Manufactured Housing Research Alliance

Improving Air Distribution System (ADS) Performance in Manufactured Homes

Final Report to HUD for Cooperative Agreement Contract Number H-21353CA

January 2, 2003

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I. Executive Summary

Virtually all manufactured housing units in the nation use forced air systems for heating and cooling distribution. The typical manufactured home air distribution system (ADS) wastes a significant amount of energy through leakage of conditioned air to the exterior. Reductions in this leakage have the potential to reduce a home's annual energy bills by up to 10%; making improving ADS performance the single most important strategy for saving energy in manufactured housing.

Building scientists were sent to 16 manufactured home plants to develop and demonstrate techniques to build tighter duct systems and to train production personnel in these techniques. The three key steps in the ADS construction process that enabled individual plants to reach the target leakage levels were: cutting accurate holes for registers in floors and for duct connections by using templates, securely and mechanically fastening ADS components rather than using tape alone, and covering seams with proven durable sealants such as mastic or appropriate tapes. The scientists adapted standard duct leakage test protocols for use in the plant environment in order to quantify performance improvements. The training of plant staff and often the plant's Design Approval Primary Inspection Agency (DAPIA) was designed to enable the plant to maintain production of the improved ADS systems.

The lessons learned while working with the 16 plants was widely distributed to the industry through articles in ***TECHNOLOGIES*** and ***Modern Home,*** seminars and symposia at major industry trade events, and posting on the MHRA web site.

As a result of this effort, the efficiency of the air distribution systems (ADS) constructed at 16 manufactured home plants whose parent companies produce over 85,000 homes per year was dramatically improved. The average rate of duct leakage to the outside was reduced to 3.7% from 13.6% observed in earlier studies of homes produced at some of these plants.

II. Introduction

Virtually all manufactured housing units in the nation use forced air systems for heating and cooling distribution. A 1996 study suggests that the air distribution system (ADS) in these homes wastes significant amounts of energy[1]. This study revealed that average energy losses due to ADS system leakage, conduction, and infiltration account for 40% of total heating energy use and 15% of total cooling energy use. These are huge numbers, representing a large and readily available opportunity to improve the energy performance of manufactured homes by improving ADS performance. Prior efforts have demonstrated that ADS losses can be cut to the practical limit of 5% to 11%[2]. Applied to the average manufactured home, such reductions would reduce annual energy bills by approximately 20%. Without question, improving ADS performance is the single most important strategy for saving energy in manufactured housing. A large component (at least half) of this potential improvement can be realized by reducing ADS leakage.

Decisions made in the manufactured home plant (henceforth simply referred to as the plant) significantly impact the performance of duct systems. Manufactured homes leave the plant with over 95% of the construction work complete. The homes are then moved to the building site, installed on a support system, connected to utilities, and minor finish work is completed on the interior. While the duct system performance can be compromised by poor site installation, steps taken in the plant can minimize site-related installation errors. That is, a program to minimize ADS leakage by targeting duct design and installation at the plant level alone can be responsible for improving total home energy efficiency by 10%.

To achieve this goal, a building scientist conducted a flexible program at each plant that combined diagnostics and testing together with plant staff training and education. Diagnostics and testing established a metric for duct system leakage; arguably the most important element of ADS performance improvements. The building scientist recommended improvements to the home's design, component materials, installation and assembly methods. The building scientist and plant staff identified plant-specific strategies for achieving the target performance level via an iterative testing and redesign process.

Staff training and education was conducted hand-in-hand with the diagnostics efforts. These efforts were intended to help plant staff fully recognize the value of the improvements recommended by the building scientist, develop and demonstrate simple methods to accomplish improvements, equip the plant (or its contractors) with the tools needed to monitor air distribution system leakage, and develop improved methods for air delivery. The educational efforts were designed to sustain the advances engineered during the testing and redesign efforts.

The overall objectives of the project were to dramatically improve the performance of air distribution systems in homes built in manufacturing plants across the nation and encourage other plants to emulate the improvements. The major tasks were as follows:

1. Identify and select candidate plants
2. Develop testing and evaluation methods and materials
3. Conduct plant diagnostics and evaluation
4. Train production and engineering staff

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[1] Alternative Energy Corporation, Air of Importance: A Study of Air Distribution Systems in Manufactured Homes, 1996

[2] Manufactured Homes: Heat Loss Assumptions and Calculations; Heat Loss Coefficient Tables; Prepared by Davis, Bob et. al. ECOTOPE, Seattle Washington, for the Bonneville Power Administration, Report No. DOE/BP-35738-3, March 1991

5. Document and disseminate results

III. Identification of Manufactured Home Plants

Of the 263 manufacturing facilities operating during the period this project was undertaken, a representative selection of 16 plants was selected for participation in this effort. Selection of plants was through a competitive process. Efforts were made to select a broad cross-section of companies, a mix of home types, and a geographic diversity of plant locations. Participating plants were required to make a financial contribution toward the project costs.

Table 1. Participating plants

Plant	City	State
Atlantic Homes	Henry, TN	TN
Castle Housing of Penn., Ltd.	Knox, PA	PA
Cavalier Homes, Inc.	Addison, AL	AL
Champion Home Builders	Lindsay, CA	CA
Champion Home Builders	Ridgeville, IN	IN
Chandeleur Homes, Inc	Boaz, AL	AL
Guerdon Enterprises, LLC	Boise, ID	ID
Homes of Legend, Inc.	Boaz, AL	AL
Horton Homes 1	Eatonton, GA	GA
Horton Homes 2	Eatonton, GA	GA
New Era Building Systems	Strattanville, PA	PA
Oakwood Homes	Etna Green, IN	IN
R-Anell Housing Group	Denver, NC	NC
Redman Homes	Sanford, NC	NC
Skyline Corp.	Goshen, IN	IN
Wick Building Systems, Inc.	Marshfield, WI	WI

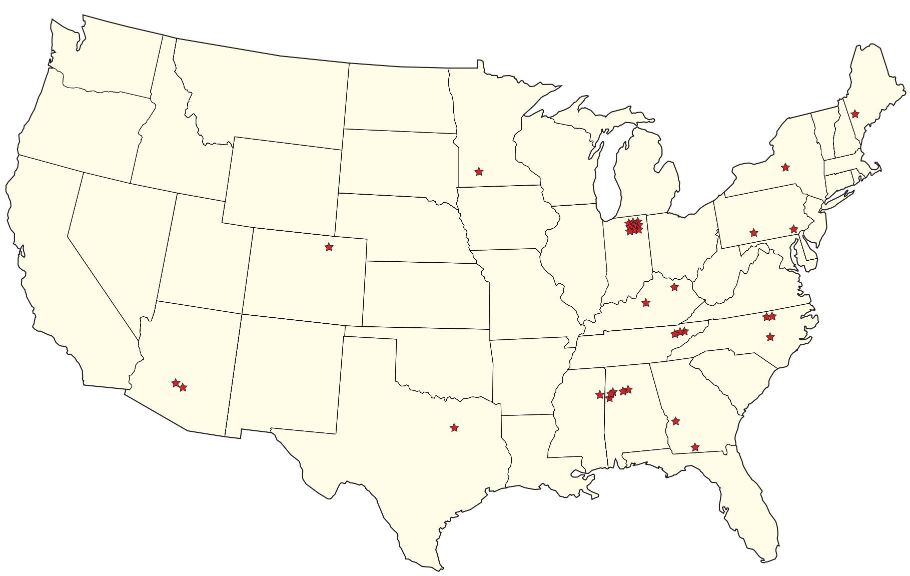

Figure 1. Plant locations

The target audience

One of the distinguishing characteristics of the manufactured housing industry is that a few companies build a large share of the homes. The industry consists of 69 companies operating 263 plants and, in 2001, producing 193,229 homes, or approximately 735 homes per plant. However, this is only part of the story. The top ten manufactured housing producers sold nearly 155,000 homes in 2001, representing 80.1% of total industry shipments.[3]

Each manufacturer has a network of plants that are typically distributed across the major housing markets. Technologies that are successful in one plant are routinely transferred to sister plants operating under the same management. All of these companies have centralized engineering that act as a conduit for technology exchanges.

By involving many of the largest companies as well as several other smaller operations in this project, tens of thousands of homes per year are directly impacted by this effort. The plants selected were drawn from manufacturers representing approximately 45% of the total manufactured home shipments, or approximately 85,000 homes in 2001 as shown in Table 2.

An additional benefit of this project is that a number of the participating manufacturers build both HUD-code and modular homes within the same plant. Often times air distribution systems are included in the in-plant construction of the modular homes (in modular homes, ducts and heating equipment are not required to be completed in the plant as they are in HUD-code homes). In every observed case where modular homes included an in-plant duct system, improvements made to the HUD-code home air distribution systems were transferred to the modular homes as well.

Table 2. Production of participating manufacturers in 2001[4]

Manufacturer	HUD-code homes produced‡	Share of shipments
Champion Enterprises, Inc.	36,495	19.1%
Oakwood Homes Corporation	18,678	9.6%
Cavalier Homes, Inc.	12,669	6.6%
Skyline Corp.	10,148	5.3%
Horton Homes	5,288	2.7%
Wick Building Systems, Inc.	1,339	0.7%
New Era Building Systems / Castle Housing of Pennsylvania, Ltd.	910	0.5%
Guerdon Enterprises, LLC	*	*
R-Anell Housing Group	*	*
Total	**85,527**	**44.3%**

‡ Figures exclude modular production
* Independent companies producing less than 750 units (0.4% market share) in 2001

IV. Testing and Evaluation Method and Materials

The diagnostic, testing, and evaluation component of the project brought building scientists in direct contact with plant personnel. Together, they identified factors that impact air distribution system performance, such as duct layout, sealing methods, and assembly procedures and measured the duct leakage in typical home designs produced by each plant. Working cooperatively, the scientists and plant staff, together with product vendors, made a progressive series of changes in the air distribution

[3] Manufactured Home Merchandiser, June 2002

[4] Manufactured Home Merchandiser, June 2002

systems. The team periodically assessed performance improvement. The process continued until there was consensus that an optimal performance level had been achieved that could be sustained by plant staff alone without involvement of the building scientist.

A common index for duct leakage is cubic feet per minute of air leaking from a duct experiencing a 25 Pascal pressure, divided by the total interior floor area of the home, expressed as a percentage. (Indices using the air handler flow rate are not practical in a manufactured housing plant where the cooling plant and air handler flow rate is not known until site installation.) "Total" duct leakage is a straightforward measurement that includes air leaks to the outside and air leaks back into the conditioned space. However, it is only duct leakage to the outside that is of concern; as only the energy used to heat or cool this air is lost. Duct leakage to the outside can only be measured in a home that is sufficiently complete to contain pressure provided by a blower door apparatus; this can be a single section home, a home pulled together in a plant or retail center or a completely installed home. In the plant environment, only the total duct leakage can be measured; outdoor duct leakage can only be estimated. Field measurements of total and outside duct leakage can be used to establish a ratio of outside to total duct leakage that should be consistent for a plant, which is used to estimate leakage to the outside from measurements taken in the plant.

The equipment used for measuring duct leakage was from The Energy Conservatory, makers of the Minneapolis Duct Blaster and Blower Door. Testing was conducted in accordance with the testing equipment manufacturer's operation manual and test protocols[5]. This equipment and protocol permits quick and accurate measurements of total duct leakage in the plant environment.

Previous studies have measured ADS leakage to the outside from as low as 2% of floor area to as high as 50%, with averages ranging from 12% to 17%[6]. A target leakage rate of 5% was established based on the practical limit that a typical plant could achieve and maintain. A "stretch" goal of 3% was set if the 5% target was easily met. The use of these targets was supported by the success of the Pacific Northwest Manufactured Housing Acquisition Program and other incidental efforts to achieve these levels[7].

Several key practices were important to conducting fast, simple and accurate total duct leakage tests amidst active factory production:

- All equipment was contained and highly organized in a single rolling "luggage" bag. Contents included duct testing apparatus, hoses, tapes, extension cords, hand and power tools and educational props. Key items like multi-plugs prevented conflict with production staff over limited electrical outlets.
- Duct testing was conducted using the testing equipment manufacturer's protocol[8].
- Duct testing apparatus was left in a "plug-and-play" configuration; hoses and power cords remained connected while moving between different floors for testing.

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[5] Minneapolis Blower Door Operational Manual for Model 3 and Model 4 Systems January 2001, and Minneapolis Duct Blaster Operation Manual March 1994, The Energy Conservatory 2801 21st Ave. S., Suite 160 Minneapolis, MN 55407, www.energyconservatory.com

[6] Alternative Energy Corporation, Air of Importance: A Study of Air Distribution Systems in Manufactured Homes, 1996; MHRA Moisture Study

[7] Field Measurements of the Heating Efficiency of Electric Forced-Air Furnaces in Six Manufactured Homes, Davis, B., and D. Baylon Prepared for the Bonneville Power Administration for the Manufactured Housing Acquisition Program, Contract No. DE-AM79-91BP13330, 1994

[8] Minneapolis Blower Door Operational Manual

- Floors with easy access to ducts were more often tested. Floors with air handlers were often tested because they were easily accessed; floors without air handlers were sometimes not tested unless the floors had the majority of the supply terminations. It was assumed that this gave conservative results as the air handler is typically a problem leakage site.
- In homes with low leakage rates, an in-line supply might be used as a location to connect the test fan to the duct on a home without an air handler. Connecting the test equipment to the crossover dropout collar was rarely done as it was the most time consuming and dangerous method for both equipment and testers.
- Whenever possible, the air handler blower was removed to provide a conveniently sized hole into the duct that accepted the duct testing fan and to eliminate errors from air handler cabinet leakage.
- Foam rubber plugs (sealed on two sides with mastic) were pre-made to fit common supply terminations and trunk dimensions in order to quickly seal these for duct leakage testing.
- Production activity rarely prevented testing from going forward. For example, if wallboard was stacked on one or more supplies such that they could not be sealed with tape, they were assumed to be sufficiently sealed and the test continued.
- A 50% minimum ratio of duct leakage to the outside to total duct leakage was assumed. If field data showed a higher ratio then that was used. If field data was inconsistent, than the highest ratio was used.

