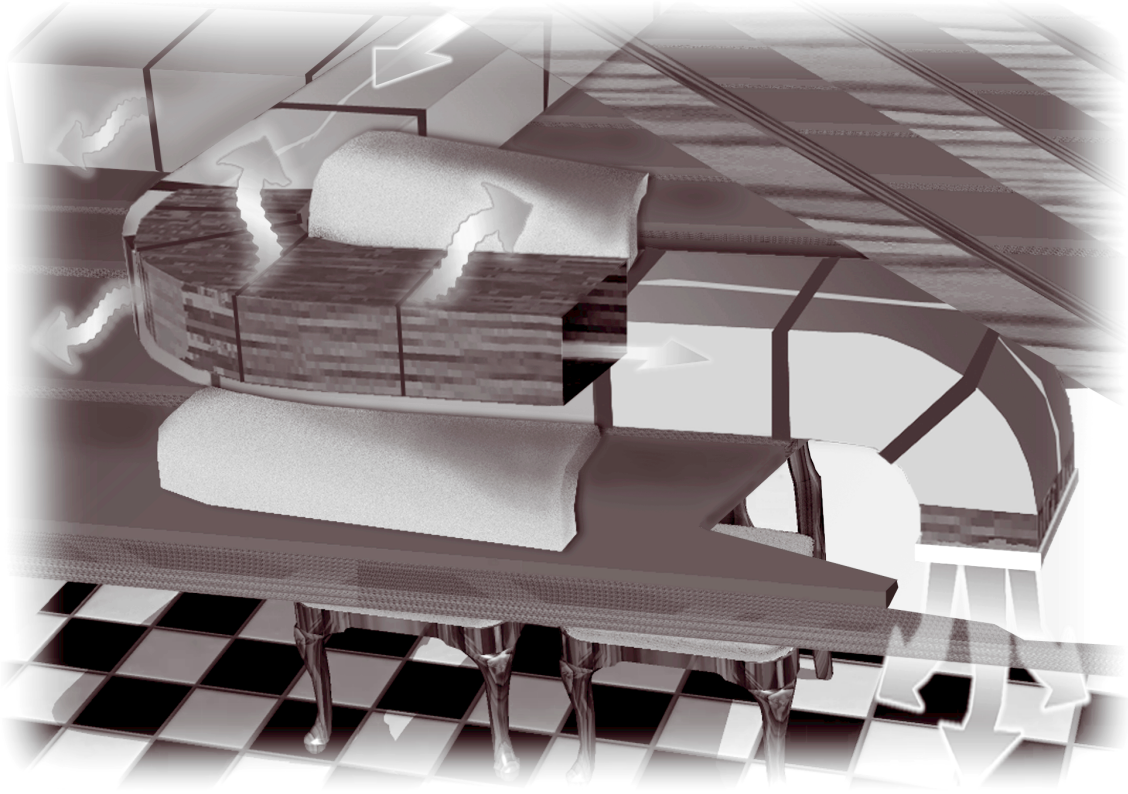
RESEARCH & DEVELOPMENT

IMPROVING THE EFFICIENCY OF YOUR DUCT SYSTEM



OFFICE OF BUILDING TECHNOLOGY, STATE AND COMMUNITY PROGRAMS
ENERGY EFFICIENCY AND RENEWABLE ENERGY • U.S. DEPARTMENT OF ENERGY

Table of Contents page

THE DUCT SYSTEM, used in air heating and air cooling your home, is a collection of tubes that distributes the heated or cooled air to the various rooms. This system can make a big difference in both the cost and the effectiveness of heating and cooling the home. The duct system can have an important effect on health of the occupants through the distribution of indoor air pollution. Changes and repairs to a duct system should always be performed by a qualified professional.

This brochure is meant to help you understand the problems that can affect the duct system and how you can:

