Energy Performance Evaluation of New Homes in Arkansas

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From August 1997 to September 1999, one hundred new Arkansas homes were evaluated in two areas in the state where there was significant building activity in order to determine the energy performance of current building practices. One of the positive findings was that homes are now being built significantly tighter than a few years ago. Homes built in the early to mid 1990's were experiencing an average of 0.5 natural air changes per hour (NACH), an acceptable level considered normal for new construction. Only 24 homes in this evaluation had leakage rates exceeding 0.4 NACH; the majority of homes (58 percent) had leakage rates of 0.35 and under.

Other findings reveal areas where improvements could be made: oversized cooling and heating systems; inadequate applications of slab insulation; poorly sealed bottom and top plates; missing, under-installed or poorly installed insulation; inadequate ventilation in tight homes; poorly built return air ducts; prevalent use of temporary (duct) tape; unsealed interior furnace doors; unvented gas fireplaces in tight homes; and solid aluminum frame windows still being used on 33 percent of homes. Forty-five percent of homes failed the minimum thermal Code requirements. In addition, 36 of the homes surveyed would have qualified for HUD/FHA financing; however, half of them failed the minimum thermal energy standards.

The performance of each home was tested with a blower door and processed through a variety of programs (Code compliance, system sizing, energy cost estimations) to help builders understand the importance of air leakage, duct leakage, system sizing, product selection and installation practices. An estimate of annual energy operating costs gave builders a comparison to minimum thermal Energy Code compliance (MEC '92).

The average heating system was about twice the size needed to meet the design-heating load. About 90 percent of all air conditioners were oversized by ½ to 3½ tons, resulting in an unnecessary cost of about $600 per home just for cooling equipment. The typical cooling system was sized about 50 percent over what was needed; 7 percent of the homes are more than 100 percent oversized. Average duct leakage was 12 percent; however, the range was from 2 to 28 percent.

For the 45 homes not passing Code, there was an annual estimated unnecessary total energy expenditure of about $2,346 ($1,135 for heating and $1,211 for cooling). If this sample of 100 homes is representative of the 10,000 built per year (based on permit data), then the total unnecessary energy expenditure for the entire state is about $235,000 per year. This excessive use of energy released 24 tons of CO_2 – 12 tons from burning natural gas and 12 tons from the generation of electricity. The total estimated unnecessary statewide release of CO_2 was estimated to be 2,400 tons per year.

The information collected in this survey will help to set the direction of how the Energy Office can improve energy performance of new construction through education, training and demonstration programs. By focusing on the needs of each audience (e.g., HVAC installers, insulation contractors, etc.), we can use these findings to improve both Code compliance and energy performance.

INTRODUCTION

Local adoption and enforcement of the Energy Code in Arkansas is voluntary. By law, builders must self-certify that they have complied with the 1994 Arkansas Energy Code by completing and signing an adhesive certification seal that is placed either on the electric circuit panel or the heating/cooling cabinet. The certification seal documents only the envelope's R- and U-values. Compliance with the Code is determined by selecting from a set of simplified options given for each climate zone or by using ARKcheck™, a state-specific software version of MECcheck™. The Code also provides for compliance through an approved third party such as a home energy rating system.

Baseline Code Compliance Survey

In 1996 the Arkansas Energy Office conducted a Code (thermal envelope) compliance survey of 100 homes throughout the state. This coincided with the Arkansas Energy Efficiency Partnership Consumer Marketing Campaign. A statewide baseline, which included many new homes that were in areas with no permits or code enforcement, was established to evaluate the success of a campaign to increase awareness of energy efficiency among new homebuyers.

After running a series of multi-media announcements to enhance public awareness of the benefits of Code compliance, the Arkansas Energy Office designed a study to evaluate the effectiveness of this campaign. A random sample of newly constructed homes throughout the state was selected. In the northwest region, 16 out of 26 (62 percent) homes failed compliance. In parts of the state where milder climates make it easier to meet the Code, there were greater levels of compliance. For instance, in the central region a survey of 45 homes indicated that 84 percent complied with the Code. The results of this study indicated that, overall, there was more work to do to increase the number of homes that comply with the minimums of the energy Code.

