Energy Efficiency Levels of Newly-Constructed Homes in North Dakota

Model Energy Code Requirements Testing

May 1999

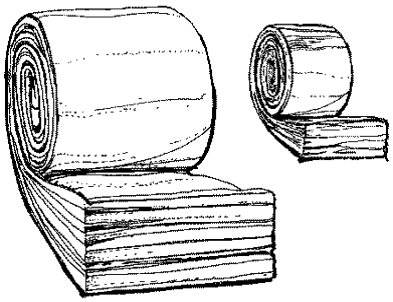
Conducted by the
North Dakota Association of Builders for the
North Dakota Office of Intergovernmental Assistance

Section

1

Purpose

The purpose of this study is to determine the energy efficiency levels of homes currently being built in North Dakota. Thirty-eight newly-constructed homes were inspected and measured to gather the data necessary to ascertain whether these houses are meeting or exceeding the requirements of the 1993 Model Energy Code (MEC).



The MEC focuses on the building envelope insulation and window requirements which are more stringent in colder climates (see Section 13 for the North Dakota map and prescriptive packages). Other requirements include the heating leakage levels.

This study was conducted using the MEC*check*™ Software Version 2.0, which is designed to demonstrate compliance with the insulation and window requirements of the Council of American Building Officials (CABO). MEC*check*™ performs a simple U-value x Area (UA) calculation for each building assembly to determine the overall UA of the building. If the total heat loss (represented as a UA) through the envelope of the building does not exceed the total heat loss from the same building conforming to the MEC, then the software declares that the house "passes." Limited elements of a performance analysis are also implemented, including a high-efficiency equipment trade-off.

Section

2

Administering Agency

This study has been administered by the North Dakota Association of Builders (NDAB), the state trade association for more than 1,400 builders and associate members across North Dakota. The NDAB committed to conduct this study in the most objective and informative method possible.

NORTH DAKOTA ASSOCIATION OF BUILDERS

The mission of the North Dakota Association of Builders is to promote the professional building industry through legislation, information and education.

Local Builders Associations

The NDAB conducted this project in coordination with the five local builders' associations in the state. Those associations are:

- Bismarck-Mandan Home Builders Association
- Dickinson Area Builders Association
- Forx Builders Association (Grand Forks area)
- Home Builders Association of Fargo-Moorhead
- Minot Association of Builders

National Association of Home Builders

The NDAB and local builders associations are part of the federation of the National Association of Home Builders (NAHB), located in Washington, DC. Nearly 200,000 member firms comprise the association which enhances the climate for housing and the building industry and promotes policies that will keep housing a national priority.

Section

3

Executive Summary

Purpose

The purpose of this study is to determine the energy efficiency levels of homes currently being built in North Dakota**. Thirty-eight newly-constructed homes were inspected and measured** to gather the data necessary to ascertain whether these houses are meeting or exceeding the requirements of the 1993 Model Energy Code (MEC).

Administering Agency

This study has been administered by the North Dakota Association of Builders (NDAB), the state trade association for more than 1,400 builders and associate members across North Dakota.

Field Inspections

The inspections of the sample homes were conducted by a professional from the insulating industry who is knowledgeable of the MEC requirements, the MEC*check™* software, and the complete building process.

Homes Tested

Thirty-eight homes across the state were inspected and tested, from all parts of the state – cities, towns and rural areas, various price ranges, and different builders. Inspections were done during construction, in April and May of 1999.

Study Findings

One hundred percent of the homes passed the MEC*check*™ testing process. The 38 homes inspected and tested met and exceeded the requirements of the 1993 Model Energy Code. This indicates that the proper techniques are used to construct homes which guarantee energy efficiency. All areas of the state and homes from most price ranges were represented in the top performing homes.

Study Conclusion

This study of newly-constructed homes in North Dakota has shown that building methods in our state are at a level that meets and exceeds requirements of the 1993 Model Energy Code. Having an energy efficient home is important to consumers, and builders are meeting the expectations and demands of their customers by producing quality housing in all parts of North Dakota.

Section

4

Field Inspections

The inspections of the sample homes were conducted by a professional from the insulating industry who is knowledgeable of the MEC requirements, the MEC*check™* software, and the complete building process. This person is experienced in gathering the information and verifying building plans and specifications and helped to ensure a high level of credibility and objectivity in this project.

Required Building Components Data

There are a number of pieces of data that have been gathered from each house. This information is entered into the MEC*check™* program to grade each house and determine whether or not it meets the MEC requirements.

Building Components List:

- Ceilings – area or perimeter, insulation and sheathing R-value
- Walls – area or perimeter, insulation and sheathing R-value
- Glazing (windows, glass doors, skylights) – area or perimeter, U-value
- Doors – area or perimeter, U-value
- Floors – area or perimeter, insulation R-value
- Basement walls – height, depth below grade, depth of insulation
- Slab floors – heated or unheated, depth of insulation
- Crawl space walls – height of wall, depth below grade, depth of insulation

A sample copy of the **Field Inspection Checklist** and the actual checklists used for the 38 homes can be found in Section 15 of this report.