It was hypothesized that improvements to three key steps in the ADS construction process would allow individual plants to reach the target leakage levels. These were:

- *Cut accurate holes.* Use a template for cutting holes in floor sheathing and ducts rather than making freehand cuts. Even small cutting errors can create large leaks or lead to wasted time patching gaps. Making an accurate hole will reduce or eliminate the need for excessive sealing.
- *Fasten components mechanically.* Components should be rigidly connected; a common cause of complaints and high-energy bills is large leaks from failed or ineffective connections. For metal ducts, use durable fittings and sheet metal screws. For glass-fiberboard ducts, use folded tabs for fittings and connect trunk sections using suitable tape and staples; strap trunks securely to floor joists to prevent movement of trunk sections. Tape alone is not an adequate fastening system. Connect flexible ducts with suitable tape, straps, and for vertical crossover duct connections, screws as well.
- *Cover seams with proven durable sealants.* Mastics offer superior sealing performance over tapes - particularly on metal ducts – and have been shown to be durable and long lasting. Appropriate tapes are effective on fiberboard connections provided the components are rigidly fastened. Tapes must be used according to manufacturer's instructions, which may require the use of a solvent to remove oil from metal ducts prior to applying tape, and the use of a squeegee tool for applying tape to fiberboard ducts.

While all connections are important, researchers expected potential gains to be realized by correcting the following four problem areas:

- *Furnace plate.* Leaky connections at the furnace boot, where pressure differences are the highest, can exact the largest performance penalties.
- *Crossover duct collar.* The connection between the internal ducts and the crossover duct must be made with a durable mechanical connection. A less than secure and tight connection at a

location that is exposed to outside conditions is a recipe for disaster. Designing a nearly foolproof connection is critical as quality is difficult to monitor in the field.

- *In-line register risers.* By far the most common type of connection, in-line register connections are prone to poor installation practices such as freehand cutting of the trunk opening to receive the boot.
- *Inappropriate use of tape for sealing connections.* Not all tapes are up to the task of permanently sealing ducts, particularly metal ducts and inside of the duct. With some product types, significant leaks may develop after a few months as the tape exceeds its useful life. Tapes need to be applied according to manufacturer's instructions.

V. Manufactured Home Plant Diagnostics and Evaluation

At each of the 16 plants visited, a professional diagnostician and ADS expert made observations and conducted a series of tests and demonstrations to identify obvious flaws and gauge the performance of current ADS design and installation practices. The results of this preliminary analysis were shared with the plant management, design, quality control, production and purchasing teams along with Design Approval Primary Inspection Agency (DAPIA) and In-Plant Primary Inspection Agency (IPIA) representatives. A group redesign process was used to prioritize the deficiencies and to develop recommendations for their resolution.

Plant staff then implemented the recommendations, potentially combining alternative design strategies, changing plant construction techniques and/or specifying different materials. Changes included specifying different sized trunk ducts, different trunk connectors, different assembly procedures and alternative sealants. Incorporation of these changes often required obtaining approval from vendors, drafting and submitting to the DAPIA for approval, modifying construction drawings, exhausting old inventories and obtaining new materials. Thus the evaluation/redesign process was often drawn out before the target level of performance was reached. Changes were shared with all plant production staff through training.

The diagnostic and redesign process followed three steps for each plant:

1. In advance of the visit, the plant manager or designated plant contact received a copy of the MHRA publication ***Manufactured Housing Duct Systems: Guide to Best Practices***.
2. The plant representative and the building scientist reviewed logistics and the plant's current practices with respect to heating equipment and duct system specification.
3. Sample materials were shipped to the plant for use prior to, and during, the building scientist's visit. The materials included different types of duct sealant, sill plate gaskets, and plant-installed non-porous marriage line gaskets.

The building scientist conducted a three to four day visit to the plant, during which the following steps were followed:

1. **Plant staff briefing.** Inspected the plant and met with key plant staff (plant manager, quality control, production manager, engineering staff, and key station supervisors) to discuss the objectives and agenda for the visit and to answer questions.
2. **Initial testing.** Ducts were tested for air tightness using a calibrated duct leakage testing system to establish a baseline and, if possible, a demonstration was conducted to illustrate leakage sites by pressurizing an exposed duct system with smoke. Duct leakage tests were conducted on a set-up home to provide a method to estimate outside leakage from total leakage values measured in the plant. Often the plants had implemented ADS

improvement measures based on conversations with, and materials provided by, MHRA prior to the plant visit.

3. **Observe duct construction practices.** The building scientist observed all duct system strategies, materials, supplies, and tools and discussed alternatives with plant staff.
4. **Set targets.** All participants met to set performance targets and select improvement options.
5. **Begin new measures.** The building scientist trained station supervisors to implement new measures and evaluated the potential for different options.
6. **Testing.** The building scientist tested duct systems constructed using the improved methods and compared them to the initial tests to gauge improvement potential.
7. **Training.** The building scientist continued application of improvement strategies and conducted on-the-job training of plant personnel.
8. **Final testing.** The building scientist tested ADS leakage rates, with as many improvement measures implemented as possible.

Typical Problems

The majority of ADS leakage occurred in the following seven areas:

- *The section of duct directly beneath the air handler*. This site is where system pressures are greatest and the trunk is weakest. It often has a hole in the top of the trunk duct for the air handler and one in the bottom for the crossover. Personnel at several different work stations perform tasks at this site. Problems included: improper furnace plate depth, catastrophic failure of the trunk from stresses when the floor was flipped (poor mechanical connection), rapid failure of sealing tape (on metal), poorly made connections, misaligned trunks or sagging below the depth of the collar, crossover collar not secure and/or and not sealed.
- *Poorly sealed perpendicular trunk connections*. These connections are used to offset one or more supplies in an otherwise in-line supply design or to connect through-the-rim-joist crossovers. The trunks have a large hole where they are connected with an additional hole cut to provide access to the inside in an attempt to seal the connection, making this joint a relatively weak spot. Seals made solely with tape typically failed. The trunk may move during transportation or installation, breaking any potential seal if not securely (mechanically) attached to structural members. Some homes had as many as six of these types of connections.
- *Trunk connectors*. Although leakage from individual connections is relatively insignificant, the cumulative leakage from the many connectors in a single system is quite substantial. A perimeter system may have 15 supplies, each with three connections (trunk to metal collar, metal collar to flex duct, and flex duct to supply boot) for a total of 45 connections.
- *Vendor-supplied duct parts formed by bent and riveted metal.* These components often leaked significantly through their seams.
- *Inappropriate application of duct components*. For example, trunk connectors designed for flex duct were used on metal ducts resulting in a connection that was nearly impossible to seal.
- *Bottom board holes*. An intact bottom board redirects much of the air that leaks from the ducts back into the house. Leaky bottom boards allow this air to leak to the outside.

- *Through-the-rim-joist crossover connections*. Through-the-rim-joist crossover connections were sealed solely with fiberglass insulation. These connections required redesign with appropriate sealing to eliminate leaks.

Patching was rarely suggested as a primary improvement method. Only in the case where the trunk was not aligned with the furnace was a patching method offered as a leakage solution.

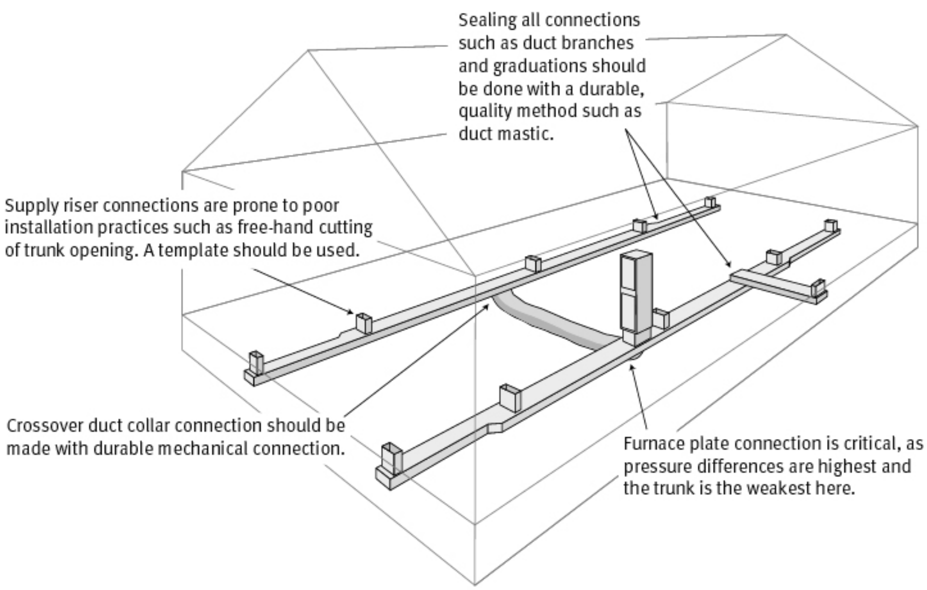

Figure 2. Typical ADS system recommendations

Evaluating the Data

This project was a diagnostic and educational effort aimed at improving air distribution efficiency and thereby reducing energy waste. It was not intended as a scientific comparison of existing ADS inefficiencies and their potential for improvement. The inefficiency of manufactured home air distribution systems has been well established and quantified in previous studies[9]. With this goal in mind, an emphasis was placed on improving ADS performance, rather than on measuring ADS efficiencies before and after implementation of remedial measures.

Measurements were taken on the first day of the building scientist's visit to the plant. At this point the plant staff had in many cases implemented a number of ADS improvements based on conversations with the building scientist and on the MHRA publication previously provided, **Manufactured Housing Duct Systems: *Guide to Best Practices***. As described earlier in this report, measurements were taken throughout the iterative redesign process. Even if all of the ADS improvements were implemented on the first day of the visit it would take several more days for the home construction to be completed, hence the building scientist was unable to test the completed home in the field on this visit. Improvements in the measured total leakage were noted and the final outside leakage was estimated. In some cases, a second visit to the plant afforded the opportunity to conduct leakage testing for set up homes with redesigned air distribution systems.

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[9] Alternative Energy Corporation, Air of Importance: A Study of Air Distribution Systems in Manufactured Homes, 1996

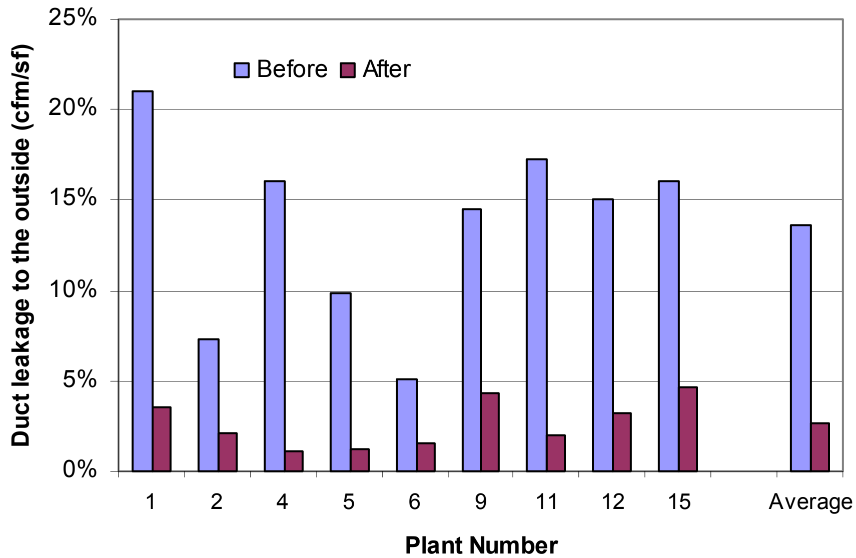
Table 3 shows average duct leakage levels achieved for a number of the plants. At least three systems were tested per plant before the building scientist judged that a consistent practice had been achieved. The average ADS leakage of all 59 homes tested for these plants upon completion of the redesign and testing process was 2.5%. This represents a more than fivefold improvement over previously cited ADS leakage rates.

Table 3. Leakage rates to the outside following implementation of ADS improvements

Plant number	No. homes tested	Leakage to the outside (cfm/sf floor area)		
		High	Low	Avg.
1	3	3.8%	3.3%	3.5%
2	3	2.3%	1.7%	2.1%
3	2	1.0%	1.0%	1.0%
4	4	1.5%	1.0%	1.1%
5	3	1.4%	1.1%	1.2%
6	4	2.6%	1.0%	1.6%
7	3	2.3%	2.1%	2.2%
8	6	5.2%	1.3%	2.1%
9	3	5.0%	3.3%	4.3%
10	5	3.0%	2.6%	2.8%
11	3	2.0%	2.0%	2.0%
12	6	5.0%	1.5%	3.2%
13	3	4.9%	0.6%	3.3%
14	2	4.5%	2.3%	3.4%
15	3	4.9%	4.5%	4.7%
16	6	5.7%	2.7%	3.7%

In nine plants, initial pre-improvement measurements were taken. Figure 3 compares the respective pre and post performance levels of eight plants in the study. The impressive improvements evidenced here demonstrate that the techniques brought to bear by the building scientist were capable of turning leaky duct systems into highly energy-efficient systems using the same production line and staff, merely by applying know-how and some inexpensive materials.

