Final Report
Iowa Residential Energy Code Plan Review and Field Inspection Training

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Draft Report
Iowa Residential Energy Code Plan Review and Field Inspection Training

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SECTION 1.0 ABSTRACT

This report provides specific information on the process and findings for the *Iowa Residential Energy Code Plan Review and Field Inspection Training* partially funded by the U.S. Department of Energy (Grant #DEFG4501-R53494). Initial work on the study began in December of 2001 with final reporting completed in September 2003. The primary goal of the grant was to determine the rate of compliance with the Model Energy Code and the International Energy Conservation Code within the state of Iowa and to provide informal training to the participating jurisdictions and builders to increase the rate of compliance with the current energy code. The statewide energy code is the 1992 CABO Model Energy Code.

The project partners consisted of Iowa Department of Natural Resources, Energy and Geological Resources Division and the International Conference of Building Officials (now the International Code Council). A residential baseline study was conducted on 47 single-family homes, and 18 multi-family dwelling units, in Iowa to determine how typical single-family homes in the state of Iowa compared to current energy codes and to identify potential building practice and energy code compliance documentation problem areas. Informal training was provided to jurisdictions that participated in the study.

The study collected energy efficient building data from the building plans and onsite data from the field. The U.S. Department of Energy's MEC*check* Energy Code Compliance software was used to analyze each of the buildings and compare them against the 1992 through 1995 Model Energy Code and the 1998 and 2000 International Energy Conservation Code. The average rate of compliance for single family homes included in the study in Iowa is included in Table 1.1

Average MECcheck Results	
1992 MEC	4.63%
1993 MEC	4.63%
1995 MEC	2.84%
1998 IECC	2.84%
2000 IECC	2.84%

Table 1.1

The compliance rate for multi-family dwelling units was significantly greater compared to the single-family homes included in the study (see Table 1.2). This can be attributed to lower thermal requirements in the building envelope and the allowance of a higher glass to wall ratio for multi-family.

Average MECcheck Results	
1992 MEC	37.49%
1993 MEC	37.49%
1995 MEC	21.49%
1998 IECC	21.49%
2000 IECC	21.49%

Table 1.2

SECTION 2.0 INTRODUCTION

The report that follows provides specific information on the process and findings for the *Iowa Residential Energy Code Plan Review and Field Inspection Training* partially funded by the U.S. Department of Energy (Grant # DEFG4501-R53494). Initial work on the study began in December of 2001 with final reporting completed in September 2003. The primary goal of the grant was to determine the rate of compliance with the Model Energy Code, and International Energy Conservation Code, within the state of Iowa and to provide informal training to the participating jurisdictions and builders to increase the rate of compliance with the current energy code. A residential baseline study was conducted to determine how typical single-family homes and multi-family dwelling units in the state of Iowa compared to current energy codes and also to identify potential building practice and energy code compliance documentation problem areas.

SECTION 3.0 PROJECT OVERVIEW

The Iowa Department of Natural Resources in collaboration with the International Conference of Building Officials (now the International Code Council) proposed to assess the current quality, and rate of compliance of energy efficient construction practices relative to the 1992 and 1995 CABO Model Energy Code and the 1998 and 2000 ICC International Energy Conservation Code. This study was designed to answer the following questions:

1. How does current residential construction in the state of Iowa compare the 1992 to 1995 Model Energy Code and 1998 to 2000 International Energy Conservation Code from both a plan review and inspection standpoint?

2. What does a typical home look like from an efficiency standpoint in Iowa?

3. What typical efficiency upgrades will be necessary to show compliance with the energy codes for those non-compliant buildings?

4. Do the buildings in the field match what is shown on the plans and documentation?

5. What are some of the problem areas for demonstrating compliance with the energy code?

Section 3.1 Project Design

The data collection project was designed to be straightforward and sequential in nature. The partners were selected because of their interest in the level of efficiency measures installed in current construction within Iowa, the problems in current construction practice in meeting the energy code requirements, and the ability to provide education to the plan review and field inspection staff that participated in the study. A brief description of the steps used in the data collection process is described below. A more thorough description is included in Appendix III of the report.

Section 3.1.1 – Development of Survey Instrument. A form was developed to collect both energy code (Model Energy Code/International Energy Conservation Code) compliance, and building practice quality data from the residential building plans and field visits. The form was developed to guide the user through the process of collecting data with the ability to satisfy both the needs of plan review and field inspection data collection. The plan review form was based on the U.S. Department of Energy's MEC*check* energy code compliance software, which was used as the data analysis tool. A page was added to collect blower door data from each of the tested houses.

Section 3.1.2 – Development of Sample

The goal of the project was to select 65 single-family homes from Iowa with approximately 50% of the sample selected from the Des Moines metropolitan area. The sample size of 65 was selected due to funding constraints but the sample size was viewed as adequate to meet the goals of the study. During the study, a portion of the single family homes was replaced by eighteen town homes when it was determined that a large population of dwelling units built in the Des Moines metropolitan area were town home projects. This study afforded the opportunity to collect data on residential projects (town homes) where little information on energy code compliance was available. Two of the homes that were selected were built by community college programs. Indian Valley Community College and Iowa Central Community College participated in the program to determine how well the homes built by the program compared to other homes in the state.

Section 3.1.3 – Select Jurisdictions for Data Collection. The following jurisdictions volunteered to participate in the project study. The project was designed for jurisdiction self-selection but there were several jurisdictions within the state of Iowa that were targeted for participation in the study due to population and building permit activity:

- City of Des Moines
- City of West Des Moines
- City of Waukee
- City of Ankeny
- City of Coralville
- City of Iowa City
- Sioux City
- City of Council Bluffs
- City of Carroll
- City of Fort Dodge (Iowa Central Community College)
- City of Centerville (Indian Hills Community College)
- Muscatine County

Two jurisdictions fell out of study and the homes were redistributed to other jurisdictions to keep the sample at 65. Muscatine County and the City of Carroll only had a plan review conducted for the selected buildings.

Section 3.1.4 – Notification of Jurisdictions.

Once the jurisdictions self-selected to participate in the study, they were contacted to ensure that they were aware of their responsibilities in participating and to schedule the onsite inspection. A letter was sent to all of the jurisdictions that volunteered to participate in the program. The letter provided basic information concerning how the study would be conducted and outlined the jurisdiction's responsibilities. The estimated number of homes that each jurisdiction needed to select for the study was stated in the letter and parameters for selecting the homes. The letters were followed-up by phone calls to ensure that the jurisdictions would participate in the study and to schedule the on-site data collection.

Section 3.1.5 – Perform Data Collection at the Selected Jurisdictions. The data collection process was divided into two phases. Data was first collected from the building plans during the "plan review" phase of the study. A two-person team, comprised of Eric Makela, Britt/Makela Group (formally of ICBO) and Kenneth Baker, Kenergy, conducted plan reviews at each of the participating jurisdictions. Only one team member visited a jurisdiction to collect the data to ensure that data could be collected in all of the jurisdictions in an efficient manner.

Each of the jurisdictions provided building plans for active "typical" projects based on the need of the project and willingness of the builder to participate in the study. Data collection was then performed on the building plans and energy code compliance documentation (if provided). Data collection included calculating areas of the building envelope (e.g. wall, glazing and roof area) documenting insulation R-values and glazing U-factors, and determining if information on non-insulation and glazing elements of the building (e.g. vapor retarders and air sealing were included) on the plans. Builder contact information was also collected from the building plans to schedule the on-site inspections. In addition, builder contact forms were used to solicit builder involvement and cooperation in the project

Woods & Associates conducted the onsite inspections. Following the plan review process, each of the builders was contacted to schedule the onsite data collection. This part of the study included a verification of the data collected during the plan review phase of the project and collecting data that did not show up on the building plans (e.g. glazing U-factor). A blower door test was also conducted on each of the homes when feasible during the onsite inspection.

A portion of the homes were replaced in the original sample due to the home either not being available for inspection and testing because it was already occupied, difficulty contacting the builder, or builders who selected not to participate in the study. These homes were replaced by additional homes in the study to ensure that the sample size did not change.

Section 3.1.6 – Data Analysis. Once the data was collected, each of the homes was input into the MEC*check* Energy Code Compliance Tool to determine the compliance margin for various years of the MEC and IECC. Data collected during the plan review process was input first. If information on efficiency levels was incomplete, basic assumptions were used to complete the model using levels of efficiency typically found in the region. Each of the homes was compared against the 1992 and 1993 Model Energy Code and the 1995 Model Energy Code through 2000 International Energy Conservation Code. For single-family construction, there is no difference in the energy code between the 1992 and 1993 Model Energy Code and the 1995 Model Energy Code through 2000 International Energy Conservation Code. Because of the similarities, only two analysis runs were conducted on the single-family homes. For town homes, the analysis considered the 1992 MEC, 1993 MEC and the 1995 MEC through 2000 MEC as there was a change in stringency in the code between the 1992 and 1993 MEC.

Data for each of the field inspected homes was then entered in the MEC*check* software to determine compliance margins with each of the code years referenced in the preceding paragraph. As with the plan reviewed homes, assumptions were made using typical construction practice in the region if levels of efficiency were not available. The next step in the process entailed examining each non-compliant house and adding conservation features to the building until it complied with the code. A list of typical efficiency upgrades was developed that would be added to the noncompliant house until compliance was met with the applicable code year. The results of this exercise will provide important data to a jurisdiction in determining if they will update their energy code. The results of the data analysis are reported in Section 4 of this report for the state as a whole.

Section 3.1.7 – Project Updates to Iowa Association of Building Officials. A project overview and updates were presented to the Iowa Association of Building Officials during their scheduled quarterly meetings. An overview of the project was presented during the January, 2002 meeting. The goal of the presentation was to solicit volunteers to participate in the program. In July 2002 a project update was provided to the membership which provided detail on who was participating and the progress to date. The final presentation was delivered in August of 2003 and provided an overview of the results of the study.

Section 3.1.8 – Energy Code Advisory Committee Training / Community College Training. Two Energy Code Advisory Committee meetings were conducted as part of the project. The first meeting was conducted in January, 2002 and focused on providing an overview of the study and also an overview of the 2000 International Energy Conservation Code (IECC). Those in attendance included representatives of the building, utility, regulatory and enforcement communities. The primary goal of the meeting was to start discussion on the potential to update the statewide energy code in the state of Iowa. A second meeting was held in August of 2003 to provide an overview of the results of the study. An overview of the 2003 IECC was provided looking at both the residential and the commercial provisions of the code. The committee was also exposed to the U.S. Department of Energy's code change for residential occupancies. The response from the committee was very favorable.

Two half-day training sessions were also delivered to the community colleges that participated in the study. Both of the colleges were building houses that were significantly more energy efficient that the current code requirements. Classes at Iowa Central Community College and Indian Hills Community College were provided an overview of the study and participated in calculating the area take-offs for the building assemblies for the data collection form. The MEC*check* analysis was conducted in class to determine compliance with the codes. An overview of the 2000 IECC was then provided to the classes.

Section 3.1.9 – Draft Report with Findings of the On-site Survey. Section 4 and Section 5 of this report provide detailed information on the findings from the plan review and field inspection portion of the study.

SECTION 4.0 STATE WIDE GENERAL REPORTING

Section 4.1 Number of Plan Check and Field Checks per Jurisdiction

Table 4.1 provides a summary of the number of homes for each jurisdiction that had been both plan reviewed and inspected, and plan reviewed only with no inspection.

An original sample of sixty-five (65) single-family homes was selected for Iowa with the number of homes that each jurisdiction would provide prorated based on building permit activity. Each of the homes selected were to represent typical construction for the jurisdiction with no more than three homes selected from any one development.

A portion of the original sample (20) selected for the study could not be used for each of the jurisdictions. There were several reasons for the homes falling out of the sample including:

- The builder could not be contacted to participate in the study,
- The selected home was completed and occupied prior to inspection, and
- Lack of availability of selected plan or model for inspection and testing

Additional homes were selected from each jurisdiction to complete the sample. In some cases, it was difficult to maintain the original sample size within a jurisdiction due to a lack of available homes from different builders. Town homes were added to the sample and replaced 18 of the single-family homes originally selected.