- **Save money**
- **Improve comfort**
- **Protect health**

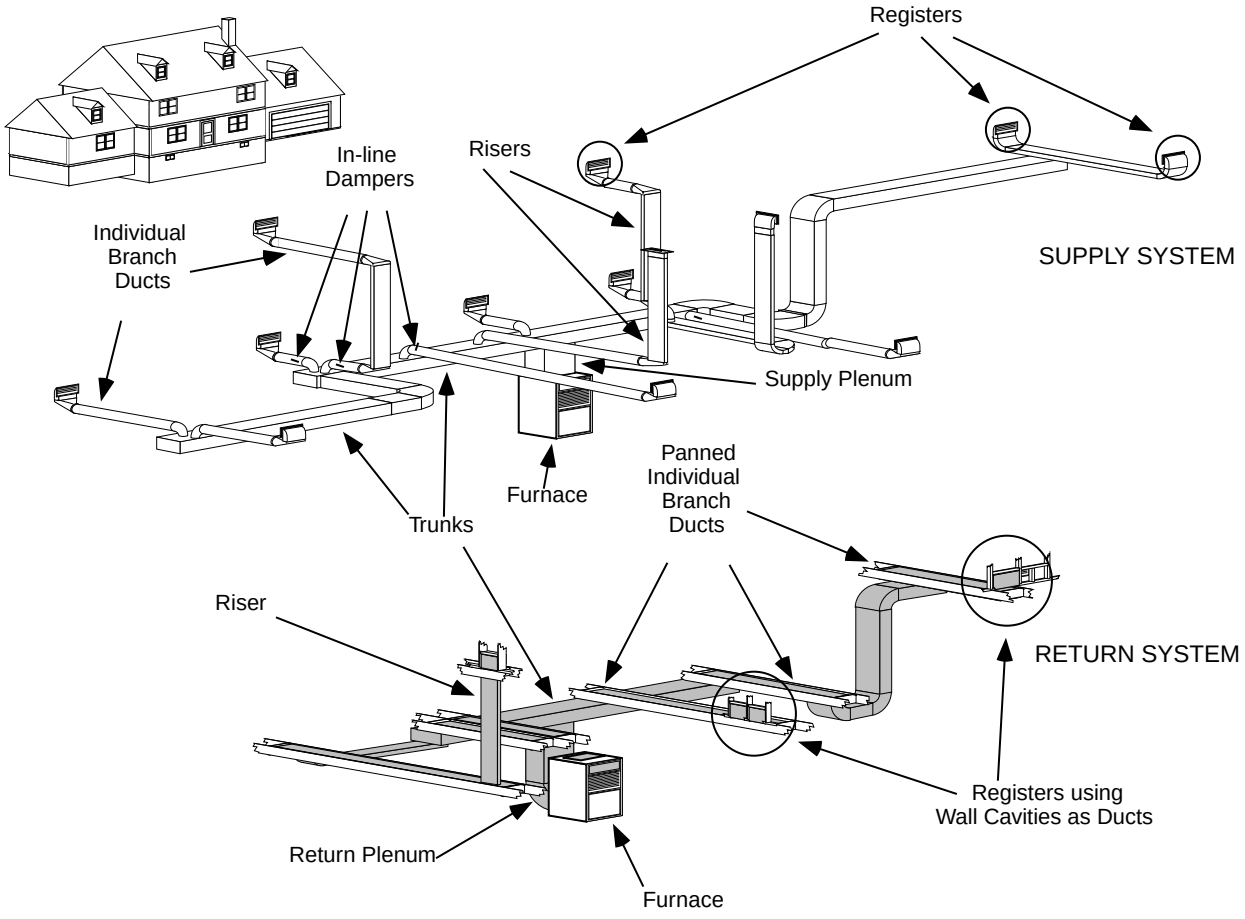


Figure 1. A Common Duct System

COMPONENTS OF THE DUCT SYSTEM

A duct system is a branching network of round or rectangular tubes—generally constructed of sheet metal, fiberglass board, or a flexible plastic-and-wire composite—located within the walls, floors, and ceilings. Usually, you can see only the outlet, which is a register covered with grillwork. Figure 1 shows a common type of duct system.

This system consists of supply ducts and return ducts. Central heating or cooling equipment (furnace, air conditioner, or heat pump) contains a fan that forces heated or cooled air into supply ducts leading to the rooms. The fan gets its air supply through return ducts, which in the best systems are installed in every room of the house. To save on installation costs, most homes have one or two return registers located in common areas such as hallways. (Some homes have no return duct systems. Such design shortcuts often result in lower efficiency and higher heating and cooling bills.)

ENERGY LOSSES AND COSTS

Typical duct systems lose 25 to 40 percent of the heating or cooling energy put out by the central furnace, heat pump, or air conditioner. Homes with ducts in a protected area such as a basement may lose somewhat less than this, while some other types of systems (such as attic ducts in hot, humid climates) often lose more.

Duct repairs could be the most important energy improvement measure you can do if your ducts are in the attic. If only one half the typical loss of uninsulated and unsealed ducts that are in attics or crawl spaces were saved, it would amount to $160 off the total heating and cooling bill in a typical home. This savings is based on the national average use of natural gas and electricity for central heating and cooling at national average energy cost of 70 cents per them, and 8 cents per kilowatt-hour. With these savings, the cost to seal and insulate the ducts would most likely be paid for after three years. These estimates apply to retrofitting an existing home. For new construction more of the ductwork would be accessible to the installer and the potential savings would be greater; and with lower cost to install sealant and insulate, the payback would be less than one year.