Figure 3. Pre-improvement and post-improvement leakage rates to the outside



VI. Production Staff Education and Training

In a parallel task to the testing and evaluation, key decision makers at each plant participated in a series of sessions intended to review good ADS practices and consider alternative designs to current methods that could increase overall operating efficiency. The MHRA publication, ***Manufactured Housing Duct Systems: Guide to Best Practices***, was the principal tool for the educational component of this project.

Participants in these workshops included designers, engineers, production supervisors, quality control personnel, and manufacturing crews. Product vendors, such as duct material suppliers, assisted in the educational component of the workshops. These sessions provided decision makers with crucial information needed to make design and manufacturing changes that improve energy performance; decisions whose impact they saw in the results of the performance assessment described in Section V.

The educational efforts included the following activities conducted with plant personnel:

- Identification of probable ADS problem sites through a visual assessment.
- Comparing plant's ADS design and construction to recommended practices described in ***Manufactured Housing Duct Systems: Guide to Best Practices.***
- Evaluating stresses to duct connections, such as flipping of floor system after ducts are installed.
- Smoke tests to demonstrate leakage sites.
- On-the-job training with production line workers, including training in the use of mastic, preferred hole cutting methods, and mechanical fastening of ducts.
- In-plant duct leakage tests of complete or partial ADS.

New ADS manufacturing and design procedures were incorporated into the plant's DAPIA-approved design manual. To facilitate retention of the new practices, examples of new procedures were left with the plant and occasionally mounted on plant walls near the station where the relevant procedure was performed. Some manufacturers took photographs and video tapes of procedures for use in training. Others incorporated the new procedures into their training manuals. Return visits to plants have found good retention of ADS improvements.

Persistence of these duct sealing measures can be inferred from increased volumes of mastic and other indicator products purchased from vendors, as well as the number of duct blasters purchased by manufacturers and DAPIAs[10]. Continued use of a duct blaster by the manufacturer or DAPIA is important to ensure continuation of the improved ADS performance. A follow-up study consisting of return visits to the plants and/or installed homes would be useful in verifying consistency of improved ADS system design and installation practices.

VII. Dissemination

Among the merits of this project were the impressive improvements in energy efficiency of homes produced by individual plants and, more importantly, the likelihood of lower energy bills for owners of new manufactured homes.

As discussed in Section II, techniques to improve the manufactured housing product are easily transferred from plant-to-plant and from manufacturer-to-manufacturer. Consistency of manufacturing systems and methods is a powerful driver in rapidly pushing innovations through the industry.

Precise estimates of expected energy savings are difficult to develop because the data of energy use is several years old. One DOE EIA study[11] noted that the average annual consumption per manufactured home for space heating and cooling was 44.5 million Btus of electricity (electric heat is used in about 76 percent of all manufactured homes). As discussed above, savings associated with reducing ADS leakage are likely to be about 10% of total energy use per home. Current home models are more efficient; however they are also considerably larger than those produced five years ago. Assuming that total energy consumption per home is similar, the 10% reduction would yield an energy savings of nearly 4.5 million Btus per year for every new home. If the ADS improvement techniques described in this report reach 85,000 homes (total production of all plants in 2001 of the companies implementing ADS improvements as part of this project), total avoided energy use would be running at a rate of approximately 380 billion Btus per year.

The benefits are magnified by the fact that manufactured homes are the most affordable, unsubsidized housing available in the nation. It is estimated that a full 85% of all new homes costing less that $75,000 are manufactured homes. This population group is the most sensitive to energy costs and the one that will most appreciate the major gains in energy efficiency resulting from this effort.

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[10] A Duct Blaster with accessory equipment costs $2,000 to $2,500.

[11] US Department of Energy, EIA, Household Consumption and Expenditures 1997: National Data

APPENDICES

A

INDIVIDUAL PLANT REPORTS

Duct leakage measurements for all plant reports are expressed as the number of cubic feet per minute of air leaking from the ducts (either total leakage or leakage to the outside) when they are pressurized to 25 pascals, divided by the overall square footage of the home, given as a percentage.

For example: 30 cubic feet per minute divided by 1,150 square foot floor area equals an estimated leakage of 2.6%.

Where the plant reports state a percentage leakage figure, these units are implied.

PLANT 1

Summary

The factory uses a fiberglass duct board trunk system with side-mounted branch takeoffs and R-4.2 flex duct branch connectors attached to standard floor boots. Initial duct leakage was measured at 138 CFM25, corresponding to a duct leakage of 21% cfm/ft^2 (~11% to the outside). After instruction from the building scientist and cross-training with staff from a sister plant, duct leakage levels of less than 4% were achieved. Duct leakage levels of less than 5% will be consistently achievable by this plant. Table 1 below demonstrates this with homes testing in the 3.3% to 3.8% leakage range after implementation of ADS improvements.

Test Results

Table 1: Results from duct leakage testing

Test home number	Home area (square feet)		Estimated leakage to the outside
1	1650		3.5%
2	1248		3.3%
3	1633		3.8%

ADS Efficiency Measures

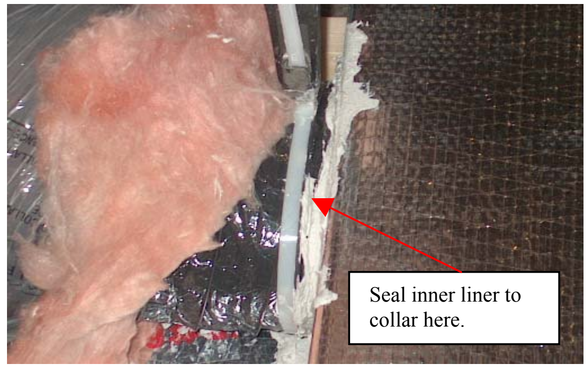
1. **Seal side mounted collars.** Fiberboard systems rely on tabs folded into the duct for mechanical fastening. These are less rigid than screw-type fastenings and increase the difficulty of sealing. Tapes designed for metal to fiberboard attachment may be used for sealing these collars; and some manufacturers have had good success with this method. The other method (practiced at this plant) is to apply enough tape to secure the collar at the top and bottom, and to apply a liberal layer of mastic completely covering the tape.

   The tape will support the duct during construction in the plant and the mastic will eventually cure to form a strong, durable seal. However, curing of the mastic could take several days depending on temperature and humidity conditions.

It is difficult to create a durable seal using tape or mastic alone.

Applying tape as a temporary seal then covering the seam and tape with mastic will result in a superior and durable seal.

2. **Secure and seal the flex duct to the side-mount collars.** The inner liner of the flex duct should be fastened and sealed. Tape may work in this location if a plastic strap is used over it; otherwise mastic makes a good seal here as well. The inner liner should first be placed on the collar and attached with a plastic strap to hold the liner in place.


Seal inner liner to collar here.

3. **Use care and attention to detail in crossover branch connections**. This is a critical area for leak prevention. Apply a good quantity of mastic between the mating surfaces of each trunk. Accurately cut the holes and use the metallic channel material shown to serve as a mechanical attachment. This material should be sealed with mastic along all exposed edges. Strap the two trunks securely to prevent any movement of the duct until the applied mastic has had sufficient time to cure. Installers should be made aware that the mating surfaces are relatively fragile and may open if any pressure is applied to either trunk prior to curing.


Metal channel is fit in place prior to covering with mastic.


Trunk-to-trunk connections are subject to damage during construction. Take care not to disturb.

4. **Seal in-line boots to the trunk and to the floor.** Apply mastic to in-line risers prior to installation with a caulk gun. Steps are: Cut a properly sized hole into the trunk, apply mastic, install riser, and fold up tabs to complete the sealing. Other risers are available that are easier to seal (less prone to being messy).

   All openings between the boot and the floor should be sealed. These small holes can add up to significant leakage.


Applying mastic to riser prior to installation. This riser style has a “hip” for mastic and is less messy than finger tabs.

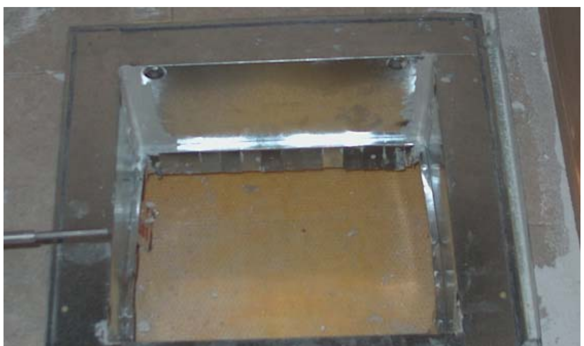

Riser is sealed to the trunk and to the floor.


Many small holes can add up to significant duct leakage.

Perimeter supplies need to be sealed to the floor to prevent leakage into the belly.

5. **Redesign the furnace plate/plenum to the duct board connection**. The furnace connection is often the leakiest site in the duct system. One option is to manufacture a metal channel designed to attach the inside of the duct board material and the plenum sidewall. The channel should be secured with screws and sealed with mastic.

   Other manufacturers are having success using liberal amounts of mastic applied by gloved hand to the folded finger tabs of the existing furnace plate.



Furnace plate prior to sealing to trunk with mastic.

Furnace plate after sealing to trunk with mastic.

6. **Use care and attention to detail in the crossover connection termination at the rim joist.** At the plant, the crossover is accomplished by extending a 6" flex connector through the marriage wall band joist in multiple locations. The connection between opposite halves of the home is done by the installer. This design leaves the essential duct sealing task to the installation crew. A faulty connection will directly impact ASD leakage.

Multiple through-the-rim 6” flex duct crossovers to be connected during home set up.

PLANT 2

Summary

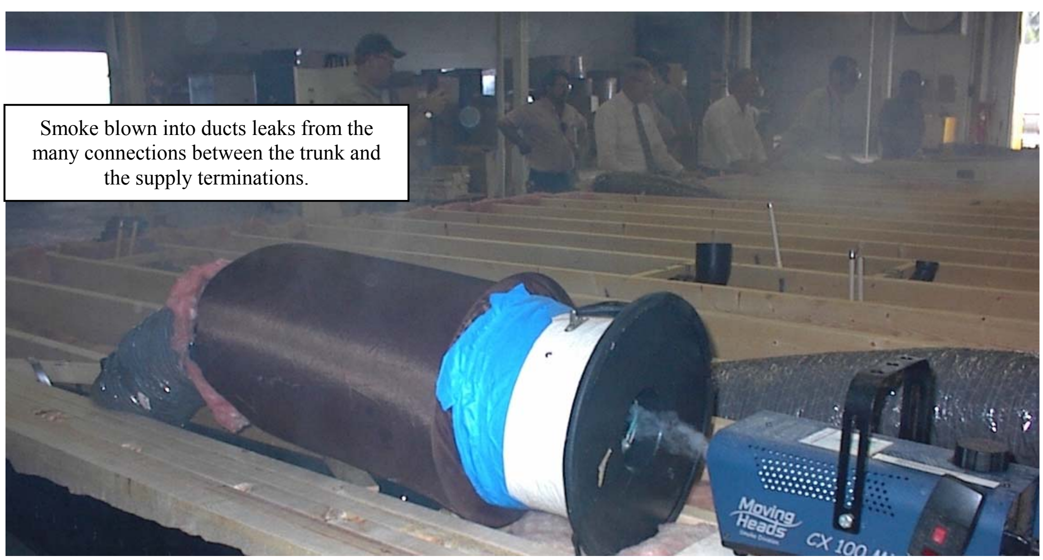
This plant produces double-section homes using 6-inch stud wall construction, cathedral ceilings, OSB sheathing for end-walls, and foam core sheathing for side-walls. Space conditioning is normally provided by a downdraft gas furnace. Conditioned air is distributed using a single graduated fiberboard trunk duct located on the furnace side with supply terminations on both sides of the home connected to the trunk with flexible duct. The use of a single trunk requires multiple crossovers of flexible duct under the marriage line to supply the "non-trunk" section.

Homes tested for this report were representative of models typically produced in this plant. Ducts were inspected and tested from floors in the production line and in a set-up home on the manufacturer's grounds. The results showed a range of duct leakage rates between 2.5% and 9% compared to the selected target leakage of 5%. A smoke test of the ducts showed leakage from many of the connections.

Test Results

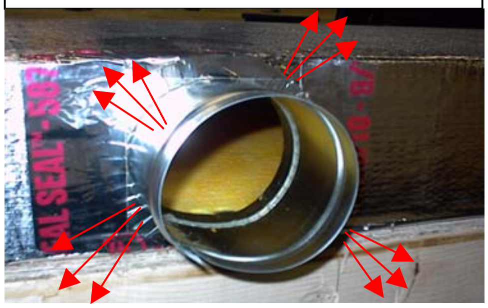
Table 1: Results from duct leakage testing

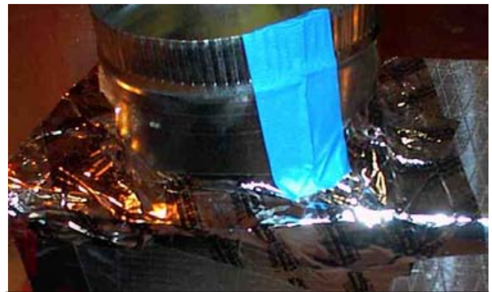
Test home number	Home area (square feet)	Estimated leakage to the outside
1	1,502	1.7%
2	1,392	2.2%
3	1,392	2.3%



Smoke blown into ducts leaks from the many connections between the trunk and the supply terminations.