Jurisdiction	**Plan Check and Field Inspected Homes**		**Plan Check Only, No Field Inspection**
	Single - Family	**Multi-family**	**Single-Family Only**
Ankeny	12	8	1
Coralville	7	0	3
Des Moines	4	0	5
Iowa City	3	0	0
Indian Valley Community College	1	0	0
Johnston	1	0	0
North Liberty	1	0	0
Sioux Center	2	0	0
Waukee	9	6	1
West Des Moines	6	4	3
Iowa Central Community College	1	0	0
Building Inspectors	0	0	2
Muscatine County	0	0	1
Carroll	0	0	2
Council Bluffs	0	0	2
Totals	47	18	20

Table 4.1

Section 4.2 Adopted Energy Codes

The minimum state wide residential energy code is the 1992 Model Energy Code, which is enforced on the jurisdictions that were selected for the study. The only exception was Muscatine County, which did not currently have a building department.

Section 4.3 Percentage of plans with energy documentation submitted, R-Values and U-Factors on Plans

One of the goals of the energy code baseline study was to determine if information was being included on the plans or in the documentation included with the plans to determine compliance with the energy code. This is required under Section 104 of the MEC and IECC. During the plan review process each set of building plans were checked to determine if documentation was submitted with the plans and/or if information on the insulation R-values or glazing U-factors were included on the building plans.

Section 4.3.1 Documentation Submitted. Each jurisdiction has policies and procedures that dictate the type of information that they need to see for each submittal for permit. This will vary according to the code adopted and jurisdictional policies. The study revealed that energy code compliance documentation was not typically submitted.

	Documentation Submitted %	R-Value on Plan %	U-Factor on Plans %
Ankeny	10	65	
Coralville		100	
Des Moines		11	
Iowa City	33	100	33
Indian Valley College		100	100
Iowa Central Community College		100	
Johnston		0	
North Liberty		100	
Sioux Center		100	50
Waukee		93	0
West Des Moines	10	60	10

Table 4.3

Section 4.3.2 R-value and U-factors on the Building Plans. The plans were also checked for insulation R-values, glazing U-factors, and other energy code compliance information. Insulation R-values that were called out typically were called out for foundations e.g. basement wall insulation, wall systems and roof assemblies. Frequently, insulation was shown in the construction detail or the cross section of the building but the R-value was not specified. Glazing U-factors were almost never identified on the building plans nor were the types of windows (e.g. double pane, vinyl framed windows). Several of the buildings that were reviewed had qualified for an Energy Star program and listed the insulation R-values on the plans.

The majority of the plans did not contain plan notes requiring the building to be sealed for air leakage, duct insulation levels, nor were there plan notes about recessed can lighting being IC Rated and air tight, a requirement in the 1995 MEC and later.

Section 4.4 - Compliance Rates for the Insulation and Glazing Requirements

The U.S. Department of Energy's MEC*check* Energy Code Compliance (Version 3.3, release 1b) software was used to determine if the building complied with a particular year of the Model Energy Code (MEC) or the International Energy Conservation Code (IECC). Each of the homes were modeled using data collected from the building plans during the plan check process and then were analyzed again based on the data collected in the field.

Section 4.4.1. Plan Check Code Compliance Analysis Single-Family*.* The plan check analysis was conducted based on the information collected from the building plans and documentation and listed in Table 4.4.1. Two energy code years were used for the analysis. The 1992 MEC was used to represent the code years of 1992 and 1993. The 1995 MEC was used to represent the code years from the 1995 MEC to the 2000 International Energy Conservation Code (IECC). There were no changes to the thermal requirements between 1992 and 1993 MEC for one- and two-family construction. A major change occurred to the thermal requirements in the 1995 MEC that carried through to the 2000 IECC.

A compliance margin for each plan-reviewed house was determined based on each of the code editions specified in Table 4.4.1. Assumptions were made during the plan review analysis stage if there was not enough information on the plans to complete the input file. The average rate of compliance for the 1992 – 1993 houses ranged from -16.50% worse than code to 43.10% better than code. Compared to the 1995 MEC, these rates range from –18.35% to 41.5%. These extremes represented two locations with two houses and one house respectively. More significant are the compliance rates for jurisdictions with larger sample sizes. Typically, most of the compliance rates for the plan reviewed structures did not comply with the energy code. This was primarily due to the lack of information on the building plans as it related to windows and heating and cooling efficiency. For example, West Des Moines had an average compliance rate –10.98% worst than code when compared against the 1992 MEC but on average was 1.79% better than code when field data was used.

Table 4.4.1 – Energy Code Compliance Rates

Single Family Structures				
Code Years				
	1992-1993		1995-2000	
	Plan Check	Field Inspection	Plan Check	Field Inspection
Ankeny	-1.00%	0.42%	-3.27%	-1.71%
Coralville	11.84%	5.73%	2.22%	8.89%
Des Moines	-2.63%	-2.60%	-5.65%	-5.28%
Iowa City	1.80%	10.13%	-4.13%	3.90%
Indian Valley College	21.40%	25.90%	18.30%	23.10%
Iowa Central Community College	43.10%	43.10%	41.50%	41.50%
Johnston	-1.70%	16.40%	-6.20%	12.70%
North Liberty	1.2%	21.3%	-1.4%	18.8%
Sioux Center	-16.50%	-0.30%	-18.35%	-2.05%
Waukee	1.05%	4.46%	-1.59%	3.57%
West Des Moines	-10.98%	1.79%	-12.59%	0.17%
Study Average	-1.59%	4.63%	-5.96%	2.84%

Section 4.4.2 Field Inspection Single-Family. The compliance margin for each house was also determined based on data collected in the field. Using field data to determine the compliance margin was an important goal of the study as this determined if the built home actually met the energy code instead of just the home as represented on the building plans and documentation. The values entered on the data collection forms used during the plan review portion of the study were verified in the field and corrected as needed. These values were then used to determine the realized rate of compliance for each code edition.

As mentioned in Section 4.4.1 the compliance rates for field inspected homes typically complied with both the 1992 – 1993 MEC and the 1995 MEC through 2000 IECC. Des Moines and Sioux Center were the only jurisdictions with negative compliance rates for the field inspected homes but this represented a small portion of the overall sample. The table clearly shows that compliance rate for the buildings “as built” are significantly higher than the buildings as designed and submitted for permit primarily because of a lack of accurate information on the building plans.

High performance (low U-factor) glazing and high efficiency heating equipment were two significant factors in the increased compliance rates between the plan reviewed homes and the field inspected homes. Figure 4.5.1a shows that the typical window was vinyl framed, low e argon and the average furnace efficiency was an 89% AFUE. Both of these features were used to trade off lower insulation levels in parts of the building envelope that would be required by more current energy codes.

Section 4.4.3 Plan Check Code Compliance Analysis Multi-Family. Table 4.4.3 shows the average rate of compliance with the plan checked sample for multi-family residential. It is important to point out that that the multi-family energy code efficiency requirements are less stringent than single-family construction. This will increase the compliance margin even though the insulation levels found in both the single- and multi-family sample were similar. Energy code compliance for the 1993 MEC was determined separately from the 1992 as there was a change in the efficiency requirements for multi-family that made the code more stringent. All of the plan reviewed town homes had positive compliance margins for all years of the energy code.

	1992-1993		1995-2000	
	Plan Check	Field Inspection	Plan Check	Field Inspection
Ankeny	16.33%	17.99%	9.82%	11.15%
Waukee	12.59%	12.34%	3.59%	3.53%
West Des Moines	10.42%	13.00%	5.16%	11.10%
Study Average	34.42%	37.49%	16.77%	21.49%

Table 4.4.3

Section 4.4.4 Field Inspection Code Compliance Analysis Multi-Family. As with the plan checked multi-family sample, the field inspection margins of compliance were all positive and typically higher than the plan reviewed houses. This was due to higher efficiency levels found in the field than what was shown on the plans or assumptions made due to lack of information on the building plans.

Section 4.5 – Statewide Analysis

Figure 4.5.1a and 4.5.1.b display the average levels of efficiency found in the single-family residential and multi-family residential building sample in Iowa on a statewide basis. The averages are based on the information collected in the field versus that collected during plan review. In addition to the levels of efficiency, the rates of compliance with the Model Energy Code and International Energy Conservation

Code are also listed for the entire sample as a whole. Further detail is provided for each of the categories in this report.

Summary of Findings – Statewide Single Family
Figure 4.5.1a
Based on Field Inspection – Sample Size of 47

Primary Roof: All Wood Rafter/Joist Truss – 100%

Average Ceiling Insulation R-Value – 41

Average Glazing Square Footage-324

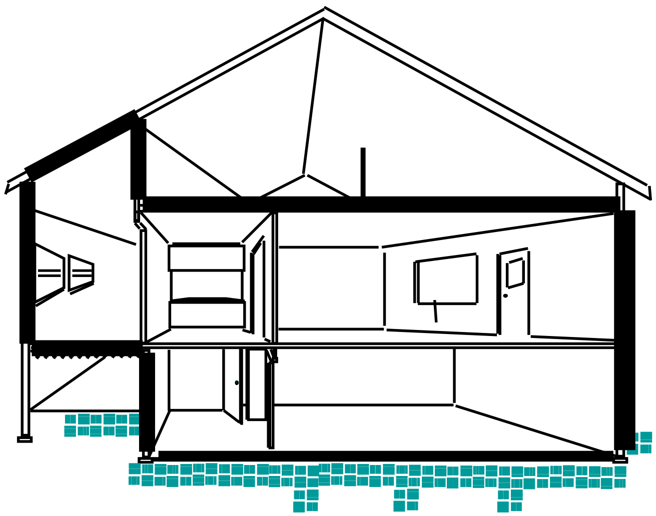
Primary Walls: Wood Frame, 16" o.c. – 100%

Average Wall Insulation R-Value – 14

Typical Glazing – Vinyl Framed Low E Argon 49%

Typical Heating System- Gas Heating 100%
Average AFUE- 89%

Average Glazing:Wall Area Ratio-14.31



Typical Entrance Door – Steel Foam Core 84%

Typical Cooling System- Air Cooled Air 96%
Average SEER- 11.9%

Foundation: Basement Insulated Concrete Wall – 72%

Average Insulation R-Value – 12

Average Square Footage: 2441

<u>Average MECcheck Results</u>

1992 MEC 4.63%
1993 MEC 4.63%
1995 MEC 2.84%
1998 IECC 2.84%
2000 IECC 2.84%

Summary of Findings – Statewide Multi Family
Figure 4.5.1b
Based on Field Inspection – Sample Size of 18

Primary Roof: All Wood Rafter/Joist Truss – 100%

Average Ceiling Insulation R-Value – 44

Primary Walls: Wood Frame, 16" o.c. – 100%

Average Wall Insulation R-Value – 13

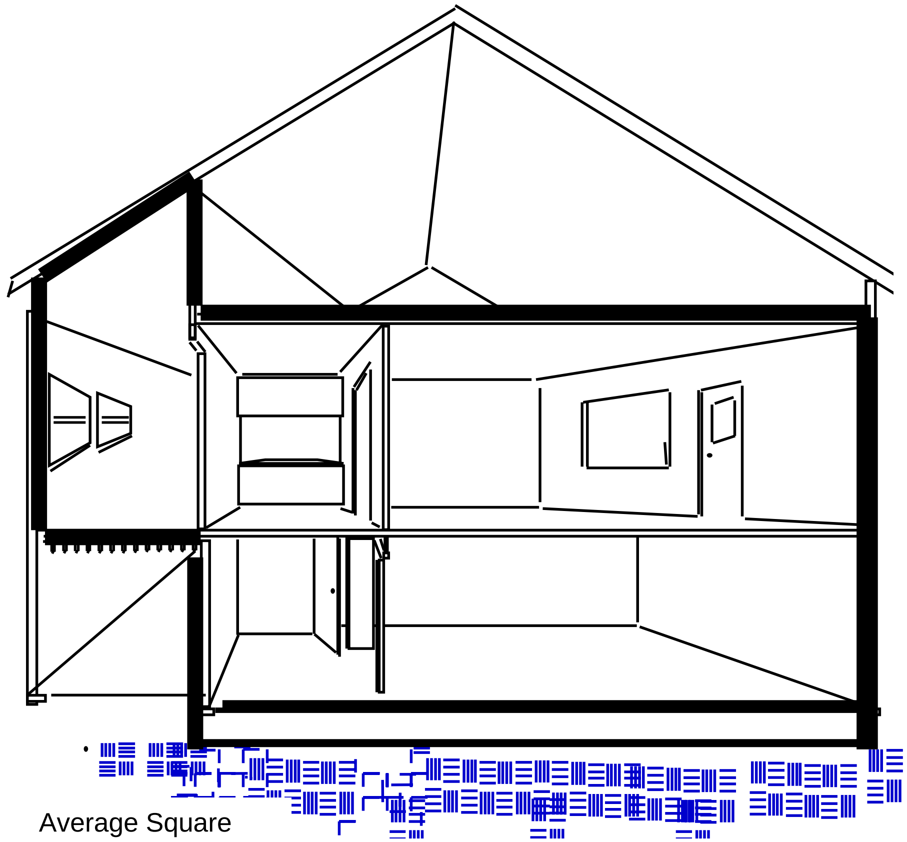
Average Glazing Square Footage-190

Typical Heating System- Gas Heating 100%
Average AFUE- 88

Typical Glazing – Vinyl Low E 67%

Typical Cooling System- Air Cooled Air 100%
Average SEER- 11.5

Average Glazing:Wall Area Ratio-17.99



Typical Entrance Door – Steel Foam Core 100%

Average Square Footage: 1587

Foundation: Slab 50%

Average Insulation R-Value – 10

Average MECcheck Results

1992 MEC – 39.3%
1993 MEC - .22.4%
1995-00 MEC – 21.49

Section 4.5.2 Determining Increases in Efficiency to Demonstrate Compliance with Different Code editions. One of the goals of the study was to determine the incremental increases in level of efficiency required to bring a noncompliant home into compliance with the particular code edition. The first step in the process was to determine typical upgrades in efficiency that could be used to bring up the level of compliance. These were based on regional construction practices. To ensure consistency the upgrades were added in order (starting with lowest cost first) until compliance was demonstrated for a particular home. For example, the first upgrade for a building might be installing basement wall insulation if there was none found during the onsite inspection. Installing an R-5 rigid board insulation on the exterior of the basement wall was the second upgrade of the building would still not comply with the code. If compliance was still not achieved further conservation measures were installed until compliance was achieved. No changes were made to the window area, assembly areas or volume of the building

