HVAC System Performance and Duct Leaks

This lesson focused on understanding the problems duct leaks lead to and how those problems affect the homeowner’s energy bills, as well as the causes of duct leaks and how to avoid them. But first, let’s briefly discuss HVAC systems in general.

**HVAC System Overview**
The acronym HVAC stands for Heating Ventilating and Air Conditioning. The diagram below gives a good basic overview of an HVAC system.

The green box is the forced air unit; basically, it has a fan and a burner and it distributes heated or cooled air throughout the duct system. The supply ducts are shown in red, and they distribute the heated or cooled air to each of the rooms of the home. The return air ducts are shown in blue, and they carry the air that is pulled out of the rooms to be recycled back through the system again. Then there is the compressor condenser, which is located outside the house and is part of the air conditioning system.
The Importance of the Duct System
Why is the duct system so important that we need an entire class or lesson on it? Well, one good reason has to do with air conditioning. Now, air conditioning loads represent a big portion of people’s energy bills. The reason for that is duct leaks. In fact, about 28% of a home’s cooling loads are due to leaks through ductwork. That’s pretty substantial, and that’s why we care about duct systems. In weatherization work, our job is to reduce our customers’ energy usage and therefore their energy bills. Finding and correcting duct leaks is a vital part of that job.

Locating the Forced Air Unit
As a weatherization professional, you’ll encounter forced air units (FAUs) in poorly chosen locations. If, for some reason (a decision to remodel or put on an addition, or simply improve the entire heating system) your customer needs to move their furnace, you should understand the difference between a good location and a poor one.

FAUs in attics. For example, below is a picture of a forced air unit and air conditioning system in an attic. Obviously, if we have ductwork in attics, we know there will be some big performance penalties — because attics are basically hot. And of course, this ductwork is insulated, but typically not very well. So we can pick up a lot of heat by locating the forced air unit in the attic.

FAUs in crawlspace. The photo on the next page is an example of a forced air unit in a crawlspace. Again, this isn’t the best location. Crawlspace typically contain moisture and insects, and we don’t want to be drawing contaminants into the house.
FAUs in closets. The sealed combustion furnace in the photograph below is located in a closet. This is oftentimes the case in older homes. And when you do find this, it’s important to make sure the doors are louvered or have a good deal of space at top and bottom like the doors in the photo. That way, there’s plenty of air access for combustion.
Sometimes, we have ductwork in conditioned space. When we look at the next picture, we see a soffit that was built around the perimeter of the room. This soffit contains the ductwork, and this is the best place to put ducts because they’re not in unconditioned spaces. So if they leak, they’re leaking to the conditioned space.

Types of Ductwork
There are three types of ductwork that we use in homes: flex duct, metal or rigid duct, and rigid fiberglass (duct board).

Flex duct. When we look at the different types, flex duct is just what it sounds like: it’s flexible. It basically has a plastic liner that has wire in it to give it spring, and this is covered with insulation and foil covering (as shown in the photo below).
Flex duct bends readily, as you see in the example above, and sometimes that’s not such a good thing. People end up taking a lot of liberties with this type of duct, and it really impacts the overall system if there are a lot of compressions and kinks and so forth.

Metal duct. In the photo below you’ll see an example of metal duct. Obviously, this is not what we want this to look like. It’s basically corrugated metal that you can bend, but essentially it’s crushed here.

Rigid duct. Next is an example of galvanized metal duct, which we call rigid ductwork, and it’s basically made out of galvanized, which is a rust-resistant metal.
Fiberglass duct. Below is a picture of fiberglass or rigid duct board. This is silver duct, and it’s compressed fiberglass that’s formed into a board. It’s not flexible but it can be cut and shaped into rectangular ductwork, like you see here, in conjunction with flex duct.

Ductwork in the Forced Air System
At the beginning of the lesson we looked at a diagram of a general HVAC system. Now let’s delve into some more terminology that’s important for understanding the ductwork in relation to the forced air furnace.

First, towards the left in the photo below, there is the supply plenum. Warm conditioned air comes out of that furnace and is distributed through ductwork that connects to this supply air plenum. The return air duct is mounted to a return air plenum, a large duct that’s attached to both the supply side of the furnace and the return air side of the furnace. The return air plenum recycles the air from the home.
This next photo shows a return air duct grille. Typically, this is what we consider a filter grille, and what that basically means is that there’s a filter behind the grille. The homeowners remove the grille to change the filters in their unit.

