SIMPLIFYING MODEL ENERGY CODE COMPLIANCE

Linda M. Connell Craig C. Conner Stephen J. Turchen

ABSTRACT

The Energy Policy Act of 1992 established the 1992 Model Energy Code (MEC) as the target of several energy-related requirements. The U.S. Department of Housing and Urban Development (HUD) loan guarantee program requires compliance with the MEC. The Rural Economic and Community Development (RECD, formerly the Farmer's Home Administration) loan guarantee program requires that single-family homes comply with the MEC. Several states and local jurisdictions have also adopted the MEC as their residential energy code.

In response to complaints that the MEC is difficult to use, a U.S. laboratory developed MEC compliance materials at the request of the U.S. Department of Energy. These materials were developed to simplify the builder's or designer's task in demonstrating compliance and to assist HUD, RECD, states, and local jurisdictions with enforcement of MEC requirements. The materials include a compliance and enforcement manual for all the MEC requirements, as well as three thermal shell compliance options: prescriptive packages, trade-off worksheet, and software.

This paper discusses how the MEC requirements were revamped into an easy-to-use and enforceable format more appropriate for use by builders, designers, and code officials. Also discussed are the objectives and methodology applied in developing the materials.

INTRODUCTION

The 1992 Model Energy Code (MEC)[1] contains energy-related building requirements that apply to many new U.S. residences. A major focus of the MEC provisions is on building envelope insulation and window requirements, which are more stringent in colder climates. Other requirements focus on the heating and cooling system (including ducts), the water-heating system, and air leakage.

In an effort to simplify its use, a U.S. laboratory, under U.S. Department of Energy guidance, developed compliance and training materials for the MEC. These materials include a compliance and enforcement manual for all the MEC requirements, as well as prescriptive packages, a trade-off worksheet, and software to help comply with the thermal envelope requirements. The materials are currently available to interested parties free of charge.

Status of States

The Energy Policy Act of 1992 (EPAct) required states to review their residential building code to determine if it was appropriate to update the code to meet or exceed the 1992 MEC. In response to EPAct, several state and local governments adopted the MEC or are moving to do so in the near future. Thus, compliance with the MEC is a matter of increasing interest to the federal, state, and local governmental agencies responsible for oversight of residential construction and to designers and builders who must meet its requirements.

There are differences in how states adopt the MEC. Tennessee, Utah, and Virginia adopted it by direct reference for the entire state. Arkansas, Georgia, and Montana adopted it with amendments. In some cases, these amendments loosen the requirements, resulting in an energy code that is less stringent. For example, Arkansas adopted the MEC but modified the wall requirements, resulting in a less stringent code. Texas, Illinois, Nevada, and many other states have local jurisdictions that adopted the MEC, though it is not mandatory statewide. In addition, some states and utilities plan to use it as a baseline for home energy rating systems (HERS), incentive or rebate programs, or for qualifying energy-efficient mortgages.

MEC Editions

Although the materials initially focused on the 1992 MEC, there are two subsequent editions available for adoption by states: the 1993 and 1995 editions. The MEC

[1]The MEC is a building energy code maintained by the Council of American Building Officials (CABO). CABO is made up of the Building Officials and Code Administrators International, Inc. (BOCA), the International Conference of Building Officials (ICBO), and the Southern Building Code Congress International, Inc. (SBCCI).

Linda M. Connell and **Craig C. Conner** are with Pacific Northwest Laboratory, City, State. **Stephen J. Turchen** is with the U.S. Department of Energy, Washington, DC.

follows a three-year code-adoption cycle, but was published in 1993 because of the large number of changes introduced in 1992. The 1993 edition introduced more stringent multifamily wall U_o-value requirements, has new requirements for duct insulation, and adopts by reference the American Society of Heating, Refrigerating and Air-Conditioning Engineers/Illuminating Engineering Society of North America (ASHRAE/IES) Standard 90.1-1989 for commercial buildings (ASHRAE/IES 1989). The 1995 edition added a reference to the National Fenestration Rating Council procedure (NFRC 1991) for thermal properties of glazing assemblies, eliminated the potential for insulating the walls of a ventilated crawlspace, and adopted by reference the codified version of the ASHRAE/IES Standard 90.1-1989.