Section

5

Homes Tested

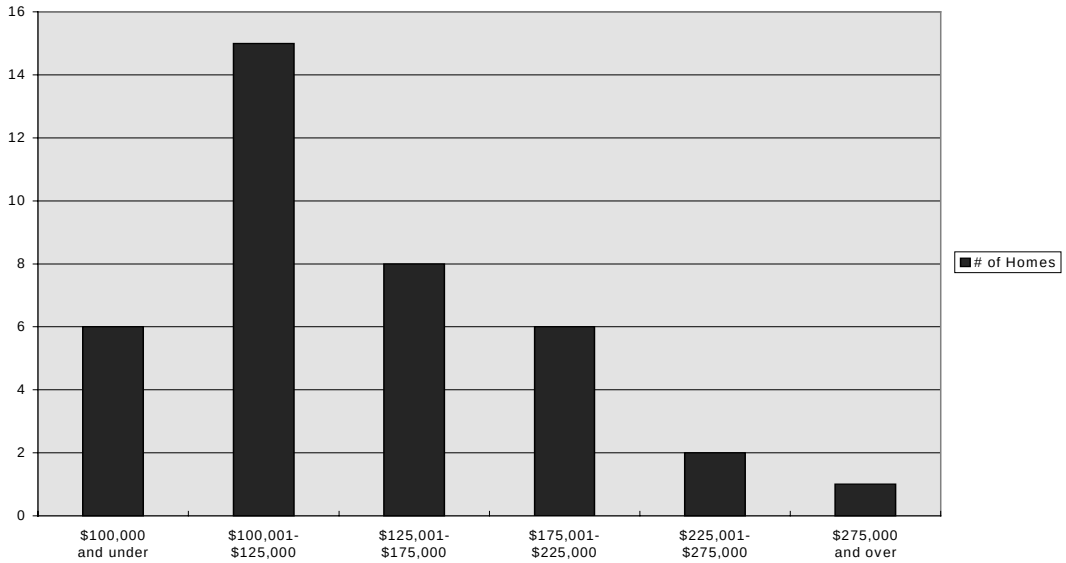
Though the project specified that 26-30 houses be inspected and tested, we surpassed that estimate by inspecting and testing 38 homes currently under construction in North Dakota.

Locations

Tested homes were located in all parts of the state, with the exception of the far southwest and northeast corners of North Dakota. This was due primarily to the lack of construction in those areas at the present time. We included homes in cities, small towns, rural areas and lakeside recreational locations. (A map of the home locations is included at the end of this section.)

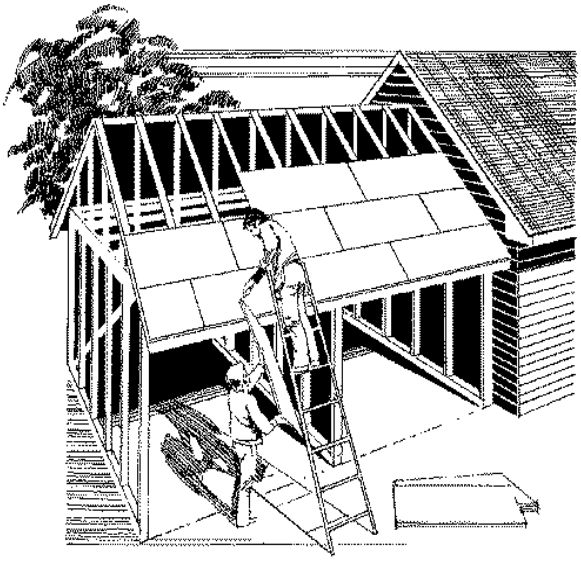
Price Ranges

The homes in the sample range in price from $67,000 to $315,000. The chart below shows the breakdown of the price ranges and the number of homes in each range. The sample group is characteristic of the price of homes being built in our state, with appropriate representation of each price range. (A chart with all homes listed and sorted by price is included at the end of this section.)



Builders

This study used a wide variety of builders, with no more than two homes coming from any one builder. (This was the case in only one instance.) Builders represented included the largest home builder in the state, as well as builders from rural areas who may only build one or two homes per year.

