New Technologies for Residential HVAC Ducts

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Executive Summary

There are many problems with residential duct systems as they are currently installed. It has been shown that they lose significant amounts of energy through leakage and conduction to their surroundings (Cummings et al. 1990, Davis 1993, Modera et al., 1991, Modera 1993, Modera and Jump 1995, Parker 1989, Parker 1993, Proctor et al. 1992, Treidler and Modera 1994). For electrical utilities this is of particular concern because the effects of this leakage and conduction are more pronounced during periods of peak electrical demand.

Unfortunately, the problems with duct systems are not widely recognized within the construction industry and there are no strong economic incentives to solve them. Duct system performance is not evaluated and HVAC contractors overcome duct system shortcomings by installing oversized equipment. Currently, most duct systems are installed with minimal insulation and by methods that give little thought to insuring proper sealing.

The lack of incentives for improved duct system performance has repressed innovation. With the exception of insulated plastic wireflex duct, residential duct systems are essentially unchanged since the 1920's. ucts with higher levels of insulation have recently become available bu duct fittings have seen no change. Fittings are uninsulated, have a large potential for leakage, and are difficult to install in a manner which will insure no leaks.

This report summarizes the potential for new technologies for ducts, duct fittings, and insulation. It begins with a review of what technology is currently in use or available and found that the only inexpensive ducts in production are insulated wireflex ducts, sheet metal ducts, fiberglass board ducts, and uninsulated plastic ducts. For duct fittings, the market was found to be dominated by sheet metal

fittings with some use of ductboard. Fittings that snap together were found for use with steel ducts but are too expensive for a residential setting. An uninsulated sheet metal duct which uses a rubber gasket was also found. Two companies are trying to develop plastic fittings, but their designs don't consider improving the method of attachment to wireflex duct.

A survey was conducted of California HVAC contractors to determine what methods they currently use, how concerned they are with sealing duct connections, and what fractions of their expenses go to duct materials and installation. It was found that insulated wireflex ducts and sheet metal fittings are used in almost all residential installations in California. Fiber board and sheet metal are used equally for plenums. It was found that there are basic misunderstandings about sealing duct connections. For example, gaskets were placed on registers in such a way that they would not prevent the register leaking air into the wall cavity. The use of duct tape to attach flexible duct was also a common practice even though it is common for duct tape to fall off after some time. The cost portion of the survey showed that HVAC equipment, duct materials, and duct installation are approximately equal parts of the contractors' costs.

Ideas are presented for new duct technologies that are foolproof to install, sufficiently insulated, and not prone to leakage. For ducts, the Gas Filled Panel (GFP) technology of Griffith et al. (1992) was FP ducts were developed and their qualities for manufacturing, ease of installation, compressibility, etc. were evaluated. A model was then made of the most promising design. Ideas for plenum fittings, attaching registers to boots, and attaching ducts to fittings were created and evaluated for their potential advantages. Several of the ideas for fittings are applicable to existing wireflex ducts and sheet metal fittings.

In order to be accepted, new designs would have to pass code requirements. The most difficult code requirement to pass economically is fire spread and smoke generation tests. The plastics currently used in buildings for windows and wall panels will not pass the stricter smoke generation criteria for duct materials.

Finally, we evaluated the major hurdle for acceptance of new technologies, economics. Analysis of initial costs for the GFP technology shows that it is more expensive than existing technology even before considering steps necessary to pass fire regulations. However, new fitting designs appear to be competitive with other options for improving ducts and offer simple payback times of no more than 6 years.

1.0 Introduction

Residential HVAC duct systems in California perform inadequately. Research has shown that installed duct systems have significant losses to their surroundings through both leakage and conduction (Cummings et al. 1990, Davis 1993, Modera et al., 1991, Modera 1993, Modera and Jump 1995, Parker 1989, Parker 1993, Proctor et al. 1992, Treidler and Modera 1994). For example, Modera et al. (1991) found that conduction losses averaged 23% of furnace output in California's mild climate. It was also found that the leakage of ducts was approximately 1 cm^2 of effective leakage area per m^2 of floor area. For a typical house with 140 m^2 (1500 ft^2) of floor area, this means the leakage in the duct system is equivalent to that from a 13 cm (5.25 inch) diameter hole.

The performance of duct systems is of particular interest to electrical utilities because research has shown that energy losses from ducts are disproportionately higher on days of peak electrical demand. Peak electrical demand in California occurs in the late afternoon on weekdays during heat waves. This is when cooling demand is high from commercial customers and more residential customers are using their air conditioners in the afternoon. On these days, duct performance is very low because most ducts are located in attics. Attics are at their highest temperatures and ducts therefore lose more energy to them by conduction. Also, the air sucked in by leaks in return ducts is hotter and increases the air temperature entering the cooling coil.

From a technical standpoint, the dismal performance of duct systems is a simple problem to correct. New connection methods, using snap-together fittings, would insure that installed ducts have negligible leakage. Increased levels of insulation would decrease conduction losses. However, this has not happened because residential HVAC contracting is a very competitive business where the only incentive is to keep first costs low. There are no standards for duct performance and consumers do not typically realize how poor duct system performance affects them. So HVAC contractors have tended to install poor duct systems and overcome their problems by oversizing the air conditioner. Since the consumer only considers air conditioner size, the oversizing convinces them they are getting a better system.

