Improving Air Distribution System (ADS) Performance in Manufactured Homes

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

Prepared in cooperation with:

U.S. Department of Housing and Urban Development
Affordable Housing Research and Technology Division
451 7th Street S.W.
Washington, DC 20410

Submitted by:

Manufactured Housing Research Alliance
2109 Broadway, Suite 203
New York, NY 10023
(212) 496-0900

January 2, 2003

Table of Contents

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

---

[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

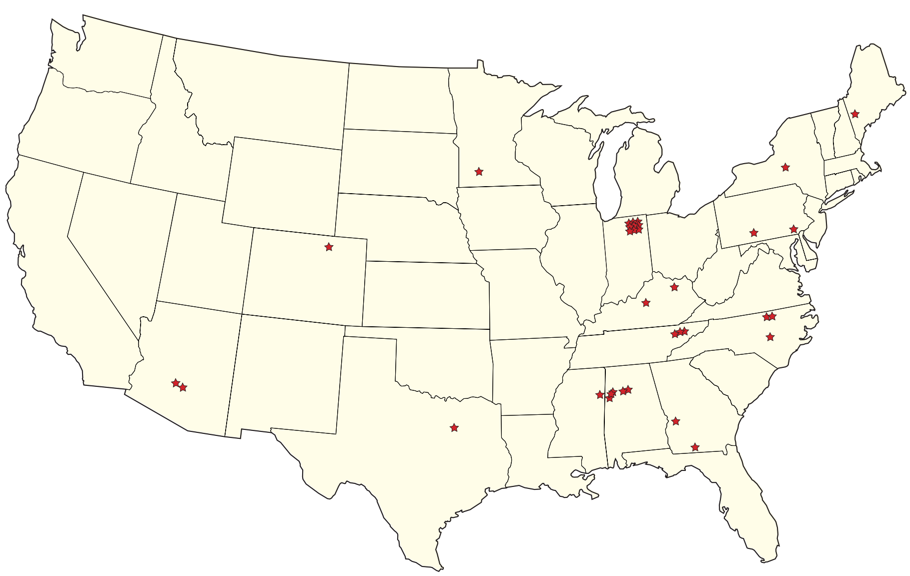


Figure 1. Plant locations

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.

---

[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.

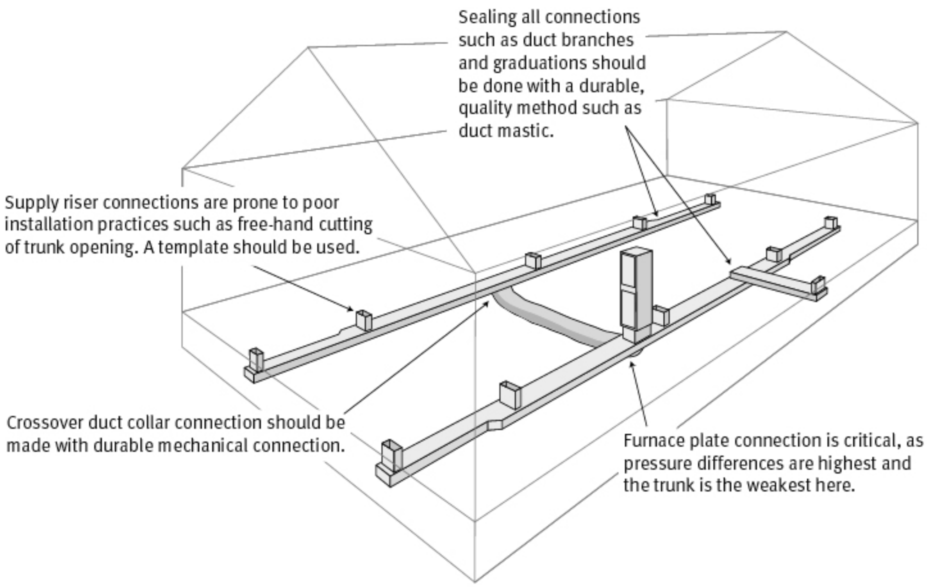


Figure 2. Typical ADS system recommendations

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.

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

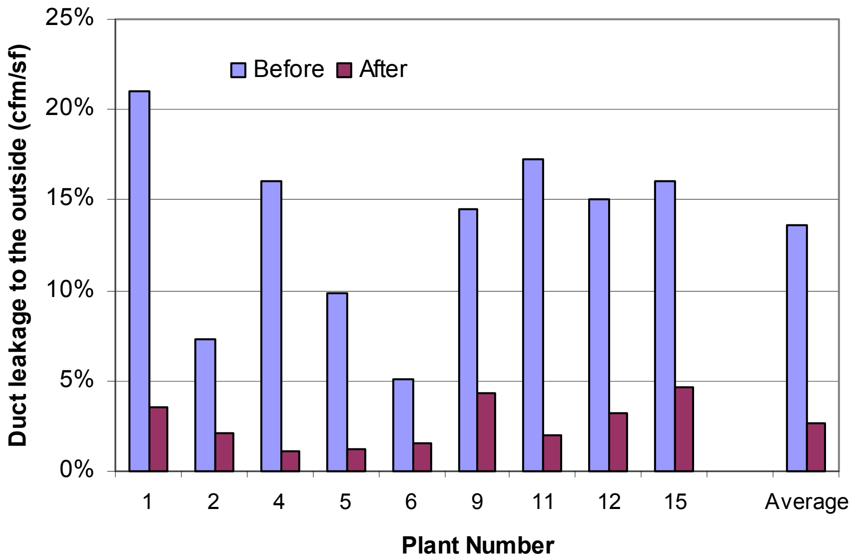
Table 3 shows average duct leakage levels achieved for a number of the plants. At least three systems were tested per plant before the building scientist judged that a consistent practice had been achieved. The average ADS leakage of all 59 homes tested for these plants upon completion of the redesign 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.

[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