Arkansas in Context

Arkansas is a rural state comprised of 75 counties that have no building permit requirements. Although the Energy Code applies to all new buildings, only 114 of the 500-plus communities have a building permit process. To date, only 12 of these have adopted the Energy Code. Little Rock, the only city in this study that has adopted the Energy Code, accounts for 7 percent of the state's population. The other 11 communities that have adopted the Code comprise an additional 4 percent.

Adoption of the Energy Code does not imply enforcement. Although a serious effort has been made to encourage all cities to enforce the Energy Code they have adopted, enforcement remains a challenge. Smaller communities, where the fire department is responsible for enforcement, appear to achieve a higher percentage of Energy Code compliance.

A PERFORMANCE-BASED APPROACH

In August 1997 the Arkansas Energy Office (AEO) initiated a study of a performance-based approach designed to encourage builders to build homes that are more efficient. This project has monitored the complete construction process of 100 newly built homes in central and northwest Arkansas; these two distinct climate zones comprise the major building areas in this state.

The 10 communities in the two geographic regions in this survey account for about 16 percent of the population. However, based on 1998 permit data, these communities accounted for 38 percent of the building permits. While the information in this report might not be representative of all new homes being built in Arkansas, it is reasonable to say that these data are representative of the areas in the state that have significant building activity.

After the homes were completed, a blower door test was used to estimate each home's air and, by subtraction, duct leakage and fireplace leakage. An analysis of the heating and cooling loads revealed how well the systems were sized. The energy performance of the home was expressed to the builder and potentially to prospective buyers by comparing its estimated utility costs with the costs associated with just meeting the Code.

Ultimately, the buyer will be able use this information to comparison shop, and the builder will be encouraged to optimize energy efficiency as a competitive marketing strategy. This will enable builders to get credit for important items such as air leakage reduction that current Code compliance methods are unable to effectively address.

Builders were contacted on an individual basis, and samples of their homes were observed during construction for energy-efficient practices. By working closely with each builder, the Energy Office hoped to influence building practices as well as to encourage more efficient product selections.

Builders could benefit from this performance evaluation in several ways:

- Better understanding of the Energy Code and how to meet its minimum requirements
- Knowledge of their home's air infiltration and duct leakage
- Exchange of good details and practices
- Assistance in making cost-effective efficiency tradeoffs
- Testing a marketing approach that will give the homebuyer an easy-to-understand cost comparison instead of just a "pass/fail" indication

THE PERFORMANCE EVALUATION

Locating Builders for the Study

Candidate homes and builders were located in a variety of ways. New construction building permits provided at least the address of a home that was being built and the builder's name. For many builders it was necessary to drive to the site, get the phone number from the builder's sign in front of the home, and then call that builder.

It was necessary to "sell" this evaluation project to a builder. Because the study was being conducted under the auspices of the Arkansas Energy Office, there was some trepidation expressed by several builders who were worried that if they did not cooperate and allow their homes to be evaluated, there would be some repercussions. The builders were assured that the report would be sent only to them.

The builders were told that this was to be a **performance evaluation** – not just a Code check. Each builder would be given the results of a blower door test, a heating and cooling load analysis and suggestions for cost-effective Code compliance if the house did not meet the Code. Some builders indicated their interest by asking if there was a cost for this service. When assured that it was free, had no negative consequences, would not disrupt their construction process and might actually be of some benefit, then they usually agreed to be in the study.

Interviewing Workers and Builders

A lot of valuable information came from direct interviews with builders and sub-contractors, both over the telephone and in the field. Many builders were happy to share information, details and techniques. In addition, information was passed back to builders that might be helpful.

Preliminary Data Preparation

Field measurements and a hand-drawn floor plan were transferred to a CAD drawing program. This included the floor plan, compass directions, and window and door locations and measurements, with some notes on the type of floor and features such as ceiling geometry and other special details. This simplistic drawing tool was useful for estimating the length of the perimeter (useful for wall area), floor area and volume. The drawing assured the builder that the correct house was evaluated and its characteristics, especially window areas, were accurately measured.

On-site Calculations

It was useful to bring the state-supplied portable computer when visiting a site or when running a blower door test. Sometimes a builder had specific questions on the Energy Code, and it was helpful to process a home through the program to get an answer on the spot. Also, when running a blower door test, results were immediately available on how tight a home was and the percent of total leakage in the ducts. Builders who were present during the blower door test were directed to leakage areas. This provided the best educational feedback possible.

