design guide

THERMAL DESIGN AND CODE COMPLIANCE FOR COLD-FORMED STEEL WALLS

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SSMA

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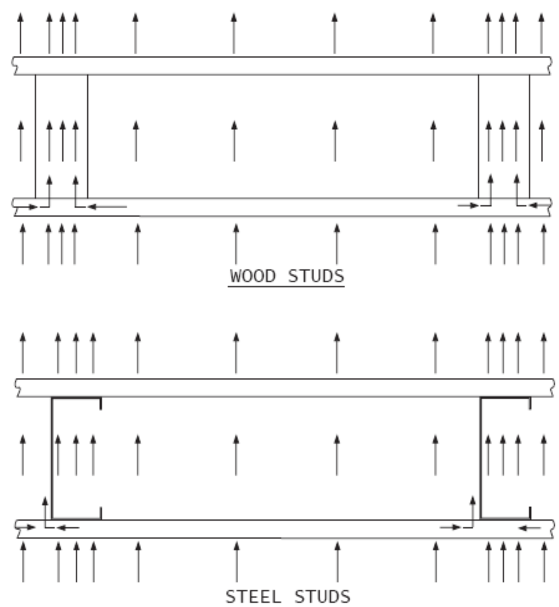
BACKGROUND AND OBJECTIVES

In the early 1990s cold-formed steel (CFS) began making gains in the residential construction market. In response, the American Iron and Steel Institute (AISI) sponsored ground-breaking research to develop recommendations for the design of walls constructed from cold-formed steel. The 1995 AISI *Thermal Design Guide for Exterior Walls* resulted from this early work.

The 1995 AISI *Design Guide* has been the industry's primary reference source on the thermal design of cold-formed steel walls since its release. Although the research in the original guide is still valid, the residential framing environment has undergone significant changes, mostly relating to recent research findings and the adoption of more stringent energy efficiency requirements, in the past decade. The need to update the 1995 design guide is driven by these six industry changes:

With any type of wall framing, heat flows directly through the cavity AND directly through the frame. Both heat flow paths must be considered when taking a whole-wall performance approach.



1. Wider use of the performance approach for achieving code compliance;
2. Availability of new test and research data;
3. An on-going shift in codes and standards away from clear wall assembly factors to more accurate and detailed framing factors;
4. The move from R-11 to R-13 as the code minimum cavity insulation in walls;
5. A better understanding of how to calculate an assembly's U-Factor and effective R-Value; and
6. Climate zone designations used in codes and standards have changed since the 1990s.

This document has two main objectives:

1. Provide the most up-to-date information on the thermal performance of cold-framed steel walls, and
2. Provide the information necessary for designers or builders to comply with modern energy codes, specifically information on appropriate whole-wall R-Values and/or U-Factors.

Use of this Document

This document is designed to meet users' differing needs. Individuals interested in whole-building performance may need detailed information on simulation tools or calculation methods, while others may need information on specific thermal properties of a wall system to comply with a local or state code. Thus, this document is set up as follows:

Section 1 is the quick reference section for those looking for the thermal properties of commonly-used CFS wall sections. This section contains a table of U-Factors derived from the Zone Method calculation technique.

Section 2 describes the two main approaches codes use for compliance – the Performance or Prescriptive Options. This section provides the user with a basic understanding of how energy codes are structured and the advantages and disadvantages of specific code compliance options.

Section 3 addresses the Simulated Performance Approach, an option in most energy codes for evaluating an entire building's energy use. This evaluation method offers flexibility to CFS assemblies for meeting and exceeding codes in a cost-effective manner.

Section 4 describes the prescriptive requirements in codes and how to meet or exceed them. This is the most-often used option for code compliance. Section 4 also provides test data and U-Factors for selected assemblies that are important for both the prescriptive and performance compliance options in codes and standards.

Section 5 discusses innovative methods evolving to increase the efficiency of cold-formed steel wall assemblies.

Informative appendices are provided containing contact information of software developers for the Whole Building Simulation Method and a discussion of alternative U-Factor calculation methods.

SECTION 1
THERMAL PROPERTIES OF CFS ASSEMBLIES

R-Values and U-Factors are the thermal property calculations a builder or designer evaluates a building with to meet energy code requirements. The R-Value is a measure of the thermal resistance of a material or assembly. The U-Factor is the inverse of the R-Value, or the thermal conductance.

When a code specifies an R-Value of insulation that must be met, you simply add the R-Values of the wall cavity insulation and any exterior continuous insulation on the wall assembly. The resulting wall insulation R-Value total must be equal to or greater than the R-Value listed in the building code.