Within one year of the release of a new MEC edition, EPAct requires the Secretary of Energy to determine whether the new edition "...would improve energy efficiency in residential buildings." The states have two years after this determination to certify that they have reviewed their energy codes to determine whether it is appropriate to revise their codes to meet or exceed the new edition. On July 15, 1994, a *Federal Register* notice declared that the 1993 MEC was more energy efficient than the 1992 MEC. This determination implies that the states must make this certification by July 1996.

Additionally, within one year of the release of a new edition, EPAct requires the Secretary of Housing and Urban Development and the Secretary of Agriculture to amend their standards to meet or exceed the requirements of the new edition if they determine that the requirements of the new edition would increase energy efficiency.

DESIGN OBJECTIVES

Although the MEC allows a great deal of flexibility, this flexibility is offered at the expense of simplicity and enforceability. The compliance materials were developed under the premise that the most accurate and flexible codes will fail if they are not easily used and understood by builders and enforcement personnel. The following objectives were applied to the development of the materials.

- **Simplicity**—The materials must be easy to use, with minimal calculations and a short learning curve.
- **Understandable**—The materials must be written in the language of builders and code officials, not the language of engineers and researchers.
- **Enforceable**—The materials must be enforceable. Requirements that cannot be verified in the field cannot be enforced. Such requirements must be identified and recast into a format that is unambiguous and that can be validated by enforcement personnel.
- **Documentable**—The materials must include forms and reports that can be used to verify compliance with the MEC.
- **Self-Contained**—The materials must be self-contained, not referencing other documents. The MEC lists more than 24 references, some of which are extremely technical. Some references contain few (if any) actual code requirements and others are optional. Additionally, some of the documents referenced in the 1992 MEC are now outdated and difficult to obtain.

USER OBJECTIVES

The primary users of the compliance materials were determined to be builders and code officials. Other intended users include utilities, designers (architects and energy consultants), subcontractors and suppliers (insulation, window, and mechanical), and federal and state agencies. Some of our perceptions about these users have greatly influenced the resulting materials and the development objectives.

Speaking the Builder's Language

The MEC specifies thermal envelope requirements in U-factors, locations exempt from the vapor retarder requirement in terms of wet-bulb temperatures, and duct insulation requirements based on duct air and design temperatures. These terms are not commonly known by builders. Builders understand R-values. Many do not understand the thermal transmission or weather data terms used by engineers. One of the most challenging aspects in developing the materials was to convert the MEC requirements into terms readily understood by builders and code officials.

Level of Interest

Builders typically do not have the background or level of interest in energy-efficient buildings that energy code developers do. Builders are motivated primarily by homebuyers and code officials to provide energy-efficient features. In attempting to implement and enforce an energy code, it is a mistake to try to force the builder to become an expert on energy efficiency. For example, builders may not have an interest in understanding the distinction between convective, radiant, and conductive heat transfer. Implementation materials should be developed and training should be conducted from their perspective, not ours.

Time to Devote to Energy-Efficiency Features

When inspecting for the standard plumbing, mechanical, and structural requirements applicable in his or her jurisdiction, the code official is first and foremost considering fire, health, and safety requirements. The amount of time available to inspect energy features will vary by location but is small. Therefore, compliance requirements should be easy to enforce within this time frame. It is not appropriate to argue the technical merit of features that require a substantial amount of time and effort to verify. For example, there are several energy-saving features of windows that are difficult to verify in the field, such as argon gas fill and shading coefficient. If extra credit is to be given for such features, a simple method for verifying their installation must be provided.