The goal was to gain compliance for the structure to a level, which could be defined as a zero (0) percent compliance margin or better. For example if adding the feature raised the margin from a –5% worse-than-code to a +2% better-than-code the analysis ended and the results recorded. No attempt was made to "optimize" the model to reduce the compliance margin down to minimal code compliance or zero. For Iowa the following upgrades were determined:

- **First:** Install basement wall insulation to an R-11, which had a major impact to energy code compliance.
- **Second:** Install rigid board insulation on the exterior of the basement wall to an R-5. This can also be used as part of the damp proofing for basement walls.
- **Third:** Install R-19 floor insulation in raised floors over crawlspaces if none was found in the field.
- **Fourth**: Increase the furnace efficiency to a 90% AFUE. This was a typical installation in several of the field inspected homes.
- **Fifth**: Increase the wall cavity insulation to an R-13. Only one of the non-compliant homes had R-11 insulation in the wall system and, while cost effective, was not added to the list of efficiency increases until late in the analysis.
- **Sixth**: Add R-5 continuous insulation to the exterior of the wall system.

			Improvements Needed to Comply (Listed in Order of Upgrades)							
					1	2	3	4	5	6
Average Compliance Rate			Total Sample Size	Total Non-compliant Homes	Basement Cavity Insul to R-11	Basement Cont Insul to R-5	Floor Insulation to R-19	Furnace AFUE to 90	Wall Cavity Insul to R-13	Wall Cont Insul to R-5
Code edition	**Plan Check**	**Field Inspection**								
1992/93	-1.59	4.63	47	16	14	2	1	0	1	2
1995/00	-5.96	2.84	47	19	15	5	2	1	1	2

Table 4.5.2 – Efficiency Upgrades to Demonstrate Compliance

Table 4.6 displays the conservation feature upgrades required to demonstrate compliance with each of the code editions for the population of single-family homes. The table also displays the total number of occurrences that each conservation feature was added to a home to show compliance with a particular year of the code. For example, 19 homes did not comply with the 1995 MEC. Of these homes, 19 homes were required to add basement wall insulation. The remaining four already had insulation placed in the basement wall. Five of the homes were required to add R-5 insulation to the exterior of the basement wall. As the next step, two of the noncompliant homes were required to insulate the raised floors to an R-19. If compliance was not reached after this upgrade, the furnace efficiency was increased to a 90% AFUE furnace. This was required for one of the homes. Increasing the wall insulation level to an R-13 was also added as an upgrade with one home requiring this modification. Finally, an R-5 rigid insulation was added to the exterior of the wall system on two of the homes. Increasing glazing efficiency was not considered an upgrade as most of the homes that did not comply with the energy code were installing high efficiency windows.

For the 1992 and 1993 code homes 79% of the non-compliant homes were required to install basement wall insulation to gain compliance. For the 1995 through 2000 editions, 88% of the homes were required to install basement insulation.

The upgrade packages presented in this report represent only one option selected to demonstrate compliance with the various code editions. Based on the compliance approach used, the packages may differ as the documentation author optimizes the compliance package based on the building configuration.

Section 4.5.3 Foundation System. Table 4.5.3(1) lists the primary foundation types for the single family homes in the study. The primary foundation type for the sample population of homes in Iowa is a concrete basement insulated wall. There were several occurrences of non-insulated walls discovered during the field visits.

Single Family Primary Foundations	Occurrence	Average Area (Ft^2)
Basement Ins Concrete Wall	72%	1093
Basement Non-Ins	19%	1064
Slab	4%	105 (linear feet)
Basement Ins Wood Frame	4%	864

Table 4.5.3(1)

Table 4.5.3(2) lists the primary foundation types for the multi-family family homes in the study. The primary foundation type for the sample population of homes in Iowa is slab–on-grade. Thirty-three percent of the town homes were built over a basement, a portion of the units surveyed were upstairs units, and had no floor associated with the unit.

Multi Family Primary Foundations	Occurrence	Average Area
Basement Ins Concrete Wall	33.33%	758.67
Basement Non-Ins	5.56%	924.00
Slab	50.00%	110.56
None (upstairs unit)	11.11%	0.00

Table 4.5.3(2)

Average basement wall insulation for single-family homes was an R-9.3 installed between framing. The insulation level was lower than what would be considered a standard R-value because uninsulated basement walls were included in the weighted average. Typically, R-11 insulation was installed when the walls were insulated.

Single Family Primary Foundations	Average Continuous R-Value	Cavity R-Value
Basement Ins Concrete Wall	9.65	9.23
Slab	0	0
Basement Ins Wood Frame	0	15

Table 4.5.3(3)
Average R-Values of Installed Insulation

Multi-family slab edge insulation foundations were insulated to an R-10. This was typical of multi-family slab foundations reviewed in Iowa.

Multi Family Primary Foundations	Average Continuous R-Value	Cavity R-Value
Basement Ins Concrete Wall	6.67	6.5
Slab	10	0

Table 4.5.3(4)

Determining insulated basement wall insulation placement is necessary for compliance with the energy codes. The MEC*check* software requires three inputs that are included in Table 4.5.3(5) and Figure 4.5.3(1). From a building code standpoint, the distance from the top of the exterior grade line to the top of the footing will be at least 6 inches less than the from the top of the footing to the top of the stem wall as shown in line A and B in Figure 4.5.3(1). Inspections found that most of the insulation installed in basement walls starting at the top of the foundation wall and went to the floor.

Primary Foundation Insulation Dimensions A, B, C and D Field Inspection Only – Measured in Feet

Single Family Insulated Concrete Basement Wall Insulation Distribution - measured in feet			
	Dimension A	Dimension B	Dimension C
Basement Ins Concrete Wall	7.18	6.53	7.13
Basement Ins Wood Frame	4.00	3.75	4.00

Table 4.5.3(5)

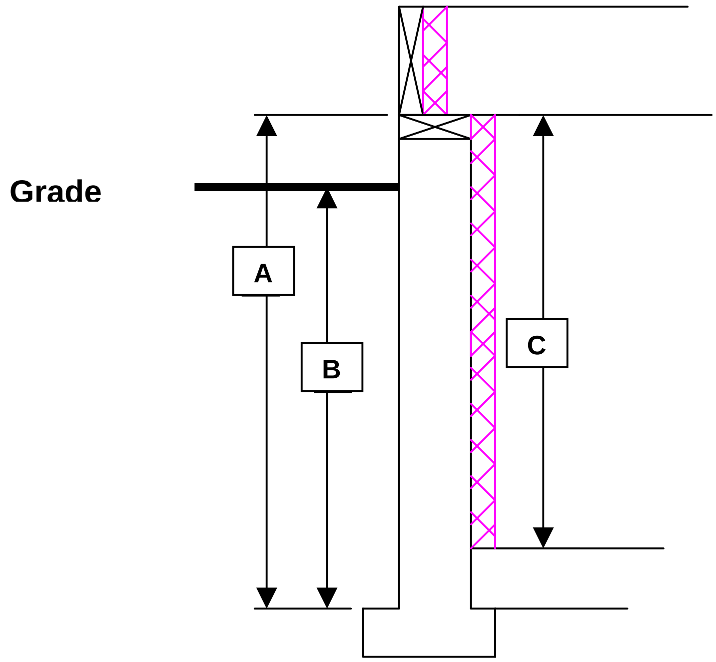


Figure 4.5.3(1)

Table 4.5.6(6) shows the percentage of single-family homes in the sample that had a secondary foundation type. For example over 27% of the single-family homes surveyed had crawlspace insulated floors which in this case was a floor over an unconditioned garage. A small number of homes also had a slab-on-grade in addition to the primary foundation type. This was typically under an entry area in a split-level house.

Single Family Secondary Foundations	Occurrence	Average Area
Basement Ins Concrete Wall	4.55%	592
Basement Non-Ins	2.27%	1624
Slab	4.55%	38
Basement Ins Wood Frame	4.55%	505
Crawlspace Insulated Floor	27.27%	276

Table 4.5.6(6)

Average R-values for the secondary foundation systems are shown in Table 4.5.6(6). For crawlspace insulated floors (e.g. floors over an unconditioned garage) the typical R-value found was an R-19 but there were a few instances where no insulation was found in the floor, which reduced the weighted average to an R 15.7.

Single Family Secondary Foundations	Average Continuous R-Value	Cavity R-Value
Basement Ins Concrete Wall	2	5.5
Slab	0	0
Basement Ins Wood Frame	0	16
Crawlspace Insulated Floor	0	15.7

Table 4.5.6(6)

For multi-family the only secondary foundation that was found was a crawlspace insulation floor (i.e. a floor over an unconditioned garage). This occurred on two story townhouses or in one case a three-story townhouse.

Multi Family Secondary Foundations	Occurrence	Average Area	Average Continuous R-Value	Cavity R-Value
Crawlspace Ins Floor	26.32%	237	0	27.8

Table 4.5.6(7)

Section 4.5.7 Exterior Wall Information. Three types of wall systems were documented within the study. Exterior walls were considered walls between the conditioned space and the outdoors. Secondary wall systems were defined as walls between the conditioned space and an attached garage. Tertiary walls were defined as the wall between the conditioned space and the ventilated attic or more commonly referred to as an attic kneewall. This condition occurred in homes with vaulted ceilings. Basement walkout walls were also documented.

Table 4.5.7(1) is a summary of the different wall systems that were found during the onsite inspections. All of the wall systems found in Iowa consisted of wood studs 16" on-center spacing, except two of the three walkout basement walls, which were concrete. Typical R-values for the primary exterior framed wall systems was R-13 with a portion of the wall systems at a R-15. Typical exterior primary walls were 2" x 4" wood stud. Rigid board insulation was found on a small percentage of the primary wall systems in addition to insulation placed between wood framing. The majority of the homes also had an attached garage associated with the house. In some cases, the wall between the house and garage was accounted for separately from the exterior wall during the area take-offs. These occurrences are recorded in Table 4.5.7(1). Walkout basement walls are considered an exterior wall by code.

If the insulation in the wall systems could not be verified on site, the insulation R-value from the plan review data was used for the analysis. In certain cases, an assumed insulation value was used during plan review because of lack of information on the building plans. This was carried through to the field inspection data.

Single Family Wall Systems	Occurrences	Average Area	Weighted Average Continuous R-Value	Weighted Average Cavity R-Value
Primary Exterior Wall	47	1936	3.15	13.8
Garage/House Wall	28	265	3.7	14.9
Kneewall	11	225.18	10	18.6

Table 4.5.7(1)

Table 4.5.7(2) shows the typical exterior walls for the multi-family units. As with the single-family homes, the typical exterior wall was 2" x 4" wood stud with spaced at 16" on center. Walls between the house and the unconditioned garage were recorded for multi-family homes. These walls were constructed identically to the exterior walls. Walkout basement walls were recorded in two of the homes in the survey. These walls were both concrete.