The situation becomes more complex when a code or standard specifies a U-Factor for the entire wall assembly instead of requiring an R-Value just for insulation. Section 4 discusses the calculation methods used to determine U-Factors. But, Table 1 is a quick reference table for builders, designers and those only interested in U-Factors necessary to comply with codes and standards.

Table 1: U-Factors for Selected Cold-Formed Steel Wall Assemblies

Stud Size	Stud Spacing	Cavity Insulation	Continuous Insulation	Assembly U-Factor
1.5”x3.5”	24” o.c.	R-13	None	0.109
1.5”x3.5”	24” o.c.	R-13	R-3	0.082
1.5”x3.5”	24” o.c.	R-13	R-5	0.071
1.5”x3.5”	24” o.c.	R-15	None	0.102
1.5”x3.5”	24” o.c.	R-15	R-3	0.078
1.5”x3.5”	24” o.c.	R-15	R-5	0.067
1.5”x5.5”	24” o.c.	R-19	None	0.095
1.5”x5.5”	24” o.c.	R-19	R-5	0.064
1.5”x5.5”	24” o.c.	R-21	None	0.090
1.5”x5.5”	24” o.c.	R-21	R-5	0.062

The presented U-Factor values may be used for any type of building (i.e., commercial or residential). Remember, a U-Factor for a given wall assembly must be equal to or lower than the U-Factor required by code.

The values in Table 1 were calculated using the Zone Method developed by the committees overseeing the American Society of Heating, Refrigeration, and Air Conditioning Engineers' (ASHRAE) 90.1 and 90.1 standards for energy efficiency. This method includes the framing member's impact on the wall assembly's thermal performance by applying a factor to the cavity insulation to account for the steel studs that pass through the assembly. Although the Zone Method is the only calculation that has passed through a consensus process, it is not the only available method for calculating thermal properties of CFS assemblies. See Section 4 and Appendix B for discussion on other methods.

SECTION 2
PATHWAYS FOR CODE COMPLIANCE

Today's codes accommodate multiple pathways towards compliance. The most commonly-used compliance approach is the Prescriptive Option, since it simply requires a builder or designer to select insulation with a specific R-Value from a table in the code. The *1995 AISI Thermal Design Guide* focuses on the prescriptive compliance pathway in its section on the CABO Model Energy Code (MEC) that was widely used at the time.

The MEC and other building codes and standards have traditionally accepted prescriptive R-Values of the wall cavity insulation to represent the wall assembly's thermal performance. This approach worked well when building materials were relatively the same but new materials have entered the market, tests and research on assembly performance has been conducted, and building codes have responded to new materials and research findings by becoming more responsive and complicated over the last fifteen years.

A variation offered in the Prescriptive Option of many codes is the U-Factor Prescriptive Option. Although U-Factor requirements are typically located in the prescriptive section of codes and standards, specifying a U-Factor is really a performance approach applied to a specific component like a wall.

A U-Factor, in simple terms, is the inverse of the whole-wall R-Value. A U-Factor takes into account the wall's insulation R-Values but also factors in the framing member's impact on wall's overall thermal performance.

To gain approval, designers have to show that a building's wall is equal to or lower than the component U-Factor required by code. In the past, the U-Factor Prescriptive Option was not used as often as the R-Value Prescriptive Option but because of the increased attention towards improving a home's energy performance U-Factor calculations are increasing in popularity.

A third pathway towards code compliance is the performance or Whole Building Simulation Method. The Whole Building Simulation Method requires a computerized simulation tool to evaluate the overall performance of the proposed design against the overall performance of a code minimum designed home, commonly called the reference home.

A fourth pathway allowed in most codes is the UA Trade-Off Method, often a subset of the Performance Option. The UA Trade-Off Method allows a designer or builder to effectively meet the insulation requirements for an entire building even though one or more components may be less than the prescriptive values listed in a code.

The UA Trade-Off Method allows you to make up for deficiencies in one part of the building by exceeding code in the building elsewhere. UA Trade-Off Method calculations are preformed by taking the U-Factor of an assembly multiplied by the area (A) of that assembly to arrive at individual UA values for each component (walls, floors, roofs). The component UA values are summed to obtain a whole-building UA, which is then compared to the UA for that type of building listed in the code. Fortunately, most software developed for the Simulated Performance Option conduct a UA Trade-Off Method analysis either directly or indirectly.