Final Data Preparation

After the final testing was completed, revised measurements or refinements were made to the CAD drawing and to the area/volume spreadsheet. The data were then processed through the ARKcheck™ program.

If the house failed ARKcheck™, a series of prioritized, cost-effective options were generated for compliance. If the house passed ARKcheck™, a certification seal was attached to an "Energy Code Facts" sheet with instructions on where to place it.

The blower door data were processed. The average air change rate of 0.5 NACH measured in the early to mid 1990's was used as a benchmark against which these new homes were measured. A surprising number of homes measured around 0.35, ASHRAE's level below which odors and other problems might become noticeable. A few homes were significantly tighter than this, and builders of these tight homes were notified about the potential for problems with moisture, air quality and potential building degradation.

Right-J™ (Manual J) was used to estimate the heating and cooling loads. Since this industry-accepted program has a built-in oversizing factor of from 15 to 20 percent, the sizing estimates of this program were compared to the rated output of the heating and cooling equipment. The default design temperatures for heating and cooling were used. The estimates for duct leakage were entered as well as the measurements for whole house air leakage.

Estimates of annual energy costs were made using REM/Design™. Various responses were given based on the home's Code compliance:

- If the house was just below Code and tighter than 0.5 NACH, a comparison was made to the estimated energy cost for to just pass the Code with 0.5 NACH. This gave the builder credit for tight construction unavailable in MEC '92.
- If the house was above Code and relatively tight, a comparison was made to the same house just meeting Code with 0.5 NACH. This showed how much money the homebuyer might save because the contractor built tighter than average.
- If the house was far below Code, a comparison was made to the energy used for a Code house with similar leakage or, if tested to be leaky, compared to a tighter home. This showed the economic benefits to the homeowner had the minimum Code requirements been met.

Report Sent to Builder

The report was sent to the builder. If a homebuyer had been involved in the testing and was interested in the report, he/she was asked to request a copy of the report from the builder. This process made it easier to get the trust of the builder because this information was transferred only between this office and the builder.

After a few weeks, the builder was called and asked if there were any questions. Usually there were none; however, on many occasions, interesting and sometimes heated questions came up that required explanations and clarifications. On one occasion, a builder requested a clarification letter in order to remove a homeowner's anxiety.

FINDINGS

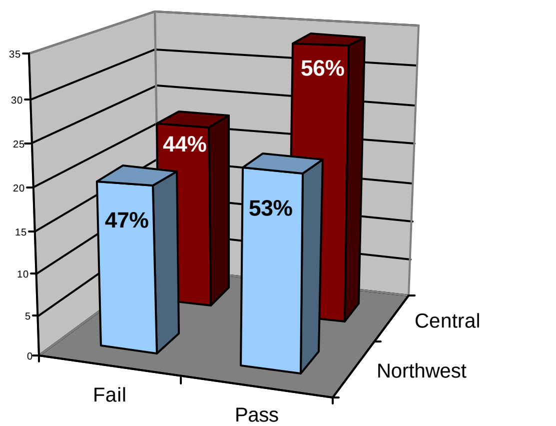
The 100 homes that were evaluated were built by 31 builders in central Arkansas and 21 in the northwest part of the state. In northwest Arkansas, 53 percent passed the Code and in central Arkansas 56 percent passed. Six homes were nominated for an EPA Energy Star designation. Many homes were very close to passing the Code. The worst failure was 33.7 percent below Code, and the best passing score was 49.5 percent above Code. (Figures 1 and 2)

Of the 100 homes surveyed, 36 would have qualified for HUD/FHA financing; however, half of these homes failed the minimum thermal energy standards. For those more easily affordable homes, energy costs play a proportionally greater role and therefore it is even more important that at least the minimum energy standards be met.