Insulation levels found in multi-family exterior walls were consistent with the insulation levels found in single-family exterior walls. The typical R-value was an R-13. Attic kneewalls were found to insulated higher than the other exterior wall systems with an average R-value of R-15.5.

Multi-Family Wall Systems	Occurrences	Average Area	Weighted Average Continuous R-Value	Weighted Average Cavity R-Value
Primary Exterior Wall	18	743.50	0.00	13.1
Garage/House Wall	14	279.29	0.00	13.6
Kneewall	6	74.00	15.5	0.00
Walkout Basement Wall	2	144.00	0.00	0.00

Table 4.5.7(2)

Section 4.5.8 Roof Information. Data on roof systems was collected to determine the average roof area and insulation R-value. Typically, the primary roof system was considered the system that was predominantly used in the home, for example, a vented attic. If a home used both standard truss systems for a flat ceiling and then a scissor truss system for a vaulted ceiling, these were combined into one roof system as they both include a vented attic. Table 4.5.8 lists the roof types and insulation R-values that were found in the sample.

Single Family Primary Ceiling/Roof Assemblies	Average Area	Weighted Average R-Value
All Wood Joist Rafter Truss	1285	40.6
Raised or Oversize Joist Rafter	1235	44.0

Table 4.5.8(1)

The predominate roof type in the sample was a standard all wood joist or truss system. One of the homes surveyed had oversized or energy trusses installed for the roof system. The predominate installed roof insulation was an R-40 with a six of the homes installing an R-38 insulation and one house installing an R-60 insulation (Iowa Central Community College). One single-family home installed a raised heel or oversize truss and installed R-44 insulation.

The roofs of the town homes were all standard joist construction with an average R-value of 42.1.

Multi Family Primary Ceiling/Roof Assemblies	Average Area	Weighted Average R-Value
All Wood Joist Rafter Truss	1129.94	42.1

Table 4.5.8(2)

Section 4.5.9 Window/Skylight Information. Information on window type, glazing efficiency and glazing area was collected during both the plan check and field inspection portion of the study. As reported earlier in the report the majority of the plan reviews did not include information on window type, thus study analysis relied on assumptions made in the plan review documentation and data collected by the field collection team. NFRC labels were the source of U-factors, in the absence of NFRC labels study analysis relied on default U-factors for the type of window (for example vinyl, low-e) observed in the field.

Primary Window Type

Table 4.5.9(1) provides information about the primary window type found in the field. The primary window type was defined as the predominant glazing type found in each of the houses. The primary window type was primarily an operable window. The table is based on the percent of occurrence based on number of homes inspected. Vinyl framed, Low E Argon windows were identified as the predominant window type in Iowa. Overall, the window efficiency recorded in very high with only 2% of the homes reporting wood clad aluminum windows.

Single Family Primary Windows	Occurrences	Average Area	Average Weighted U-Factor
Vinyl Framed Low E Argon	49%	302	0.33
Vinyl Framed Low E	30%	318	0.36
Vinyl Framed	9%	240	0.37
Aluminum / Wood	2%	233	0.56
Wood Framed Low E Argon	11%	401	0.34

Table 4.5.9(1)

A default U-factor was applied to the window if no U-factor was identified in the field. The default U-factor was taken from Table 102.5.2(1) of the 2000 International Energy Conservation Code. The study found that typically no glazing U-factor information was shown on the building plans. Glazing area shown on the building plans was typically consistent with that found in the field.

Secondary Window Type.

Several houses within the sample included secondary windows that were typically located in the basement and used as egress windows. Table 4.5.8(2) includes the type of window and frequency of occurrence in the single-family sample. A default U-factor was applied to the window if no U-factor was found in the field. The default U-factor was taken from Table 102.5.2(1) of the 2000 International Energy Conservation Code. Overall, the efficiency of the secondary windows was similar to the primary windows. Glazing area on average was much less than the primary windows due to the small window size and number of windows required in the basement for egress.

Single Family Secondary Windows	Occurrences	Average Area	Average Weighted U-Factor
Vinyl Framed Low E Argon	13%	62.00	0.28
Vinyl Framed Low E	13%	8.00	0.33
Vinyl Framed	63%	27.30	0.40
Wood Framed Low E Argon	13%	84.00	0.31

Table 4.5.9(2)

Multi-family glazing U-factor and area are shown in Table 4.5.9(3). On average, the glazing in multi-family dwelling units was less efficient than the single-family sample. There were several more cases of standard vinyl framed windows reported in the multi-family sample. The average glazing area was also less than that of the single-family sample. This is primarily due to the limited exterior wall area in multi-family construction.

Multi Family Primary Windows	Occurrences	Average Area	Average Weighted U-Factor
Vinyl Framed Low E	67%	197.58	0.35
Vinyl Framed	33%	173.50	0.44

Table 4.5.9(3)

Section 4.5.10 Skylight Type. Three of the single-family buildings in the sample included skylights. These were recorded during both the plan check process and verified in the field. Table 4.5.10 shows the area and U-factor for each occurrence. A default U-factor was used for the metal skylight and an NFRC label was used for the vinyl framed, low e argon skylight.

Primary Skylight Type	Average Square Feet	U-factor
Metal	8	1.3
Vinyl Framed Low E Argon	11	.39

Table 4.5.10

Section 4.5.11 Door Information. The type and area of doors located in the exterior wall, or in the wall between the house and garage, was recorded during the plan check process and the field inspection process. Only the data recorded in the field was included in this report as there was typically no information included on the building plans for exterior doors.

Main Entrance Doors.

Table 4.5.11(1) includes information on the main entrance door to the house. The primary door type in Iowa was a steel foam core door (83.72%). All of the entrance doors were 20 Ft^2 in area with the exception of three 30 Ft^2 entrance doors found in the field. A typical 3-foot wide entrance door is approximately 20 square feet. A default U-factor was assumed for all of the structures that were surveyed in the field due to a lack labeling in the field. Table 102.5.2(2) of the 2000 IECC was used to determine the U-factors. No storm doors were reported in the study. Less than seven percent of the entrance doors found in the field were classified as glass doors and very few of the entrance doors were wood or wood panel. Note the unlabeled doors were doors where the area was recorded but not the door type. Based on construction practice in Iowa, these were assigned a U-factor of 0.35, typical for a steel foam core door. Nine homes had and an additional exterior door located in the exterior wall. All of the additional doors were glass doors. One was labeled as U-factor .30, others assumed to be .56.

Main Entrance Door	Occurrence	U-Factor
Steel Foam Core	85%	0.35
Wood	6%	0.4
Glass	6%	0.56
Unlabled	2%	0.35

Table 4.5.11(1)

All multi family main entrance doors, except one glass door, were reported as steel foam core, 20 Ft^2 in area with an assumed U-factor of .35. The glass door was unlabeled and was assumed to have U-factor of .56 based on Table 102.5.2(2) of the 2000 IECC.

Garage/House Door.

Table 4.5.11(2) includes information on the door to the garage. The typical door type in Iowa was identified in the field as either a solid wood door (58.14%) or a solid core door (23.26%). Solid doors are typically installed to meet the building code requirements. The average area for the doors to the garage was 18.53 Ft^2. A typical 2'10" foot wide door is approximately 18 square feet. The solid wood and solid core doors had a U-factor of 0.40. A default U-factor was assumed in all of the structures due to lack of labeling in the field. Table 102.5.2(2) of the 2000 IECC was used to determine the U-factors. No storm doors were reported in the study.

House / Garage Door	Occurrence	U-Factor
Steel Foam Core	23%	0.35
Wood	53%	0.4
Solid Core Flush	21%	0.4
Unlabled	2%	0.35

Table 4.5.11(2)

Section 4.5.12 Duct Information - Field Inspection Only Data. The jurisdictions in Iowa did not require mechanical plans to be submitted for the permit process. Therefore, information concerning the duct system was collected during the field inspection process. Data was collected for both the return and duct systems.

Table 4.5.12(1) provides field data for the duct type (e.g. flexible), sealing methods used and insulation R-values for the supply and return duct. Because of the similarity in single- and multi-family heating and cooling installation practices, the field data was combined. Supply duct systems used flexible ducts in 85% of the buildings. Sheet metal ducting was used in approximately 94% of the structure as much of the ductwork was run in the basement. For return duct systems, sheet metal returns were used in the majority of the buildings (94%) with flexible ductwork occurring in less than 50% of the buildings surveyed. Framing cavities were also used in several of the buildings for return air but this information was not recorded on the data collection sheets.

An important element of the study looked at the method of duct sealing that was used on the return duct systems. The data collected in the field shows that no unlisted or labeled tape (i.e. duct tape) was found on the installations. The primary duct sealant method for supply air systems was mastic and tape, occurring in over 65% of the installations. Zip ties were found a significant number of times (86% of the buildings) but this was typically to hold the insulation for the flexible duct systems. UL 181 approved tape was also found in the field in approximately 22% of the occurrences. Other connectors that were found in the field included screws that are used more as a connector than a sealant. No data was collected for the type of sealant used for return ducts using framed cavities as these were concealed during the onsite inspections. The original intent for this study was to perform a duct blaster test on all of the duct systems but, after performing air leakage tests during the initial field visit, the results from this effort were found to be inclusive and the testing abandoned. Several penetrations were found in the return air systems from piping and electrical that resulted in massive leakage in the systems.

Duct Sealant and Insulation R-value		
	Return Ducts	**Supply Ducts**
Duct Type Flex	43%	85%
Duct Type Sheet Metal	94%	94%
Duct Type Fiber Glass	0%	0%
Duct Sealant UL181 Tape	22%	22%
Duct Sealant Mastic	5%	5%
Duct Sealant Mastic + Tape	66%	66%
Duct Sealant Duct Tape	0%	0%
Duct Sealant Zip Ties	75%	86%
Duct Sealant Screws	95%	95%
Insulation R-Value	1.83	4.33

Table 4.5.12(1)

Several of the return duct systems that were found in the field had no insulation. These were installed in the basement, which was considered a conditioned space by code. The average duct insulation for the return duct systems was an R-1.83. For the supply duct systems, the average insulation was an R-4.3. Insulation was always found on the supply duct systems but there was a large occurrence of R-4.2 duct insulation and a smaller occurrence of R–6 insulation.

Duct Location

Table 4.5.12(2) shows frequency of ducts located in the attic, crawlspace/basement, or a combination of the attic and crawlspace/basement (combination). Single- and multi-family systems are included on this table. For return duct systems, the majority of the systems were located in the crawlspace or basement. This was typically the basement as very few of the buildings surveyed had crawlspaces. The return ducts were installed without insulation as the basements were considered conditioned. The town homes that were built on a slab-on-grade foundation had all ductwork located in the attic. For supply systems, the majority of the single-family systems had ducts located in both the attic and the crawlspace (see % of occurrence for Combination). Two story homes often supplied the first floor with ducts in the basement and the second floor with ducts in the attic. Ducts were found in conditioned space in approximately 4.88% of the units surveyed. Conditioned space locations included running the ductwork between floors in a two-story house.

Duct Location	Return Ducts	Supply Ducts
Combination	23%	66%
Attic	58%	17%
Crawlspace/Basement	11%	9%
Interior	3%	3%

Table 4.5.12(2)

Section 4.5.13 Furnace and Air Conditioning Efficiency. This section reports on data found during the field inspection portion of the study because of the lack of mechanical plans submitted during the plan check process. Typically, the jurisdictions in Iowa did not require the applicant to submit mechanical plans for permit.

Furnace Efficiency.

The typical heating system found in the field as a gas furnace. The average furnace efficiency found in the field was an 89.95% AFUE. The majority of the furnaces found in the field had an AFUE of 90% or greater. There were only a few occurrences of minimum efficiency (78% AFUE) furnaces.

Multi-family system types matched the single-family sample as all of the heating systems found were gas furnaces. The furnace efficiency was also comparable to the single-family sample as the average AFUE was 88.28%. Again, very few of the dwelling units visited had minimum efficiency systems.

Cooling Efficiency.

All air conditioning systems found in the field for single family homes were air-cooled except for one heat pump cooling system. The average SEER for the cooling system was 11.76, which is slightly higher than minimum efficiency at 10.0 SEER. The heat pump was reported to have an SEER of 19.

The multi-family units had air cooled cooling systems with an average SEER of 11.56. As with the single-family sample, several of the multi-family dwelling units had systems with cooling efficiencies between 12 to 12.5 SEER.

Section 4.5.14 Air Leakage Testing. Each of the field inspected homes was blower door tested to determine the Natural Air Changes Per Hour (nACH) at 50 Pascals.