There are advantages and disadvantages to each of the presented pathways for code compliance. The Performance Option offers the most flexibility, but it is more complex to use than other approaches. The R-Value Prescriptive Method by component is the most straightforward way to comply, but it does not always lead to the most cost-effective assembly. The U-Factor Prescriptive Method requires data that is not typically found in energy codes so there is some burden of proof that the designer must meet. This document should provide the necessary proof required by most code officials to use the U-Factor Prescriptive Method, although users are advised to always check with local code officials before using any substantiating information not directly found in the pages of the applicable code or standards.

SECTION 3
THE PERFORMANCE APPROACH

Since the mid 90s, the use of software packages for energy simulations of homes and small commercial buildings, although not routine, has grown considerably. Simulation tools have become very affordable. There are even a few programs that are free, but more sophisticated programs, that conduct specific code evaluations, can cost several hundred dollars.

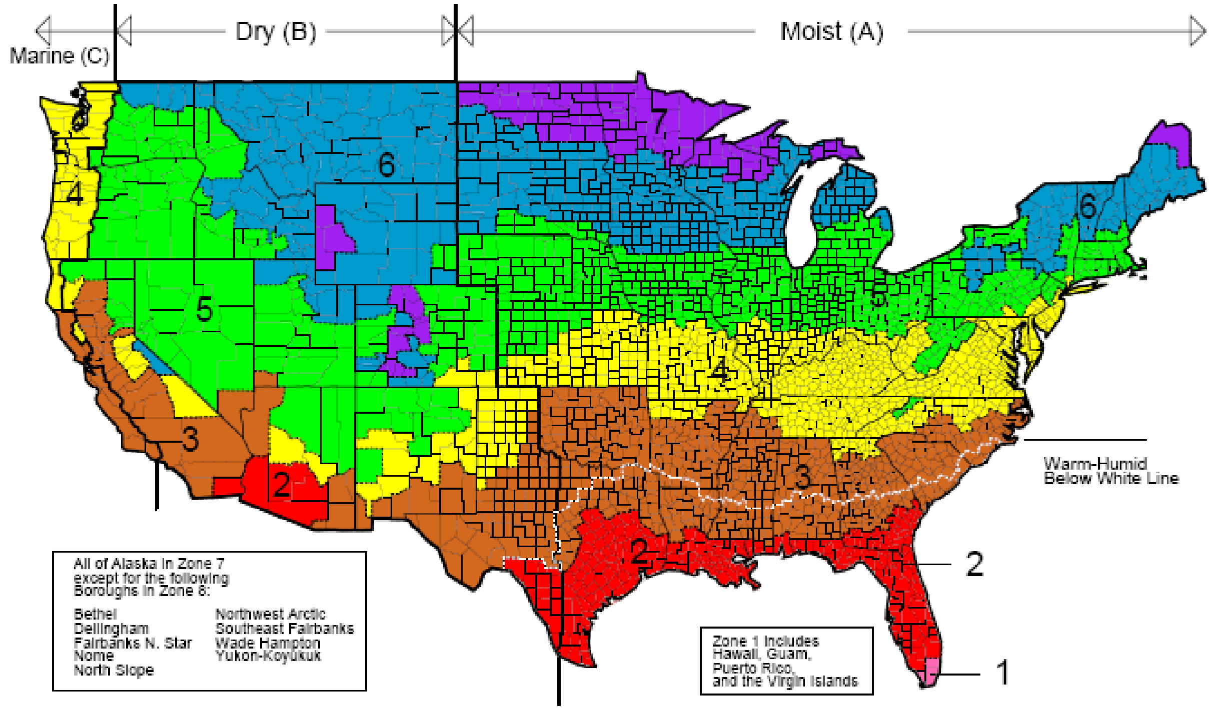
What is the advantage of using a simulation tool to check compliance with a code? For a steel wall assembly, the benefits are best understood by first examining the prescriptive code requirements.

The main emphasis in this document is addressing codes produced by the International Code Council (ICC). The ICC produces the International Energy Conservation Code (IECC) and the energy provisions in the International Residential Code (IRC).

In the IECC, IRC, and standards like ASHRAE 90.1 and 90.2, a CFS wall must conform to higher standards in terms of required R-Value of insulation than wood. For example, the 2006 IECC and IRC both contain a table with cavity insulation in a wood framed wall shown in one column and what the code determined to be an “equivalent” steel framed assembly in a second column. To create this equivalence, the steel wall is required to have at least an R-5 of continuous insulation on the exterior of the wall. This typically results in a steel wall that performs better than a wood wall, but can also add considerable cost to a steel home. For example, the cost of R-5 XPS (1-inch) exterior insulation required in IECC Climate Zones 1 and 2 (See Figure 1) would add $0.80 to $0.85 per square foot of wall area versus a wall with just cavity insulation.