Almost half (44 percent) of homes were within plus or minus five percent of passing Code. A little more than ¼ were above and slightly less than ¼ were below that five percent target. (Figure 2)

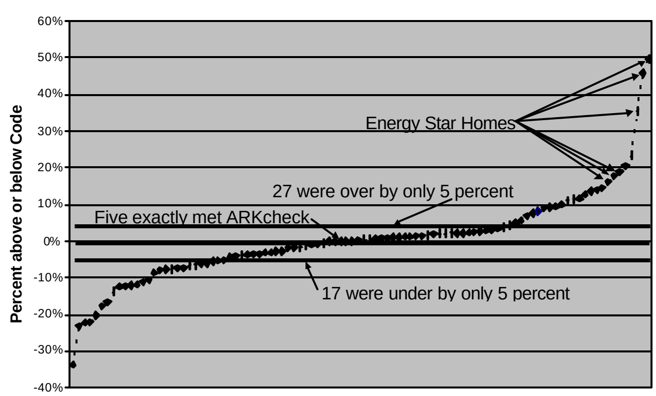
Many homes that came close to passing Code were tighter than average. This was reported to the builder by comparing the projected dollars per year performance of the home with a Code compliant house assuming average air leakage.

Figure 1. Passing Code in Central & Northwest AR



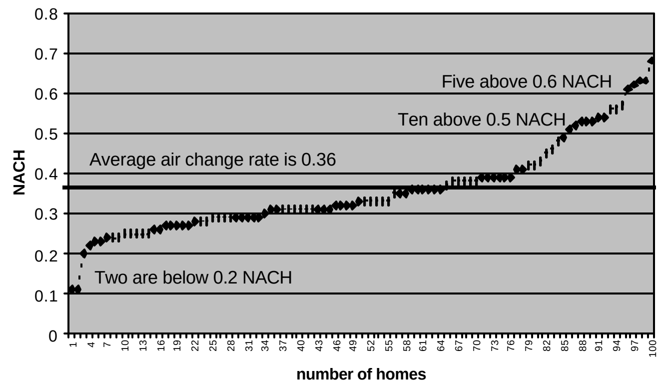
Window type and area play an important role in passing the Code. Window areas, described as the percent of window in the gross wall area, ranged from 4 to 28 percent. The average window area was 12.3 percent; 71 homes had window areas between 10 and 15 percent.

Figure 2. Code Passing / Failing



Only five years ago, the average air leakage for new construction was about 0.5 NACH. Current findings (Figure 3) indicate that builders and subcontractors are doing a better job of reducing unwanted air leakage. Only 24 homes had leakage rates exceeding 0.4 NACH. The majority of homes (58 percent) had leakage rates of 0.35 and under. A very few homes were attempting to incorporate mechanical ventilation.

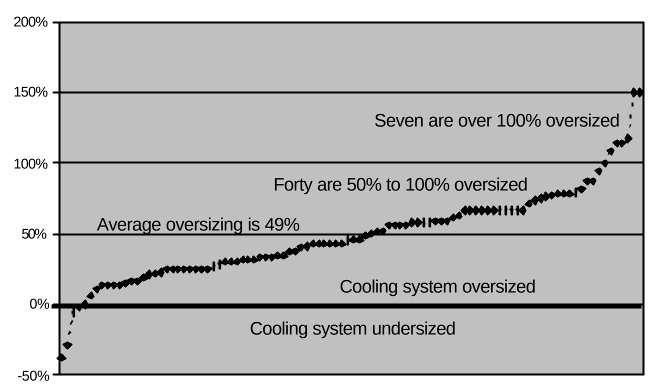
Figure 3. Natural Air Changes per Hour (NACH)



Oversizing of heating and cooling systems remains a problem. (Figure 4) The average heating system oversizing was about twice the size needed to meet the heating load. Forty-three percent are between two and three times the needed size, and 5 percent are more than three times larger than needed.

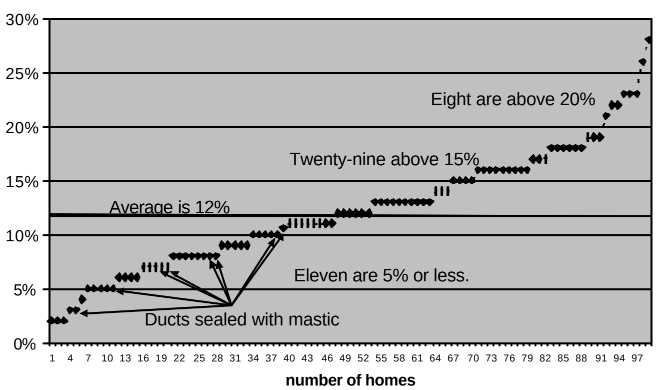
The average oversizing for cooling systems was about 50 percent. Forty are between 50 to 100 percent oversized, and seven are 100 percent and over. On average, one ton of cooling was installed for each 540-sq. ft. of floor area. The calculated (Manual-J) floor area per ton was closer to 800-sq. ft. of floor area.