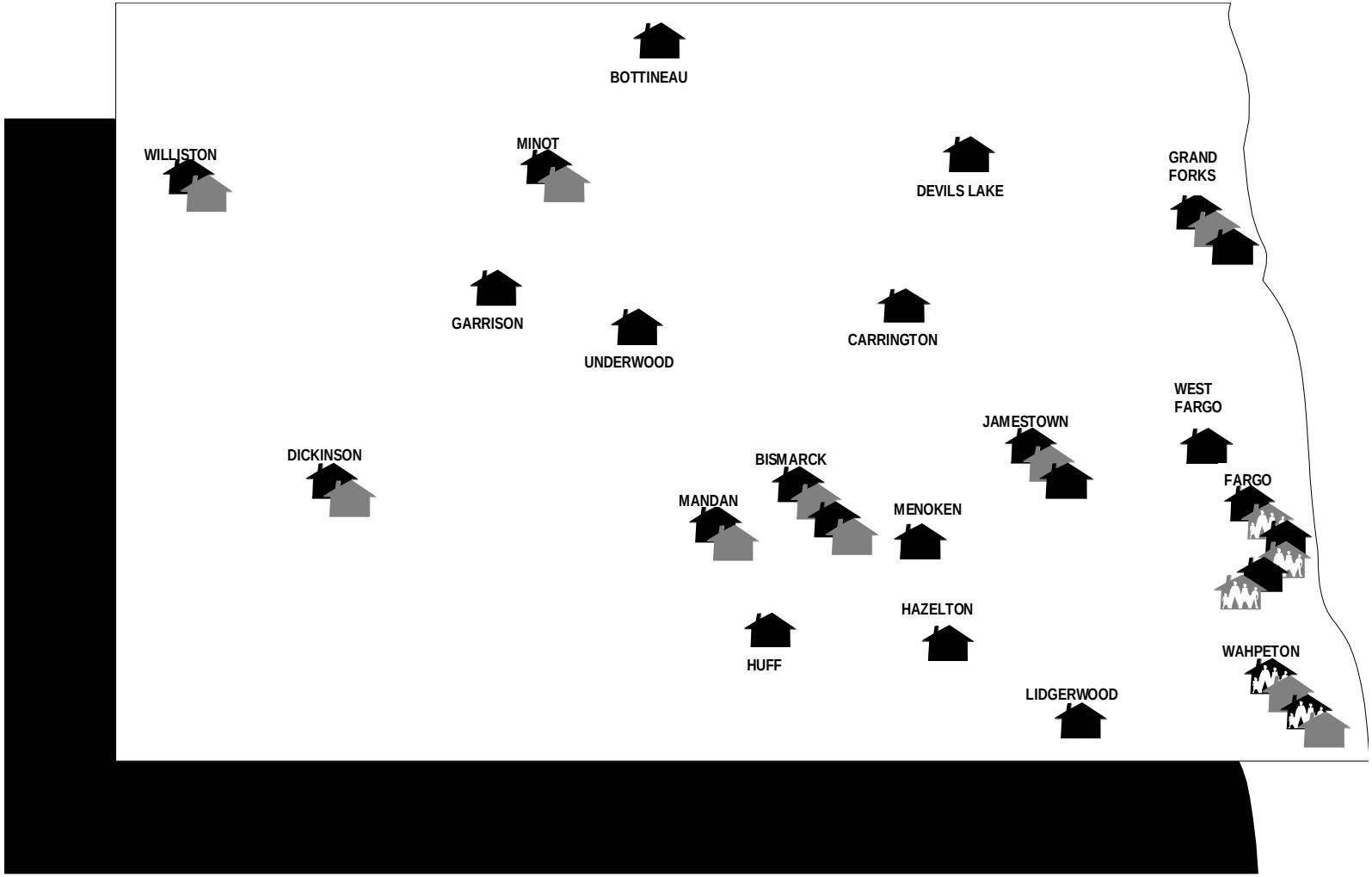


Also included were a few homes that are currently being built off-site – on lumberyard and high school/college campuses. These homes will later be moved to their final locations and placed on permanent foundations.

Timing of Inspections

All homes were inspected during the months of April and May of 1999. The homes were in various stages of construction, with all MEC*check™* required building components being measurable and verifiable.

NORTH DAKOTA – Locations of the 38 Homes Tested



MEC Requirements Testing -- Sorted by Price (Lowest to Highest)

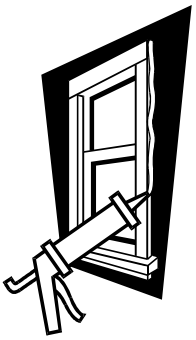
#	CITY	APPROX. PRICE	ALLOWABLE UA	THIS HOME'S UA	MARGIN	PASS/FAIL
5	Fargo	$ 67,000	223	168	55	PASS
12	Bismarck	$ 95,000	309	295	14	PASS
4	Fargo	$ 96,500	258	215	43	PASS
7	Jamestown	$ 100,000	297	235	62	PASS
8	Jamestown	$ 100,000	382	280	102	PASS
21	Minot	$ 100,000	609	488	121	PASS
6	Jamestown	$ 105,000	322	203	119	PASS
16	Mandan	$ 110,000	315	307	8	PASS
13	Menoken	$ 110,000	275	227	48	PASS
29	Wahpeton	$ 110,000	260	221	39	PASS
31	Wahpeton	$ 115,000	272	240	32	PASS
33	Grand Forks	$ 120,000	251	239	12	PASS
24	Fargo	$ 123,000	297	245	52	PASS
1	Bismarck	$ 125,000	335	316	19	PASS
28	Fargo	$ 125,000	388	284	104	PASS
19	Garrison	$ 125,000	306	221	85	PASS
17	Huff	$ 125,000	319	317	2	PASS
3	Lidgerwood	$ 125,000	342	261	81	PASS
15	Mandan	$ 125,000	352	292	60	PASS
20	Minot	$ 125,000	337	301	36	PASS
32	Wahpeton	$ 125,000	303	261	42	PASS
27	West Fargo	$ 130,000	372	339	33	PASS
34	Williston	$ 130,000	373	339	34	PASS
9	Carrington	$ 135,000	344	272	72	PASS
10	Grand Forks	$ 135,000	222	187	35	PASS
30	Wahpeton	$ 139,000	367	277	90	PASS
11	Bismarck	$ 150,000	385	307	78	PASS
23	Devils Lake	$ 150,000	582	571	11	PASS
14	Hazelton	$ 160,000	421	325	96	PASS
2	Bismarck	$ 190,000	423	339	84	PASS
22	Bottineau	$ 200,000	557	464	93	PASS
37	Dickinson	$ 200,000	484	395	89	PASS
18	Underwood	$ 200,000	504	437	67	PASS
38	Williston	$ 200,000	389	301	88	PASS
26	Fargo	$ 215,000	506	405	101	PASS
36	Dickinson	$ 250,000	705	565	140	PASS
35	Grand Forks	$ 270,000	483	405	78	PASS
25	Fargo	$ 315,000	644	635	9	PASS