By using the Performance Option in a code, a builder or designer can eliminate continuous exterior insulation by improving other components of the building. For example, a builder may decide to use better windows or modify the stud spacing to improve energy performance.

Figure 1: IECC Climate Zone Map (Source: U.S. Department of Energy)



Codes describe windows by two primary characteristics: the solar heat gain coefficient (SHGC) and the assembly U-Factor. Typically, a designer will select a window with a SHGC greater than the code minimum, resulting in a window that is better than the code requires. If every other part of the home was code minimum, but the windows, the overall building will perform better than the reference building in an energy simulation program. This is an important concept for CFS framing because in many southern climates, better than code windows may exceed code minimums enough to qualify CFS to be installed without exterior insulation.

Another example of the Performance Option potentially reducing CFS framing costs is when wall studs are spaced wider than in the code reference building. The resulting building will have a lower amount of framing material. Lower amount of framing allows for more insulation and better overall energy performance. Therefore, common framing practices, such as 24" o.c., already being used result in a design that exceeds code requirements. A building that has a roof or wall system marginally deficient under a code's prescriptive requirements should run a simulation tool on the home to determine if over-designers elsewhere in the building can be taken advantage of.

As previously stated, some codes and standards have requirements for continuous insulation. The Performance Option may minimize the impact of continuous insulation on walls, floors, or ceilings.

To make the Performance Option effective, a user needs to know which building systems to concentrate on in their simulations. Otherwise, one could spend a significant amount of time looking at simulations that might otherwise yield no practical construction or cost advantages. To help builders or designers recognize the advantages of the Performance Option, SFA sponsored initial research to look at options that a builder might use in lieu of exterior foam insulation.

Tables 2 and 3 show the results from the simulations ran on a typical home in IECC Climate Zone 2. The homes were first designed to the IECC minimum prescriptive requirements, but without the continuous R-5 insulation. The simulations were run using REM/Design, a software package used to show compliance with the 2006 IECC, with isolated above-code changes. See Table 4 and Appendix A for more information on REM Design and other software packages.

The information in Tables 2 and 3 is a good starting point for new users of simulation software because the tables identify the options that will most likely yield significant benefits. Note, since most of the current CFS market is located in IECC/IRC Climate Zone 2 the simulations were limited to Zone 2.

Table 2: System Improvements with High Potential for a Vented Crawl Space in Climate Zone 2

Minimum 2006 IECC Requirements	System Upgrade(s) that can Improve Compliance	Percent Improvement in Energy Costs Versus 2006 IECC
SEER 13, HSPF 7.7 heat pump	SEER 15, HSPF 8.5 heat pump	1.54%
No overhangs, and windows with U=0.75 and SHGC=0.40	2 ft roof overhangs, and single-hung low E vinyl windows with U=0.35 and SHGC=0.33	1.30%
Windows with U=0.75 and SHGC=0.40	Single-hung low E vinyl windows with U=0.35 and SHGC=0.33	0.73%
Tank type gas water heater with 0.62 Energy Factor	Demand type gas water heater with 0.80 Energy Factor	2.76%
Tank type gas water heater with 0.62 Energy Factor	Tank type gas water heater with 0.90 Energy Factor	4.38%
R-13 wall cavity insulation at 16" o.c., and R-30 attic insulation	R-19 wall cavity insulation at 24" o.c., and R-50 attic insulation	0.32%
R-13 wall cavity insulation at 16" o.c., R-30 attic insulation, and R-2.6 doors	R-19 wall cavity insulation at 24" o.c., R-38 attic insulation, and R-4.4 doors	0.32%

Table 3: System Improvements with High Potential for Slab-On-Grade Home in Climate Zone 2