Duct systems lose energy in two ways: by conduction of heat from the warm surface, and air leakage through small cracks and seams. For simplicity, we'll talk about warm air for heating, but the same information applies to cooling when the air conditioner is on.

Conduction

One way duct systems lose energy is for the warm air inside the ducts to heat the duct walls, which in turn heat the cold air outside the ducts. If the ducts are in an attic or vented crawl space that is nearly as cold as the outdoors, this heat is completely lost. If the ducts are in a basement, some of the heat lost from the ducts may be recaptured by warming the basement ceiling enough to reduce the heat lost from the house.

ENERGY LOSSES AND COSTS

Air Leakage

Another way that ducts lose energy is through air leakage. Sometimes this leakage is from accidental holes in the ducts or poorly connected duct sections; but even if the ducts are sealed, their operation can cause the house itself to leak more air than would otherwise be the case.

An understanding of pressure differences in the duct system helps to better understand air leakage in the home. Air moves from high pressure to low pressure. To get air to move from the supply duct into the room it serves, the air in the duct has to be at a higher pressure than the air in the room. Similarly, to move air from the room into the return duct, the air in that duct has to be at a lower pressure than the air in the room. The registers are the openings through which this air is intended to move. The duct walls provide the barriers that prevent air from moving where we don't want it to go.

The fan of the central furnace creates these pressure differences. When the fan stops, these pressures quickly equalize and the flow of air through the duct stops, too.

Figure 2 shows a duct system that does not leak. The furnace fan produces a high pressure in the supply ducts and a low pressure in the return ducts. The high pressure forces warm air from the supply ducts to flow into the rooms, and low pressure draws room air back into the return ducts.