The average Natural Air Changes Per Hour for single-family homes tested was .26 nACH. As a comparison, the 1995 Model Energy Code assumes a nACH of .51 for the standard or "code house".

The testing was conducted in homes that were typically at, or near, the final inspection. The sheetrock had been installed, and the weatherstripping had been installed around all of the windows and doors located in the exterior walls and those leading to the garage. Table 4.5.14(1) shows a frequency distribution of the homes tested and the calculated nACH. The majority of the homes (51.6%) tested in the .20 - .29 nACH range with all of the homes tested testing at less than .49 nACH. Only thirty-one of the homes were tested due to weather constraints or homes not being ready to test during the inspection.

Natural Air Changes per Hour nACH	Number of Occurrences	Frequency
<.20	5	16.1%
.20 - .29	16	51.6%
.30 - .39	9	29.0%
.40 - .49	1	3.2%

Table 4.5.14(1)

Table 4.5.14(2) shows the frequency distribution of the multi-family town home units that were tested during the study. The average nACH for the town home units was .32, which was higher than the single-family homes that were tested. Over ninety percent of the units tested at .39 nACH or less. The higher rate of air leakage could be due to air leakage through the common wall between units on multi-family construction. Only 10 of the town homes were tested due to weather conditions or the units not being ready to test during the field visit.

Natural Air Changes per Hour nACH	Number of Occurrences	Frequency
<.30	4	40%
.30 - .39	5	50%
.40 - .49	0	0
.50 - .59	1	10%

Table 4.5.14(2)

SECTION 5.0 ISSUES AND RECOMMENDATIONS

Section 5.1 Selection of Project Sample

Gaining cooperation with the building officials was a fairly straight forward process but gaining cooperation with the builders was more difficult. The program design had been modified from an earlier program implemented in Nevada to try to solicit better builder cooperation. While more successful, there is still room for improvement in getting the builders to cooperate and participate in the program. Of the original sample of 65 homes that were selected for the study, twenty of the home were replaced by additional homes. The following course of action is recommended with respect to completion of similar studies:

Recommendations:

Gain cooperation from the local homebuilder associations prior to the start of the study so that they can notify their membership. The homebuilder groups and their membership must be comfortable that the results of the study will remain anonymous and that this study is for general, existing benchmark purposes only and not an audit of the builder's performance.

Gain cooperation from the building official association(s) to ensure that they are active participants in the study. This can go as far as allowing the jurisdictions to self-select to participate in the study. This program was very successful in gaining cooperation with the Iowa Association of Building Officials.

Request that the jurisdictions contact the builders prior to selecting their project for the study to ensure that the builder will cooperate. In addition, having the builders sign a "Builder Participation Form" prior to starting the data collection process will ensure that the builder is aware of the project and is willing to participate. In addition, the builder participation forms, it would also be advantageous for the data collection team to contact the selected builders prior to the starting the data collection process to confirm that they will participate in the study. There were cases where the builder did not know that their projects had been selected for the study, which lead to confusion in gaining access to the building site.

Select homes located in tract developments versus custom homes. This will allow the flexibility of going into a track and looking at the buildings in various stages of construction. This will also allow field inspection to be conducted on the model if the selected buildings are not finished.

Section 5.2 Data Collection Staff

Selecting staff to collect building data that are knowledgeable about the builders in the region and that have experience in both plan review and field inspection are critical to the success of study. Using locally based data collection staff will provide the needed flexibility to collect on-site data from one or two houses at a time without needing to travel in and out of the region or state on a scheduled basis. Also, selecting staff that require little to no training in reviewing plans and collecting information in the field will reduce the amount of time that the building official and builder will need to allow for the study. For future studies the following course of action is recommended:

Recommendations:

The data collection teams used in the study were very experienced in collecting data which was critical because of out of state travel. Typically conducting the plan review portion of the study is a straight forward process and can be scheduled and implemented easily. The field portion of the study is much more difficult to implement and schedule requiring flexibility. For this reason one recommendation would be to utilize trained home energy raters and/or home inspection staff located in the region that are trained in both plan review and field inspection and that can operate a blower door effectively. This will limit the quantity of time that the staff will need to spend at the jurisdiction office and on the construction site. Those involved in these professions will typically also have contact with local builders and potentially builder associations. While the program was successful in meeting the sample size there, having a staff person located in the state would have reduced the number of projects that were dropped from the study.

Section 5.3 Scheduling of Plan Review and Field Data Collection

A better screening process should be used to select projects that are close to completion during the plan review so that the field inspection can be scheduled directly afterward. The field collection portion of the study should closely follow plan review to ensure that the homes that were selected are not occupied once the team is ready to go into the field. For future studies the following course of action is recommended:

Recommendations:

Ensure that the builder is still building the model (if a tract development) that was selected for the study. The jurisdiction may not know that a particular model has been discontinued. When in doubt, call the builder directly before selecting the plan set.

Contact the builder within one-week of finishing the plan review portion of the project to start scheduling field inspections. If two to three homes are selected from the same development, try to schedule to visit all of them on the same visit. It is important to work around the builder's schedule as their participation is voluntary and should be respected accordingly. This may mean getting to the site prior to, or after, the construction trade crews or to the models prior to them opening.

Try not to select buildings in the sample that will not be finished after 3 months. It is best to select buildings that either are close to being completed or will be done in one-to two-months. Selecting buildings that will take longer to finish will lengthen the study and there will be a chance that the home may not be built.

Section 5.4 Data Collection Tool

The data analysis portion of the program was very straight forward due to upfront planning. The data collection tool was developed from the analysis tool to ensure that date entry would be seamless from the form into the software. Selecting the data analysis tool should be the first step in the process and then the development of the data collection tool as was done in this program. The following course of action was used in this study:

Recommendations:

Determine the goals of the project before selecting the data analysis tool. The tool should meet the needs of the study but should also allow for a data collection tool that can be completed easily and quickly by the data collection team.

The data collection form should be developed based on the data analysis tool. MEC*check* met both the goals of the project and the data collection form was easily developed based on the inputs into the software.

Allow the data collection team to participate in the development of the form. It is critical that the team in the field be comfortable in using the form and is allowed to give comments on its design. This will go far in ensuring that they will collect the correct information.

Decide what type of information that must be collected during the study and what can be ignored. Collecting too much information can be more of an obstruction than the data is worth especially if the data will not be used in the final reporting for the project. The data collection team will only have a limited quantity of time to collect data due to time and budget constraints so limiting the data collected will be important.

Appendix I
Jurisdictional Results

ANALYSIS SUMMARY – Ankeny

Summary

- Sample Size Single Family
  - Plan Check- 13
  - Field Check- 12
- Sample Size Multi Family
  - Plan Check and Field Check 8

The following documentation is based on single family field checks

- Some Energy Code Compliance Documentation was submitted with 2 of 12 plans
- R-Values Shown on Plans on 9 of 12 structures
- U-Factors NOT Shown on any Plans

Pass/Fail of Each Code edition

			Improvements Needed to Comply (Listed in Order of Upgrades)								
					1	2	3	4	5	6	7
Average Compliance Rate			Total Sample Size	Total Non-compliant Homes	Ceilings to R-38	Basement Cavity Insul to R-11	Basement Cont Insul to R-5	Floor Insulation to R-19	Furnace AFUE to 90	Wall Cavity Insul to R-13	Wall Cont Insul to R-5
Code edition	**Plan Check**	**Field Inspection**									
1992/93	**-1.66**	**0.69**	12	6	0	4	1	0	0	1	2
1995/00	**-5.45**	**-2.85**	12	8	0	5	3	0	0	1	2

Summary of Findings – Ankeny
Based on Field Inspection – 12 Houses

Primary Roof: All Wood
Rafter/Joist Truss – 100%

Average Ceiling Insulation R-Value – 39.39

Primary Walls: Wood Frame, 16” o.c. – 100%

Average Wall Insulation R-Value – 13.94

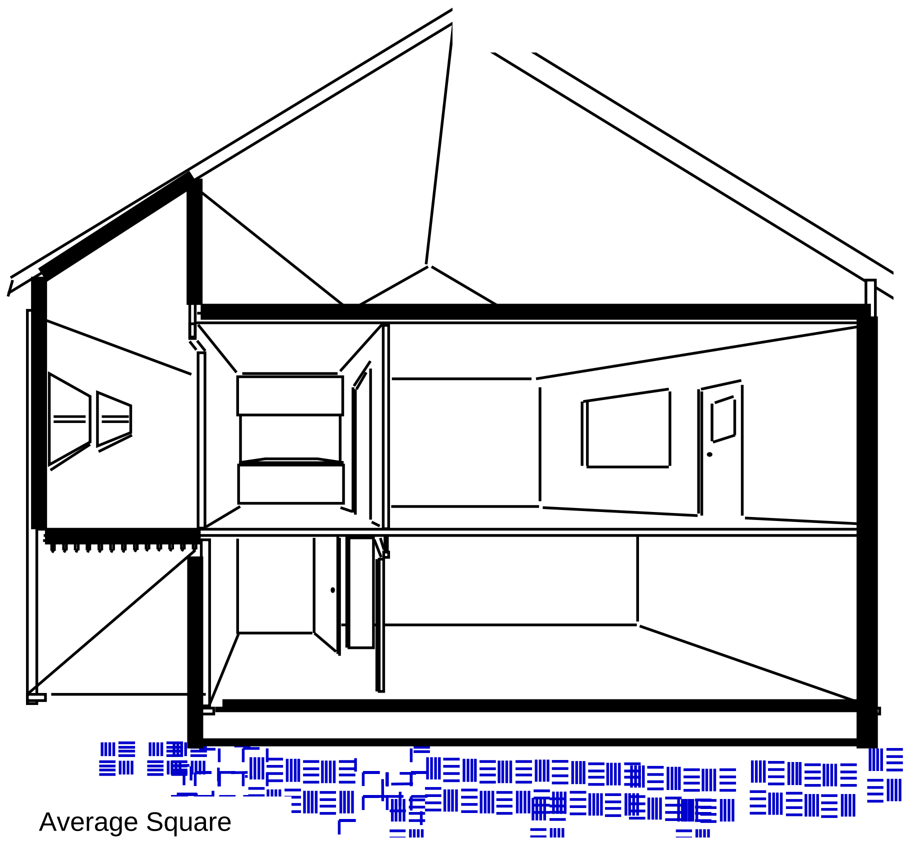
Average Glazing Square Footage-294

Typical Heating System- Gas Heating 100%
Average AFUE- 89

Average Glazing:Wall Area Ratio-14%

Typical Glazing – Vinyl Low E 50%

Typical Cooling System- Air Cooled Air 100%
Average SEER- 12



Typical Entrance Door – Steel Foam Core 75%

<u>Average MECcheck Results</u>

1992-93 MEC - .69
1995-00 MEC - -2.85

Average Square Footage: 3012

Foundation: Basement Insulated Conc. – 75%

Average Insulation R-Value – 12.11

Foundation Systems

- Primary Foundation Type – 75 % of field checked structures in the Ankeny sample had Basement Insulated Concrete Wall Foundations, with an average of R-12 insulation
  - Primary Foundation Area/Linear Ft. – The average foundation area was 1204 square feet.
- Secondary Foundation Information

  Three field inspected homes had secondary foundations.