Minimum 2006 IECC Requirements	System Upgrade(s) that can Improve Compliance	Percent Improvement in Energy Costs Versus 2006 IECC
SEER 13, HSPF 7.7 heat pump	SEER 15, HSPF 8.5 heat pump	1.46%
No perimeter slab insulation, and R-2.6 doors	R-5 perimeter slab insulation, and R-4.4 doors	0.24%
Windows with U=0.75 and SHGC=0.40	Double low E vinyl windows with U=0.35 and SHGC=0.33	0.57%
Tank type gas water heater with 0.62 Energy Factor	Demand type gas water heater with 0.80 Energy Factor	2.67%
Tank type gas water heater with 0.62 Energy Factor	Tank type gas water heater with 0.90 Energy Factor	4.29%
R-13 wall cavity insulation at 16" o.c., and R-30 attic insulation	R-19 wall cavity insulation at 24" o.c., and R-38 attic insulation	0.32%
R-13 wall cavity insulation at 16" o.c., and R-30 attic insulation	R-19 wall cavity insulation at 24" o.c., and R-50 attic insulation	0.73%
R-13 wall cavity insulation at 16" o.c., and no slab insulation	R-19 wall cavity insulation at, 24" o.c., and R-5 slab insulation (2 ft. width)	0.32%
R-30 attic insulation, and no slab insulation	R-38 attic insulation, and R-5 slab insulation (2 ft. width)	0.73%

The system upgrades in the tables will also show improvements in other climate zones, but not necessarily the same percentage. Every building is different and needs its own simulations to confirm the building is complying with the local code in effect if using the Performance Option.

Ghosting is a temperature-driven phenomenon in walls where dark streaks appear on the walls over the studs. Climate Zones 1 and 2 represent the southern-most areas of the United States. In these climates, the risk of ghosting is negligible. In colder climates, ghosting is mitigated by providing a thermal break.

It is recommended that only in Climate Zones 1 and 2 should the UA Trade-Off Method be used to eliminate exterior continuous insulation unless the designer has carefully studied the local climate and believes the chances of ghosting are minimal. For example, it is likely that ghosting is not of concern in most of Climate Zone 3. However, more research is needed to definitively identify ghosting criteria in moderate climates before the industry could recommend going without at least R-3 continuous insulation except in Climate Zones 1 and 2. In buildings where frequent re-painting occurs due to occupancy changes, ghosting may never be an issue, even in colder climates.

Simulation Tools

The author, the Steel Framing Alliance, nor any of our affiliates endorse a specific software package for simulations. However, in order to use the Performance Option, some information is necessary to understand what programs are available. Always check with your governing code authority on a specific program before applying it to a proposed design.

The use of the Performance Option requires simulations to be run with "approved" software. The term "approved" is used loosely because although there are a number of organizations that certify, review, or otherwise assess software, the determination of what is acceptable rests with the local building department. Building officials and designers most often look to the U.S. Department of Energy (DoE), Energy Star, RESNET (Residential Energy Services Network- a nationally-recognized organization of home energy raters), or states like California for guidance on software tools to approve.

On one hand, it is encouraging that the software industry is healthy and competitive as evidenced by over 300 software tools listed in DoE's directory of simulation tools (http://www.eere.energy.gov/buildings/tools_directory/). On the other hand, the sheer number of options can be intimidating. Fortunately, a group of simulation tools has risen to the top as the most widely-used and recognized in the United States. These include but are not limited to:

1. REM Design, available from Architectural Energy Corporation;
2. RESCheck, a free download from the U.S. DoE;
3. Energy 10, available from the Sustainable Building Industry Council;
4. Energy Gauge (Residential), available from the Florida Solar Energy Center; and
5. EnergyPro, a package specifically approved for use in California available from Global Dodd/Energy Soft Inc.

Some programs are available for free, however, most average around $400 to $500 for a simple license. Costs can be higher or lower depending on how many licenses are required and features desired. Table 4 shows how several simulation tools address key issues that should be considered when selecting a software package.

Table 4: Summary of Simulation Tools

Software Package	Codes and Standards Covered	Building Types Covered	Calculation Method
REM/Design	ASHRAE: 90.2 MEC: 1992, 1993, & 1995 IECC: 1998, 2000, 2001, 2003, 2004, & 2006 State codes: Southern Nevada, & New York	Single- and multi-family residential	Parallel Path Method with two paths. 2003 IECC factors applied to cavity insulation path
REScheck	MEC: 1992, 1993, & 1995 IECC: 1998, 2000, 2003, & 2006 IRC: 2006 State codes: AK, GA, MA, MN, NH, NJ, NY, VT, WS, & Pima County, AZ	Single-family homes*	Parallel Path Method with a single path modified using 2003 IECC correction factors
Energy 10	ASHRAE: 90.1-2004	All types	Modified Zone Method
Energy Gauge USA	IECC: 1998, 2000, 2003, 2004, & 2006 State codes: Florida	Single-family homes*	Parallel Path Method (without modifications)
Energy Pro	CA Title 24	All types	ASHRAE Zone Method

*RESCheck and Energy Gauge developers offer companion programs that address commercial buildings. See Appendix A for contact information on each simulation tool.