Section

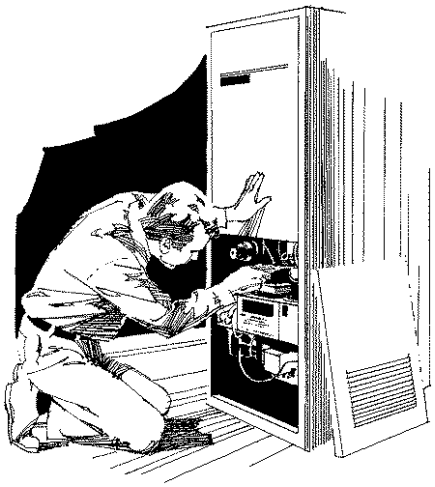
6

Study Findings

One hundred percent of the homes passed the MEC*check*™ testing process. The 38 homes inspected and tested met and exceeded the requirements of the 1993 Model Energy Code. This indicates that the proper techniques are used to construct homes in North Dakota which guarantee energy efficiency. Some of those techniques include:



- Sealing joints and other openings to eliminate air leakage
- Installing vapor retarders
- Installing heating and cooling equipment having high efficiency levels
- Insulating ductwork and sealing ductwork joints



Builders in North Dakota realize that they must construct quality housing, not only due to the climate conditions in our state, but also for consumers who demand energy efficiency in their homes.

A chart can be found at the end of this section which lists all homes and sorts them by "margin," which indicates the performance level of the home. A higher margin signifies a higher level of energy efficiency.

MEC Requirements Testing -- Sorted by Margin (Best Performers First)

#	CITY	APPROX. PRICE	ALLOWABLE UA	THIS HOME'S UA	MARGIN	PASS/FAIL
36	Dickinson	$ 250,000	705	565	140	PASS
21	Minot	$ 100,000	609	488	121	PASS
6	Jamestown	$ 105,000	322	203	119	PASS
28	Fargo	$ 125,000	388	284	104	PASS
8	Jamestown	$ 100,000	382	280	102	PASS
26	Fargo	$ 215,000	506	405	101	PASS
14	Hazelton	$ 160,000	421	325	96	PASS
22	Bottineau	$ 200,000	557	464	93	PASS
30	Wahpeton	$ 139,000	367	277	90	PASS
37	Dickinson	$ 200,000	484	395	89	PASS
38	Williston	$ 200,000	389	301	88	PASS
19	Garrison	$ 125,000	306	221	85	PASS
2	Bismarck	$ 190,000	423	339	84	PASS
3	Lidgerwood	$ 125,000	342	261	81	PASS
11	Bismarck	$ 150,000	385	307	78	PASS
35	Grand Forks	$ 270,000	483	405	78	PASS
9	Carrington	$ 135,000	344	272	72	PASS
18	Underwood	$ 200,000	504	437	67	PASS
7	Jamestown	$ 100,000	297	235	62	PASS
15	Mandan	$ 125,000	352	292	60	PASS
5	Fargo	$ 67,000	223	168	55	PASS
24	Fargo	$ 123,000	297	245	52	PASS
13	Menoken	$ 110,000	275	227	48	PASS
4	Fargo	$ 96,500	258	215	43	PASS
32	Wahpeton	$ 125,000	303	261	42	PASS
29	Wahpeton	$ 110,000	260	221	39	PASS
20	Minot	$ 125,000	337	301	36	PASS
10	Grand Forks	$ 135,000	222	187	35	PASS
34	Williston	$ 130,000	373	339	34	PASS
27	West Fargo	$ 130,000	372	339	33	PASS
31	Wahpeton	$ 115,000	272	240	32	PASS
1	Bismarck	$ 125,000	335	316	19	PASS
12	Bismarck	$ 95,000	309	295	14	PASS
33	Grand Forks	$ 120,000	251	239	12	PASS
23	Devils Lake	$ 150,000	582	571	11	PASS
25	Fargo	$ 315,000	644	635	9	PASS
16	Mandan	$ 110,000	315	307	8	PASS
17	Huff	$ 125,000	319	317	2	PASS