COMPLIANCE MATERIALS

Building shell requirements can be determined using any of three compliance approaches: the prescriptive packages, the trade-off worksheet, or the software. In addition to the three compliance approaches, the manual discusses the basic requirements that all buildings must meet. The basic requirements include provisions that limit air leakage through the building envelope and regulate heating and cooling systems and duct insulation levels.

The materials are based on a whole-house U-factor × area (UA) calculation that allows building components to be traded off against each other, thus allowing a wide variety of home designs to comply. Requirements, however, are given from the user's perspective. For example, building shell requirements are given in terms of the insulation R-value, not the component U-factor.

The UA approach compares a proposed building UA to a code building UA (the code building has the same dimensions and features as the proposed building but is built to the U-factor requirements specified in the MEC). Although the MEC specifies U-factor requirements for individual building components, a whole-house UA tradeoff is widely used and accepted, and is justified by the inclusion of the following text in the MEC (section 502.1.1):

> The stated U_o, U, or R value of an assembly may be increased or the stated U_o, U, or R value of an assembly may be decreased, provided the total heat gain or loss for the entire building does not exceed the total resulting from conformance to the values specified in Table Nos. 502.2.1 and 502.3.1.

The materials allow tradeoffs between ceiling, wall, floor, basement wall, slab-edge, and crawlspace wall insulation as well as window U-factor and area. The software and prescriptive packages approaches also allow a tradeoff between the building envelope and heating and/or cooling equipment. The software approach also allows the user to trade off the depth of the foundation insulation.

All three of the thermal shell compliance approaches ask the user to specify insulation R-values and window and door U-factors. The compliance approaches provide

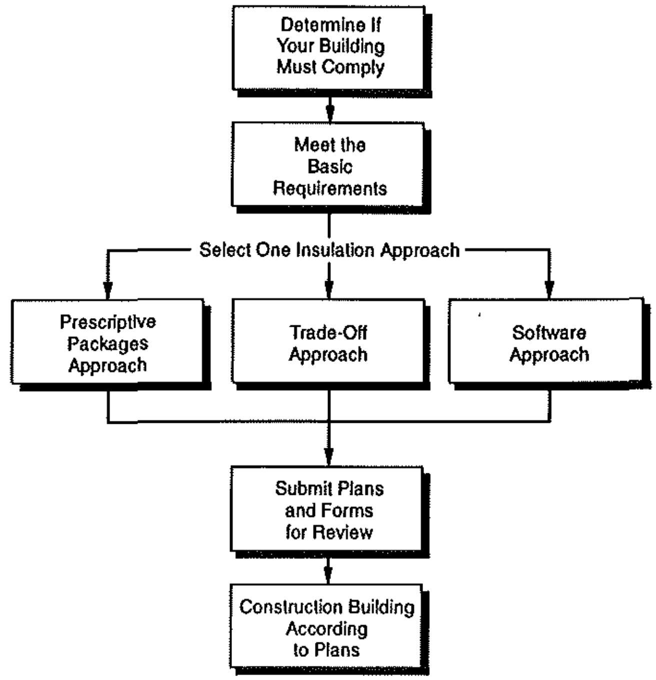


Figure 1 Compliance path.

a U-factor or F-value[2] that corresponds to the insulation R-value entered. For the prescriptive packages and software approaches, this is invisible to the user. For the trade-off worksheet approach, the user looks up the U-factors in tables that provide R-value to U-factor conversions. In all three cases, some basic construction assumptions were necessary to make these conversions. For example, to derive a 2 × 6 wood-framed wall U-factor from an insulation R-value, one has to assume a framing factor and provide default values for the resistance of siding, drywall, air spaces, and other construction materials.