In general, there is a lack of consistency related to how each of the software programs calculate the thermal resistance or conductance (R-Value or U-Factor) of CFS members and assemblies. If a user selects the default values or library files for CFS framing, they may end up with a less than accurate building model, particularly in colder climates. A proficient user can adjust the U-Factors for a component, in any program, to achieve accurate results.

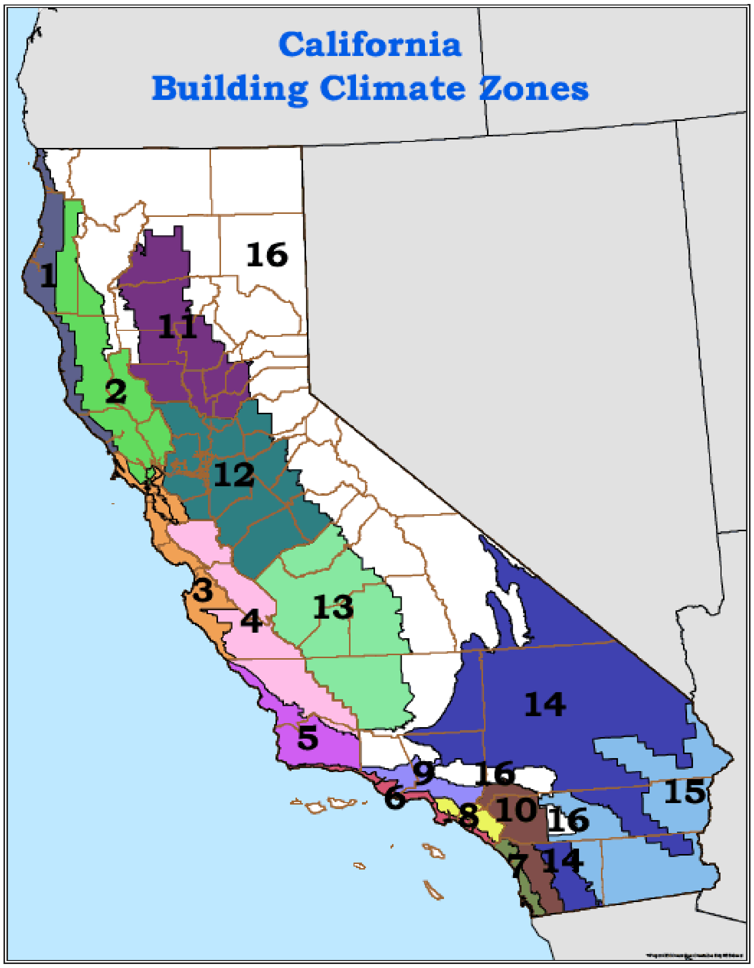
Most simulation programs come with libraries of all the required information for framing assemblies but a few programs do require the user to input these thermal characteristics. Section 4 discusses various calculation methods used to determine the thermal properties for CFS assemblies. These calculated thermal property values can then be used as thermal inputs for software programs for CFS wall components, if required or desired.

Note that California has its own requirements and approved software that comply with California's Title 24 energy provisions. Likewise, Florida codes support Energy Gauge software. Always confirm your assumptions and software tool with the appropriate building code department.

Instructions for Using the Simulated Performance Approach

1. Select a simulation program. Many software developers offer training that can decrease your learning curve if you are not already proficient with the software. With a moderate amount of building knowledge, most of the packages will require less than a day's time to become proficient enough to run relatively conventional buildings. More sophisticated designs with innovative heating and air-conditioning equipment will require longer learning times. Appendix A provides contact information for several applicable software developers.
2. Secure completed floor plans, wall sections, and specifications for the proposed building. If specifications for the energy systems are not yet determined, run the initial simulation using minimum prescriptive code requirements for insulation R-Value and equipment efficiency. Some simulation tools do this automatically. Most tools provide menus to select your climate zone. Codes also provide climate zone information. For example, see Figure 1 for a national climate zone map from the IECC and IRC or Figure 2 for California, which has its own code and climate zones.
3. If the selected software is approved by your governing code authority for use as a compliance tool, then it is appropriate to use the default U-Factors built into the software or in its library. However, you may create a more accurate model by importing your own U-Factors based on Table 1 or calculated using the methods discussed in Section 4 and Appendix B.

