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## **Low Cost Interior Duct Systems for High Performance Homes in Hot Climates**

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# Low Cost Interior Duct Systems for High Performance Homes in Hot Climates

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## ABSTRACT

The advantages of well designed and constructed interior duct systems are numerous. Among these advantages is improved energy efficiency through the elimination of duct leakage to outside and the elimination of conductive heat gains/losses. Occupant comfort is improved because conditioned air that remains in the ducts after the mechanical system has reached the set point temperature is not being impacted by temperatures in the attic. This method eliminates hot/cold air blows at equipment startup. Interior duct systems result in improved indoor air quality due to elimination of duct leaks. The use of a passive return air strategy eliminates return air ducting in the attic. The elimination of this source of induced infiltration leads to improved indoor air quality (IAQ) and reduces material and labor costs. Opportunities are created due to a variation of different ceiling heights, dropped ceiling and soffits to accommodate the distribution system that improve aesthetics. Consequently this method is best suited to new construction when design choices can be significantly impacted. This measure will only present one opportunity to be implemented in the life cycle of the home but once implemented will last the life of the dwelling.

While the advantages of well designed and constructed interior duct systems are recognized, the implementation of this approach has not gained a significant market acceptance. Homes in hot climates are still typically designed and built with duct systems in the attic. This paper presents a cost effective method that was used by four builders in the Gainesville, FL area to construct interior ducts in over a dozen site built homes.

## Introduction

A significant body of literature exists to support the implementation of interior ducts (ducts located inside conditioned spaces) in energy efficient housing. An excellent literature review of the subject and demonstration of interior ducts for site built production housing in the Pacific Northwest is available (Lubliner et al. 2008). In this marine climate, simulations show that compared to base case leaky ducts, interior ducts can save between 9% and 28% in heating energy costs and between 8% and 17% in cooling energy costs (Hales & Baylon 2008). For manufactured housing in hot-humid climates, prototype homes with interior ducts have been built by two manufacturers, and experiments have been conducted to determine savings (Moyer et al. 2008). A cooling energy savings of 18% was determined in controlled experiments using a 1,600 sq. ft. HUD-code manufactured home research facility (the MHLab) at the Florida Solar Energy Center facilities in Cocoa, FL.

We conducted simulations to predict the savings from interior ducts using the EnergyGauge USA®(V2.8.02) software. Meeting expectations, the results vary depending on the

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base case scenario. For the modeled MHLab, which has a HERS index of 87, the simulations confirmed a measured savings of approximately 18% and a HERS reduction to 79. When the MHLab is artificially modified (by assuming better windows, slab on grade floor, Energy Star appliances, higher SEER HVAC equipment etc.) to a high performance home with a HERS Index of 64, moving the ducts inside the lab will result in a cooling energy savings of only 14% and a HERS Index reduction of 3 points to a HERS 61. The reason the HERS index changes much less in the latter case is due to the fact that the cooling loads are only about 14% of the annual load in the HERS 64 home. It is about 25% for the HERS 87 home. Both simulations assumed the measured duct leakage to outside of 50 CFM @ 25 pascals or only about 3% of the floor area for the ducts in the vented attic. The simulations also assumed zero leakage for the interior ducts. The energy benefits of moving ducts to conditioned space are still significant.

While the advantages of well designed and constructed interior duct systems are recognized, the implementation of this approach has not gained significant acceptance in the marketplace. Slab-on-grade homes that are prevalent in hot climates are still typically designed and built with duct systems in the attic due to low initial costs and ease of implementation. Previous attempts to construct interior ducts using modified trusses to create the duct chase have been costly and unpopular with production builders in hot-humid climates.

We have successfully designed and deployed a low cost, approximately \$0.40 / sq. ft. of floor area, interior duct system in several high performance homes constructed by two builders in the Gainesville, FL area. A cost analysis was performed (see chart below) to determine the initial costs associated with two approaches to achieving the goal of maintaining the ducts within the thermal envelope of the home. The cost using our method was \$1.14 sq/ft less than the spray foam applied to the underside of the roof sheathing even when the additional cost of a radiant barrier was considered, see Table 1. These homes have a HERS Index from <60 to -2, which exceeds zero energy. The approach is described below for the HERS -2 zero energy home (details for the home are online at <http://www.baihp.org/casestud/pdf/BAIHP-TWH-ZeroEnergy-02-10.pdf>).

