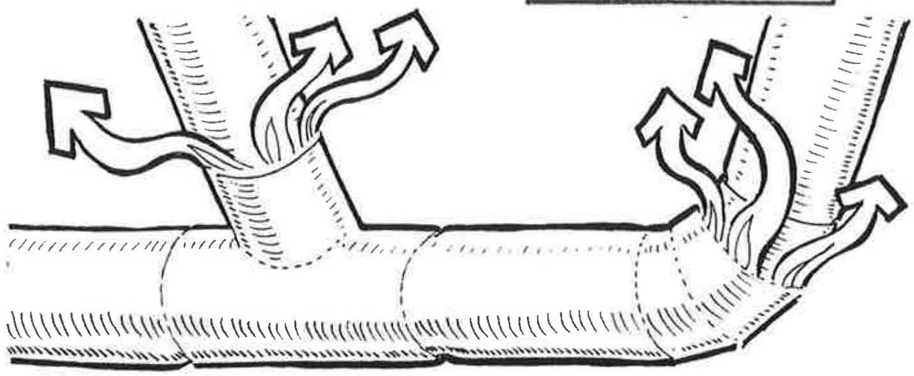
Heat Losses from Forced Air Heating Systems (Duct Losses)



Past analysis of air infiltration in residential buildings has found that there is more air leakage in houses with forced air and combustion heating systems. The total heat losses due to leakage in homes with ducting located in unheated spaces is especially great. But how much?

A major study to find out was undertaken in the U.S. Pacific Northwest. The results were presented at the recent ASHRAE conference in Vancouver.

Energy consumption and airtightness data for 820 electrically heated houses built since 1980 were examined. Half of the buildings were energy-efficient structures built to the Model Conservation Standards (MCS) developed in the region; the rest were conventional new houses representative of current building practices.

The houses were monitored for one year. They were audited to determine insulation levels and occupancy characteristics. In the analysis of the monitored data was found that heating system type is important in determining the relative efficiency of electrically heated houses.

Houses with electric forced air heating systems used an average of 22% more space heating energy than those without them (on average an extra 1.40 kWh/ft^2).

Through the use of fan pressurization and tracer gas tests it was observed that houses with forced air systems had much higher levels of air leakage. The tracer gas tests indicated an average of 70% higher levels of air change rate in the conventional houses with forced air space heat as opposed to baseboard systems.

There was no study of natural gas heated homes, but the basic principles would still apply.

The energy efficient houses were built in 1984 and monitored during the 1985-1986 heating season. The thermal performance of the MCS houses was superior, using an average of 2.55 kWh/ft^2 less space heat electricity than the conventional group.

When the Model Conservation Standard was developed it was assumed that the air change rate in conventionally built houses averaged about 0.6 air changes per hour (ACH). In theory this presented a major opportunity for energy conservation savings.

The MCS houses were designed to be draft-free with sealed polyethylene vapour barriers and heat recovery ventilators. It was assumed that the MCS houses would have a natural air change rate (induced by wind and temperature difference) of about 0.1 ACH plus another 0.5 ACH provided by mechanical ventilation (heat recovery ventilators with a minimum 60% of the heat being recovered). This results in a net reduction of 0.3 ACH over the conventional houses.

Analysis of the energy efficient houses found that heating system type accounted for dramatic differences in electric space heat consumption. The energy losses are due to conductive heat loss and airflow leakage from the heating ducts. In addition to inefficiencies during operation, leaks in heating ducts contribute to air infiltration.

How big a problem is this leakage?

Overall, forced-air heating systems used an average of 17% to 22% more space heat than non forced-air electric resistance systems. The study also demonstrated a strong link between forced-air heating systems and air leakage in the houses.

Duct leaks increased the blower door measured equivalent leakage area of a house by an average of about 10%.

Duct air leakage and associated heat transfer are serious for building energy consumption budgets. Although the increased effective leakage area from duct systems may only be about 15% more than in houses without ducts, the overall increase in air leakage and space-conditioning energy consumption is likely to be much greater.