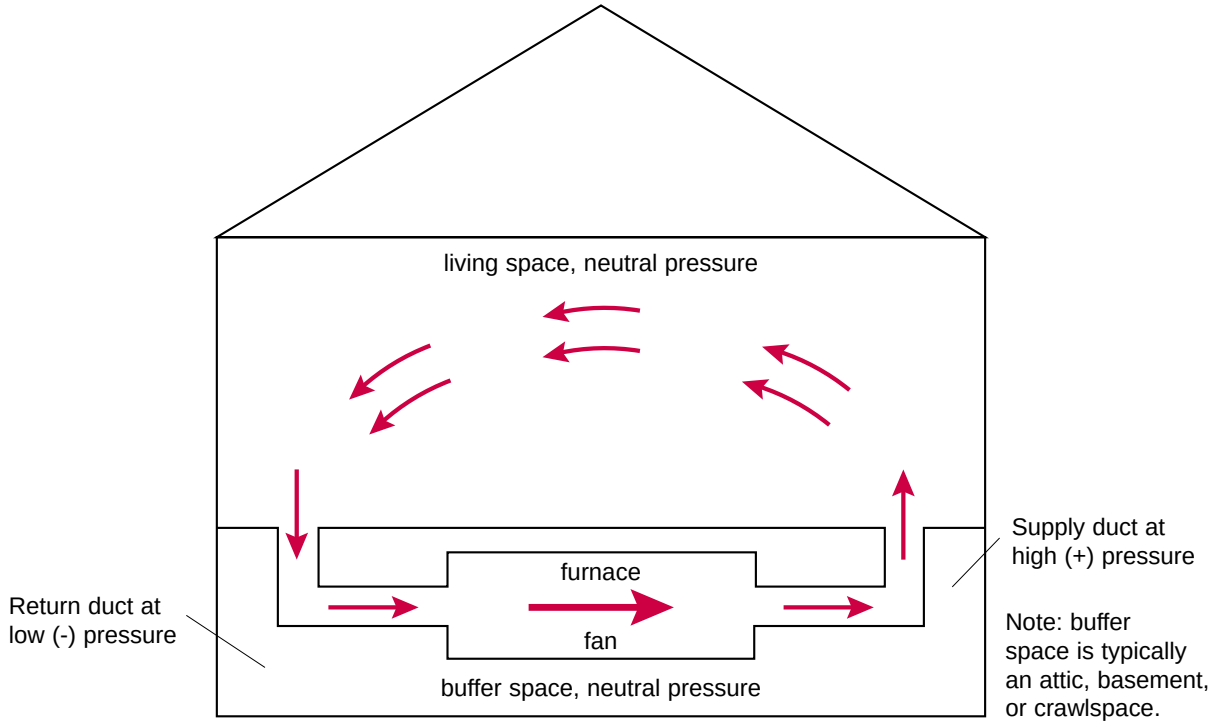


Figure 2. Ideal Duct Schematic - No Leakage

ENERGY LOSSES AND COSTS

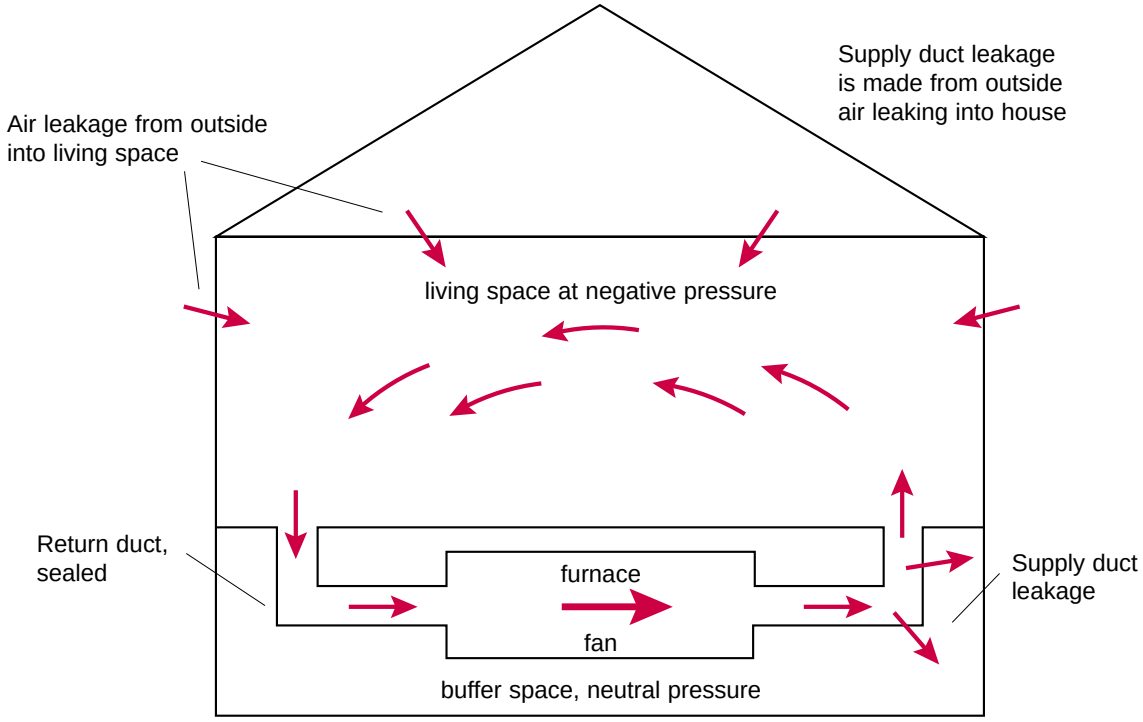


Figure 3. Duct Systems With Supply Side Leaks

Leaky Supply Ducts

Figure 3 shows perhaps the simplest example of duct leakage. Here the supply ducts leak, but the return ducts are air tight. Even though half the duct system is good, two bad things still happen. First, some of the air that has just been warmed by the furnace is lost. Second, this air has to be replaced. If it isn't, the house would soon be pumped down to a vacuum, and we know that doesn't happen. What does happen is that cold air from the outside is drawn into the house through cracks and small holes in the outside walls. Usually these occur around doors and windows. Some houses have more of these than others, but no house is air tight. So we've lost some of the hottest air in the house (air that just came from the furnace), and replaced it with the coldest air around (air from the outside). In other words, a leaking supply duct is an energy loser in two ways: the energy loss that does not go to the rooms, and the extra energy needed to heat cold air that leaked into the house.

ENERGY LOSSES AND COSTS

Leaky Return Ducts

Suppose the supply ducts are tight but the returns leak, as shown in Figure 4. The return duct is at a low pressure— lower than the house or the outside — so cold air from the outside is pulled into this duct. This cold air is heated in the furnace (along with air that came from the house through the return registers). The amount of air delivered to the house by the supply registers is greater than what the return ducts took from the house (the difference being the cold air that leaked into the return ducts). To equalize the flows, heated room air leaks out of the house through the same holes and cracks that, in the previous example, allowed air to leak in. So cold air is pulled in and warm air leaks out. In addition to creating energy losses, leaky return ducts can create health problems (see below).