**Table 1. Cost Analysis**

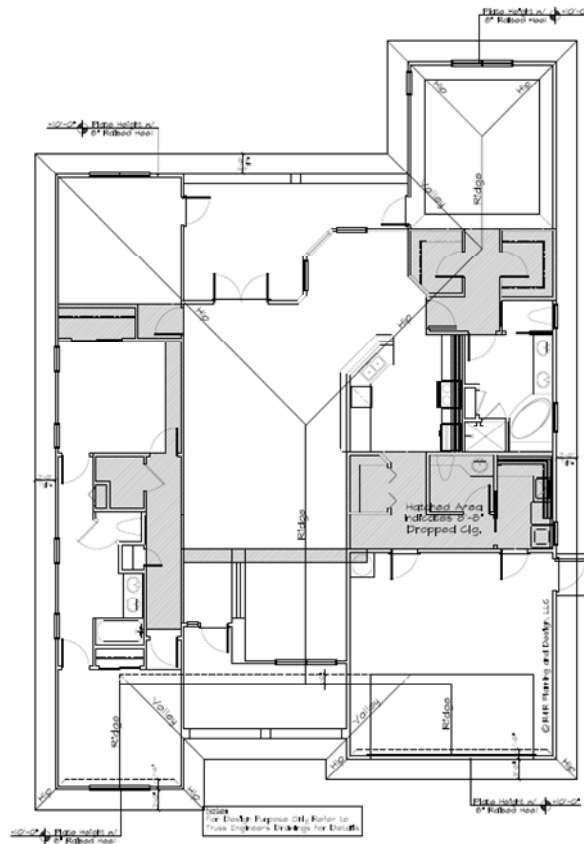
<b>Duct location</b>	<b>Unvented Attic</b>	<b>Conditioned Space</b>
<b>Floor Area (sq.ft.)</b>	2,250	2,250
<b>House Volume (cu.ft.)</b>	25,500	22,500
<b>Roof Pitch</b>	7/12	7/12
<b>Heat Transfer Area (sq.ft.)</b>	2,520	2,250
<b>R-Value</b>	21	38
<b>Insulation Cost</b>	\$5,625	\$1,688
<b>(\$/sq.ft. of floorArea)</b>	\$2.50	\$0.75
<b>DCS Cost (\$)</b>	N/A	<b>\$875</b>
<b>(\$/sq.ft. of floor Area)</b>	N/A	<b>\$0.39</b>
<b>Radiant Barrier Cost (\$)</b>	\$0	\$500
<b>Total Cost (\$)</b>	<b>\$5,625</b>	<b>\$3,063</b>
<b>(\$/sq.ft. of floor Area)</b>	<b>\$2.50</b>	<b>\$1.36</b>

Note: Above costs were obtained from a local insulation contractor on 4/28/10

## Implementation of Our Approach

This paper addresses interior duct from two different perspectives. The first relates to business practices and the second involves overcoming technical obstacles. First, the builder must make a clear and consistent commitment. Then this commitment must be communicated to all of the relevant trades. The first trade is the design professional. The best opportunity to minimize costs while ensuring an aesthetically pleasing outcome is during the preliminary schematic design phase. With information derived from the HVAC designers Manual J and D calculations, the designer can finalize plans which consider the size requirements and path of the distribution system. This results in less duct material being used due to preplanning and the elimination of many supply runs through the use of side wall supplies connected directly to the main trunk-line. Shaded areas in the plan below, as shown in Figure 1, denote areas where ceiling sheetrock are to be installed after the home is dried in, as shown in Figure 2.

**Figure 1. Floor Plan- Shaded Area Indicates Dropped Ceiling within Conditioned Space**



**Figure 2. Home at Dried in Stage of Construction**



After several design stage discussions that evaluated cost effective performance features, such as increased equipment efficiencies, improved windows, extended roof overhangs, etc., the development of the construction documents for this home encouraged the designer (and the second author of this paper) to incorporate the ducts within the conditioned space in future floor plans (Jenkins 2010). From a residential designer's perspective, incorporating the A/C chases within the space proved easy enough to be negligible in terms of complicating the design process. In fact, adding dropped soffits in strategic areas actually helped define the character of the interior spaces.

The next procedural step is to have a team meeting on site after the home has been "dried in". The primary goal and objective is to minimize the need to alter or redo work due to lack of knowledge of the requirements of an integrated systems approach. One of the builders led a meeting that provided him with the opportunity to clearly communicate that the home would be built differently compared to his normal practice of having ducts in the attic and the fact that this particular home will be a zero energy home. The builder also expressed his expectations regarding quality of workmanship and the importance of a collaborative effort in accomplishing his goals. Key trades represented in the meeting included the designer, sales/marketing professionals, and mechanical, insulation, plumbing, electrical, framing, sheet rockers and solar contractors. Questions raised in the discussion were quickly answered by the appropriate trade representative. Since the original prototype home was constructed, seven more homes have been built with ducts in the conditioned space. Additional team meetings were unnecessary.