Duct Leak Problems
Duct leakage can cause a lot of problems. First of all, it can cause energy loss of up to 25 to 30%. That’s huge. It really impacts people’s energy bills. Duct leaks can average 200 to 300 cfm (cubic feet of air per minute) and can be as much as 700 cfm. They reduce comfort because the occupants aren’t receiving conditioned air to the space in the right volumes.

Duct leaks can also lead to indoor air quality problems — by pulling air into the house from undesirable spaces like crawlspace or attics. And they can also lead to moisture problems. If we have a system, say, that puts the house under positive pressure, then that can force moisture-laden air out through the wall system where it can condense on the sheathing and lead to mold-related problems. In the next photo, for example, you can see a piece of paper being blown up off the floor. This was a house where I cut a hole in the floor to put in a shower drain. While I was doing this work the HVAC system was operating, and because we had so many supply duct leaks outside the building envelope it created negative pressure in the house — enough that the air being drawn out was enough to push the piece of paper right off the floor.
So duct leaks can move quite a bit of air. When you see black marks on insulation (like in the photo on the next page), that’s a good indication of duct leakage — the fiberglass acts like an air filter.

Duct leaks can also lead to air quality problems or even life-threatening situations. For example, shown below is an unsealed furnace filter in a garage that houses the air handler. If there is a running car in the garage, the HVAC system is going to suck carbon monoxide into the home. So it’s very important that if we have units in garages that the ductwork be sealed and that the filter be located inside the home.

Common Causes of Duct Leaks
Now we’re going to look at some common defects you’ll see on a daily basis that cause duct leaks and duct problems. First of all, in the next picture we can see a metal plenum supply duct with a round duct transition. Around the perimeter of the duct there are numerous gaps. Obviously, that represents pretty significant duct leakage.
In the **photo below**, you can see a crawl space and there’s some flex duct that’s actually pulling away from the transition (the upper duct at the top). There’s an open return air duct, which will suck air from this crawl space into the system, simply because it’s not very well attached to the system. Someone just took some flex duct and attached it to a plenum, used some duct tape, but then didn’t seal the transition.

In the **following photograph**, someone put the flex duct to a boot (the silver area is a boot that connects to a register). All they did was use a few sheet-metal screws to attach the flex duct to the boot. That’s a problem because it’s not well-sealed. In a little bit, we’ll walk through how we properly seal a flex duct-to-boot connection.
And below there is another transition where you can see the metal collar that’s attached to the metal duct. It’s got some big gaps around it. That’s going to leak like a sieve.

In this next photo, someone used an elbow, and they taped the transition between the elbow and the straight pipe, but they didn’t seal the seams in that elbow. So there will be leakage there as well.
Where the arrow is in the picture below, you can see a little hole. That is an example of one of those cracks and gaps that add up to the 300 to 400 cfm of air leakage from duct systems.

And in the next example, we can see that the duct tape is completely falling off. Duct tape often has rubber-based adhesive and so it dries out. Therefore, it’s important to be very careful about the type of duct tape you select: you need to select the right adhesives for the application.
The **photo below** shows some pressure-sensitive tape that's used to seal a duct to a transition, and you'll notice that the fiberglass is not pulled over that, so it's not very well insulated.

Something to avoid is using building cavities constructed of framing members as ducts. This is not allowed by newer codes in many areas because they're very difficult to seal. In the **photo on the next page** someone has used a floor joist space for a return air duct. They probably put some metal panning over this and then used that actual wood cavity as ductwork. This is very undesirable because this space almost always communicates with the outside, which means air will be pulled in from these locations. And, again, they are very difficult to seal.
The next photo shows examples of flex duct that’s bent underneath this beam and compressed. We want to avoid this type of things. Flex ducts should never be bent around corners because the airflow is going to be substantially reduced.

Here is an example of where the strap was put in place and the flex duct was sandwiched between the insulation. Flex duct is very easy to compress, and when it’s compressed you can’t get the appropriate airflow through the duct and the occupants won’t get the comfort they want.
This is a pretty sharp bend in the photo below. That is going to restrict airflow. You can see in the upper part of this picture that the duct is actually sheared. This will result in some pretty major air leakage.

Next we see a duct that’s been bent over a truss. Probably less than 50% of the desired airflow will get through that duct. Again, this has a big impact on the total system performance.
Our final problem photo shows a 10-inch-diameter duct in an 11-inch joist space, and then there’s a sewer line that goes halfway through it, so this duct is going to be compressed to only a couple of inches of actual airflow space. So obviously, it’s not going to work very well.

Also, when we use straps to fasten or suspend ducts, it’s important that the straps themselves don’t constrict the airflow.