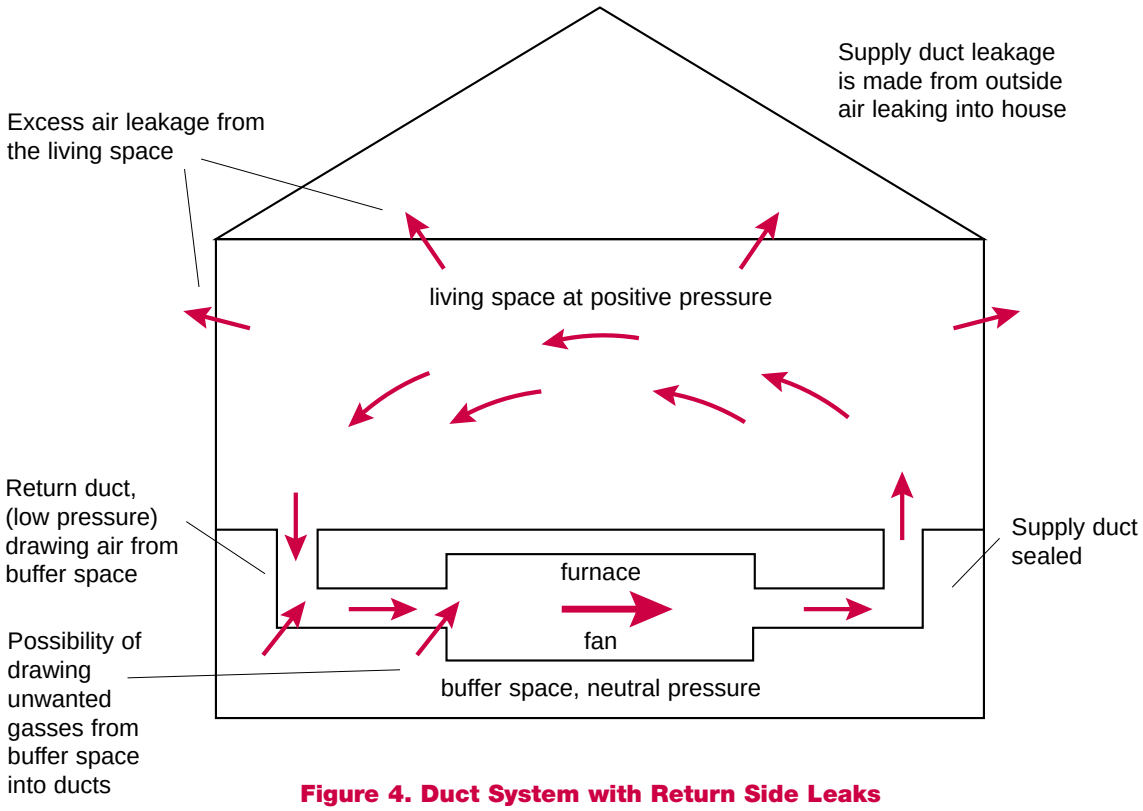


Figure 4. Duct System with Return Side Leaks

ENERGY LOSSES AND COSTS

Zone Pressurization

Ducts can cause air leakage in the house even if neither the supply nor the return ducts leak themselves. Figure 5 shows how this can happen. Imagine that a home has a return register in one room but no supply (the room on the left in Figure 5), and a supply register in another room but no return. Now close the door between these rooms. The room with the supply duct (the room on the right in Figure 5) will have relatively high pressure. The supply duct will be trying to blow this room up like a balloon. Similarly, the room with the return will have relatively low pressure. So inside air will leak out from the room on the right, and outside air will leak into the room on the left. This places an added load on the heating equipment. The situation described here is somewhat simplified to show the basic idea, but variations of it are common in real homes. Most new homes built today do not have duct returns in each room. The problem can be avoided in rooms with no return register and doors that are often closed by installing an opening covered by a louvered grill in the door or in the adjoining wall.

Energy Losses When the Fan Is Off

So far, we've been talking about what happens when the central furnace fan is running. But even when it's off (which is most of the time) the leaks in ductwork add to the air leaks in the rest of the house. The cracks in ductwork typically have an area that is 10 to 20 percent of the leakage area of the house. Over the course of a heating season, the energy losses from ducts when the fan is off can be nearly as great as when the fan is on!