Secondary Foundation Types	Secondary Foundation Area/Linear Ft	Secondary Foundation R-Value	Secondary Foundation Insulation Placement
Basement Non-Insulated	200	0	Cavity
Crawlspace Insul Floor	18	30	Cavity
Slab	36	10	Continuous

Wall Information

- Primary Exterior Walls
  - o Type –all walls are 16" o.c. Wood studs
  - o Area – 2089 Square Feet
  - o Weighted Average of Insulation R-Value – 13.9
- House/Garage Walls – 2 field checked structures had secondary wall systems, typically between the garage and house.
  - o Type –all walls are 16" o.c. Wood studs
  - o Area – 203 Square Feet
  - o Weighted Average of Insulation R-Value - 19
  - o Insulation Placement – Cavity

Roof Information

- Primary Roof
  - o Type – All primary roof structures in the Ankeny sample set were All Wood Joist Rafter Truss Systems
  - o Average Area – 1370 Square Feet
  - o Weighted Average of Insulation R-Value – 39

Window/Skylight Information

- Primary Window
  - o Half of the windows were Vinyl Framed Low E, the remainder were Vinyl framed, or Vinyl framed Low E Argon Filled;
  - o Average Square Feet Glazing Area - 318 square feet
  - o Weighted Average U- Factor – .36
  - o Default U-factor used? – The default U-factor of .35 was used in 75% of the

calculations, however that is a conservative estimate, based on the windows recorded;

Door Information

- Main Entrance Door
    - 75% of the Main Entrance doors were found to be Steel Foam Core
    - Average Area – 21.67 Square feet
    - Default U-Factor for Steel Foam Core doors is .35, no labeling was found on-site
    - No Storm Doors were reported

- Garage/House Door
    - 50% of the House/Garage doors were Solid Core Flush
    - Average Area – 18 Square feet
    - Weighted Average U-Factor - .38
    - Default U-Factor for Solid Core Flush doors is .40, no labeling was found on-site
    - No Storm Doors were reported

- Other Exterior Door
    - Three "Other Exterior Door" were found, all glass
    - Average Area – 26.7 Square feet
    - Weighted Average U-Factor - .87
    - Default U-factor for Glass doors is .56, no labeling was found on-site
    - No Storm Doors were reported

Duct Information

- Return Duct
    - Location – 83% of return duct systems were in the crawlspace
    - Material Type – 100% were constructed of sheet metal type ducting, two houses also had flex type ducting
    - Sealant – Distribution of sealant use is as follows:

Sealant Use	
Return Duct Sealant UL181 Tape	58%
Return Duct Sealant Mastic	25%
Return Duct Sealant Mastic+Tape	8%
Return Duct Sealant Duct Tape	0%
Return Duct Sealant Zip Ties	50%
Return Duct Sealant Screws	100%

    - Insulation R-Value – Average of .5

- Supply Duct
  - Location – All supply duct systems were located in a combination of the attic and crawlspace/basements
  - Material Type – All were constructed of flex type and sheet metal ducting
  - Sealant – Distribution of sealant use is as follows:

Sealant Use	
Supply Duct Sealant UL181 Tape	58%
Supply Duct Sealant Mastic	25%
Supply Duct Sealant Mastic+Tape	0%
Supply Duct Sealant Duct Tape	0%
Supply Duct Sealant Zip Ties	100%
Supply Duct Sealant Screws	100%

  - Insulation R-Value- Average of 6.

Mechanical System

- Heating System
  - Heating System Type – All structures had Gas Furnaces
  - Efficiency – Average Efficiency was 89 AFUE

- Cooling System
  - All of Structures had Air Conditioning – all were Air Cooled Air Systems.
  - Efficiency – Average Efficiency of 12 AFUE

Blower Door Testing

- Air Changes Per Hour – .25

ANALYSIS SUMMARY – West Des Moines

Summary

- Sample Size Single Family
    - Plan Check- 10
    - Field Check- 6
- Sample Size Multi Family
    - Plan Check and Field Check 3

The following documentation is based on single family field checks

- Some Energy Code Compliance Documentation was submitted with 1 of 6 plans
- R-Values Shown on Plans on 4 of 6 structures
- U-Factors Shown on one plan

Pass/Fail of Each Code edition

			Improvements Needed to Comply (Listed in Order of Upgrades)								
					1	2	3	4	5	6	7
Average Compliance Rate			Total Sample Size	Total Non-compliant Homes	Ceilings to R-38	Basement Cavity Insul to R-11	Basement Cont Insul to R-5	Floor Insulation to R-19	Furnace AFUE to 90	Wall Cavity Insul to R-13	Wall Cont Insul to R-5
Code edition	**Plan Check**	**Field Inspection**									
1992/93	**-1.66**	**0.69**	12	6	0	2	1	0	0	1	2
1995/00	**-5.45**	**-2.85**	12	8	0	2	3	0	0	1	2

Summary of Findings – West Des Moines
Based on Field Inspection – 6 Houses

Primary Roof: All Wood Rafter/Joist Truss – 100%

Average Ceiling Insulation R-Value – 40

Primary Walls: Wood Frame, 16" o.c. – 100%

Average Wall Insulation R-Value – 14

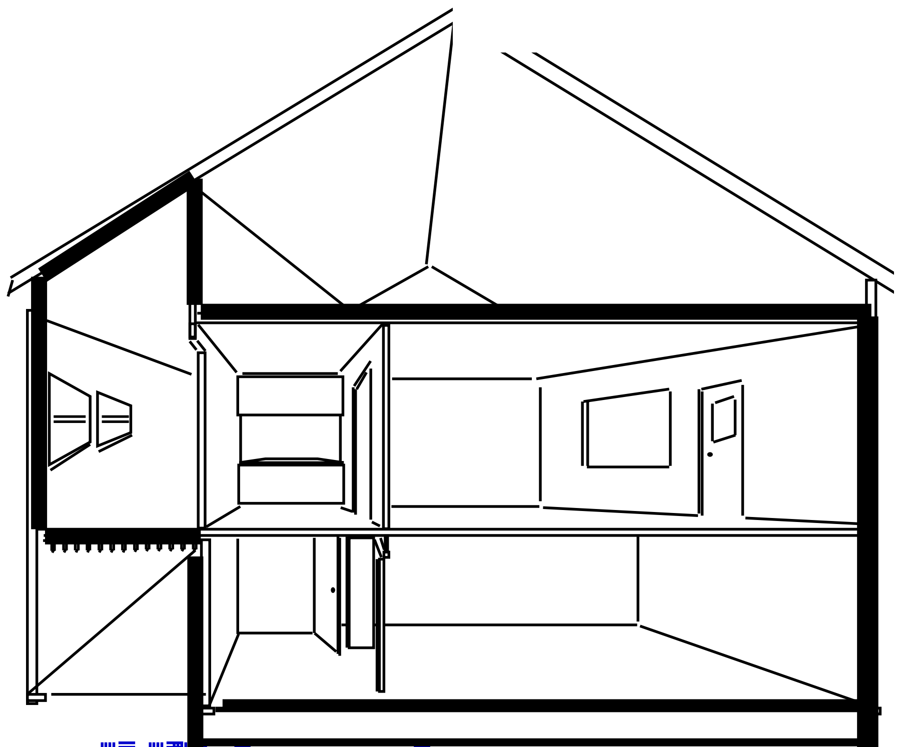
Average Glazing Square Footage-453

Typical Heating System- Gas Heating 100%
Average AFUE- 90

Average Glazing:Wall Area Ratio-18%

Typical Glazing – Vinyl Low E 50%, Low E Argon 50%

Typical Cooling System- Air Cooled Air 83%
Average SEER- 13



Typical Entrance Door – Steel Foam Core 83%

<u>Average MECcheck Results</u>
1992-93 MEC – 2.98
1995-00 MEC - .28

Average Square Footage: 3025

Foundation: Basement Insulated Conc. – 83%

Average Insulation R-Value – 12

Foundation Systems

- Primary Foundation Type – 83 % of field checked structures in the West Des Moines sample had Basement Insulated Concrete Wall Foundations, with an average of R-12 insulation
    - Primary Foundation Area/Linear Ft. – The average foundation area was 1103 square feet.
- Secondary Foundation Information

  Two field inspected homes had secondary foundations.

Secondary Foundation Types	Secondary Foundation Area/Linear Ft	Secondary Foundation R-Value	Secondary Foundation Insulation Placement
Basement Insul Wood Frame	400	19	Cavity
Crawlspace Insul Floor	310	19	Cavity

Wall Information

- Primary Exterior Walls
    - Type –all walls are 16” o.c. Wood studs
    - Area – 2244 Square Feet
    - Weighted Average of Insulation R-Value – 14
- House/Garage Walls – 3 field checked structures had secondary wall systems, typically between the garage and house.
    - Type –all walls are 16” o.c. Wood studs
    - Area – 331 Square Feet
    - Weighted Average of Insulation R-Value - 13
    - Insulation Placement – Cavity

Roof Information

- Primary Roof
    - Type – All primary roof structures in the West Des Moines sample set were All Wood Joist Rafter Truss Systems
    - Average Area – 1234 Square Feet
    - Weighted Average of Insulation R-Value – 40

Window/Skylight Information

- Primary Window
    - Half of the windows were Vinyl Framed Low E, half were Vinyl Framed, or Vinyl Framed Low E Argon Filled;
    - Average Square Feet Glazing Area - 424 square feet
    - Weighted Average U- Factor – .34
    - Default U-factor used? – The default U-factor of .35 was used in 67% of the calculations, however that is a conservative estimate, based on the windows recorded;

Door Information

- Main Entrance Door
    - 83% of the Main Entrance doors were found to be Steel Foam Core
    - Average Area – 20 Square feet
    - Default U-Factor for Steel Foam Core doors is .35, no labeling was found on-site
    - No Storm Doors were reported

- Garage/House Door
    - 67% of the House/Garage doors were Solid Core Flush
    - Average Area – 18.7 Square feet
    - Weighted Average U-Factor - .39
    - Default U-Factor for Solid Core Flush doors is .40, no labeling was found on-site
    - No Storm Doors were reported

- Other Exterior Door
    - One "Other Exterior Door" were found - glass
    - Average Area – 18 Square feet
    - Weighted Average U-Factor - .56
    - Default U-factor for Glass doors is .56, no labeling was found on-site
    - No Storm Doors were reported

Duct Information

- Return Duct
    - Location – 50% of return duct systems were a combination of the attic and crawlspace/basement
    - Material Type – 83% were constructed of sheet metal type ducting, four houses also had flex type ducting
    - Sealant – Distribution of sealant use is as follows:

Sealant Use	
Return Duct Sealant UL181 Tape	16%
Return Duct Sealant Mastic	0%
Return Duct Sealant Mastic+Tape	67%
Return Duct Sealant Duct Tape	0%
Return Duct Sealant Zip Ties	67%
Return Duct Sealant Screws	83%

    - Insulation R-Value – Average of 2

- Supply Duct
  - Location – 67% of the supply duct systems were located in a combination of the attic and crawlspace/basements
  - Material Type – 85% of the supply ducts were constructed of sheet metal, 67% also had flex type assemblies.
  - Sealant – Distribution of sealant use is as follows:

Sealant Use	
Supply Duct Sealant UL181 Tape	16%
Supply Duct Sealant Mastic	0%
Supply Duct Sealant Mastic+Tape	67%
Supply Duct Sealant Duct Tape	0%
Supply Duct Sealant Zip Ties	67%
Supply Duct Sealant Screws	83%

  - Insulation R-Value- Average of 3.7

Mechanical System

- Heating System
  - Heating System Type – All structures had Gas Furnaces
  - Efficiency – Average Efficiency was 90 AFUE

- Cooling System
  - All of Structures had Air Conditioning – 5 were Air Cooled Air Systems, 1 was a heat pump
  - Efficiency – Average Efficiency of 13 AFUE

Blower Door Testing

- Air Changes Per Hour – .26

ANALYSIS SUMMARY – Waukee

Summary

- Sample Size Single Family
  - Plan Check- 10
  - Field Check- 9
- Sample Size Multi Family
  - Plan Check and Field Check 1

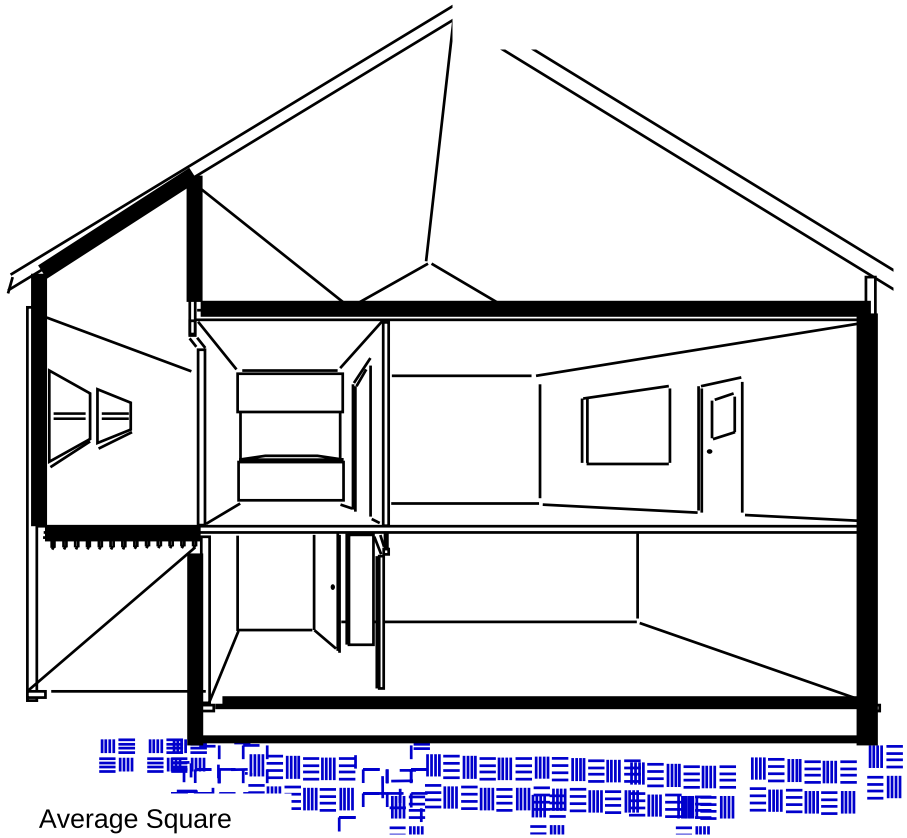
The following documentation is based on single family field checks