Assessing Duct Leakage
In weatherization work, we have several tools at our disposal for diagnosing and quantifying leaky ducts.
**Duct blaster.** The first is what we call a duct blaster and it’s a very simple little device that quantifies duct leakage. It’s a fan with a duct that goes through the return air side of the air handler. You seal the supply ducts and the blaster measures the air entering the handler.

**Manometer.** A manometer is used to measure air pressure. Some manometers give a direct readout of how many cubic feet of air per minute are actually leaking through the ducts.

**Blower door.** In a blower door test, all the doors and windows in the house are shut, and a large fan is set up in one doorway to suck air. This test tells how leaky the house is. Sometimes, contractors will cover up all the ducts in the house and then do a second blower door test, and then second test results from the first to arrive at duct leakage. But this is not nearly as accurate as doing a duct blast test.

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**Proper Duct-Sealing Techniques**

Now that you’ve seen some of examples of what NOT to do and we’ve briefly discussed diagnostic tests, let’s go over some techniques for good duct sealing and installation.

**Correct duct-to-boot connection.** This is how you properly tie a flex duct to a boot connection (photo below): Basically, you take the inner liner of the flex duct, which has the wire on it, and you pull it over the boot. You wrap a few wraps of the appropriate duct tape, then you tension a draw-band, using a
mechanical tension device. Then you pull the insulation over that, add another draw-band, and you have a pretty tight seal.

Sealing boot-to-register connections. Another area we need to be conscious about sealing is where the boots come through the floor for registers. Make sure that the boot is actually sealed to the subfloor, because when the register is installed, it can get backpressure that causes it to leak back down into a crawlspace or other unconditioned area. Sometimes we will take a foil-like material and actually tape the boot to a drywall connection like the one in the next photo.

Types of duct tape. In terms of doing things right, let’s talk for a moment about duct tape. The three most commonly used types of duct tape are shown below. All the way to the left is a pressure-sensitive foil tape with an acrylic adhesive. The middle tape is foil with a butyl-based adhesive. It’s very sticky and seals pretty well. And then finally, on the right, we see a clear acrylic tape (UL 181) that’s often used on flexible duct. These are the types of duct tapes that do the best job of sealing.
**Mastic sealants.** A good material for sealing ducts is mastic sealant. For example, in the next photo, a worker is brushing on some mastic sealant where the flex duct connects to the metal return air boot. Mastic sealant is fairly easy to use. You just brush it on, and it cleans up with water. There are a number of different manufacturers of these products. They are long-lasting and do a good job of sealing ducts. If you have to seal larger holes, you may need to put some reinforcing, like a fiberglass mesh, over those areas, and then coat it with mastic.

You can imagine the leaks closest to the furnace are the ones that cause the most problems because that’s where the pressure is the highest. So it’s really important to seal those leaks like has been done in the next photograph. This is a good example of a plenum area that’s been sealed with mastic sealant.
Here is another example *(see photo below)* of the proper way to seal an awkward transition in rigid metal ductwork. The mastic is perhaps a bit overdone, but still a good job.

We only need to apply the mastic where two ducts come together or anywhere there are seams in the ductwork from the manufacturing process. **The next picture** is also a good example of how to do it right. The fiberglass insulation in one area is black because it was trapping dirt — an indication that this area needed to be sealed. So the contractor simply pulled back the fiberglass, put some mastic sealant around all those seams and connections, and presto, the problem in that area was solved.
Now it’s also important to recognize that air handlers themselves can leak. So sometimes contractors will use acrylic tape to seal those leaky areas around air handlers. In the next photo there is some mastic sealant where this furnace unit actually connects with the plenum. As you can see, someone put some mastic down and sealed that location. It’s very important to seal where the unit itself connects to any plenums, whether they be supply or return air plenums.

*Good mechanical joints and long sweeping bends.* While it’s important to use draw-bands, appropriate tapes, and masking, it’s even better to use those in conjunction with good mechanical joints and gentle bends.
Summary
We’ve covered a lot of ground in this lesson. To summarize, weatherization contractors should focus on the following points when they work on improving the efficiency of HVAC systems:

• Ducts need to be adequately and properly sealed with masking sealants or appropriate tapes.
• Install ducts so runs are straight whenever possible — with no kinks or crushed areas that restrict airflow.
• Use long, sweeping bends instead of sharp-angle bends that can restrict airflow.
• Fasten any transitions from flex duct to other materials with draw-bands and use appropriate tape.
• Test the system for leakage.