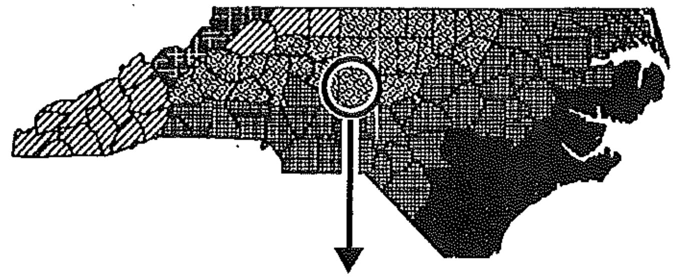
Figure 1 illustrates the process presented by the materials for determining and documenting compliance.

Compliance Materials Manual

The compliance materials manual provides guidance on how to meet the 1992 MEC requirements using all of the materials. It is not necessary to have a copy of the MEC or any other references to use it. The manual

- describes which buildings must comply and provides a summary of how the materials are used to demonstrate this compliance;
- includes a description of the checklists and forms that accompany the manual and can be used to determine and document compliance;
- discusses all of the basic requirements, including provisions that limit air leakage through the build-

[2]The slab-edge UA is determined by multiplying an F-value (Btu/h·ft·°F) by the perimeter (ft).

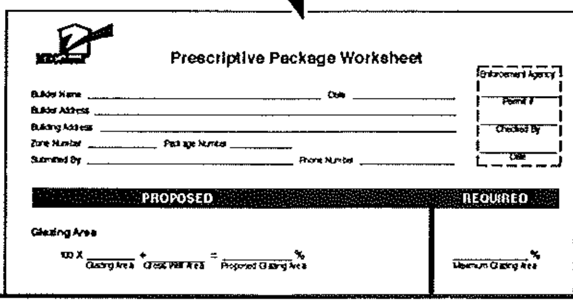


1. Find your climate zone.

Prescriptive Packages - Zone 8
1992 Model Energy Code for Single-Family Buildings

Package	Glazing Area Percent	Glazing U-Value	Ceiling R-Value	Wall R-Value	Floor R-Value	Basement Wall R-Value	Slab Perimeter R-Value	Crawl Space Wall U-Value	Heating/Cooling Equipment Efficiency
1	12%	0.65	R-30	R-13	R-19	R-8	R-4	R-10	Normal
2	12%	0.75	R-38	R-15	R-19	R-8	R-6	R-11	Normal
3	15%	0.40	R-19	R-13	R-15	R-7	R-2	R-8	Normal
4	15%	0.55	R-30	R-13	R-19	R-8	R-6	R-11	Normal
5	15%	0.65	R-38	R-19	R-19	R-7	R-2	R-8	Normal
6	16%	0.45	R-30	R-13	[illegible]-19	R-7	R-4	R-9	Normal

2. Select a Prescriptive Package.



3. Complete the *Prescriptive Package Worksheet.*

Figure 2 Prescriptive packages approach.

ing envelope and regulate heating and cooling systems and duct insulation levels;

- offers three alternative thermal shell compliance approaches: prescriptive packages, the trade-off worksheet, and the software; and
- provides plan check and field inspection guidelines.

Prescriptive Packages

Existing state codes were reviewed to determine preferred code formats. The results of this review supported the use of prescriptive packages based on climate zones. The prescriptive packages in the materials were developed using this same format. They are the simplest of the three thermal shell compliance approaches. With this approach, a package of insulation and window requirements is selected from a list of packages developed for a specific climate zone. Each package specifies insulation levels, window areas, window U-factors, and sometimes heating and cooling equipment efficiency. Figure 2 illustrates this process.

Each state was divided into climate zones drawn along county boundaries to coincide with jurisdictional boundaries. These divisions were considered more enforceable than the MEC's heating degree-day (HDD)-based requirements. For each zone, a variety of prescriptive insulation packages meeting the MEC were developed. The packages were presented as combinations of insulation R-values and window U-factors. Builders may choose any prescriptive package in their zone. In meeting the prescriptive requirements of the chosen package, they will be determined to comply with the thermal envelope requirements.

