limits airflow. This may be due to a change since the original install or due to bad design from the beginning.
3. Pushing high CFM through small duct runs may result in too high an average max velocity (typically 1500 FPM) leading to noise and a clear sense of "moving air" that feels cold to the skin.
4. Duct compressions appearing minor to the eye can severely restrict airflow through the duct. Duct compressions of just 15% can increase pressure loss by 400-800% which greatly restricts airflow. The added pressure drop can result in discomfort and increased energy usage by the blower. Duct compressions have greater effect on smaller sized ducts.

NCI STANDARDIZED DUCT SIZING

Airflow values are expected averages and should only be used as a reference. Ducts exceeding 25’ in length or with excessive transitions will have less capacity than shown. Always test and balance the duct system to verify sizing in the field.

Flexible Duct

Duct Size	CFM
5″	50
6″	75
7″	110
8″	160
9″	225
10″	300
12″	480
14″	700
16″	1000
18″	1300
20″	1700

Round Metal Pipe

Duct Size	CFM
5″	60
6″	85
7″	125
8″	180
9″	240
10″	325
12″	525
14″	750
16″	1200
18″	1500
20″	2000

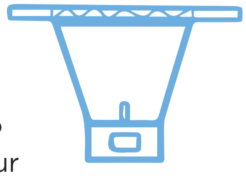
Rectangular Duct

CFM	4″	CFM	6″	CFM	8″	CFM	10″	CFM	12″
60	**6x4**	60	**4x6**	90	**4x8**	120	**4x10**	150	**4x12**
90	**8x4**	110	**6x6**	160	**6x8**	215	**6x10**	270	**6x12**
120	**10x4**	160	**8x6**	230	**8x8**	310	**8x10**	400	**8x12**
150	**12x4**	215	**10x6**	310	**10x8**	430	**10x10**	550	**10x12**
180	**14x4**	270	**12x6**	400	**12x8**	550	**12x10**	680	**12x12**
210	**16x4**	320	**14x6**	490	**14x8**	670	**14x10**	800	**14x12**
240	**18x4**	375	**16x6**	580	**16x8**	800	**16x10**	950	**16x12**
270	**20x4**	430	**18x6**	670	**18x8**	930	**18x10**	1100	**18x12**
300	**22x4**	490	**20x6**	750	**20x8**	1060	**20x10**	1250	**20x12**
330	**24x4**	540	**22x6**	840	**22x8**	1200	**22x10**	1400	**22x12**
-		600	**24x6**	930	**24x8**	1320	**24x10**	1600	**24x12**
		650	**26x6**	1020	**26x8**	1430	**26x10**	1750	**26x12**
		710	**28x6**	1100	**28x8**	1550	**28x10**	1950	**28x12**
		775	**30x6**	1200	**30x8**	1670	**30x10**	2150	**30x12**
40	**21/2 x10**	-		1300	**32x8**	1800	**32x10**	2300	**32x12**
70	**21/2 x14**			1400	**34x8**	1930	**34x10**	2450	**34x12**
150	**21/2 x30**			1500	**36x8**	2060	**36x10**	2600	**36x12**
-		100	**31/2 x14**	-		2200	**38x10**	2750	**38x12**
		220	**31/2 x30**			2350	**40x10**	2900	**40x12**
						-		3050	**42x12**

TEST THE DUCTWORK | AIR FLOW

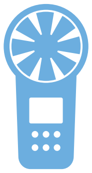
To assess system functionality and duct condition, measure duct airflow against manufacturer's rating using tools like a balancing hood or an anemometer.

Use a balancing hood:



1. Buy or rent a balancing hood
    - Set the balancing hood to read in exhaust mode. Your air balance hood will likely have several different modes that it can be set to. Follow the manufacturer's instructions to make sure your hood is set to exhaust mode to ensure an accurate air flow measurement.
    - Some manufacturers may recommend that you set the hood to a different mode, based on the context in which air flow is being measured. Be sure to follow their recommendations for how to best use their equipment.
2. Place the balancing hood firmly over the grille
    - Apply a steady amount of pressure to seal the hood over the grille. Allowing air to escape from the top of the hood will decrease the accuracy of your measurement.
3. Read the screen on the bottom of the hood to get your measurements
    - The reading on the screen will give you an air flow reading in cubic feet per minute (CFM).
    - If your balancing hood does not measure in CFM, convert the units to CFM.
4. Be aware that your readings may fluctuate over time
    - Air volume is not constant as it moves through a grille. Instead, it changes constantly along with surrounding environmental conditions.
    - To counter this, take several measurements and average them out for a single usable reading.