Because of the lack of incentives for improvement, ducts and duct fittings show few signs of innovation. Insulated wireflex duct is the one exception. It has lower labor and material costs than its competitors and has become the most commonly used duct in California. A glance at catalogues for HVAC fittings shows they are still made of sheet metal, just as they have been since the 1920's. We found residential duct fittings available in the United States which use gaskets or snap fittings to ensure a leak proof connection. One Swedish duct system was found which uses rubber gaskets to seal connections, but no consideration was given to insulation.

This project was divided into five primary tasks. First, we made a survey of existing and planned products for ducts and fittings. This included looking at products used in other applications as well as those being produced by duct manufacturers. To complement this review of existing products we conducted a phone survey of HVAC contractors to determine their methods of installation, costs, and materials used. We also asked about their opinions on some potential new duct technologies. Since little innovation had been found in either survey we worked on developing potential new designs for ducts and fittings. The ducts were assumed to be made of plastic and to compress more for shipping than curren products (i.e. flexduct), while the fittings were assumed to be of insulated plastic. The goal was a system which was sufficiently insulated, leakproof, and foolproof to install. Finally we considered the economic and code requirements which would have to be met by any new technologies.

2.0 Survey of Existing Technologies

To determine the range of existing technologies for ducts and fittings we used several methods. The Thomas Register was searched for duct products which emphasized ease of installation. The HVAC contractors who participated in our survey were asked if they used any unusual or exceptional products. Finally, contacts from industry and in the research community were asked about any products they had learned about.

Table 1 lists the insulation products we found while Table 2 lists the duct types we found. In both tables, names of some manufacturers are given. The list of manufacturers for insulated plastic wireflex ducts, sheet metal ducts, foam insulation, and glass fiber insulation are not complete. These products are made by many companies.

2.1 Survey of Duct and Insulation Products

Glass fiber insulated plastic wireflex ducts dominates the market in California. In many ways, it fits our requirements for new ducts. It has low material costs and is easier to install than its competeitors. No fittings are needed to go around corners because the duct bends and no time is spent on insulation because wireflex is insulated. In addition, wireflex compresses so well that all of the ducts for a typical house can be carried at once by one or two workers.

But wireflex is not an ideal product. At insulation levels higher than 23 $m^2\cdot°C/W$ (R-4 $hr\cdot ft^2\cdot°F/Btu$) it does not compress as easily. Ducts insulated to 23 $m^2\cdot°C/W$ will compress by a factor of 10 in length while ducts with twice as much insulation will compress by a factor of 7. The boxes for ducts insulated to 46 $m^2\cdot°C/W$ (R-8 $hr\cdot ft^2\cdot°F/Btu$) are 170% of the size used for R-4 insulated ducts. More importantly, no one has produced a foolproof method of easily attaching wireflex to fittings. All of the current methods, while simple to do in an open area, are potentially very difficult in an attic or crawlspace. This can lead to mistakes in installation by workers who are pressed for time. Other problems with wireflex are that its outer liner tears easily and the insulation can compress where the duct is supported. Finally, it is unclear how durable the plastics in insulated wireflex duct are. One contractor in the telephone survey described in Section 3.0 claimed that a significant portion of his business was replacing wireflex where the inner liner had disintegrated.

Among the technologies we found for ducts and duct insulation, there are three new technologies which have not been fully developed as potential alternatives for fiberglass insulation: gas filled panels (GFPs) for both ducts and insulation, the Haines system for ducts, and the “Ultimate R” for duct insulation. The other products listed have already benefitted from economies of scale and are not competitive with fiberglass insulation and wireflex ducts.

The Haines System for ducts would use a duct very similar to wireflex but with a foam as the insulation. Consequently, it offers little advantage over flex duct and would not change the performance of duct systems. The Ultimate R is a system of cardboard forms which are placed over duct systems which lay on joists in the attic. Cellulose is then sprayed over the duct to achieve an R-value of up to 39 ($hr \cdot ft^2 \cdot °F/Btu$) with little effort. It is of interest how much savings will result from such a high insulation level but the technology is only of use where there is adequate space, a rare situation in California houses.

GFP’s are the one new technology we found for ducts which could offer significant advantages over existing products and be used in all situations. Their advantages are: they can be designed as ducts rather than add on insulations, can be made to compress completely for shipping and can achieve a higher insulation level for a given thickness. If new building codes require higher levels of insulation, the additional compressibility of GFPs and the higher specific R-value could be of value for squeezing ducts into existing spaces. The questions which must be answered about GFP ducts are: how much higher performance would be obtained, how much would this higher performance cost, and how will safety and performance requirements be met?

2.2 Survey of Duct Fitting Products

Table 3 shows the types of fittings which we found in the marketplace or in development. There are two companies which are trying to produce plastic fittings that attach to insulated wireflex duct. In both cases, wireflex duct would still be attached to the new fittings just as it is presently attached to sheet metal fittings. The advantages of the fittings are: insulation is incorporated into their design, they are less likely to be bent or torn and they can’t leak along seams like sheet metal fittings. One of the plastic fittings, Flexmate, is designed to easily be mounted to joists. This could reduce the number of supports needed for the ductwork.

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