The state climate zones were established based on HDD boundaries in the MEC requirements. The most important of these HDD boundaries in the MEC requirements were determined to fall at HDD = 500, 1000, 1500, 2500, 6000, 7000, 8500, 9000, 11500, and 13000. For example, the unheated slab insulation requirements begin at HDD = 2500, and change from a required depth of 24 to 48 in. at HDD = 6000.

An HDD average was assigned to each county based on climate and location data obtained from the National Oceanic and Atmospheric Administration (NCDC 1992) and weighted by population data obtained from the U.S. Bureau of the Census (1988). The state maps show the zone to which each county is assigned.

The prescriptive packages were generated based on commercially available insulation levels. Existing state codes were examined to provide information on the most commonly used insulation levels and component combinations. The packages were selected based on

MECcheck

Trade-Off Worksheet

Builder Name: CAREFUL BUILDERS, INC. Date: 12/1/94
Builder Address: 120 "W" ST., GREENSBORO, NORTH CAROLINA 27411
Building Address: 1010 CONSTRUCTION AVE., GREENSBORO, N.C. Zone #: 8
Submitted By: JOHN DOE CAREFUL Phone Number: 704-321-9445

Enforcement Agency:
Permit #
Checked By
Date

PROPOSED | **REQUIRED**

U-values and F-values can be found in Tables 4-1 through 4-10.

Required U-values can be found in Table 4-11.

Ceilings, Skylights, and Floors Over Outside Air

Description	Insulation R-Value	U-Value	x Area	= UA
Ceiling W/Attic	R-38	0.030	729 ft²	21.9
Floor Over Outside Air	R-19	0.047	32 ft²	1.5
Skylight	–		ft²	
Ceiling, Vaulted	R-19	0.051	592 ft²	30.2
			ft²	
		Ceilings: Total Area	1353 ft²	

Required U-Value	x Area	= UA
0.036	1353 ft²	48.7

Walls, Windows, and Doors

Description	Insulation R-Value	U-Value	x Area	= UA
Wall w/ Sheath	R-13+6	0.054	1339 ft²	72.3
Window	–	0.38	204 ft²	77.5
Door Entry	–	0.54	20 ft²	10.8
Sliding Glass Door	–	0.43	84 ft²	36.1
Wall w/o Sheath	R-13	0.075	258 ft²	19.4
Door/Garage	–	0.35	18 ft²	6.3
			ft²	
		Walls: Total Area	1923 ft²	

Required U-Value	x Area	= UA
0.16	1923 ft²	307.7

Floors and Foundations

Description	Insulation Depth	Insulation R-Value	U-Value or F-Value	x Area or Perimeter	= UA
Floor Over Unconditioned		R-19	0.047	938 ft²	44.1
Basement Wall				ft²	
Unheated Slab	24 in.	R-8	0.78	55 ft	42.9
Heated Slab	in.			ft	
Crawl Wall	in.			ft²	

Required U-Value or F-Value	x Area or Perimeter	= UA
0.05	938 ft²	46.9
	ft²	
0.82	55 ft	45.1
	ft	
	ft²	

Total Proposed UA: 363.0

Total Required UA: 448.4

Total Proposed UA must be less than or equal to the Total Required UA.

Statement of Compliance: The proposed building design represented in these documents is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the requirements of the 1992 CABO Model Energy Code.

John Doe Careful — Builder/Designer
Careful Builders, Inc. — Company Name
12/1/94 — Date

Version 2.0 / July 1, 1995 / U.S. Dept. of Housing and Urban Development / Rural and Economic Community Development / U.S. Dept. of Energy / Pacific Northwest Laboratory

Figure 3 Example Trade-Off Worksheet

several criteria, including common practice, reviewers' input,[3] and cost effectiveness.

Trade-Off Worksheet

The trade-off worksheet is a "pencil-and-paper" approach that allows insulation- and window-efficiency levels to be traded off in different parts of the building. The worksheet guides the user through a UA computation for the user's proposed building and for the code (required) building. If the proposed building UA is less than or equal to the required building UA, the proposed building meets the insulation and window requirements. Figure 3 illustrates a completed trade-off worksheet.