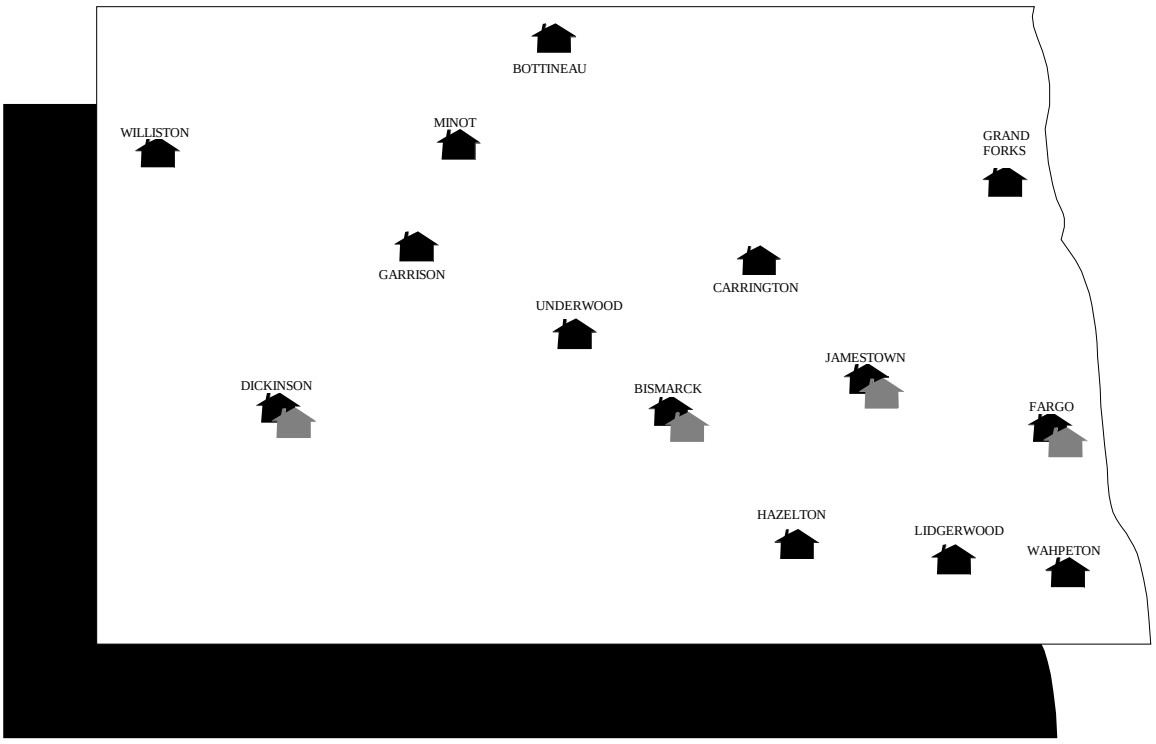
Section

7

Study Findings – By Area

Homes performing at the highest levels were not located in any one area of the state, but from all parts. Small towns and larger cities were both represented in this group. A map of the 18 homes having the highest margins between the allowable UA and the actual UA is below.

NORTH DAKOTA – Locations of the Top 18 Performing Homes

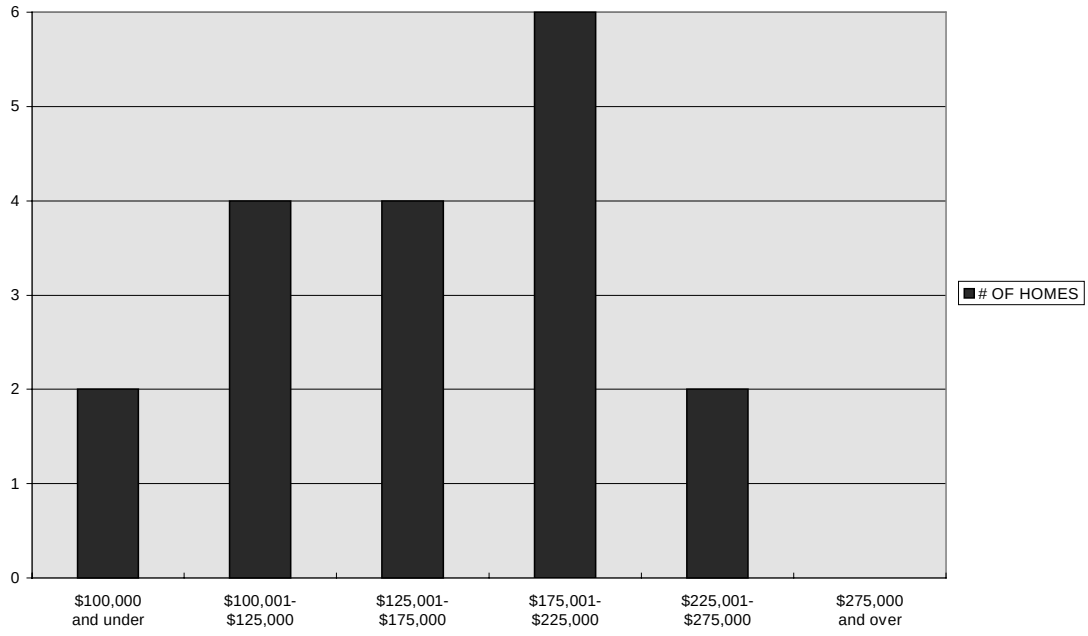


Section

8

Study Findings – By Price

The price of the home did not automatically make the home a better performer. Homes from all price ranges, except the highest price range, were included in the **top 18 performers**. The chart below provides information on the number of top performing homes in each price range.