Smoke is seen leaking under the collar flange.



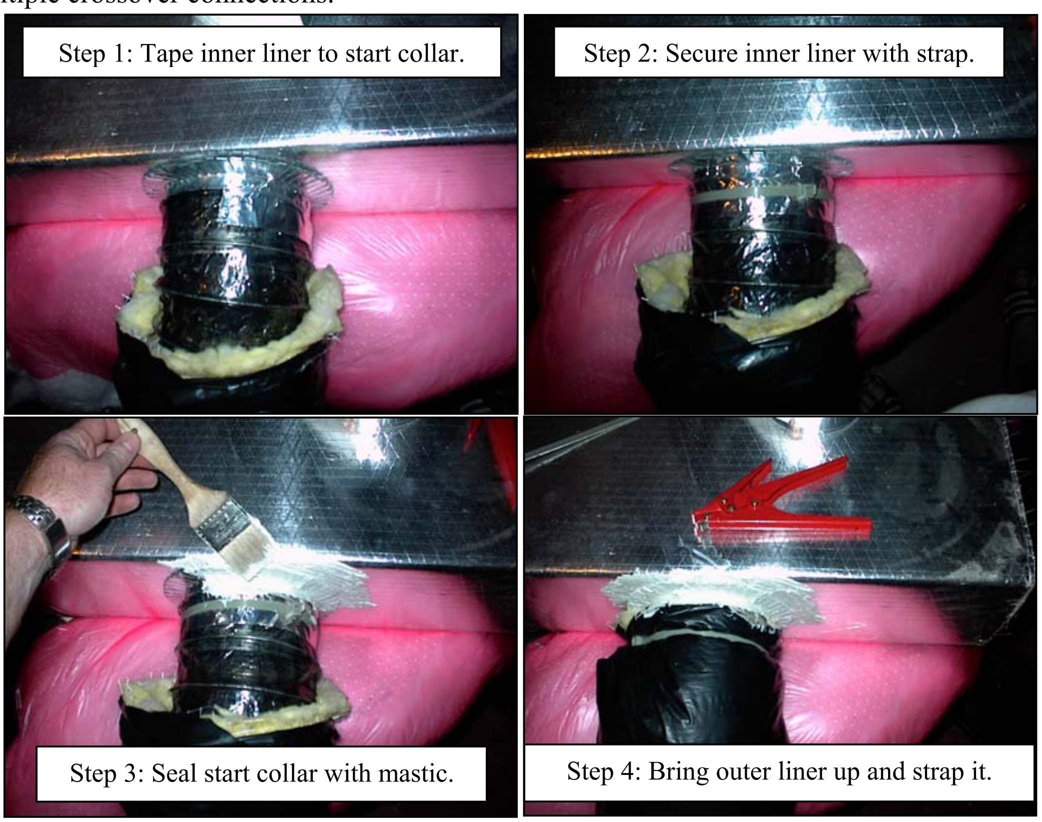


Round collars completely sealed with tape (above) or mastic (below) show no leakage.

ADS Efficiency Measures

1. **Seal start collars to trunk**. Start collars are known to leak, especially when freehand cut "round" holes are used. Use mastic or 100% tape coverage to seal start collars to the fiberboard.

2. **Seal flex duct to metal collars and boots with tape**. Straps alone will not seal flex duct to metal. Use appropriate tape to make this seal. Use tape and straps in conjunction with the multiple crossover connections.



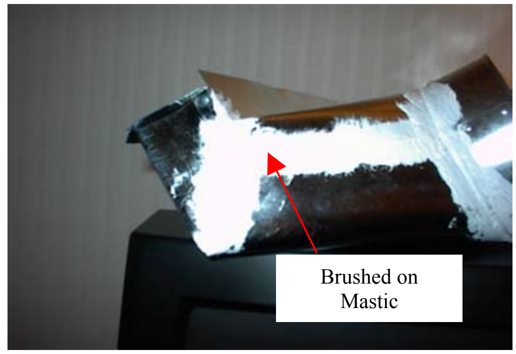
Step 1: Tape inner liner to start collar.

Step 2: Secure inner liner with strap.

Step 3: Seal start collar with mastic.

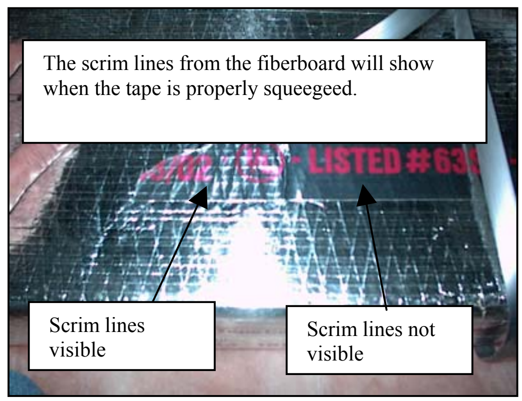
Step 4: Bring outer liner up and strap it.

3. **Seal boots with mastic**. Supply boots have gaps that will leak conditioned air into the floor system, which in turn can leak to the outside. Because there are six or more in each section, this can add up to significant leakage. Cover all the seams completely with tape or brushed-on mastic.



4. **Use a squeegee tool on taped joints in fiberboard ducts.** Moderate stress is applied to the trunk when it is moved from the overhead station where it is assembled to the floor below. Be sure taped seams are properly squeegeed to ensure maximum adhesion strength. Take care not to break any seams when moving and installing this duct into the floor.

Considerable tape is used to make the fiberboard connections; this is a weak mechanical connection.



The scrim lines from the fiberboard will show when the tape is properly squeegeed.

5. **Positioning of the trunk is important for a proper seal with the air handler**. The furnace plate connection is the most important connection to seal. In several homes the trunk was not secured snuggly to the floor joists resulting in a gap between the trunk opening and the furnace plate. Also, trunks were found that were not aligned exactly under the air handler. These are difficult repairs to make leak free. To minimize these incidents, develop an engineered plan for these situations rather than having the production staff make one up on the fly.

This trunk (near the air handler) will not reach the furnace plate for a proper leak free connection .

The trunk here missed the air handler site and needed repairs.

6. **Properly fasten and seal the air handler plate to the duct board**. This requires carefully marking the duct board using the furnace plate as a guide and carefully cutting the hole into the trunk. The manufacturer recommends using a duct board knife to make this cut. <u>This hole should not be oversized;</u> there is only 1/4 of lip available for sealing to the duct board. Tape will not seal the plate to duct board. Use mastic as shown.


Use appropriate depth plate. Mark fiberboard carefully.


Cut hole carefully using a fiberboard knife – make the hole snug!


Apply generous amount of mastic or other sealant to the hip of the furnace plate


Fold tabs into fiberboard duct and check for firm fit.

Additional mastic can be used to fill any remaining gaps in this connection. Mastic should not be used as a substitute for a poorly made cut. Mastic will not provide structural support – only air sealing. Mastic should be allowed to fully cure before use.

7. **For improved airflow, minimize excess length and curves in the flexible duct sections.**

PLANT 3

Summary

This plant uses a perimeter duct system with fiberboard trunk ducts (5-3/8” x 13-3/8”) and flexible supply ducts (2” x 12”). Crossover ducts are 3” x 13”. Results from the testing are summarized in the Table below. Only two units were available for testing. Both units easily met the 3% leakage to the outside target.

Test Results

Table 1: Results from duct leakage testing

Test home number	Home area (square feet)	Estimated leakage to the outside
1	1,728	<1.0%
2	1,538	<1.0%

ADS Efficiency Measures

Provided duct leakage testing orientation

- Provided instruction on how to use the duct blaster during two field tests (plant set ups)
- Illustrated common problem areas affecting duct tightness
- Provided guidance to minimize measurement error when pressure testing
- Provided guidance during duct leakage testing

PLANT 4

Summary

Four floors were tested in the plant to measure total duct leakage. The results from measured leakage are as shown in Table 1. All homes met the preferred duct leakage rate of 3%. Leakage to outside and total duct leakage were measured on one single section home. In this home 24% of the total leakage was attributable to the outside.

Test Results

Table 1: Results from duct leakage testing[1]

Test home number	Estimated leakage to the outside
1	~1.0%
2	~1.0%
3	~1.5%
4	~1.0%

ADS Efficiency measures

Below is an interior view of the marriage wall which shows the plant-installed marriage line gasket and the through-the-rim crossover duct.

[1] All homes have through-the-rim crossovers with substantial gaskets. It is anticipated that the crossover will add very little to the duct leakage.

Close up of crossover configuration. Note the use of mastic to air seal the trunk prior to the application of the gasket.

DAPIA installing calibrated duct fan at the preferred location to measure duct leakage. Removing the blower and measuring close to the ducts minimizes measurement errors.

DAPIA installing calibrated fan at a supply to measure duct leakage in a floor section that is without a furnace. Although this is a less preferred location to access the ducts, with the small leakage levels experienced, any error is negligible.

PLANT 5

Summary

Duct leakage was measured in three homes. The plant had engaged in air distribution sealing activities prior to this visit and was already using mastic for sealing. The total duct leakage measured 5% (estimated leakage to the outside of 2.5%). After completing training the total duct leakage was lowered to less than 1.5%. The current duct sealing practice will satisfy 5% leakage to the outside set as the project target with no further efforts. The current practice is likely achieve 3% leakage to the outside, however, some additional suggestions are presented here which will help the plant improve consistency and achieve a higher margin of safety in attaining this value.

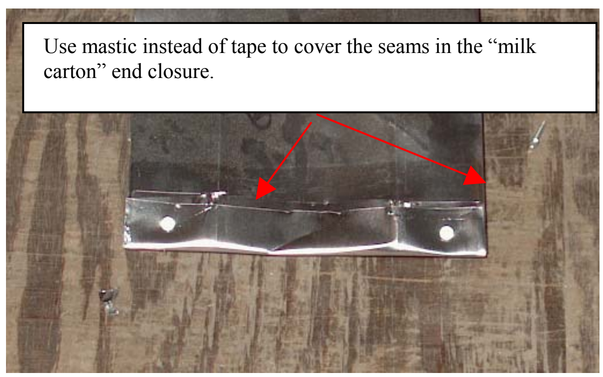
Test Results

Table 1: Results from duct leakage testing

Test home number	Home area (square feet)	Total leakage in the plant	Total leakage in the field	Leakage to the outside (of set-up home)
1	2,027	1.5%	4.2%	1.1%
2	2,027	1.8%	5.1%	1.1%
3	2,027	1.3%	5.0%	1.4%

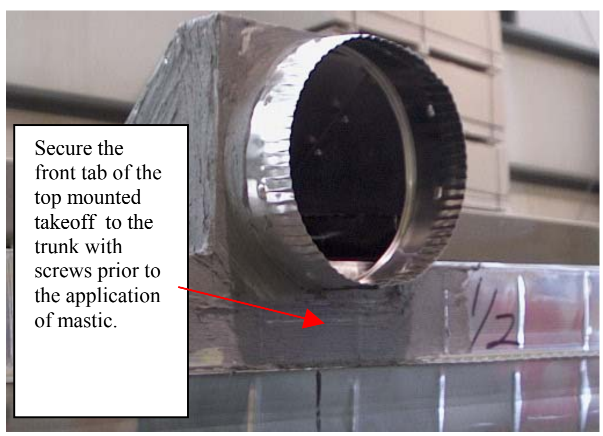
ADS Efficiency Measures

1. **Use brush on mastic along the seams in the end closure.**
   The trunk ends were capped by folding the end over. The technique was tested and found to be airtight, however, in other plants this technique has been shown to leak at the seams. Careful attention should be paid to preserve the integrity of the seams when folding the trunk.

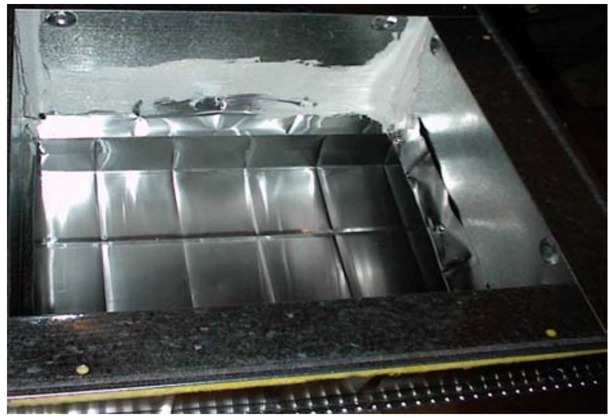


Use mastic instead of tape to cover the seams in the "milk carton" end closure.