- NO Energy Code Compliance Documentation was submitted
- R-Values Shown on Plans on 8 of 9 structures
- U-Factors NOT Shown on any Plans

Pass/Fail of Each Code edition

			Improvements Needed to Comply (Listed in Order of Upgrades)								
					1	2	3	4	5	6	7
Average Compliance Rate			Total Sample Size	Total Non-compliant Homes	Ceilings to R-38	Basement Cavity Insul to R-11	Basement Cont Insul to R-5	Floor Insulation to R-19	Furnace AFUE to 90	Wall Cavity Insul to R-13	Wall Cont Insul to R-5
Code edition	Plan Check	Field Inspection									
1992/93	1.76	7.43	9	2	0	2	0	0	0	0	0
1995/00	-2.66	5.94	9	2	0	2	0	0	0	0	0

Summary of Findings – Waukee
Based on Field Inspection – 9 Houses



Average MECcheck Results

1992-93 MEC – 7.43
1995-00 MEC – 5.94

Foundation Systems

- Primary Foundation Type – 100% of field checked structures in the Waukee sample had Basement Concrete Wall Foundations, 7 of the nine were insulated, 2 were not. The resulting average insulation R-value was 9.56

  - Primary Foundation Area/Linear Ft. – The average foundation area was 798 square feet.

- Secondary Foundation Information

  Four field inspected homes had secondary foundations, each were floors extending over unconditioned garages.

Secondary Foundation Types	Secondary Foundation Average Area/Linear Ft	Secondary Foundation Average R-Value	Secondary Foundation Insulation Placement
Crawlspace Insul Floor	350	19	Cavity

Wall Information

- Primary Exterior Walls
  - Type –all walls are 16" o.c. Wood studs
  - Area – 2009 Square Feet
  - Weighted Average of Insulation R-Value – 13

- House/Garage Walls – 4 field checked structures had secondary wall systems, typically between the garage and house.
  - Type –all walls are 16" o.c. Wood studs
  - Area – 308 Square Feet
  - Weighted Average of Insulation R-Value - 13
  - Insulation Placement – Cavity

Roof Information

- Primary Roof
  - Type – All primary roof structures in the Waukee sample set were All Wood Joist Rafter Truss Systems
  - Average Area – 1196 Square Feet
  - Weighted Average of Insulation R-Value – 39.78

Window/Skylight Information

- Primary Window

  - 8 of the nine windows were Vinyl Framed Low E Argon, the remainder was Vinyl Framed Low E
  - Average Square Feet Glazing Area - 268 square feet
  - Weighted Average U- Factor – .35
  - Default U-factor used? – The default U-factor of .35 was used in 100% of the

calculations, however that is a conservative estimate, based on the windows recorded;

Door Information

- Main Entrance Door
    - 100% of the Main Entrance doors were found to be Steel Foam Core
    - Average Area – 20 Square feet
    - Default U-Factor for Steel Foam Core doors is .35, no labeling was found on-site
    - No Storm Doors were reported
- Garage/House Door
    - 100% of the House/Garage doors were Solid Core Flush
    - Average Area – 18.9 Square feet
    - Weighted Average U-Factor - .40
    - Default U-Factor for Solid Core Flush doors is .40, no labeling was found on-site
    - No Storm Doors were reported
- Other Exterior Door
    - No “Other Exterior Door” were found

Duct Information

- Return Duct
    - Location – 8 of 9 return duct systems were in the crawlspace
    - Material Type – 100% were constructed of sheet metal type ducting, two houses also had flex type ducting
    - Sealant – Distribution of sealant use is as follows:

Sealant Use	
Return Duct Sealant UL181 Tape	11%
Return Duct Sealant Mastic	0%
Return Duct Sealant Mastic+Tape	89%
Return Duct Sealant Duct Tape	0%
Return Duct Sealant Zip Ties	100%
Return Duct Sealant Screws	100%

    - Insulation R-Value – One house had insulation of R-6

- Supply Duct
  - Location – All supply duct systems were located in a combination of the attic and crawlspace/basements
  - Material Type – All were constructed of flex type and sheet metal ducting
  - Sealant – Distribution of sealant use is as follows:

Sealant Use	
Supply Duct Sealant UL181 Tape	11%
Supply Duct Sealant Mastic	0%
Supply Duct Sealant Mastic+Tape	89%
Supply Duct Sealant Duct Tape	0%
Supply Duct Sealant Zip Ties	100%
Supply Duct Sealant Screws	100%

  - Insulation R-Value- Average of 4.2

Mechanical System

- Heating System
  - Heating System Type – All structures had Gas Furnaces
  - Efficiency – Average Efficiency was 89 AFUE

- Cooling System
  - All of Structures had Air Conditioning – all were Air Cooled Air Systems.
  - Efficiency – Average Efficiency of 11.78 AFUE

Blower Door Testing

- Air Changes Per Hour – .28

ANALYSIS SUMMARY – Coralville

Summary

- Sample Size Single Family
    - Plan Check- 10
    - Field Check- 7
- Sample Size Multi Family
    - Plan Check and Field Check 0

The following documentation is based on single family field checks

- NO Energy Code Compliance Documentation was submitted
- R-Values Shown on Plans on 8 of 9 structures
- U-Factors NOT Shown on any Plans

Pass/Fail of Each Code edition

			Improvements Needed to Comply (Listed in Order of Upgrades)								
					1	2	3	4	5	6	7
Average Compliance Rate			Total Sample Size	Total Non-compliant Homes	Ceilings to R-38	Basement Cavity Insul to R-11	Basement Cont Insul to R-5	Floor Insulation to R-19	Furnace AFUE to 90	Wall Cavity Insul to R-13	Wall Cont Insul to R-5
Code edition	Plan Check	Field Inspection									
1992/93	11.84	5.7	7	1	0	1	0	0	0	0	0
1995/00	2.2	8.9	7	1	0	1	0	0	0	0	0

Summary of Findings – Coralville
Based on Field Inspection – 7 Houses

Primary Roof: All Wood Rafter/Joist Truss – 100%

Average Ceiling Insulation R-Value – 40

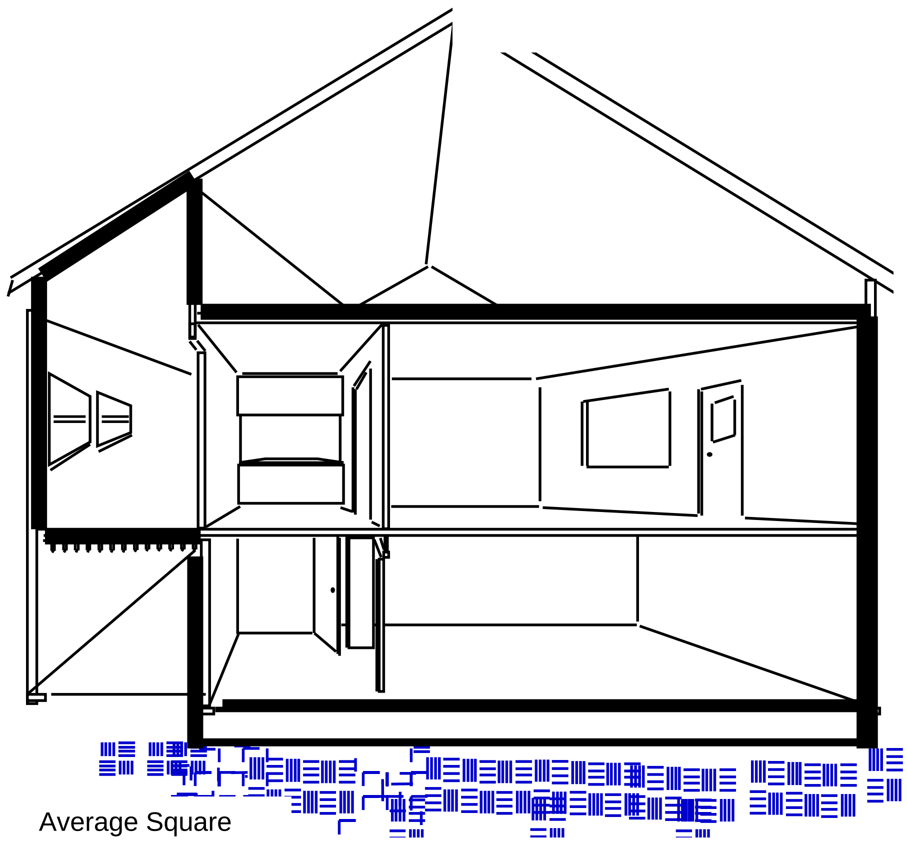
Average Glazing:Wall Area Ratio-13.51

Average Glazing Square Footage-381

Average Glazing:Wall Area Ratio-14%

Typical Glazing – Vinyl Low E Argon 71%

Typical Entrance Door – Steel Foam Core 100%



Typical Heating System- Gas Heating 100%
Average AFUE- 90

Typical Cooling System- Air Cooled Air 100%
Average SEER- 12

Average MECcheck Results

1992-93 MEC - 5.73
1995-00 MEC - 8.89

Average Square Footage: 2990

Foundation: Basement Insulated Conc. – 71%

Average Insulation R-Value – 8.19

Foundation Systems

- Primary Foundation Type – 86% of field checked structures in the Coralville sample had Basement Concrete Wall Foundations, 5 of the six were insulated. The resulting average insulation R-value was 8.19.

  - Primary Foundation Area/Linear Ft. – The average basement foundation area was 878 square feet.

- Secondary Foundation Information

  Three field inspected homes had secondary foundations.

Secondary Foundation Types	Secondary Foundation Average Area/Linear Ft	Secondary Foundation Average R-Value	Secondary Foundation Insulation Placement
Crawlspace Insul Floor	312	19	Cavity
Basement Insul Wood	610	13	Cavity
Basement Insul Concrete Wall	612	11	Cavity

Wall Information

- Primary Exterior Walls
  - Type –all walls are 16" o.c. Wood studs
  - Area – 1901 Square Feet
  - Weighted Average of Insulation R-Value – 14

- House/Garage Walls
  - Type –all walls are 16" o.c. Wood studs
  - Area – 234 Square Feet
  - Weighted Average of Insulation R-Value - 15
  - Insulation Placement – Cavity

Roof Information

- Primary Roof
  - Type – All primary roof structures in the Coralville sample set were All Wood Joist Rafter Truss Systems
  - Average Area – 1312 Square Feet
  - Weighted Average of Insulation R-Value – 40

Window/Skylight Information

- Primary Window

  - 5 of the seven windows were Vinyl Framed Low E Argon, the remainder was Vinyl Framed Low E
  - Average Square Feet Glazing Area - 331 square feet
  - Weighted Average U- Factor – .30

- Default U-factor used? – The default U-factor of .35 was used in 14% of the calculations, however that is a conservative estimate, based on the windows recorded;

Door Information

- Main Entrance Door
    - 100% of the Main Entrance doors were found to be Steel Foam Core
    - Average Area – 20 Square feet
    - Default U-Factor for Steel Foam Core doors is .35, no labeling was found on-site
    - No Storm Doors were reported
- Garage/House Door
    - 100% of the House/Garage doors were Solid Core Flush
    - Average Area – 18 Square feet
    - Weighted Average U-Factor - .40
    - Default U-Factor for Solid Core Flush doors is .40, no labeling was found on-site
    - No Storm Doors were reported
- Other Exterior Door
    - No “Other Exterior Door” were found

Duct Information

- Return Duct
    - Location – 6 of 7 return duct systems were in the crawlspace
    - Material Type – 86% were constructed of sheet metal type ducting, two houses also had flex type ducting
    - Sealant – Distribution of sealant use is as follows:

Sealant Use	
Return Duct Sealant UL181 Tape	0%
Return Duct Sealant Mastic	0%
Return Duct Sealant Mastic+Tape	86%
Return Duct Sealant Duct Tape	0%
Return Duct Sealant Zip Ties	86%
Return Duct Sealant Screws	86%

    - Insulation R-Value – No insulation was reported on return ducts.