[3]Review comments on all of the materials were solicited from key stakeholders, including representatives from the U.S. Department of Energy, the U.S. Department of Housing and Urban Development, the Rural Economic and Community Development, the National Association of Home Builders, the National Multi Housing Council, the North American Insulation Manufacturers Association, state energy offices, and the building industry (builders, consultants, and enforcement personnel).

The trade-off worksheet allows the direct entry of U-factors for all components, while the software approach only allows the entry of U-factors for windows and doors. The worksheet is therefore more amenable to less common constructions that require custom U-factors to be computed. For this same reason, the trade-off worksheet is more difficult to use because it requires the entry of U-factors and the calculation of a UA for each building component. The worksheet also does not provide for additional tradeoffs, such as for high-efficiency heating and cooling equipment.

The MEC-required U_o-values for building envelope components are based solely on the HDD of the proposed building location. The required U_o-values used in the trade-off worksheet are obtained from a table that lists U_o-value requirements for each climate zone (corresponding to the zones described for the prescriptive packages approach).

Software

The software approach is the most flexible of the three compliance approaches. The software allows tradeoffs between all building envelope components and heating and cooling equipment efficiencies. Unlike the prescriptive packages and trade-off approaches, the software approach enables basement wall, slab-edge, and crawlspace wall insulation depths to be traded off as well as insulation R-values.

As with the other approaches, the software approach compares a proposed building UA against a code building UA to determine compliance. Figure 4 shows the software's main screen. The building components that comprise the building envelope are selected by the user and displayed on this screen. The user supplies the areas and insulation R-values to be installed in these components, and the software does the UA calculations based on common construction assumptions.

The software contains a list of more than 3,000 cities. Each city is associated with an HDD and cooling degree-hour (CDH) value. The HDD value is used to determine the requirements for that city; the CDH value is used in the implementation of the high-efficiency cooling equipment tradeoff.

A tradeoff for high-efficiency heating and/or cooling equipment is also offered. This credit is applied as a percentage increase in the code building UA. Figure 5 shows the heating and cooling efficiency screen, where the user enters equipment efficiencies. The methodology