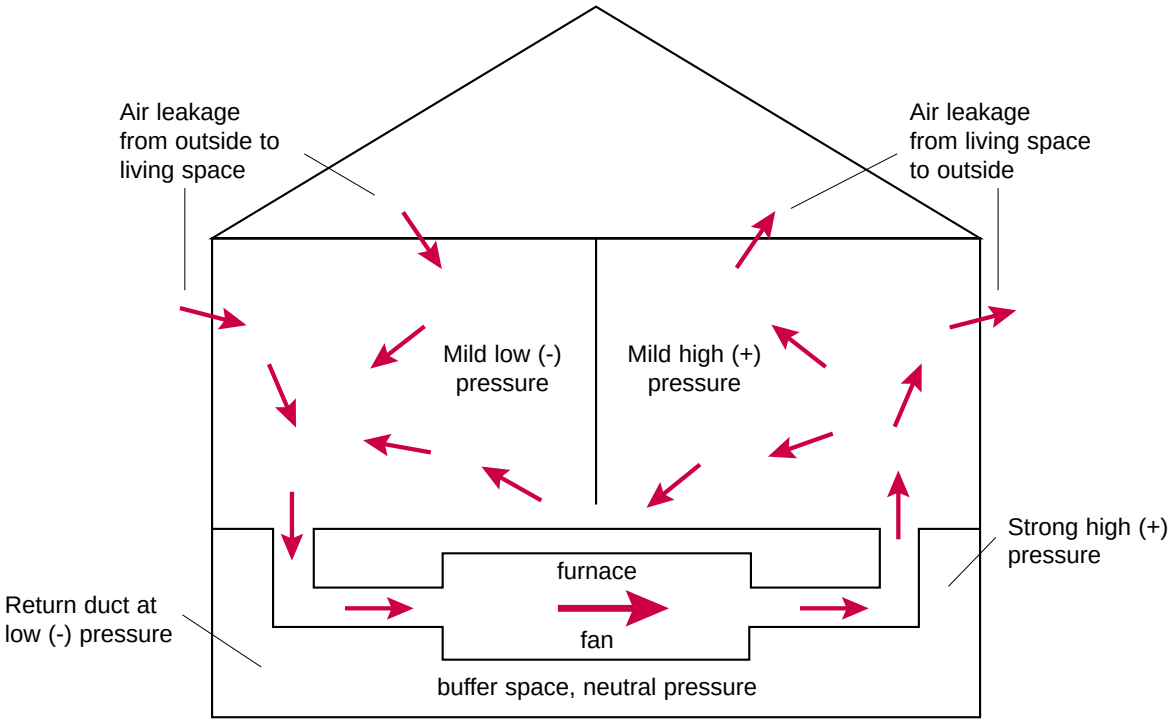


Figure 5. Excess Air Leakage in the House Caused by Isolation of Zones

HEALTH HAZARDS

Leakage in the duct system can be hazardous to your health. Especially problematic are leaky returns in an enclosed space such as a basement or garage that also contains the furnace. This was the situation shown in Figure 4. If the return ducts leak, their low pressure can pull down the pressure in the basement or garage as well, and this can suck flue gases from the furnace and radon gas from the soil surrounding the home. The flue gases can be hazardous to health if they contain carbon monoxide. Exposure to radon gas from the ground is the second leading cause of lung cancer (after smoking).

Although experts disagree about how common these hazards are, by upgrading the energy efficiency of the duct system you have an opportunity to avoid these potential problems in your home.

INSPECTION OF THE DUCT SYSTEM

You probably wonder how you can know if your system is losing large amounts of energy. Although it is often difficult to be sure without testing, some tell-tale signs, if present in your duct system, should make you have it checked by a professional.

It will help to make a simple diagram of the system. This can be a rough sketch. There is no need for blueprint quality here.

The first thing you need to do is find the central heating unit. That should be no problem if it is located in a basement. It is probably something you pass by almost every day. However, it may be located in an attic or crawl space.

Safety Tips

To get near the ducts, you may have to look into spaces you have never been in before, especially if the duct system is located in an attic or crawl space. Therefore, be sure to follow common-sense safety rules:

- Guard against falls, cuts, and other personal injuries.
- Do not open up or probe into any electrical devices, wires, or connections.
- Wear an approved mask if you go into an area with fiberglass or loose fill insulation.
- Before you touch any uninsulated duct, hold your hand about an inch from it to check if it is hot. This is especially important in furnaces fueled with gas or oil, because the vent pipe that carries the flue gases to the chimney looks like a small duct yet may have a temperature of several hundred degrees Fahrenheit. Generally the vent will be a round sheet-metal pipe about six inches in diameter that leads upward from the furnace cabinet. (If the furnace is one of the new high efficiency models, it might be vented horizontally.)

Filters

While you are at it, you might want to locate the filter, which is usually within the central fan unit or at the return register. The filter removes dust and other small particles that otherwise could interfere with the operation of the blower and the furnace heat exchanger. When it fills up with dust, it cannot do its job and needs to be changed.

INSPECTION OF THE DUCT SYSTEM

Experts recommend that the filter be changed several times during each heating season. At about a dollar each, frequent filter changes are a low-cost way to save energy, protect your heating equipment, and remove some of the dust that otherwise would be delivered to the living space.