Induced air leakage from combustion systems with chimneys would probably be greater than the results shown in this study since only flueless electric forced-air systems were examined.

Ducted forced-air homes were leakier and used more heat than unducted homes. Ducted conventional homes were 26% leakier than unducted conventional and used 40% more heating energy. The incremental leakage and thermal losses due to presence of ducting were substantially lower in energy efficient homes. Ducted MCS homes were 22% leakier and used 13% more heating energy than unducted MCS homes.

Differences in leakage produces a net pressurization in most homes during furnace fan operation. Fan induced leakage in return ducts was substantially greater than in supply ducts.

Incremental leakage and thermal loss due to ducting in the energy-efficient homes tested was reduced by construction features used. The relative importance of each of these features is not specifically determined. These include:

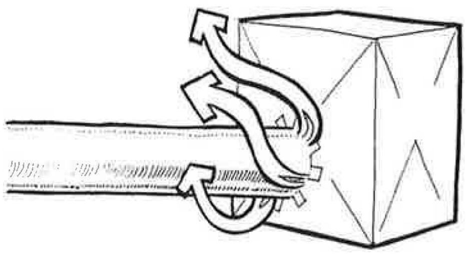
- ducts located inside the heated space whenever possible
- duct insulation greater than called for by code
- above code envelope insulation
- continuous vapour barrier construction
- heat recovery ventilation

A group of houses were chosen to measure the impact of remedial work, as duct leakage reduction may be a relatively easy and cheap conservation measure. Homes were selected based on the presence of a ducted heating system outside the conditioned area.

A typical configuration consists of supply ducts located in a vented crawl space and a return duct in a vented attic. The homeowners of these houses tended to be energy-conscious, as noted by their willing ongoing participation in an energy research project, and the homes are probably better built than the norm. Thus, the leakage identified in the study are probably conservative.

Part of the leakage problem lies in poor standards for installers as the building code does not require specific sealing measures. The contractor does not always check on the quality of the subtrades work. At least a visual inspection of the installation should be done. All of the serious errors observed were direct and obvious. Any inspection of the crawlspace would have noted the errors.

A visual inspection is made easier by noting that errors tend to occur with specific components:
- 90° elbows can fall apart;
- seams at Y-joints may be ripped;
- obvious dirt on fibreglass duct insulation is a sign of air leakage;
- furnace filter slots are usually poorly sealed;
- the ends of flexible ducts are often poorly sealed;
- the longevity of duct tape is questionable;
- duct tape is inadequate for sealing butterfly or finger joints where a round duct is butted into a square plenum. For this application, a commercial latex sealant designed for heating applications is needed.



It is cost effective to include duct repair in residential retrofit programs, such as utility-sponsored weatherization. Code requirements should articulate and enforce duct installation standards for any new housing that includes forced-air heating systems.

Other than visual inspection there are no useful diagnostic tools.

In many areas, it would be unheard of to locate heating ducts outside the heated building envelope, yet, in many milder climate areas, it is quite common. Especially in single storey bungalows the house design often makes it difficult to find a good place to locate ducts inside the building. What has been noted about ducts outside the heated envelope also applies to ventilation only ducting.

Steps to take to avoid problems:

1. in new construction, locate ducts inside the conditioned space;

2. inspect installations for obvious errors;

3. use sealant on duct joints and seams;

4. pay special attention to specific components (elbows, Y-joints, flexible duct, finger joints);

5. caulk and seal floor penetrations.

This item summarizes material the following papers presented at the ASHRAE Annual Meeting, Vancouver,B.C. June 1989

Effects of Ducted Forced-air Heating Systems on Residential Air Leakage and Heating Energy Use
L.A. Lambert, P.E.; D.H. Robison, P.E.

Evidence of Increased Levels of Space Heat Consumption and Air Leakage Associated with Forced Air Heating Systems in Houses in the Pacific Northwest.
D.S. Parker

Field Investigation of Residential Infiltration and Heating Duct Leakage
D.H. Robison, P.E.; L.A. Lambert, P.E.