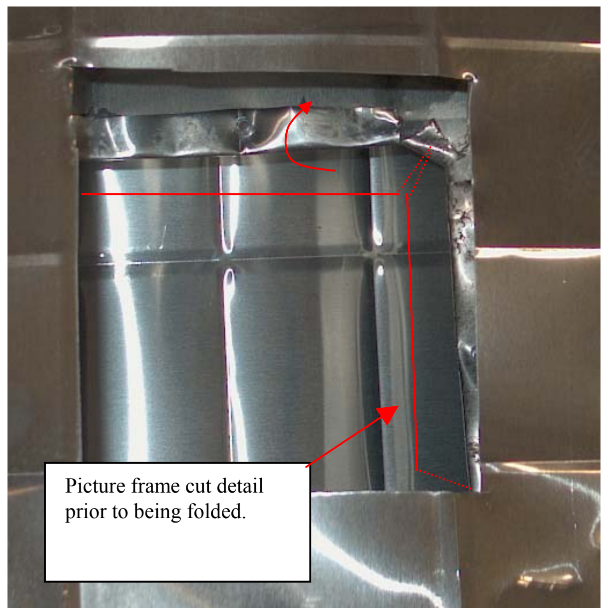
2. **Consider improving the top mount connection**
   Top mounted trunk takeoff connections being used are a good choice for air sealing. A more secure attachment to the trunk can be achieved by fastening the front tab onto the front of the trunk with screws prior to the application of mastic to all seams.



Secure the front tab of the top mounted takeoff to the trunk with screws prior to the application of mastic.



3. **Redesign furnace plate seal**.
   There is often little tolerance for locating the furnace base over the trunk. This is the worst leak site in the duct system. MHRA recommends making a "picture frame cut" into the trunk, screwing it into the furnace base and sealing with mastic. This will result in a more airtight and durable connection. (See the MHRA publication Duct Systems: Guide to best practices Figure 5.4 for a good illustration.) The furnace manufacturer should review this recommendation.



4. **Make picture frame connections in branch connections.**
   When making branch connections between two metal trunk sections, make a "picture frame"-shaped cut into the lower trunk and fold the bottom trunk flaps into the top trunk. This will result in a more air-tight connection. Screws should be used to provide the mechanical connection prior to applying mastic on the exposed seams.

PLANT 6

Summary

Two duct systems were tested that had been sealed using foil tape, the current plant practice. The first system tested was in a floor in the plant and the second system was in a completed single section home. These ducts showed total leakage of 9.2% (72 CFM25, total) and 8.4% (68 CFM25, total) respectively. The single section home was also tested for duct leakage to the outside. The results showed that 40 CFM25 outside or 60% of the duct system total leakage was to the outside.

Following the training of plant personnel, three more floors were tested in the plant to measure total duct leakage. Mastic was used in place of the foil tape. The resulting leakage rates are shown in Table 1 and represent a significant reduction in total duct leakage to the outside.

Test Results

Table 1: Results from duct leakage testing of four floors sealed with mastic

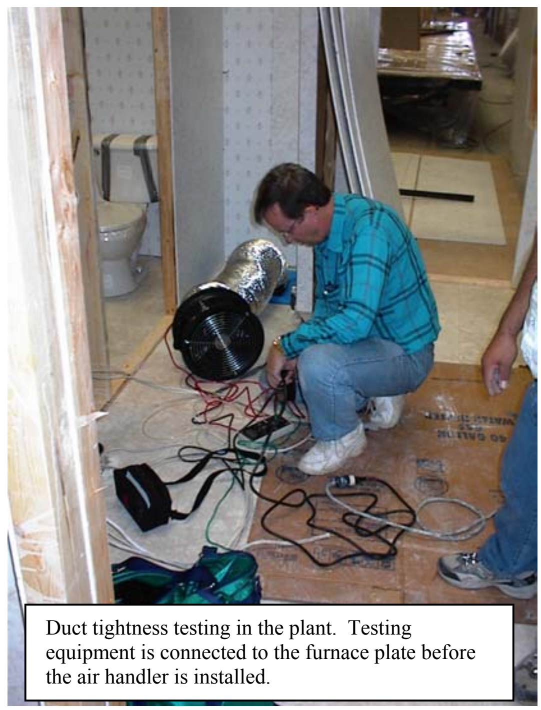
Test home number	Home area (square feet)	Estimated leakage to the outside
1	950	~1.8%
2	1,150	~1.0%
3	1,000	~1.1%
4	1,150	~2.6%

These homes are projected to meet the 3% target for duct leakage when properly set up in the field.

ADS Efficiency Measures

Blower door testing being conducted in a single section home outside the plant.

Duct tightness testing in the plant. This home section has no air handler unit so testing equipment is connected to a supply opening.



Duct tightness testing in the plant. Testing equipment is connected to the furnace plate before the air handler is installed.

Training plant personnel on the proper application of mastic to the duct system.

Furnace plate sealed with mastic.

PLANT 7

Summary

Three floors were tested where the ducts had been sealed with mastic. These three floors met the 3% duct leakage target, averaging 1.7% leakage to the outside.

Test Results

Table 1: Results from duct leakage testing

Test Home	Home area (square feet)	Estimated leakage to the outside[2]
1	1,590	2.3%
2	1,590	2.1%
3	1,590	2.2%

ADS Efficiency Measures

The duct system used was a standard in-floor rectangular shape residential-type fiberglass, fabricated in the facility from flat stock. Trunk ends and butt joints were secured with UL approved sealing tape. Aluminum supply risers and furnace connectors were installed to the main trunk after the trunk was secured to the floor and the floor attached to the chassis. Flexible circular insulated ducts were used in some locations to provide supply air to the perimeter area of the home. These flexible ducts, and their metal connectors to the trunk duct, were installed before the floor was secured to the chassis.

This facility uses a "loop" type duct system which incorporates two crossover points, one near each end of the floor, for double-wide homes. The crossovers are an in-floor type. The perimeter rim joist is notched and shimmed to allow space for the crossover. The face of one perimeter joist, around the perimeter of the crossover duct, is surfaced with two one-inch wide strips of fiberglass duct material to serve as a gasket when the two floors are mated in the field. Also, a sheet-metal insert sleeve approximately 18" long and sized to the inside dimensions of the duct is shipped with the home for installation into the crossover when the floors are mated. Personnel indicated there had been problems and complaints associated with the sheet-metal insert in the field. The building scientist noted that on some floors online, it was impossible to install the insert into the crossover. This problem was determined to be caused by under-sizing the hole in the rim joist, thus squeezing the crossover duct down where it entered the rim joist.

A mock-up of the crossover was built to measure leakage at that point. This was done for two reasons; f to evaluate the crossover for leakage since no mated double-section homes were available for duct leakage testing, and second, to evaluate an alternative crossover design. The mockup was built using two 30"-long pieces of 2x10, with a hole cut in each piece to accommodate two short 30" sections of crossover duct with the ends capped and sealed. The existing crossover design (metal insert sleeve and fiberglass gaskets) was tested and found to be virtually air-tight. Next, a new configuration was fabricated and tested. This configuration did not use a metal insert sleeve. The crossover ducts were stapled to the 2x edge of the hole in the simulated rim joist member using two wide-crown staples into both long dimensions of the crossover (total of 4 staples per crossover duct). Mastic was applied to seal each crossover duct to the back of the rim joist, and one inch "P"-shaped

[2] This estimate assumes that 50% of total duct leakage will manifest as leakage to the outside.

foam gasket material (same as used to seal the mating line) was applied to one rim joist only and used to seal at the rim joist mating surfaces. Test of this new design was also found to be essentially air-tight. The new design was deemed to represent a cost saving in material and labor and also be easier to use in the field.

PLANT 8

Summary

Four floors were tested. The average total leakage was less than 30 CFM25. These tests indicate excellent duct tightness. With proper crossover connections, these homes will exceed the duct leakage tightness target in the field. While duct leakage to the outside could not be established in the plant, outside leakage on average is about half of the total leakage values. If homes consistently satisfy the duct leakage requirement using *total* leakage values, then it is given that they will also pass the requirements for leakage to the outside.

Test Results

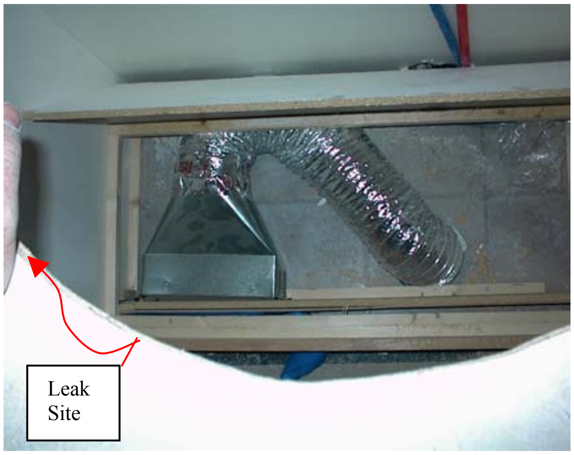
In-plant testing was conducted November 15 and 16, 2001 to measure the total duct leakage in a sample of homes. Tests were conducted using the factory cover of the crossover collar. (The "factory cover" *covers*, but does not *seal*, the crossover collar.) Although anticipated to contribute to the measured leakage, most of these homes still satisfied the targets for duct leakage.

Table 1. Results from duct leakage testing

Test home number	Home area (square feet)	Total leakage	Estimated duct leakage to the outside[3]
1	728	4.4%	2.2%
2	728	4.3%	2.2%
3	938	2.6%	1.3%
4[4]	938	Could not pressurize	Could not pressurize
5	756	3.2%	1.6%
6[5]	756	10.4%	5.2%

Note: The plant puts axles on its homes only near the end of construction. Thus for most of the production process, it is impossible to get under the home to properly seal the crossover collar for leakage testing. This can complicate in-plant duct testing procedures. The tests relied on the flex collar covering, which, although not designed as a seal, in most cases provided adequate sealing for the tests.

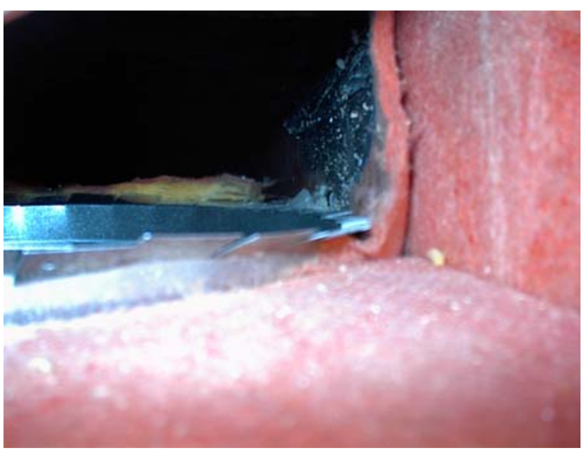
[3] This estimate assumes that 50% of total duct leakage will manifest as leakage to the outside.
[4] Ducts in home # 4 would not pressurize for the test. Remote visual inspection suggests that the crossover was uncovered.
[5] Higher than normal duct system leakage in home #6 was unresolved. However it is obvious from inspection that the crossover flex collar was originally located over a stabilizing bar of the frame and subsequently had been moved. It is likely that either the movement of the flex collar caused some leakage or that when the home was flipped, the fiberboard duct trunk system was partially crushed. Such damage has been observed at other manufacturers employing a similar process.



ADS Efficiency Measures

This is a view looking down through a bathroom sink cabinet to the toe-kick supply. This supply was not mounted flush to the cabinet and the cabinet fascia was cracked. By sealing this supply 14 cfm was added to the total duct leakage measurement. In theory this leak would all be eliminated under leakage to the outside test. To fix the problem, screws were used to mechanically fasten the connection and the duct test was repeated.

Low clearance under the homes in the plant limited the access to the underside of the homes. The status of the belly and crossover collar cannot be confirmed until the end of the construction process when the home is lifted onto axles.



A partial repair of the crossover collar may be the source of unresolved leakage in this duct. Prior to being relocated, the collar was located over a metal stabilizing bar welded to the frame.

PLANT 9

Summary

Opportunities exist for cost effective improvement in the distribution, durability and quality control in the observed air distribution system. This plant uses a metal trunk duct, typically with perimeter supplies and metal tape for sealing. The trunk is constructed offline except for the in-line registers. In-plant duct leakage tests had to be conducted in three sections due to the “off-set” air handler location.

Test Results

A single 1,512 sf home tested in the field measured 550 CFM25 (total duct leakage at a 25 Pascal test pressure) or 36.4%. This extremely high leakage rate was attributed to a flaw in the manufacturing process. After repair, the duct leakage was measured at 76 CFM25 leakage to the outside (5%).

The same installation flaw seen in the field was observed in three of four homes inspected in the plant. Leakage in a completed trunk with five perimeter supplies was measured at 12 CFM25 or less than 2 CFM25 per supply. Duct measurement in a completed home in the lot was made difficult by having no access into the ducts other than the supply outlets. For a 5-in-line, 2-perimeter 1,125 sf section the leakage measured was 64 CFM25 or 5.6%. Since this is total leakage as opposed to leakage to the outside, this leakage rate may be acceptable; however the typical outside leakage from the furnace (previously measured at 40 CFM25) and the crossover connection may degrade performance below acceptable levels when set up in the field.

After the construction defect was corrected, three floors were tested in the plant to measure total duct leakage. The results from measured leakage are as shown in Table 1. The homes did not meet the preferred target for duct leakage of 3% and are expected to barely meet the 5% target.

Table 1: Results from duct leakage testing of three floors[6]

Test home number	Estimated leakage to the outside
1	4.6%
2	3.3%
3	5.0%

Systems using perimeter supplies should be designed with superior durability because these connections are very difficult to isolate and repair. Air leakage test results were acceptable; however, the metal used to seal the ducts has been shown to fail unless the metal surfaces are first cleaned of residual oil. This is currently not being done.