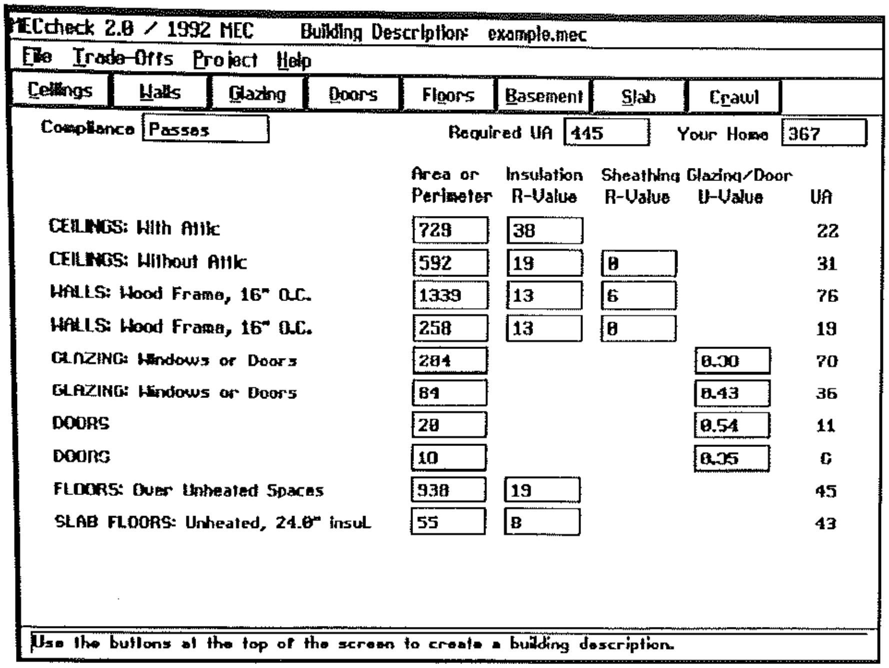


Figure 4 Software Main Screen

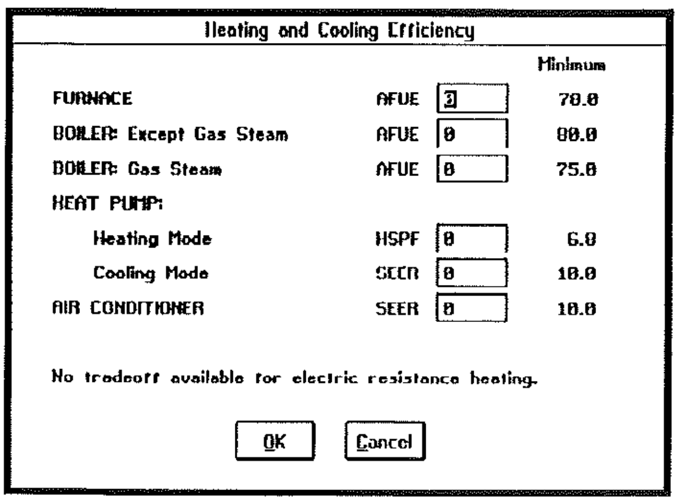


Figure 5 Heating and Cooling Efficiency Screen

used to implement the equipment tradeoff is briefly described later in this paper.

METHODOLOGY

Basic Requirements Methodology

The MEC specifies basic requirements that are mandatory for all buildings. Some of these requirements apply to a building's heating and cooling system (including ducts) and hot water system. Other requirements apply to material and equipment identification and to sealing the building envelope.

Some of the mandatory requirements were considered too complex to be practical and/or enforceable. To make them usable, they were restructured to reduce ambiguity. The presentation of some of these requirements no longer resembles that given in the MEC.

The revised duct insulation requirements provide an example of a MEC requirement that was restructured for use in the manual. The MEC requires (with some exceptions) that ducts be insulated to the insulation levels given by

$$\text{Insulation R-Value} = \frac{\Delta t}{15}$$

where

Δt = design temperature differential between the air in the duct and the duct surface (°F).

This calculation is not intuitive, does not usually result in commercially available duct R-values, and can also vary within a home. Additionally, it is not clear what is meant by the duct surface temperature, which for uninsulated ducts is close to the ambient temperature when the system is off and is close to the temperature of the air inside the ducts when the system is on.

Because of the complexity of determining the duct insulation requirements, a simple table of minimum R-values was established. The duct surface temperature was assumed to be equal to the temperature of the air outside the ducts, and seasonal outside design temperatures for approximately 700 cities were used to estimate this temperature. Temperatures of 55°F and 130°F were assumed for supply ducts in the cooling and heating seasons, respectively. Return duct R-value requirements were set equal to supply duct requirements for simplicity and to reduce confusion at the job site. Duct insulation R-value requirements were then established for each of the cities based on these temperatures and the duct location (different assumptions were made for the ambient air temperature in unconditioned basements than for that in the other unconditioned spaces). The resulting R-values were weighted by new housing starts and averaged for each of the 17 climate zones. Table 1 shows the resulting duct insulation requirements as they appear in the manual.

TABLE 1 **Duct Insulation R-Value Requirements**

Zone Number	Ducts Located in Attics, Crawlspaces, Exterior Cavities, Outside	Ducts Located in Unheated Basements
Zones 1-8	R-6	R-6
Zones 9-16	R-8	R-6
Zone 17	R-9	R-6

Basement and Crawlspace Wall UA Methodology

The UA calculation for below-grade basement and crawlspace walls considers the effect of the soil in determining the heat loss through the walls, even though the MEC U_0-value requirements are specified in terms of the wall and air films only. To consider the impact of the surrounding soil in the tradeoff, the insulation R-value requirement for the code building based on the MEC-specified U_0 is first determined without considering the soil. Then, the heat loss is computed for both the code building (insulated to the required level) and the proposed building. Both computations consider the surrounding soil and are based on walls the same depth below grade.