Figure 2: California Climate Zones Map
(Source: California Energy Commission)



4. Run additional simulations by changing items that can improve the building's performance. Some programs do whole-building evaluations as well as a UA Trade-Off, which allows a user to specify less insulation in one part of the home if it is made up elsewhere. The items listed in Tables 2 and 3 show some options that may help with code compliance without the use of exterior insulation and can be used as a starting point to conduct simulations.

SECTION 4
PRESCRIPTIVE COMPLIANCE APPROACH

In order to comply with the IECC, IRC, state-specific codes, and ASHRAE 90.1 or 90.2 standards, a designer must be able to show that an assembly can achieve the U-Factor or R-Value specified for a given climate zone. Following the pure prescriptive approach, a CFS wall must be designed with R-Values equal to or greater than those specified in the code. Table 5 shows examples of Prescriptive Option requirements from the 2006 IECC (which is identical to the IRC energy provisions in this case). The example is based on a home to be built in New Orleans located in IECC limate Zone 2.

Table 5: 2006 IECC Climate Zone 2 Residential Wall Requirements

Wall Framing Material	Cavity Insulation R-Value	Continuous Exterior Insulation R-Value	U-Factor
Wood	R-13	None	0.082
Metal	R-13	R-5	0.082

In this example, a CFS wall assembly would need to have at least R-13 in the cavity and R-5 continuous exterior insulation to be code compliant.

When selecting the U-Factor Prescriptive Method, it is incumbent upon the designer or builder to show how a given assembly is equal to or lower than the values in their climate specific code. In the New Orleans example, the target U-Factor is 0.082. Compliance can be shown either through calculations or test data.

Prior to discussing test data or calculation methods, it is important to remember that the test data reported in the 1995 *AISI Thermal Design Guide* was limited to a clear wall assembly. A clear wall assembly typically has one top track, one bottom track, and studs spaced at 16 or 24 inches on center. This results in a framing factor, or ratio of framing to gross wall area, of about 11% for 24 inch stud spacing and 14% for 16 inch stud spacing.

The framing factor is the area in a wall that is taken up by the framing, including studs, tracks, headers, jambs, and all other framing. It is typically expressed as a percent or fraction of the framing relative to overall wall (or floor or ceiling) area. Typical wall framing factors run from about 15% to as high as 25%. The term framing fraction is also frequently used in place of framing

The framing factor has and continues to be an issue of debate in codes and standards deliberations. We highly recommend that a builder or designer confers with the local building official on the accepted framing factor calculation method in their community. The actual framing factor taken from construction plans can sometimes be lower than the assumptions used in a code.

Determining the Thermal Characteristics for Code Compliance

The effective R-Value is the thermal resistance of an entire assembly as opposed to just the R-Value of the cavity insulation. The UA is calculated by inverting the effective R-Value and multiplying it by the surface area (A) of the component. In simple terms, a U-factor is the inverse of the R-Value.

The term "effective" is often used interchangeably with the terms "composite," "whole-wall," or "assembly" for both U-Factor and R-Value. In each case, it is a measure of the overall thermal performance of the wall, floor, or ceiling by taking into account all components of the assembly.

There are at least four pathways to determine the effective or composite U-Values for a CFS framed building assembly – the Correction Factor Method, the Zone Method (sometimes called the ASHRAE zone method), the Modified Zone Method, and results of wall assembly tests. Note that the Parallel Path Method used for wood framing should not be used for metal assemblies.

For CFS wall assemblies, we recommend the Correction Factor Method. Descriptions of other calculation methods are provided in Appendix B, since they are used in some state codes or are valid for other applications. For example, California requires the use of the Zone Method for CFS assemblies.

Correction Factor Method

The most straightforward calculation approach employs correction factors that were developed and adopted by various national model codes and standards. Correction factors appear in the 2003 IECC and ASHRAE Standard 90.2 (2007) as shown in Table 6.

The 2003 IECC and ASHRAE 90.1 and 90.2 standards are based on an identical approach with the following equations:

Equation 1

$$U_w+1/[R_s+(R_{ins} \times F_c)]$$

here:

U_w = U-Factor of CFS wall corrected for impact of CFS members
R_s = R-Value of all elements in the path through the wall excluding the framing and the cavity insulation (i.e., R-Values of the gypsum board, inside and outside air spaces, sheathing, and exterior continuous insulation if present)
R_{ins} = R-Value of the cavity insulation
F_c = Correction factor from Table 6

Table 6: Cold-Formed Steel Correction Factors

Nominal Stud Size	**Stud Spacing**	**Cavity Insulation**	**Factor (F_c)**
2x4	16" o.c.	R-13	0.46
2x4	16" o.c.	R-15	0.43
2x4	24" o.c.	R-13	0.55
2x4	24" o.c.	R-15	0.52
2x6	16" o.c.	R-19	0.37
2x6	16" o.c.	R-21	0.35
2x6	24" o.c.	R-19	0.45
2x6	24" o.c.	R-21	0.43

Table 7 shows the R-Values and U-Factors calculated using the Correction Factor Method for common CFS assemblies. Interior gypsum board and OSB sheathing were assumed for each assembly, as were inside and outside air films.