Section

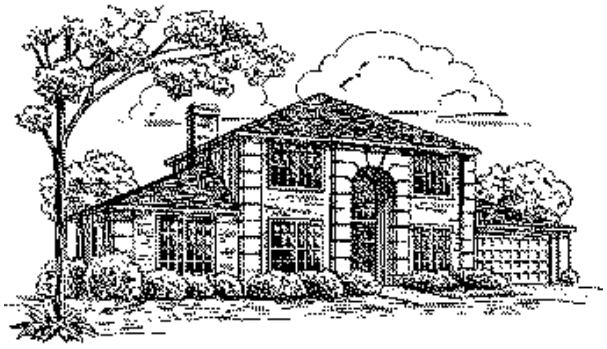
9

Study Conclusions

This study of newly-constructed homes in North Dakota has shown that building methods in our state are at a level that meets and exceeds requirements of the 1993 Model Energy Code. Conclusions drawn include:

- Builders are constructing quality housing that meets the demands of today's consumers.
- Products used in home building – windows, doors, insulation, etc. – are good quality and have good energy efficiency levels.
- Due to our climate, the need for energy efficient construction is greater.
- Well-built homes are being constructed in all parts of the state, not just in larger cities but in small communities and rural areas.
- The total price of the home does not determine the energy efficiency level. Homes in all price ranges passed the testing, with even the lowest priced homes having good margins in their UA values.

Having an energy efficient home is important to consumers, and builders are meeting the expectations and demands of their customers by producing quality housing in all parts of North Dakota.



Section

10

Appendix

A. Definitions

B. Summary of Basic MEC Requirements

C. North Dakota Map and Prescriptive Packages

Appendix

A

Definitions

Appendix A

Definitions

Addition The MEC applies to new residential buildings and additions to existing buildings. Additions can be shown to comply by themselves without reference to the rest of the building. Alternatively, the entire building (the existing building plus the new addition) can be shown to comply.

1992 1993

Basement Wall Basement walls that enclose conditioned spaces are part of the building envelope. Basement wall refers to the opaque portion of the wall (excluding windows and doors). To be considered a basement wall, at least 50% of the total wall area (including openings) must be below grade. For walls less than 50% below grade, include the entire opaque wall area as part of the above-grade walls.

1995

Basement Wall Basement walls that enclose conditioned spaces are part of the building envelope. Basement wall refers to the opaque portion of the wall (excluding windows and doors). To be considered a basement wall, at least 50% of the wall's total wall area (including openings) must be below grade. Treat walls on each side of the basement individually when determining if they are above grade or basement walls. For any individual wall less than 50% below grade, include the entire opaque wall area of that individual wall as part of the above-grade walls.

Building Envelope The building envelope includes all components of a building that enclose conditioned spaces (see the definition of conditioned space). Building envelope components separate conditioned spaces from unconditioned spaces or from outside air. For example, walls and doors between an unheated garage and a living area are part of the building envelope; walls separating an unheated garage from the outside are not. Although floors of conditioned basements and conditioned crawl spaces are technically part of the building envelope, the MEC does not specify insulation requirements for these components and they can be ignored.

Ceiling The ceiling requirements apply to portions of the roof and/or ceiling through which heat flows. Ceiling components include the interior surface of flat ceilings below attics, the interior surface of cathedral or vaulted ceilings, and skylights.

Conditioned Space A space is conditioned if heating and/or cooling is deliberately supplied to it or is indirectly supplied through uninsulated surfaces of water or heating equipment or through uninsulated ducts. For example, a basement with registers or heating devices designed to supply heat is conditioned. An indirectly heated basement is also conditioned if the basement ceiling is not insulated and heat is indirectly supplied to the space, such as through uninsulated ducts or through uninsulated surfaces of water heaters or space heating equipment.

Crawl Space The MEC*check* crawl space wall insulation requirements are for the exterior walls of unventilated crawl spaces (i.e. not directly vented to the outside) below uninsulated floors. A crawl space wall component includes the opaque portion of a wall that encloses a crawl space and is partially or totally below grade, as measured from the sill to the top of the footing.

Door Doors include all openable opaque assemblies located in exterior walls of the building envelope. Doors with glass can be treated as a single door assembly, in which case an aggregate U-value (a U-value that includes both the glass and opaque area) must be used; OR the glass area of the door can be included with the other glazing and an opaque door U-value can be used to determine compliance of the door.

Dwelling Unit A single housekeeping unit of one or more rooms providing complete, independent living facilities, including permanent provisions for living, sleeping, eating, cooking and sanitation.

Envelope See Building Envelope

Floor Area Not all floors in a building are considered when computing the floor area for compliance purposes:

- Floors over unconditioned spaces (such as floors over an unheated garage, basement, or crawl space) must be insulated and the area of these floors must be included.
- Floors over outside air (such as floors of overhangs and floors of an elevated home) must also be insulated and the areas of these floors must be included.
- In most locations, slab-on-grade floors of conditioned spaces must be insulated along the slab perimeter. The area of the slab floor is not required for MECcheck compliance, but the slab perimeter must be included.
- Floors of basements and crawl spaces are not subject to an insulation requirement and do not have to be included as a building envelope component, even if the basement or crawl space is conditioned. In some cases, however, crawl space wall insulation is required to extend down from the top of the wall to the top of the footing and then horizontally a short distance along the floor.
- Floors separating two conditioned spaces are not subject to an insulation requirement and do not have to be included as a building envelope component.

Glazing Glazing is any translucent or transparent material in exterior openings of buildings, including windows, skylights, sliding glass doors, the glass areas of opaque doors, and glass block.

Glazing Area The area of a glazing assembly is the interior surface area of the entire assembly, including glazing, sash, curbing, and other framing elements. The nominal area or rough opening is also acceptable for flat windows and doors.

1992 1993

Gross Wall Area The gross wall area includes the opaque area of above-grade walls, the opaque area of walls of conditioned basements less than 50% below grade (including the below-grade portions), all windows and doors (including windows and doors of conditioned basements), and the peripheral edges of floors.