Use an anemometer:



1. Purchase an anemometer
    - Select one that has cubic feet per minute (CFM). If the anemometer only has feet per minute (FPM), then convert to CFM.
    - To convert FPM to CFM:
      $CFM = FPM \times \pi r^2$
      $\pi = 3.14$ // r = radius of duct
2. Set up the anemometer
    - Power on the anemometer and select CFM as the unit or FPM if there is no CFM setting.
3. Hold the vane wheel next to the duct or fan to be measured
    - Align the vane wheel with the direction of air flow for more accurate readings.
    - Move the anemometer around to determine airflow at different portions of the duct or fan.
    - Always keep the axis of the vane wheel within 20 degrees of the direction of airflow to ensure accurate readings.
4. Pause the anemometer on a particular reading
    - The readings on your anemometer will constantly fluctuate as air flows past the vane wheel reader. Most anemometers will have a "hold" button that allows you to freeze the meter on one specific airflow reading and record it.
    - Some anemometers will also allow you to digitally save and record your reading to the device.
5. Measure at different points across the duct
    - Record the measured CFM coming from the duct.
    - Some anemometers will have a "high/low" button that displays the highest and lowest amount of airflow measured in the duct.
    - The anemometer can only tell you the lowest airflow reading that it measures, not the lowest that your duct or fan has ever produced.

TEST THE DUCTWORK | DUCT LEAKAGE

Conditioned air must travel through ductwork to provide heating or cooling to the living areas. Duct leaks waste energy by letting conditioned air escape through loose connections, gaps, damaged duct sections, and disconnected duct runs. Leaks rob households of indoor comfort and force HVAC systems to expend more energy to maintain ideal indoor environments.

On average, **25% of air is lost through leaks**. In other words, one fourth of the air conditioning and heating is not being delivered to the home's living areas. Duct leaks cost average homes 20 to 30 percent of their heating and cooling energy.

A duct leak test, uses specialized equipment to measure airflow and identify leaks. Seal visible major leaks detected through visual inspection and smoke pencil checks before conducting the test.

Using Test Equipment

1. Using a duct leakage tester and blower door together (most common)

- Confirm that all open-flame areas have been extinguished for at least 24-hrs and ash is covered with a damp towel or newspaper.
- Setup blower door per manufacturer's instruction.
- Turn off all gas appliances including the furnace.
- Close and lock all windows. Close all exterior doors. Close all interior doors to rooms that do not have vents and registers.
- Take an outdoor pressure reading.
- Turn on blower door fan and run test. The manometer will calculate the amount of leakage.
- Check for leaks using a smoke pencil along ductwork outside of the conditioned space, i.e., crawlspace or attic.
- Check for leaks using a smoke pencil along ductwork inside of the conditioned space.

2. Using a flow hood

- Turn on the buildings air handler.
- Place the flow hood over each vent and register and record the pressure reading at each.
- Depending on the type of flow hood, the pressure may have to be converted to CFM. Use the manufacturers provided conversion table to convert correctly.

3. Using a blower door and pressure pan

- Diagnostic testing only.
- Setup the blower door to depressurize the building to 50 Pa.
- Turn off the air handler.
- With the blower door operating, place the pressure pan over each vent or register.
- Read the pressure pan gauge to determine the pressure difference between the duct system and the building.

Visual Inspection

1. Visually inspect all ductwork you have access to

- Climb into the attic, crawlspace and/or basement and look at the ducts that are visible.
- Look at each section of the duct and all connections for obvious gaps, disconnections, and tears.
- Identify patches on the ducts as potential signs of previous leaks; scrutinize these areas closely since leaks may persist.

2. Turn on HVAC system and inspect accessible ductwork

- Examine duct connections by placing your hand over the metal; if you detect airflow, it indicates loose connection and an air leak.
- Move an incense stick or smoke pencil steadily along the ducts and watch for movement – this shows you air is escaping the duct system.

3. Mark areas of obvious or suspected duct leaks

- Mark them by drawing an arrow on the duct with a grease pencil so you know where the leaking is. Once you finish testing for leaks, return to these problem areas and perform sealing to eliminate the leak.

COST OF DUCT REPLACEMENT

While cleaning and repairing ducts can extend their lifespan, replacement is often necessary. National averages for duct replacement ranges from $1,450 to $8,000. Complex projects can exceed $12,000. The factors affecting cost include:

- Removal of existing system
- Installation of new vents and registers
- Sealing the system
- Insulation addition
- Material used
- Location of the ductwork
- Size of the duct system
- Permits

Location	Cost per 100 Linear Feet
Manufactured home	$1,000-$2,900
Crawl space	$2,200-$6,000
Attic	$1,450-$4,650
Basement	$1,300-$4,500
Wall	$1,000-$4,000

House Size (square feet)	Estimated Length of Ductwork (Feet)	Estimated Cost
1,000-2,500	110-300	$1,155-$6,212
2,000-3,500	220-375	$2,310-$7,750
3,000-4,500	330-500	$3,465-$10,380

RECOMMENDED PRACTICE

★★★ **Professional Grade**

- All minimum and better practice items
- Assess duct leakage with duct-blaster or blower door and pressure pan
- Complete a Manual D and compare to existing ducts

★★ **Better Practice**

- All minimum practice items
- Check total external static pressure (TESP)
- Verify duct balancing
- Measure airflow at registers with flow-hood

★ **Minimum Practice**

- Interview the homeowner
- Visually evaluate the ducts
- Confirm duct capacity meets heat pump needs
- Non-diagnositic commissioning