How to Distinguish Between Supply and Return Ducts

Once you have found your central heating equipment, you will notice ducts leading away from it. There is a supply duct and a return duct, but which is which? In one common type of installation, the return duct leads down from the basement ceiling to enter the furnace near the floor. The supply duct runs out from the top of the furnace. This kind of system is shown in Figure 1. There are many types of installations and it is not always easy to tell which is the supply and which is the return just by looking at the ducts, particularly if you are not familiar with them.

You can wait until the furnace comes on, or the thermostat can be pushed up for a short while to force the furnace to come on. If the ducts are made of sheet metal, you should be able to feel the supply ducts getting warm. The returns will not change much in temperature. Another possibility is to follow what you think are the supply ducts to one of the registers. If this is in fact the supply side, you should be able to feel air coming out of the register.

How to Identify Trunks and Branch Ducts

After you have identified the supply and return sides of the duct system, you can follow the supply side. Most often, you will see something like what is shown in Figure 1— a long, boxlike structure called a trunk which sprouts smaller branch ducts that lead out toward the rooms of the home. Another common installation has all the supply ducts branching directly from the furnace like the arms of an octopus.

Building Spaces Used as Ducts

So far we have assumed that the duct system is completely separate from the other components of the home. Often this is not so. To save money, builders sometimes use the building structure itself as part of the duct system. One common tactic is to use the spaces between basement or ceiling joists as ducts. (Joists are the horizontal-running boards—generally 2” x 10” or 2” x 12”—that support the floor above.)

Although this type of construction can be made to operate efficiently, it often leads to significant energy losses. One reason is that joist-space ducts are likely to be uninsulated. Another problem is that they may have unintended leakage paths to the outside, typically through the end of the joist cavity.

With returns, it is even more common to see portions of the building structure used as part of the duct system. Some homes have no return at all; the furnace simply has an intake grille through which basement air is drawn in to be warmed and distributed to the home.

TELL-TALE SIGNS OF PROBLEM DUCTS

Now that you know here each branch duct leads, you are in a better position to ask whether your system is likely to be a big energy loser. Here are the things to look for.

Uninsulated Ducts in Unconditioned Spaces

Heat transfer through duct walls can contribute significantly to energy losses. Conductive heat losses are typically at least as great as the energy losses due to air leakage. If the duct system runs through an attic or vented crawl-space and is not insulated, you can be sure that much energy is being wasted. If the ducts are in a basement, you will have to weigh the fact that insulating the ducts will cause the basement to get colder. If both the ducts and the basement walls are uninsulated, you should consider insulating the basement walls instead of the ducts.

Disconnected, Torn, or Damaged Ducts

A thorough inspection of the duct system should be made to look for holes large enough to see. Some sections of duct that are supposed to be joined together may have fallen away from each other, leaving a gap through which large quantities or air can leak. Flexible duct sections may have been torn during installation or afterward. Fiberglass ductboard sections are subject to damage if weight is placed on them. Whatever the cause, visible holes in ductwork are a clear indication that the system needs fixing.

Blind-Alley Ducts

Occasionally found in duct systems that use joist spaces or other parts of the building structure to channel air flow, blind-alley ducts occur as a result of mistakes made during installation. A blind-alley duct leads nowhere (except possibly to the outside), while the register it was supposed to serve has no source of heat. The room containing this register will then be too cold. If it is an important room, the thermostat setting may be raised in an attempt to get enough heat to this room. If a room always seem too cold or a register doesn't seem to have any air flowing out of it, it may be worth investigating.

Inadequate Return-Side Ductwork

As we've noted, it is common to find building spaces pressed into service as part of the duct system. These tend to be leaky, especially on the return side. Even worse, some homes are designed without any return ductwork at all. In that case, unless the furnace is in the conditioned space, it will be surrounded by cold basement or crawl-space air and will have to use more energy to warm this cold air for delivery to the home than it would have if warmer air from the living space were available from return ducts. A system without return ductwork can also depressurize the furnace room, giving rise to the health hazards we've already discussed.

TELL-TALE SIGNS OF PROBLEM DUCTS

Other Evidence of Supply-and Return-Side Leakage

In any kind of duct system, the joints between duct sections should be sealed against leakage. If duct tape was used for this purpose, it often loses adhesiveness after a few years. In such cases you can see it falling off the ducts or you can easily pull it away. Duct sealing should be done using a silicone caulking or a special cement (mastic) with an embedded fabric. If your return ducts are insulated, you may see accumulations of soot or other dark material on the insulation where it covers loose duct joints. This dark area is a coating of dust which over time has accumulated on the surface as the air is being pulled through the insulation.