1995

Gross Wall Area The gross wall area includes the opaque area of above-grade walls, the opaque area of any individual wall of a conditioned basement less than 50% below grade (including the below-grade portions), all windows and doors (including windows and doors of conditioned basements), and the peripheral edges of floors.

Multifamily A multifamily building is a residential building three stories or less in height that contains three or more attached dwelling units. Multifamily buildings include apartments, condominiums, townhouses, and rowhouses. Hotels and motels are considered commercial rather than residential buildings.

Net Wall Area The net wall area includes the opaque wall area of all above-grade walls enclosing conditioned spaces, the opaque area of conditioned basement walls less than 50% below grade (including the below-grade portions), and peripheral edges of floors. The net wall area does not include windows, doors, or other such openings, as they are treated separately.

Opaque Areas Opaque areas as referenced in this guide include all areas of the building envelope except openings for windows, skylights, doors, and building service systems. For example, although solid wood and metal doors are opaque, they should not be included as part of the opaque wall area (also referred to as the net wall area).

Raised Truss Raised truss refers to any roof/ceiling construction that allows the insulation to achieve its full thickness over the exterior walls. Several constructions allow for this, including elevating the heel (sometimes referred to as an energy truss, raised-heel truss, or Arkansas truss), use of cantilevered or oversized trusses, lowering the ceiling joists, or framing with a raised rafter plate.

R-Value R-value ($h \cdot ft^2 \cdot {}^\circ F/Btu$) is a measure of thermal resistance, or how well a material or series of materials resists the flow of heat. R-value is the reciprocal of U-value:

$$R\text{-}Value = \frac{1}{U\text{-}Value}$$

Single Family As defined by the MEC, a single-family building is a detached one- or two-family residential building, irrespective of height.

Slab Edge

Slab edge refers to the perimeter of a slab-on-grade floor, where the top edge of the slab floor is above the finished grade or 12 in. or less below the finished grade. The slab perimeter should include the length of all edges of a slab foundation that are part of the building envelope and are less than 12 in. below grade (i.e. all edges separating conditioned space from unconditioned space).

The insulation can be installed using any of the following configurations, but in all cases it must start at the top of the slab:

- The slab insulation extends from the top of the slab downward to the required depth.
- The slab insulation extends from the top of the slab downward to the bottom of the slab and then horizontally underneath the slab for a minimum total linear distance equal to or greater than the required depth.
- The slab insulation extends from the top of the slab downward to the bottom of the slab and then horizontally away from the slab for a minimum total linear distance equal to or greater than the required depth. The horizontal insulation must be covered by pavement or at least 10 in. of soil.

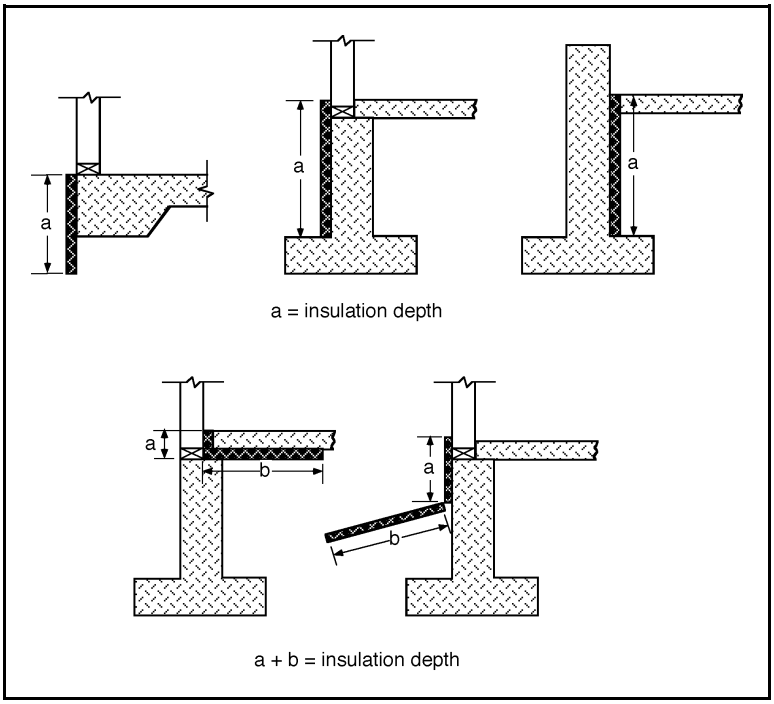


Figure A-1. Slab Insulation Depth Requirement

The top edge of insulation installed between the exterior wall and the interior slab can be cut at a 45° angle away from the exterior wall.

U-Value

U-value (Btu/h·ft²·°F) is a measure of how well a material or series of materials conducts heat. U-values for window and door assemblies are the reciprocal of the assembly R-value:

$$U\text{-}Value = \frac{1}{R\text{-}Value}$$

For other building assemblies (such as a wall), the R-value used in the above equation is the R-value of the entire assembly, not just the insulation.