ADS Efficiency Measures

The following deficiencies were noted in the plant and brought to the attention of the plant staff for correction.

1. It was suspected that the in-line supplies were not well sealed. Homes with more in-line supplies had higher measured duct leakage. Examination of several taped supplies also suggests that this could be a source of significant leakage.

[6] Test results are considered conservative as the ducts were tested without crossover connections.

In-line supply connector showing tape at trunk connection. Cutting a properly sized hole and applying mastic to the connector prior to insertion into the floor is the preferred method of insuring a good seal.

2. Furnace connection, distribution box. Secure the crossover duct splitter box to the furnace connector boot with screws when the boots are assembled off line. This is a critical leak area worthy of regular in-plant inspection.

   Redesign the furnace connection box without tabs. Such a redesign may <u>encourage</u> the use of screws which are sometimes being left out. Also be sure the optional plate is removed when it is unnecessary.

   The furnace gasket supplied by the furnace manufacturer seems to be excessively small. Be sure this gasket doesn't leak. Consider a larger gasket.

   The outdoor air ventilation duct is connected directly to the furnace. If this is not changed when the air conditioning A-coil is installed, ventilation air will not receive direct dehumidification which can result in poor humidity control.

3. In-Line Supplies. Use the correct in-line supply riser length to match the joist dimension or cut length to fit.

   Consider a better sealing method than tape which is slow and prone to failure.

   In-line supply risers with a screw down hip are preferable to those with finger tabs.

   Consider converting the in-line risers to short perimeter-type flex duct connections or use wider (4-inch) in-line risers for more accurate positioning.

   Investigate using spiral "zip saw" or other method to cut the trunk for the in-line supply risers and perhaps for cutting the perimeter takeoffs as well. Such a tool will make use of templates more practical.

4. Perimeter supplies. For the perimeter flex duct assembly, use mastic foil tape on the inner liner and a strap and cloth duct tape on the outer liner.

   Redesign the rectangular-to-round flex duct take-offs for the perimeter supplies with wider or single tabs. Larger tabs will leak less often and offer a larger target for screw fastening at this connection.

   Trim the vinyl flooring away from the perimeter supply.

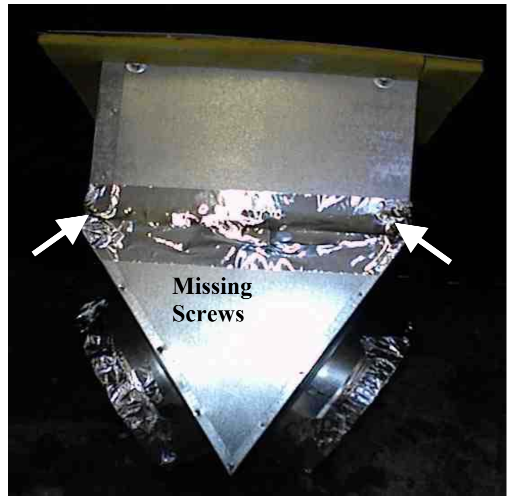
5. General recommendations. A significant portion of the duct leakage may be redirected into the home by sealing the perimeter of the belly material and carefully repairing any penetrations to the bottom board. This may be simpler than many of the other recommendations.

   Clean metal surfaces with a solvent before applying tape for improved durability.

   Investigate why walls often partially cover supply outlets and correct.

Detailed plant observations:

1. The metal “crossover duct splitter box” was not mechanically secured to the “furnace connector boot” in three of four inspected homes. This critical connection was held together with only one layer of foil tape. The crossover duct splitter box could become disconnected from the furnace connector boot due to the weight of the splitter box and crossover duct.. The crossover duct splitter box and furnace connector boot were pre-assembled off line and should have been secured with 4 screws when the furnace was installed. To avoid this oversight, these screws should be installed off line when these duct pieces are first assembled.



2. The in-line supply register risers have several shortcomings:
   The very narrow profile of the connector (less than 3”) leaves insufficient room for the hand and arm to reach in, cut the rectangular opening in the supply trunk, install the riser and tape the joint. Installed through the subfloor, these connectors take considerable time to install. Installation of two risers took two men approximately 30 minutes. The resulting connections have four times as much air leakage compared to the perimeter connectors.

   Twelve-inch long connectors being used are too tall for use with the 10” floor joists. The boots extended into the supply trunk blocking airflow and causing duct leakage. As installed, the in-line ducts inspected will significantly restrict supply airflow. Furthermore, the supply riser is not made square to the supply trunk, and in several instances scrap metal cut from the supply trunk was found still partially attached to the trunk further restricting airflow.

The supply register discharge opening in the floor was often partially blocked by interior walls that overlapped the hole or by poorly cut vinyl flooring.

One solution to these problems is to install wider (4-inch) in-line boots. Another option is to convert the in-line boots to short perimeter type flex duct connections.
Investigate using a zip spiral saw for a better method to cut the trunk for the in-line supplies.

3. Tabs: The furnace connection box and rectangular-to-round flex duct take-offs have numerous tabs that are bent over to mechanically fasten these joints. This task is time consuming and involves numerous sharp edges and unnecessary leakage sites. Often the tabs do not get bent over as intended.
   A single bendable flange is superior to many small tabs. Redesign this box without tabs.

   The tabs on the rectangular-to-round flex duct take-offs for the perimeter supplies are too small. Redesign these take-offs with wider or single flaps, which offer a larger target for screw fastening and allow less air leakage.

4. Use a square hole-cutting template that will allow perimeter take-offs to be quickly aligned, directly scored, and accurately cut into the supply trunk.

5. Un-insulated supply duct condensation: Un-insulated supply ducts in the floor system are prone to condensing moisture during air conditioning. Insulating metal supply ductwork reduces condensation, mold and rot potential inside the belly. Any moisture condensing in the floor system can get trapped in place by the bottom board. Specific recommendations follow:
   - Insulate all supply trunk ducts
   - Add a 4-6 inch insulation wrap on the exterior of crossover collars and in-line boots.

6. The perimeter flex duct assembly uses a strap on the inner liner and cloth duct tape on the outer liner. Instead, use mastic foil tape on the inner liner, and a strap and cloth duct tape on the outer liner.

7. The outdoor air ventilation duct is directly connected to the furnace. If this is not changed when the air conditioning A-coil is installed, ventilation air will not receive direct dehumidification, which has been known to result in poor humidity control.

8. Crossover ducts: Recommend using a minimum of R-6 (preferably R-8) crossover duct insulation. Also, use of insulated metal elbows will improve joint durability and significantly improve supply airflow.

9. Tape or cap off duct openings during assembly. This will facilitate testing and keep construction dust from entering the duct openings.

10. Redesign the furnace boot gasket. The gasket between the furnace and the furnace connection boot should be two or three times larger to assure proper sealing.

11. A significant portion of the duct leakage might be redirected back into the home by sealing the perimeter of the bottom board and carefully repairing any penetrations to the bottom board. Currently, air can just as easily leak outdoors as back into the house. If leaking air is directed back into the house, then duct leakage matters less. This may be simpler to accomplish than many other recommendations.

PLANT 10

Summary

Two floors were tested in the plant to measure total duct leakage. The results are shown in Table 1. Total duct leakage was measured at 6.3% and 6.7%. Approximately 45% of this was determined to leak to the outside, resulting in the homes barely meeting the preferred target for duct leakage of 3%. Greater attention to details of sealing connections can ensure meeting this target consistently.

Three additional homes were then set up in the plant lot and tested for duct leakage. Leakage to the outside on these homes was found consistently to fall just below the 3% target rate.

Test Results

Table 1: Results from duct leakage testing

Test home number	Home area (square feet)	Total leakage	Estimated leakage to the outside
1 (in plant)	1,512	6.3%	2.9%
2 (in plant)	1,458	6.7%	3.0%
3 (in field)	1,512	7.5%	2.9%
4 (in field)	1,458	7.8%	2.8%
5 (in field)	1,458	7.4%	2.6%

ADS Efficiency Measures

All air duct connections including the furnace connector, boots (whether prefabricated or produced at the factory), and ends, are sealed with mastic suitable for that purpose. Register boots are sealed with mastic at the duct and at the floor. All seams are sealed with mastic. Flex duct connections are completed as per the manufacturer's instructions and the connections sealed with mastic.

Ends of ducts are capped with a 2x6 block, covered with duct material and sealed with mastic.

Gaskets for through-the-floor crossover ducts are made of foam with a non-porous coating and a minimum diameter of 1-1/2".

PLANT 11

Summary

Three floors were tested in the plant to measure total duct leakage. The results are as shown in Table 1. The average total leakage was less than 50 CFM25, total. These tests indicate excellent duct tightness. With proper crossover connections, these homes will exceed the duct leakage tightness target in the field. While duct leakage to the outside could not be established in the plant, outside leakage on average is about half of the total leakage values. If homes consistently satisfy the duct leakage requirement using *total* leakage values, then it is given that they will also pass the requirements for leakage to the outside.

Test Results

Table 1. Results from duct leakage testing

Test home number	Home area (square feet)	Total leakage	Estimated leakage to the outside
1	1,760	3.8%	~2.0%
2	1,150	3.6%	~2.0%
3	1,170	4.1%	~2.0%

These homes all have total duct leakage levels less than 5% and are anticipated to meet the 3% target level when installed in the field and leakage to the outside can be measured.

ADS Efficiency Measures

Testing total duct leakage in-the-plant through available openings into the ducts: a supply termination on the floor decking (left) and the crossover collar underneath the home (right) can be used to measure low flows with little loss in accuracy. Total duct leakage can be used to estimate leakage to the outside when the home is set up.

Data from field tests show that in each of three field tested homes, less than 40% of total duct leakage leaks to the outside. Several of the ducts in these homes had furnace alignment problems that were repaired with tape. The ducts with mis-aligned furnaces had more leakage than others.

PLANT 12

Summary

This is an extensive facility with two production lines. Generally, the same type of construction is conducted on each line. Some homes are built with ducts in the floor and others with overhead ducts on each line. All of the homes tested in the plant were typically constructed models. The plant had recently invested considerable effort to reduce duct leakage. The success of this initiative is noted in the excellent performance of many duct systems.

Duct systems were inspected and tested from floors in each of the production lines. The resulting duct leakage to the outside was found generally to be between 3% and 5%. It is likely that the plant can bring duct leakage consistently below 3%.

Test Results

Table 1. Results from duct leakage testing

Test home number Line A	Home area (square feet)	Total leakage	Estimated leakage to the outside
1	1,570	4.3%	2.1%
2	1,570	3.5%	1.8%
3	1,570	2.9%	1.5%

Test home number Line B	Home area (square feet)	Total leakage	Estimated leakage to the outside*
1	1,570	8.3%	4.1%
2	1,570	10.1%	5.0%
3	1,570	8.9%	4.5%

ADS Efficiency Measures

Total duct leakage measured from six floors in the plant averaged 6.3% (total duct leakage/ floor area). A test of three additional homes indicates that less than 40% of this (2.5%) is estimated to leak to the outside.

In two floors with higher leakage rates, the furnace plate had not been positioned directly over the trunk and the resulting gap was bridged with folded metal and tape. This type of repair could account for the excess leakage in these homes.

Homes built without misalignment problems and taped repairs are projected to easily qualify for the 5% duct leakage target. With little additional measures, homes could consistently achieve the 3% duct leakage target.

1. **Maintain excellent duct tightening practices**. The plant is doing many things correctly with regards to duct sealing as part of their manufacturing process. Some examples are illustrated below:

Ducts are sealed prior to placement where access is easy.

Generous amounts of mastic cover all trunk seams.

Mastic is used to cover all take-off boot seams.

Mastic and fiberglass taped seams are allowed to cure before use.

2. **Maintain furnace plate and duct riser seal**. The furnace plate connection is arguably the most important connection to seal. The plant uses a "caulk and screw down" design for both the furnace plate connection and the straight risers. The trunk is not opened until after the connections are secure – resulting in a perfectly aligned hole.

Mastic is applied to the flange of the boot before it is screwed into the trunk.

PLANT 13

Summary

The plant has demonstrated the capability to produce homes that have duct leakage to the outside below 5% (two tested around 1%, and the third at 4.9%). Minor modifications in the installation process should enable the plant to achieve the 3% target consistently (the third unit had slight punctures in the crossover). These modifications will be included in subsequent plant quality control documents.

Testing Results

Field and plant testing and inspections were conducted on December 18 and 19 to verify that the plant is capable of consistently producing homes to these standards.

Table 1. Results from duct leakage testing

Test home number	Home area (square feet)	Estimated leakage to the outside
1	1,568	0.6%
2	1,680	1.3%
3	1,456	4.9%

* Duct leakage for test home #3 (tested in the field) was traced to staple punctures in the crossover duct. This was brought to the attention of the installer.

ADS Efficiency Measures

- Provided instruction on how to use the duct blaster during three field tests
- Illustrated common problem areas affecting duct tightness
- Provided guidance to minimize measurement error when pressure testing
- Reviewed plant manufacturing and installation process
    i. Ductwork is mastic sealed, transition crossover is flex duct
    ii. Flex used on duct crossover (installed by plant in manufacturing process)

PLANT 14

Summary

Two floors in the plant and two homes set up in the field were tested for duct leakage. The results from measured leakage (from the two homes set up in the field) showed an average of 2.5% leakage to the outside. These homes meet the preferred targets for duct leakage of 3%. However, the two homes tested in the plant showed a higher total duct leakage and have an estimated leakage to the outside of 4.4%. All of these homes achieved the target 5% duct leakage. Methods to improve duct sealing were demonstrated that could consistently result in less than 3% leakage for all the homes.