Figure 4. Percent Cooling System Oversized



Average duct leakage using the "subtraction method" was 12 percent of total house leakage. (Figure 5) Twenty-nine homes were experiencing greater than 15 percent duct leakage. Ducts sealed with mastic were all below the 12 percent average. Eleven duct systems had leakage rates of 5 percent or less.

Figure 5. Percent duct leakage



Fireplace leakage was also evaluated: 33 homes had no fireplace, 54 had vented gas fireplaces, two were vented wood, and 11 were unvented gas fireplaces. Of the vented gas and wood fireplaces, the average percent of total-house leakage was 5.3 percent. Thirty-eight homes had fireplace leakage 5 percent or less, 10 were greater than 10 percent and the highest was 19 percent. The biggest concern was the seven homes with unvented gas fireplaces experiencing natural air change rates less than 0.35 per hour.

Eighty-one of the homes were built on a slab. The majority of these, especially in central Arkansas, had no slab insulation. Slab insulation was ineffectively installed in many homes in northwest Arkansas (Figures 6 and 7). Only in a few cases was the vertical edge of the slab carefully insulated around the perimeter.

The estimated cost of the energy use of the 45 homes that did not pass Code was compared to the energy cost if they had been built to Code. Since these were new homes, most were already close to Code, and the saving was small on an individual basis. Taken as a whole, these homes consumed an excess amount of natural gas energy for heating (206 MBtu per year) and an excess amount of electricity for cooling (17,140 kWh). The unnecessary energy use of these 45 homes converts into an expenditure of about $1,135 per year for heating and $1,211 per year for cooling. If this sample of 100 homes is representative of the entire population of homes being built in Arkansas (about 10,000 per year), the total unnecessary expenditure for the entire state is about $235,000 per year.

The excessive use of energy in these 45 homes released into the atmosphere 12 tons of CO_2 from burning natural gas and another 12 tons from the generation of electricity: a total of 24 tons of carbon dioxide, one of the "greenhouse gases." Again, taking these 100 homes as representative of the 10,000 built annually, the total estimated unnecessary statewide release of CO_2 was about 2,400 tons per year.

CONCLUSIONS

Almost all contractors and builders try to build a quality product. The sub-contractors focus only on their jobs and do the best they can but are responsible only for their specific assignment, not for the final product. The place where the work of one profession met with another was typically where there were problems:

- Where the concrete finisher meets the termite inspector

- Where the framing contractor meets the concrete finisher
- Where the electrician meets the framing and drywall contractors
- Where the framing and drywall contractors meet HVAC contractors
- Where the insulation contractor meets the electrical and plumbing contractors

It is important that builders understand that all of their subcontractors have substantial and sometimes negative impacts on the safe and efficient operation of a home. The builders need to know what the problem areas are so they can to work more closely with their sub-contractors to instruct and monitor exactly how they want their job to be done.

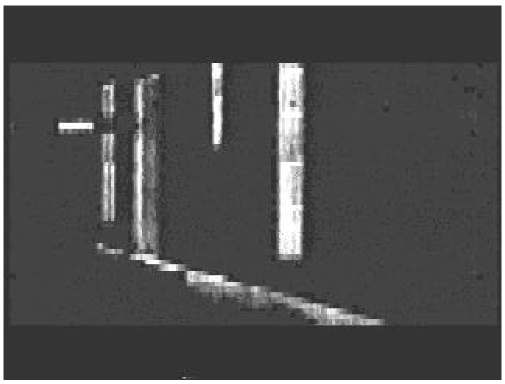


Figure 6

Slab heat loss of the house pictured on the right is captured with an infrared camera.

Figure 7

These pictures were taken when the outside temperature was only 40° F.

ACKNOWLEDGEMENTS

This work was completed as a result of a US DOE grant for Special Projects: Codes and Standards I. I would like to thank the following people for their support and comments: Susan Recken and Chris Benson (Arkansas Energy Office), Annette Ditmer (Pacific Northwest National Laboratory), all of the builders who allowed their work to be evaluated, Jan Partain and the staff of the Arkansas Department of Economic Development under which the Arkansas Energy Office operates.

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