Another fairly common type of energy-wasting air leakage is found in systems where ducts, water pipes, or vent pipes lead between the basement and the attic. If there are openings around these pipes that allow heated air to flow out or cold air to flow in, then the pressure difference between the basement and the attic is likely to increase air infiltration into the basement. It is usually a good idea to seal this flow path.

These are all signs that serious duct leakage may be occurring, leakage that could, with reasonable effort, be eliminated.

GET A PROFESSIONAL!

Because of the possible effects that changing the duct leakage pattern can have on indoor air pollution, you should not attempt to repair duct leaks. Suppose, for example, that you find several disconnected duct joints in your supply system. Wouldn't it make sense to hook them back up? Probably it would, but if the return system has leaks you can't fix, you might end up with an unbalanced system like the one in Figure 4.

There are many variations on this theme, but this illustration shows that safe duct repairs require a licensed heating, ventilating, and air-conditioning contractor to repair ducts. Try to find one that has sent their technicians to a good duct-repair school. Such courses typically involve at least a week of intensive training.

One of the special tools that would be used by a technician is a blower door— a temporary barrier set up to cover an open outside doorway, in which is mounted a fan that is used to apply a small pressure to the house. The main use of the blower door is to test for air leakage in the house, but it is also used in duct leakage tests. One test for duct leakage involves simultaneously pressurizing the house with the blower door and the ducts with a smaller version of this device. Another test uses the blower-door result plus some simple pressure measurements to estimate duct leakage.

GET A PROFESSIONAL!

A contractor's representative or service technician should be able to answer the following questions to your satisfaction:

- How do faulty duct systems lose energy? (They should know at least as much about the subject as you do now.)
- How would you test my duct system to see if it needs repair?
- What would you do to fix it if you find that work is needed?

Our discussion of health issues should not deter you from doing something about duct leakage, which could be contributing to a potentially serious health problem right now and you might not know it. When a qualified professional repairs your duct system, it is quite likely that the quality of your indoor air will improve. A qualified practitioner will perform the tests necessary to make sure that no problems are created where they didn't exist before.

OPPORTUNITIES IN NEW HOMES

We have discussed the ductwork in existing homes. If you are building a new home, you're in luck! You have the opportunity to make sure that the duct system will deliver top-notch comfort and efficiency by specifying to the builder that you want a leak-free, insulated duct system.

Even better, discuss with your builder the option of locating the ducts within the conditioned space and hiding them so that they don't show. It is possible to box in ductwork installed near the intersection of a wall and the ceiling, or to use other builders' tricks so that the raw duct materials will not be visible. It will be easier to do this than might at first appear because an energy-efficient duct system in an energy-efficient home can be less bulky than a standard duct system. This is because the amount of heating and air conditioning needed will be much less than in a standard installation. This will permit the use of a smaller furnace and air conditioner, which require a smaller amount of air flow in the duct system.

When it is possible to reduce the size of the duct system and the central unit, you save on equipment, materials, and installation costs, possibly enough to pay for the cost to hide ducts that are located within the conditioned space. In that case, energy savings will start to flow immediately. Even if some additional cost is involved, a duct system properly installed inside the conditioned space is energy loss-free and will likely be one of your best investments.

FOR FURTHER INFORMATION

The first two references below are readable guides requiring no specialized knowledge, although the professional can pick up quite a bit from them, too. The others are really intended for the professional, but could be a next step for the homeowner who becomes deeply interested in the subject.

Home Energy Magazine, Special Issue-Ducts Rediscovered.September/ October 1993. 2124 Kittredge Street, No. 95, Berkeley, CA 94704.

This Old House; Heating, Ventilation, and Air Conditioning. Trethwey, Richard. Little, Brown. 1994

Duct Design for Residential Winter and Summer Air Conditioning and Equipment Selection (Manual D). Air Conditioning Contractors of America, 1513 16th Street, N.W., Washington, DC 20036.

Flexible Duct Performance and Installation Standards. Air Diffusion Council, One Illinois Center, Suite 200, 111 East Wacker Drive, Chicago, IL. 60602-5398.

A Guide to Insulated Air Duct Systems. North American Insulation Manufacturers Association, 44 Canal Center Plaza, Suite 310, Alexandria, Va 22314.

Installation Standards for Residential Heating and Air Conditioning Systems. Sheet Metal and Air Conditioning Contractors' National Association, Inc., 4201 Lafayette Center Drive, Chantilly, VA 22021.

Energy-Efficient Design of New Low-Rise Residential Buildings. Standard 90.2-1993. American Society of Heating, Refrigerating, and Air Conditioning Engineers, 1791 Tullie Circle, N.E., Atlanta, GA 30329.

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