Test Results

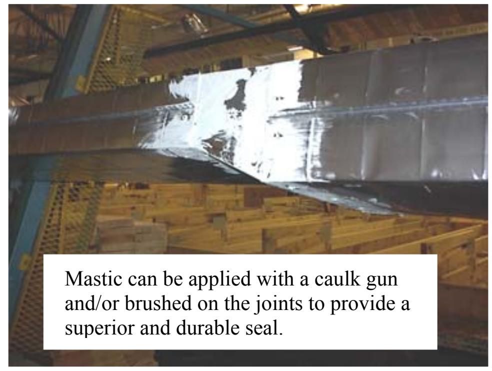
Table 1. Results from duct leakage testing

Test home number	Home area (square feet)	Estimated leakage to the outside
1 (in plant)	784	4.2%
2 (in plant)	896	4.5%
3 (in field)	1,740	2.3%
4 (in field)	2,128	2.6%

Note: In-plant test assumes 50% of total leakage is to the outside. Single floor test includes the air handler connections. Data from the two field tests shows the outside leakage fraction to be 37% of the total leakage. If this were consistent for the homes tested in the plant then the estimated duct leakage to the outside would be 3.1% and 3.3% for these homes.

ADS Efficiency Measures

1. **Trunk assembly**
   The plant pre-builds most of their duct systems and stores them on a rack prior to insertion into the floor system. A smoke test at this point revealed that several of the connections leaked – particularly the duct graduation connectors and the branch sections – even though the plant is already using a curable sealant on the connections. This is an ideal application for brushed-on mastic to provide superior sealing of the metal duct system. A more thorough application, using a brush, for critical connectors using the current sealant material should result in similar improvement.



Mastic can be applied with a caulk gun and/or brushed on the joints to provide a superior and durable seal.

2. **Perimeter Supply Assembly**
   The perimeter supplies are made using rigid metal collars, flex duct and metal boots. No leakage was observed in this part of the duct system.

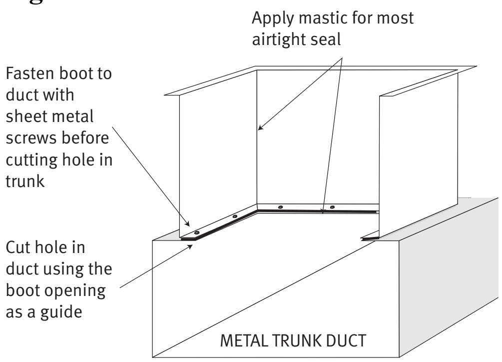
3. **Crossover System**
   The plant is using a 12" diameter flexible crossover attached to a metal collar from each section's main trunk. The set up checklist should stipulate specific requirements to make this a durable, airtight seal.

4. **Furnace Connection**
   The furnace base is potentially the worst leak site in the duct system. The plant is currently making a successful furnace seal by paying close attention to detail.

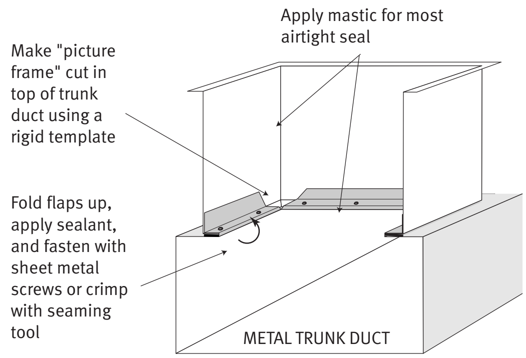
   The following are alternative recommendations for leak free furnace plate assembly: MHRA recommends making a "picture frame cut" into the trunk and screwing it into the side of the furnace base, and sealing with mastic. This is a superior performing and more durable connection. (See Figure 5.4 from MHRA publication ***Duct Systems: Guide to Best Practices*** for a good illustration.)

Fold trunk into furnace plate and fasten together with screws. Seams are then visible and more easily sealed.

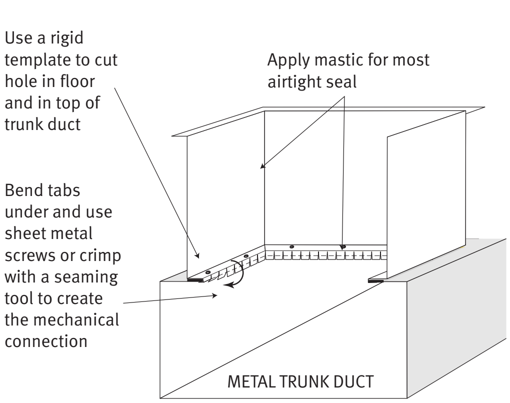
Figure 5.4 Furnace Boot Connections



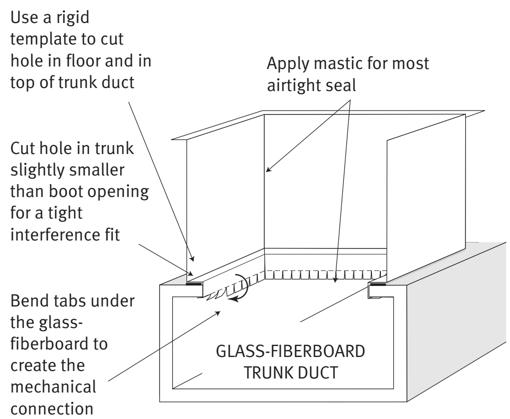
Screwed mechanical fastening



Flapped and screwed mechanical fastening



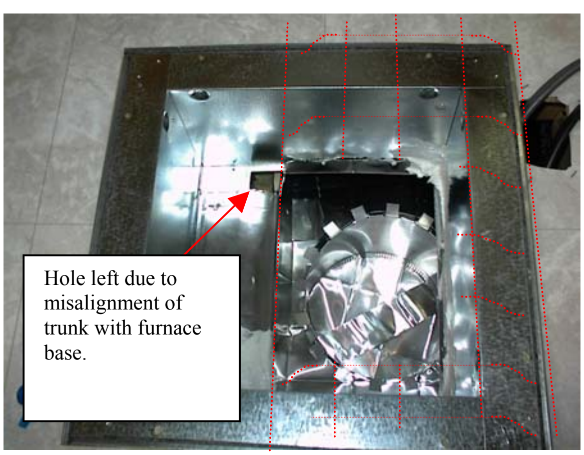
Tabbed and screwed mechanical fastening

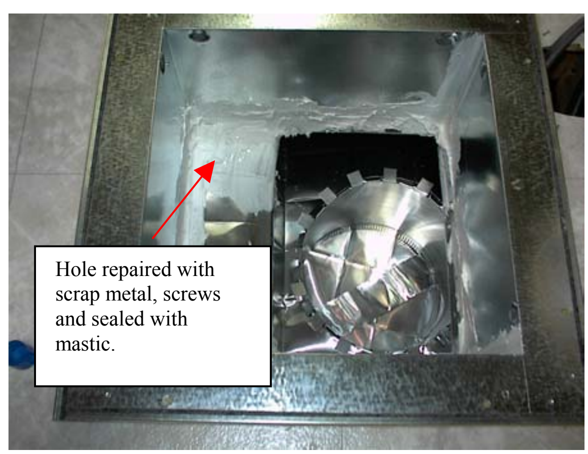


Tabbed mechanical fastening

The furnace manufacturer should review this recommendation.

In cases where the furnace plate misses the trunk, care needs to be taken to avoid creating hard to seal holes (as shown below). The chance of creating such difficult to seal holes can be minimized by using wider trunk ducts.





Branch ducts have zero clearance for saw cut through floor sheathing; the picture frame cut cannot be used.

Cardboard spacer provides clearance for later saw cut through floor sheathing.

When the furnace is located over a branch duct, cutting through the floor sheathing can result in cutting through the duct, thus preventing the picture-frame-cut fastening method. A cardboard spacer installed earlier in the process will prevent accidental cut-through.

PLANT 15

Summary

The plant uses a fiberglass duct board trunk system with side-mounted branch takeoffs and R-4.2 flex duct branch connectors attached to standard floor boots. Total duct leakage was measured at 274 CFM25, corresponding to a 32% cfm/ft^2 duct leakage (16% to the outside). This duct system did not meet the target of 3% to 5% leakage. The following list of measures was reviewed during the plant visit and was recommended to achieve performance at the required leakage levels. Duct leakage levels of 5% or less were obtained on homes tested subsequent to the implementation of ADS improvements as seen in Table 1 below.

Test Results

Table 1. Results from duct leakage testing

Test home number	Home area (square feet)	Estimated leakage to the outside
1	1,680	4.5%
2	1,904	4.9%
3	1,120	4.7%

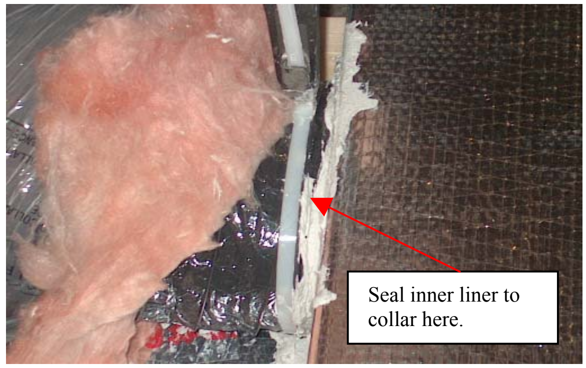
ADS Efficiency Measures

1. **Seal side mounted collars.** Fiberboard systems rely on tabs folded into the duct for mechanical fastening. These tabs are less rigid than screw-type fastenings and increase the difficulty in sealing. Tapes designed for metal to fiberboard attachment may be used for sealing the collars and some manufacturers have had good success with this method. The other method (practiced at this plant) is to apply enough tape to secure the collar at the top and bottom and to apply a liberal layer of mastic completely covering the tape.
   The tape will support the duct during construction in the plant and the mastic will eventually cure to form a durable strong seal. However, mastic curing could take several days depending on temperature and humidity conditions.

It is difficult to create a durable seal using tape or mastic alone.

Applying tape as a temporary seal then covering the seam and tape with mastic will result in a superior and durable seal.

2. **Secure and seal the flex duct to the side-mount collars.** The inner liner of the flex duct should be fastened and sealed. Tape may work in this location if a plastic strap is used over it; otherwise mastic makes a good seal here. The inner liner should first be placed on the collar and attached with a plastic strap to hold the liner in place.



Seal inner liner to collar here.

3. **Use care and attention to detail in crossover branch connections**. This is a critical area for leak prevention. Apply a good quantity of mastic between the mating surfaces of each trunk. Accurately cut the holes and use metallic channel to serve as a mechanical attachment. The channel should be sealed with mastic along all exposed edges. Strap the two trunks securely to prevent any movement of the duct until the mastic has had sufficient time to cure. Installers should be made aware that the mating surfaces are relatively fragile and may open if any pressure is applied to either trunk prior to curing.

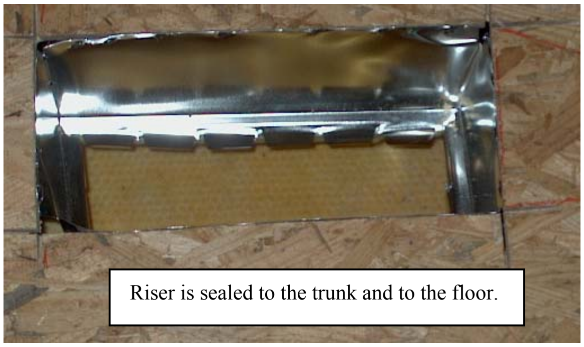
Metal channel is fit in place prior to covering with mastic.

Trunk-to-trunk connections are subject to damage during construction. Take care not to disturb.

4. **Seal in-line boots to the trunk and to the floor.** Apply mastic to in-line risers prior to installation with a caulk gun. Steps are as follows: cut a properly sized hole into the trunk, apply mastic, install riser, and fold up tabs to complete the sealing. Other risers are available that are easier to seal and less prone to being messy.

   All openings between the boot and the floor should be sealed. These small holes can add up to significant duct leakage.

Apply mastic to riser prior to installation. This riser style has a "hip" for mastic and is less messy than finger tabs.



Riser is sealed to the trunk and to the floor.

Many small holes can add up to significant duct leakage.

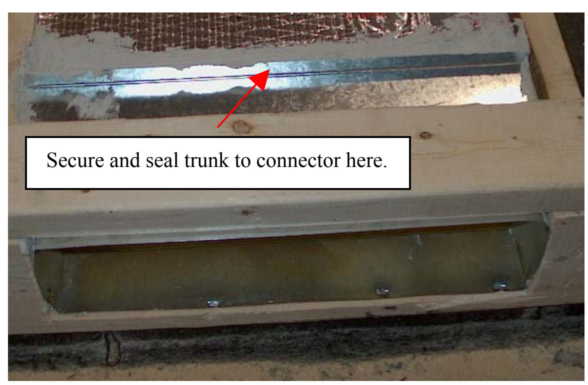
5. **Redesign the furnace plate/plenum to the duct board connection**. The furnace connection is often the leakiest site in the duct system. One option is to manufacture a metal channel designed to attach the inside of the duct board material and the plenum sidewall. The channel should be secured with screws and sealed with mastic.