The soil was included in the UA calculation for below-grade walls because it provides more accuracy in estimating the impact of increasing or decreasing insulation levels above or below the MEC-required level. The inclusion of soil in the software UA calculation allows the user to trade off insulation depth by more accurately accessing the impact of partially insulating a below-grade wall. The heat loss through the lower uninsulated portion of a partially insulated wall has much less impact if that portion of the wall is below grade.

Addition of Cavity Insulation and Insulating Sheathing

A problem with the wall presentation in the prescriptive packages and trade-off worksheet was the question of how to present the many possible combinations of wall cavity insulation and insulating sheathing. This problem was solved by allowing the builder to add the two together to arrive at a total wall R-value. The sheathing was assumed to cover 80% of the building, with the remaining 20% covered by structural sheathing with an R-value of 0.83. Table 2 indicates that the error introduced by this method is marginal for reasonable combinations. For example, an R-19 requirement can be met with any of the last three combinations listed in Table 2 with an error of at most 7%.

TABLE 2 **Combinations of Wall Cavity Insulation Plus Insulating Sheathing**

Wall R-Value + Sheathing R-Value	U-Value
R-11 + R-2	0.076
R-13	0.075
R-11 + R-4	0.068
R-13 + R-2	0.069
R-15	0.069
R-13 + R-6	0.057
R-15 + R-4	0.058
R-19	0.054

Heating and Cooling Equipment Trade-Off Methodology

The National Appliance Energy Conservation Act of 1987 (NAECA 1987) establishes minimum allowable efficiencies for residential-style heating and cooling equipment. The materials include an option for trading heating or cooling efficiency above these NAECA minimums for lowered envelope efficiency. The software gives proportional credit to any heating or cooling equipment above the NAECA minimums. The prescriptive packages include high-efficiency heating packages developed under the assumption of a furnace annual fuel utilization efficiency (AFUE) of 90% or more or a heat pump heating seasonal performance factor (HSPF) or 7.8 or more. They also include high-efficiency cooling packages developed under the assumption of a seasonal energy efficiency ratio (SEER) of 12 or more.

The high-efficiency equipment tradeoff was developed as follows:

1. For each climate zone, a baseline house configuration that just meets the MEC was identified and its overall coefficient of conductive heat transfer (U_0) was calculated.
2. Software developed by Lortz and Taylor (1989) was used to calculate the total annual energy consumption of the baseline prototype in each of 881 cities, assuming NAECA minimum heating and cooling efficiencies.
3. For each location and each of several possible increased efficiencies, the amount that the prototype U_0 could be relaxed (increased) while keeping total annual energy consumption at or below that of the baseline prototype was determined.
4. For each efficiency level, the ratio of the fractional U_0 change to the fractional efficiency change was calculated. This is the trade-off ratio that is applied as a percent increase to the code UA or a decrease to the proposed UA.

CONCLUSIONS

The U.S. Department of Housing and Urban Development, the Rural Economic and Community Development program, and many states have recently adopted the MEC, and several other states are actively working to do so. The successful implementation of the MEC depends on the builders' and code officials' understanding of the requirements. The compliance materials were developed as an aid to implementing and gaining support for the MEC. In addition to making the MEC easier to understand and enforce, the materials alleviate some of the resistance to the code by making it comprehensible to users. For example, the prescriptive packages allow builders to see at a glance the general impact the code will have on their current construction practices, which may be minimal. We believe that user-friendly, simplified materials will create more universal acceptance of the code, thereby leading to increased energy savings.

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