- Supply Duct
  - Location – 5 of the seven supply duct systems were reported in the crawlspace
  - Material Type – All were constructed of flex type and sheet metal ducting
  - Sealant – Distribution of sealant use is as follows:

Sealant Use	
Supply Duct Sealant UL181 Tape	0%
Supply Duct Sealant Mastic	0%
Supply Duct Sealant Mastic+Tape	86%
Supply Duct Sealant Duct Tape	0%
Supply Duct Sealant Zip Ties	86%
Supply Duct Sealant Screws	86%

  - Insulation R-Value- One was reported to have an insulation R-value of 4.2

Mechanical System

- Heating System
  - Heating System Type – All structures had Gas Furnaces
  - Efficiency – Average Efficiency was 90 AFUE

- Cooling System
  - All of Structures had Air Conditioning – all were Air Cooled Air Systems.
  - Efficiency – Average Efficiency of 12 AFUE

Blower Door Testing

- Air Changes Per Hour – .27

APPENDIX II
PROJECT PROCEDURES

Selection of Data Analysis Tool

The U.S. Department of Energy's MEC*check* energy code compliance tool was selected as the data analysis tool for the study. MEC*check* was selected because it is the most widely used energy code compliance software in the market, provided a method of analyzing a large population of buildings in a cost effective manor and provided consistent results. The analysis for all code editions could be done with one building input into the software. One of the goals of the study was to determine the rate of compliance with various versions of the energy code, which the software was able to accomplish. The software also allowed the ability to model high efficiency heating and cooling equipment, which are typical trade-offs.

Development of Data Collection Tool

A data collection form was developed for use with the plan review portion of the study and that could be taken into the field to confirm energy efficiency values noted on the plans. The input screens from the MEC*check* software were used as a basis for the form. This allowed easy input from the form to the software during the data analysis portion of the study.

The number of assembly types in a typical home was also considered during the form development. It was important that space was provided to record as many assembly types per home as possible. For example, homes could have both a vented attic and a cathedral ceiling formed by rafters. Residential construction with vaulted ceilings and an attached garage would have exterior walls (wall between the conditioned space and the outside), attic kneewalls (between the conditioned space and attic) and a wall between the house and the unconditioned garage.

The survey instrument was developed using Microsoft Excel. Using Excel for the development of the instrument allowed the data collection staff to complete the form on laptop computers and than email them to the computer where the data analysis occurred. Completing the forms on computer allowed the files to be sent back and forth between the plan review data collection staff and the field collection staff.

A copy of the data collection tool is included in Appendix III.

Development of Access Data Base

Microsoft Access software was used as the database for the project. Access was selected because of its ability to store and query data for the project. This project utilized most of the capabilities within Access for analyzing the data. A link was established with Microsoft Excel to generate a portion of the averages used in the reporting and to generate other numbers needed in the report. Given the quantity and variation of data collected within this study, the combination of Access and Excel provided project researchers with all the necessary data management capabilities.

Data Collection Team

Two separate data collection teams were used in Iowa. Eric Makela, formally ICBO, was used to collect plan review data in several of the jurisdictions in central and eastern Iowa. Ken Baker, Kenergy, was used to collect data in the western and central portions of Iowa. Using one person per jurisdiction was found to be the most cost effective method of collecting data as one person can perform plan review on 4 homes in an afternoon, which was a typical quantity that was collected from a jurisdiction.

Woods & Associates from Las Vegas, Nevada, was used to collect data in the field. The team is the primary Energy Star provider in the Las Vegas metropolitan area, also working in California and Arizona providing Energy Star and energy code compliance services including blower door and duct blaster testing. Once the sample was pulled and the data was collected from the building plans, the Excel files were sent to Woods & Associates for scheduling the onsite visit.

Selection of Participants

During the initial design of the study, several jurisdictions were targeted for participation because of population and building permit activity. The sample size that was set at 65 single family homes and it was proposed to select a sample from around Iowa with the major portion of the homes coming from the Des Moines metropolitan area. It was estimated that 50% of single family home construction in Iowa is concentrated in around Des Moines.

A presentation was delivered at an Iowa Association of Building Officials meeting on January 17, 2001, to provide an overview of the program and request that the jurisdictions participate in the program. Forms were developed for the jurisdictions to complete and submit if they were interested in participating in the program. One portion of the form requested that the jurisdiction estimate single-family home building permit activity for the year. This information was used to determine the number of homes to select from each jurisdiction as the sample of 65 was proportionally spread over the jurisdictions interested in participating in the study.

Several jurisdictions volunteered to participate in the program. The Department of Natural Resources contacted a portion of the jurisdictions to solicit their participation in the study as the jurisdiction was viewed as a high priority because of building permit activity. Some of the jurisdictions were represented by 3rd party plan review and inspection companies that represented a few jurisdictions in the state. Those that participated in the program included:

- City of Des Moines
- City of West Des Moines
- City of Waukee
- City of Ankeny
- City of Coralville
- City of Iowa City
- Sioux City
- City of Council Bluffs
- City of Carroll
- City of Fort Dodge (Iowa Central Community College)
- City of Centerville (Indian Hills Community College)
- Muscatine County

All of the jurisdictions participated in the plan review portion of the study. Homes selected in the City of Carroll and Muscatine County did not participate in the field data collection portion of the study because the building sites were not available.

Notification and Scheduling of Jurisdictions

Once the sample was selected, a letter was drafted and sent to each of the jurisdictions that provided information on the data collection process, what was expected of the jurisdictions, and copies of the builder participation forms. Each of the jurisdictions was then contacted by phone to schedule the site visit and to answer any questions that they might have on the study. A copy of the letter is included in Appendix IV.

Selection of Residential Projects within Jurisdictions

To meet the sample of 65 homes, the number of homes that each jurisdiction was requested to provide was selected based on building permit activity. Larger jurisdictions with significant building permit activity selected a larger sample (up to 12 homes) than small jurisdictions (1 home). The jurisdictions were requested to select homes from different builders to broaden the sample. Typically, homes in track developments were selected over custom homes.

Builder participation forms were also developed that were to be completed by the selected builder. The forms requested information on location, schedule for completion and a statement that they agreed to participate in the study. The letter was drafted based on experience in conducting a residential baseline study in Nevada where several of the selected buildings were dropped from the sample because the builders declined to participate after the jurisdiction selected the home for the sample. The goal of the study was to have each of the jurisdictions complete the builder forms and sent back to ICBO. It was hoped that completing the forms would limit the number of homes that fell out of the study.

The builder commitment letter was reasonably successful. A portion of the jurisdictions did not get the builder to sign the forms resulting in builders that had no knowledge that their homes were selected for the study. Because of this, a portion of the original sample was dropped and was replaced by other buildings.

The study was designed to collect data on single-family homes in Iowa. Midway through the study it was decided to include town homes as a significant number of dwelling units constructed in the Des Moines metropolitan area consisted of this construction type. In addition, there was very little data on town home compliance with the energy code in Iowa. Town homes were selected from the City of Ankeny, Waukee, and West Des Moines where the majority of these projects were located. Eighteen town homes were selected for inclusion in the study, replacing the same number of single-family homes to maintain the sample of 65.

The sampling allowed for one than one town home to be selected from a single project. Town homes located on the interior of a building had less exterior wall area and therefore a greater glass to wall ratio than a unit located on the end of a building. In addition, town homes located on a mid or top floor may not have a floor as part of the building envelope where as a unit located on the first floor would have a floor but not roof/ceiling assembly as part of the building envelope.

Plan Review Data Collection

The plan review team visited each of the jurisdictions to collect data from the building plans. The goal of the plan review process was to collect data from the plans and to answer any questions that the jurisdictions might have on compliance with the energy code. The data collection team took time to visit with each of the jurisdictions to try to determine plans for code adoption and to ask about any problems or issues that they are having in enforcing the energy code.

The data collection forms were completed electronically using laptop computers. Building plans were provided to the review team and a space was provided to work. Information collected included building assembly areas e.g. wall, window, floor and roof area. Levels of efficiency were collected whenever possible as often only a portion of this information was included on the building plans. For example, insulation R-values were shown on the building plans but window U-factors were routinely left off. Heating and cooling efficiency was also not included on the building plans. Energy code compliance documentation was typically not included as part of the permit process. In certain circumstances, the level of detail on the building plans was not sufficient to do an area take-off requiring the data collection team to use an educated assumption. Typically, this was the case with basement wall construction.

Once the forms were completed, they were forwarded onto Woods & Associates (W & A) for scheduling the onsite inspections.

Field Inspection

Once W & A received the inspection forms and the builder commitment letter, they proceeded to schedule the onsite inspections. Because of budget constraints, it was important to schedule as many of the onsite inspections as possible during a one-week period of time to keep travel costs within the travel budget. In addition, blower door and duct blaster equipment needed to be shipped back and forth the Iowa, which needed to be accounted for.

Scheduling and performing the onsite inspections proved to be more difficult than originally planned. Several of the builders were aware of the program and that they had been selected for the program. However, there were several of the builders who were not aware of the program and had not been contacted by the jurisdiction. A significant of time was spent trying to contact builders to schedule the onsite inspections. In addition, the completion date for the projects needed to be coordinated as the projects needed to be near final to conduct the testing. This also complicated the scheduling as a few of the projects that were selected were completed and occupied shortly after the plan review was conducted. As a result of these complications a portion of the original sample selected for plan review was dropped from the study and replaced by single-family homes or town homes to ensure data for 65 buildings. An effort was made to select replacement homes from the same jurisdictions that were used in the original sample. Several replacement homes were selected when the team was at the building site and could meet with a representative of the builder.

The field collection team used the data collection form completed by the plan review team as a basis for the inspection. They verified area (Ft^2) of the different parts of the building envelope, focusing on glazing area. They also verified insulation levels and glazing U-factors and made general notes concerning installation practices. Several times the NFRC labels were not on the windows during the time of inspection and only information concerning the type (e.g. vinyl frame, low E) of window could be collected. Default U-factors were assigned to these windows. Also, there were instances where the insulation R-values could not be verified and information had to be solicited from the onsite superintendent. Rigid board insulation placed on the exterior of basement walls was one of the elements found difficult to verify as there was backfill and a protective cover installed over the insulation. Information concerning heating and cooling efficiency was also collected during the field collection portion of the study.

Data collection for the replacement homes lengthened the process as the team needed to do area take-offs on site and needed to coordinate gaining access to the building plans to conduct the plan review portion of the study. Arrangements were made to ship the building plans to ICBO.

The field inspection team also conducted a blower door test on several of the homes to determine the natural air change per hour. The intent was to conduct a blower door test on each of the homes selected for the study but do to weather conditions, or the home not being at the stage where a blower door test could be conducted, this was not practical. The team made every effort to perform the air leakage tests on the selected homes and town homes.

Once the data collection forms were completed in the field they were shipped to ICBO for analysis.

Data Analysis

Each of the data collection forms was reviewed to ensure that all of the data that could be collected was included on the form. The most frequent missing information was insulation R-values and glazing U-factors for the buildings. If the information was not included on the building plans or could not be verified in the field default efficiency levels were assigned to the building assembly.

Once the forms were checked, data for each of the buildings was entered into the U.S. DOE MEC*check* software to determine compliance rates for the different versions of the energy code. Each of the single-family homes was compared to the 1992 Model Energy Code and the 2000 International Energy Conservation Code. There was no difference in the results between the 1992 and 1993 Model Energy Code and the 1995 Model Energy Code and 1998 and 2000 International Energy Conservation Code so only two results were reported. For town homes, comparisons were ran for the 1992 and 1993 Model Energy Code and also the 2000 International Energy Conservation Code were determined because there was a difference in the required efficiency levels between the 1992 and 1993 Model Energy Code.

Models were built for the plan reviewed homes and the data collected during the field collection process. Compliance rates were determined for both plan review and inspection for the code years referenced above. If the location was of the proposed site was included in the MEC*check* it was used to model the building. For all locations that did not have site identified in MEC*check*, a county location was selected for the analysis. If the models using field data did not comply with a particular version of the energy code, selected efficiency levels were added to the building until compliance was demonstrated. The increased levels of efficiency were recorded.

Each of the homes was then entered into an ACCESS database to perform the analysis. The database was coupled with Excel to help in the data analysis.