   Other manufacturers are having success using liberal amounts of mastic applied by gloved hand to the folded finger tabs of the existing furnace plate.

Furnace plate prior to sealing to trunk with mastic.

Furnace plate after sealing to trunk with mastic.

6. **Use care and attention to detail in crossover connections termination in the rim joist.** Care must be taken to insure that the duct board material is not pushed away from the metal connector or duct leakage will be excessive. A heavy application of mastic is recommended on both sides of all mating surfaces to assure proper sealing. Tape may be used to hold the material together while the mastic is curing. Cover all tape edges with mastic.



Secure and seal trunk to connector here.

PLANT 16

Summary

Some homes built in this large facility have ducts in the floor and others have overhead ducts. All of the homes tested in the plant were typically constructed models. The plant had recently invested considerable effort to reduce duct leakage on all of its production plant-wide. The success of this initiative is noted in the high performance of typical duct systems.

During the plant visit the duct leakage to the outside was found generally to be between 3% and 6%. It is likely that the plant can bring duct leakage consistently below 3%.

The plant experimented with many ways to seal ducts consistent with their production process.

Test Results

Table 1. Results from duct leakage testing

Test home number Line A	Home area (square feet)	Total leakage	Estimated leakage to the outside
1	2,010	6.3%	3.1%
2	2,010	6.5%	3.2%
3	2,010	11.4%	5.7%

Test home number Line B	Home area (square feet)	Total leakage	Estimated leakage to the outside
1	2,379	7.6%	3.8%
2	2,379	5.3%	2.7%
3	752	7.45%	3.7%

Several ducts had furnace alignment problems that were repaired with tape. These ducts had more leakage than others.

ADS Efficiency Measures

Total duct leakage measured from six floors in the plant averaged 7.4% (total duct leakage/ floor area). A test of three additional homes located in the field indicated that less than 40% of the total duct leakage is estimated to leak to the outside.

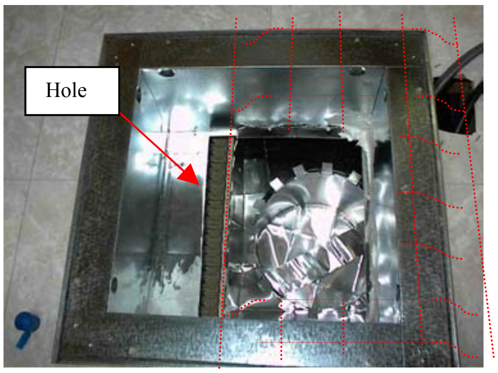
One floor had higher than average duct leakage of 5.7%. In this floor, the furnace plate had not been positioned directly over the trunk and the resulting gap was bridged with folded metal and tape. This type of repair could account for the excess leakage in this home.

Homes built without misalignment problems and taped repairs are projected to easily qualify for the 5% duct leakage target. With a few additional measures, homes could consistently achieve the 3% duct leakage target.

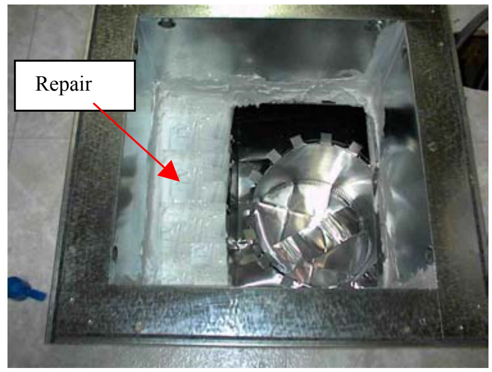
1. **Avoid trunk misalignment and use better repair methods for the occasional misalignment.** Trunks were found that had been misaligned in the floor section and required

repair when the furnace plate was installed. If training does not resolve the alignment problem, consider a template or a guide that makes proper trunk alignment easier to obtain.

Repairs currently being made with tape should be made using scrap metal and mastic as shown below.

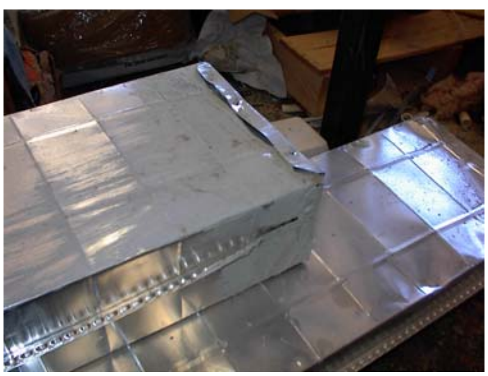


Hole left due to misalignment of trunk with furnace base.



Hole repaired with scrap metal, screws and mastic.

2. **Don't overuse fiberglass tape.** Fiberglass tape is used to strengthen a connection. There is no need to strengthen the end cap connections. The tape can hide a poorly sealed seam. End cap seams will be better sealed by mastic alone.



B

TECHNOLOGIES AND MODERN HOMES ARTICLES

Air Duct Systems

Virtually all of the nation's manufactured homes use forced air systems for heating and cooling distribution. Recent studies suggest that the duct systems in these homes have relatively high leakage rates, contributing to high energy costs, moisture problems, and homeowner discomfort. A recent study revealed that the system losses in an average duct system accounts for 40% of an average home's total heating energy use and 15% of total cooling energy use. These large numbers represent a readily available opportunity for making cost-effective improvements in the design and installation of duct systems. Prior efforts have demonstrated that duct system heating losses can be cut to a reasonable limit of 5% and cooling to 3%. Such reductions, applied to the average manufactured home, would reduce energy bills by an astounding 23%.

In a continuing endeavor to assist manufacturers in improving the performance of their duct systems, MHRA is sending building scientists to plants across the nation, evaluating their current practices, identifying methods to improve performance and then retesting the systems. The effort is made possible partly with funding from the US Departments of Energy and HUD. Plants interested in the duct system evaluation, should contact MHRA.

As a first step, MHRA Project Coordinator, Francis Conlin visited two plants evaluating their duct system practices. Here is a sampling of his initial findings.

Plant #1

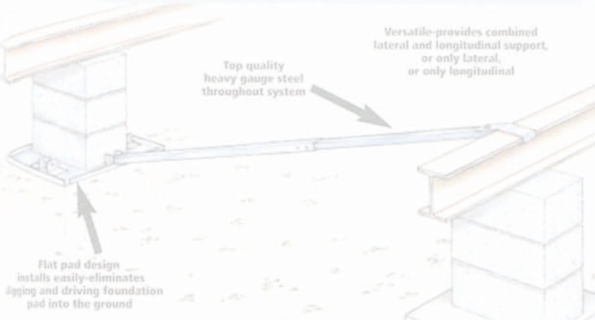
This plant uses a metal trunk duct, predominantly with perimeter supplies and metal tape used for sealing. The trunk is mostly constructed offline except for the in-line registers.

Problem	Solution
• Metal crossover duct splitter box is not mechanically secured to furnace connector boot in three of four homes—critical connection held together with one layer of foil tape. This can lead to disconnections of the crossover duct splitter boxes.	• The crossover duct splitter box and furnace connector boot were pre-assembled off-line and should have been secured with 4 screws. Install screws offline when duct pieces are first assembled.
• Connector for in-line supply register riser has very narrow profile (less than 3”), making installation through subfloor time-consuming.	• Install wider (4”) in-line boots or convert the in-line boots to short perimeter type flex duct connections.
• Furnace connection box and rectangular-to-round flex duct takeoffs have numerous tabs that are bent over to mechanically fasten these joints. This is time-consuming and involves many sharp edges and unnecessary leakage sites.	• Redesign box without tabs or use a single bendable flange instead of hard-to-seal tabs; redesign takeoffs with wider or single flaps.
• Uninsulated supply ducts in the floor system are prone to moisture condensation during air conditioning.	• Insulate all supply trunk ducts; add a 4 to 6” insulation wrap on the exterior of the crossover collars and in-line boots.

Plant #2

This plant uses a metal trunk duct with predominantly in-line supplies, occasional metal branch sections and metal tape for sealing.

	Problem	Solution
	• Metal "cross-over collar" is being deformed into an oval shape to accommodate a larger 12" cross-over duct. This can cause significant leakage after setup.	• Use a tensioning tool to connect duct to collar (collar will go back to round shape); use at least 4 screws through tabs into trunk and tape along collar seam to secure connection.
	• Section box and holes in trunk for supply risers are cut "blindly" with a hand held knife—hole will not be as accurate. Hand held knives are more prone to slipping and cutting through side wall of trunk.	• Use zip spiral saw or similar tool, combined with a template to cut a more accurate hole that is easier to seal.
	• Metal tape is used to seal the furnace-to-trunk connector. This area has the highest pressure and temperature, and is the most important connection in the entire system. Metal tape performs poorly when used under the heating coil to seal this connection.	• Use superior mastic fiberglass tape instead of metal tape to seal connection.
	• Both folded and rolled up end cap systems are used; folded end cap is screwed shut, but large gaps are simply taped over. After a period of time, vibrations and poor adhesion can cause this seal to fail, resulting in significant leaks.	• If adequately folded and fastened with screws, the "rolled up" end closure system may be a more durable, leak-proof seal; use seam sealing pliers to squeeze connection tight.
	• Outdoor air ventilation duct is connected directly to top of furnace—ventilation air will not receive direct dehumidification. This has been associated with poor humidity control in humid climates.	• Ventilation air intake should be redirected to pass over the cooling and dehumidification coils when air conditioner is installed in the field.



MINUTE MAN ANCHORS DEVELOPS NEW FOUNDATION SYSTEM

Minute-Man Anchors Inc. has a new Longitudinal/Lateral Bracing System (LLBS) for anchoring manufactured homes. According to Minute-Man, this new foundation system exceeds design requirements for all HUD Code wind zones. Each installed LLBS has an ultimate load of 7,000 pounds. The LLBS can eliminate or reduce the spacing of most anchors and hardware, which can result in saving both time and money.

The foundation system consists of a flat pad design (footing pad) that installs quickly, eliminates any ground excavation and can be placed by driving the pad into the ground. This is accomplished by four steel extensions, one at each pad corner and connected to the bottom of the pad that is driven into the ground. To provide bracing requirements, an adjustable, heavy gauge steel tube connects the footing pad to the home's main I-beam. This foundation system is versatile in that it can provide combined lateral and longitudinal resistance to imposed loads. The LLBS also can be installed to provide only lateral or longitudinal support conditions.

For further information, contact Kelly Hogan or Frank Cockman of Minute-Man Anchors Inc. at 800-438-7277 or *minutemananchors@hotmail.com*.

Cutting Edge is a forum for new products, services and ideas for manufactured housing. If you think your new product or service is a good candidate for *Cutting Edge,* forward materials (including publication-quality photos, slides or drawings) to Mark Nunn at MHI, 2101 Wilson Blvd., Ste. 610, Arlington, VA 22201 or *mark@ mfghome.org.* For questions call 703-558-0665.

MHRA GUIDE CAN INCREASE ENERGY EFFICIENCY

Virtually all manufactured homes in the nation use forced air systems for heating and cooling distribution. While manufactured homes generally have more tightly sealed ducts than their site built counterparts, if not carefully installed and sealed they can become leaky, wasting a significant amount of energy. Recognizing that a few simple changes in the factory can translate to big savings on energy bills for homeowners, the Manufactured Housing Research Alliance (MHRA) embarked on a program, co-funded by the U.S. Department of Housing and Urban Development and manufacturers, to assess current duct system practices and improve efficiency.

MHRA sent building scientists into 16 plants nationwide to train production employees in the techniques and materials needed to build tightly sealed ducts. In most cases, these changes were simple to make and incurred no additional cost. The result is a more comfortable home, up to a 25 percent increase in energy savings to homeowners, eliminating a potential source of moisture problems, and in some cases enabling the Heating, Ventilation and Air Conditioning (HVAC) supplier to downsize cooling equipment.

With the growing interest in saving energy, this program is a major victory for the industry. The techniques to reduce duct leakage are low cost (in some cases less expensive than current practices) and add to customer satisfaction.

The techniques used to achieve these results are described in MHRA's publication ***Manufactured Housing Duct Systems: Guide to Best Practices***, available from MHRA by calling 212-496-0900 or online at ***www.mhrahome.org***.

NEW AIR CONDITIONERS AND HEAT PUMPS PROVIDE FLEXIBILITY

NORDYNE has introduced the Platinum Series line of Intertherm and Miller air conditioners and heat pumps to solve some of the most common design and comfort issues in the manufactured housing industry. The new line of air conditioners and heat pumps provide manufacturers with more flexibility in their floor plans.

The Platinum Series provides the ability to place the furnace anywhere in the floor plan by allowing the return air to be placed high on the wall in lieu of the grill in the door of the utility closet where the furnace resides. The electrical hook-up has also been pre-wired to reduce the installation labor cost to the retailer. Consumers can take advantage of improved air distribution to provide a balanced comfort level throughout the home, quiet operation and reduced noise levels, a two-year parts and labor warranty, and a five-year quality pledge on the Platinum air conditioner or heat pump, and a matching Intertherm or Miller furnace.

The Platinum Series products are sold through a network of independent distributors serving manufactured home retailers nationwide. For additional information, contact Carol Baker of NORDYNE at 636-561-7586, or Chris Horner of The Vandiver Group at 314-991-4641.