Appendix

B

Summary of Basic MEC Requirements

1993 Model Energy Code

Summary of Basic Requirements

Air Leakage	Joints, penetrations, and all other such openings in the building envelope that are sources of air leakage must be caulked, gasketed, weatherstripped, or otherwise sealed. The maximum leakage rates for manufactured windows and doors are shown on the reverse side.
Vapor Retarder	Vapor retarders must be installed on the warm-in-winter side of all non-vented framed ceilings, walls, and floors. This requirement does not apply to the following climate zones nor where moisture or its freezing will not damage the materials. • Texas — Zones 2-5 • Alabama, Georgia, N. Carolina, Oklahoma, S. Carolina — Zones 4-6 • Arkansas, Tennessee — Zones 6-7 • Florida, Hawaii, Louisiana, Mississippi — All Zones
Materials and Insulation Information	Materials and equipment must be identified so that compliance can be determined. Manufacturer manuals for all installed heating and cooling equipment and service water heating equipment must be provided. Insulation R-values, glazing and door U-values, and heating and cooling equipment efficiency (if high-efficiency credit is taken) must be clearly marked on the building plans or specifications.
Duct Insulation	Supply and return ducts for heating and cooling systems located in unconditioned spaces must be insulated to the levels shown on the reverse side of this sheet. Exceptions: Insulation is not required for exhaust air ducts, ducts within HVAC equipment, and when the design temperature difference between the air in the duct and the surrounding air is 15°F or less.
Duct Construction	All transverse joints must be sealed with mastic, tape, or mastic plus tape. The HVAC system must provide a means for balancing air and water systems.
Temperature Controls	Thermostats are required for each separate HVAC system in single-family buildings and each dwelling unit in multifamily buildings (non-dwelling portions of multifamily buildings must have one thermostat for each system or zone). Thermostats must have the following ranges: Heating Only 55°F - 75°F Cooling Only 70°F - 85°F Heating and Cooling 55°F - 85°F A manual or automatic means to partially restrict or shut off the heating and/or cooling input to each zone or floor shall be provided for single-family homes and to each room for multifamily buildings.
HVAC Piping Insulation	HVAC piping in unconditioned spaces conveying fluids at temperatures above 120°F or chilled fluids at less than 55°F must be insulated to the levels shown on the reverse side of this sheet.
Swimming Pools	All heated swimming pools must have an on/off pool heater switch. Heated pools require a pool cover unless over 20% of the heating energy is from non-depletable sources. All swimming pool pumps must be equipped with a time clock.
Circulating Hot Water	Circulating hot water systems must have automatic or manual controls and pipes must be insulated to the levels shown on the reverse side of this sheet.
Electric Systems	Each multifamily dwelling unit must be equipped with separate electric meters.

Version 2.06/April 1998/U.S. Dept. of Housing and Urban Development / Rural Economic and Community Development/U.S. Dept. of Energy/Pacific Northwest Lab.

Duct Insulation R-Value Requirements

Zone Number	Ducts in Unconditioned Spaces (i.e. Attics, Crawl Spaces, Unheated Basements and Garages, and Exterior Cavities)	Ducts Outside the Building
Zones 1-4	R-5	R-8
Zones 5-14	R-5	R-6.5
Zone 15-19	R-5	R-8

Maximum Leakage Rates for Manufactured Windows and Doors

Frame Type	Windows (cfm/ft of Operable Sash Crack)	Doors (cfm per ft^2 of Door Area)	
		Sliders	Swinging
Wood	0.34	0.35	0.5
Aluminum	0.37	0.37	0.5
PVC	0.37	0.37	0.5

Minimum Insulation Thickness for HVAC Pipes[(a)]

Piping System Types	Fluid Temp Range (°F)	Insulation Thickness in Inches by Pipe Sizes[(b)]			
		Runouts 2 in.[(c)]	1 in. and Less	1.25 in. to 2 in.	2.5 in. to 4 in.
Heating Systems					
Low Pressure/Temperature	201-250	1.0	1.5	1.5	2.0
Low Temperature	120-200	0.5	1.0	1.0	1.5
Steam Condensate (for feed water)	Any	1.0	1.0	1.5	2.0
Cooling Systems					
Chilled Water, Refrigerant, or Brine	40-55 Below 40	0.5 1.0	0.5 1.0	0.75 1.5	1.0 1.5

(a) The pipe insulation thicknesses specified in this table are based on insulation R-values ranging from R-4 to R-4.6 per inch of thickness. For materials with an R-value greater than R-4.6, the insulation thickness specified in this table may be reduced as follows:

$$New\ Minimum\ Thickness = \frac{4.6\ x\ Table\ 2\text{-}2\ Thickness}{Actual\ R\text{-}Value}$$

For materials with an R-value less than R-4, the minimum insulation thickness must be increased as follows:

$$New\ Minimum\ Thickness = \frac{4.0\ x\ Table\ 2\text{-}2\ Thickness}{Actual\ R\text{-}Value}$$

(b) For piping exposed to outdoor air, increase thickness by 0.5 in.
(c) Applies to runouts not exceeding 12 ft in length to individual terminal units.

Minimum Insulation Thickness for Circulating Hot Water Pipes

Heated Water Temperature (°F)	Insulation Thickness in Inches by Pipe Sizes[(a)]			
	Non-Circulating Runouts	Circulating Mains and Runouts		
	Up to 1 in.	Up to 1.25 in.	1.5 - 2.0 in.	Over 2 in.
170-180	0.5	1.0	1.5	2.0
140-160	0.5	0.5	1.0	1.5
100-130	0.5	0.5	0.5	1.0

(a) Nominal pipe size and insulation thickness.