The next step is to have the sheet rock installed as indicated in the design plan. By keeping the top plate of the non-load bearing interior walls  $\frac{3}{4}$ " from the bottom cord of the roof trusses, the drywall can be slipped through this space (Figure 3). This method eliminates the dead wood required in small spaces to accept the drywall and the waste of drywall that results from having to cut small pieces of the material. It also reduces labor costs but does require an additional visit by the drywall contractor.

**Figure 3. Drywall Installed Between Top Plate and Bottom of Roof Truss**



Then the supply ductwork is installed under the drywall after being fabricated and sealed on the ground, as shown in Figure 4. The main supply trunk lines and supply ducts are then hung from the drywall using 2" nylon strapping material. Hard ducts are used whenever possible.

**Figure 4. Ductwork Installation Under Drywall**



Hard duct



Flex duct

The picture below left in Figure 5 illustrates a method that we had the opportunity to improve. Typically, duct mechanics will cut a hole in the trunk line and insert a collar to accept the flex duct. The other end of the flex duct will be connected to the supply boot. This method results in a chase that is larger than necessary. By field fabricating a duct board box and affixing it directly to the trunk line, we reduced the size of the chase by almost a foot. This improved method provides greater design opportunities and reduces costs. The picture on the far right illustrates the duct system after framing was added to accept the final drywall.



**Figure 5. Improved Method for Duct Installation**



On the second and final visit of the drywall crew, the sheetrock is installed on the ductwork chase, along with the rest of the home as shown in Figure 6, left. The finished product is pictured at right.

**Figure 6. Sheetrock Installation**



A key to low costs in one-story homes is the elimination of all return duct work by using over the door transom returns from bedrooms. The transoms must be sized in a manner that ensures that rooms with doors that can be isolated from the main return are maintained under close to a neutral pressure with the home (<2.5 Pascals) when the mechanical system is operating. The returns were sized to be at least 1 ½ times larger than the rooms' cumulative supply duct areas. The supply ducts were sized by Manual D. Another benefit is that by eliminating all ducted returns, labor and material costs are reduced. In addition, the system's overall operating static pressure is reduced, allowing for less wear on the AH fan motor. This measure did not require any alteration to the method that this builder was employing and he has not received any noise or light related complaints in over 100 homes constructed this way with over the door transom returns. Pressure mapping during the final commissioning confirmed that this passive return air system is working as designed. The measured duct leakage to outside was also zero cfm as intended.



Illustrated in Figure 7, the air handler is also inside the conditioned space. It is located behind a door for aesthetics and noise reduction. A large return grill returns the air to the air handler, and an over the door transom is positioned on the right.

**Figure 7. Air Handler in Conditioned Space**



## **Conclusions**

Once a commitment has been made to implement this approach of installing an HVAC's duct system within the conditioned space and underneath the ceiling plane, and the necessary design work has been completed, there are only three steps to complete the goal. The first step is to install the dry wall as per plan to create the top of the chase. The second step is to build and install the duct system under the installed drywall. The final step is to install framing members around the ducts as needed to accept the final finished drywall.

As demonstrated, the many benefits associated with the installation of a HVAC duct system within the thermal envelope can be obtained for \$1.14 per sq/ft less than the same home employing an unvented attic with spray foam applied to the underside of the roof sheathing. The total cost of material and labor to implement this measure was \$875 for a 2,250 sq/ft home or less than \$.39 per sq/ft. and requires to no new materials or contractor skills than are currently available.

The successful implementation of this method of installation will be dependent on the commitment of the builder and willingness of the designer, construction managers and the subcontractors to understand and perform within the new scope of requirements. Along with site visits for maintaining quality control, final performance testing and commissioning should be conducted to ensure that the home is performing as intended. With effective communication and cooperation among the partners involved, this cost effective method will increase energy efficiency, improve comfort, improve IAQ and will last the life time of the home.

The builder home demonstrated in this paper recently received the first month's electric bills in March 2010. The home was then being used as a model home and has been performing better than expected with the first month's bill totaling \$-96 (that is negative). The zero energy home pictured in Figure 2 of this paper will be fully instrumented with data logging equipment

and monitored for a period no less than one year. Real time data will be available at [www.infomonitors/tw1](http://www.infomonitors/tw1).

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