Table 7: U-Factor and R-Value Calculated by Correction Factor Method for Selected Assemblies

Stud Size	Stud Spacing	Cavity Insulation R-Value	Continuous Insulation	Assembly R-Value	Assembly U-Factor
1.5"x3.5"	24" o.c.	R-13	None	7.82	0.019
1.5"x3.5"	24" o.c.	R-13	R-3	10.82	0.080
1.5"x3.5"	24" o.c.	R-13	R-5	12.82	0.071
1.5"x3.5"	24" o.c.	R-15	None	8.29	0.102
1.5"x3.5"	24" o.c.	R-15	R-3	11.29	0.078
1.5"x3.5"	24" o.c.	R-15	R-5	13.29	0.0067
1.5"x5.5"	24" o.c.	R-19	None	10.39	0.095
1.5"x5.5"	24" o.c.	R-19	R-5	15.39	0.064
1.5"x5.5"	24" o.c.	R-21	None	10.87	0.090
1.5"x5.5"	24" o.c.	R-21	R-5	15.87	0.062

The entries in Table 7 are limited to 24 inch stud spacing because this framing strategy is most cost-effective. For buildings with 16 inch stud spacing, Equation 1 can be used to determine U-factors. Alternatively, a spreadsheet calculator is available at www.newportpartnersllc.com/Judy/calculator_with_correction_factors.xls. For stud spacing other than 16 or 24 inches, one of the methods in Appendix B or test data must be applied.

Existing Test Data

There are two sets of test results that are most applicable to CFS wall assemblies. One is from a study conducted in the mid 1990s under funding from AISI (Barbour-1994) and the other from a database of more recent tests conducted by Oak Ridge National Laboratory.

The earlier test data from Barbour was based on clear wall assemblies. Selected results are shown in Table 8.

Table 8: Clear Wall Assembly Test Results

Nominal Stud Size	Stud Spacing	Cavity Insulation	Exterior Sheathing	Assembly R-Value	Assembly U-Factor
2x4 x 43 mil	24" o.c.	R-11	½ Inch Plywood	7.9	0.127
2x4 x 43 mil	24" o.c.	R-11	R-5 Continuous Insulation	13.7	0.073
2x4 x 33 mil	24" o.c.	R-11	½ Inch Plywood	8.3	0.120
2x4 x 33 mil	24" o.c.	R-11	R-5 Continuous Insulation	13.9	0.072
2x6 x 33 mil	24" o.c.	R-19	½ Inch Plywood	10.1	0.099
2x6 x 33 mil	24" o.c.	R-19	R-5 Continuous Insulation	16.6	.060

Source: Barbour, 1994 (Except U-Factors were calculated separately as the inverse of the R-Value).

Table 9: Whole-Wall Test Results of Cold-Formed Steel Assemblies With 22 to 25% Framing

Stud Size	Stud Spacing	Cavity Insulation	Continuous Exterior Insulation	Assembly R-Value	Assembly U-Factor
1.5"x3.5"	24" o.c.	R-13	None	7.07	0.141
1.5"x3.5"	24" o.c.	R-13	R-4	10.93	0.091
1.5"x3.5"	24" o.c.	R-13	R-4	11.08	0.090
1.5"x3.5"	24" o.c.	R-13	R-5	11.85	0.084
1.5"x3.5"	16" o.c.	R-13	None	6.77	0.147
1.5"x3.5"	16" o.c.	R-13	R-4	10.47	0.096
1.5"x3.5"	16" o.c.	R-13	R-5	11.15	0.090

Source: Oak Ridge National Laboratory Hot Box Test database available at http://www.ornl.gov/sci/roofs+walls/AWT/Ref/steel.htm (except U-factor which were calculated as the inverse of the R-Values).

Notes: All assemblies have ½ inch gypsum board on the interior and ½ inch OSB sheathing on the exterior. For Extruded Polystyrene Insulation (XPS), ¾ inches equals R-4 and 1 inch equals R-5. Other insulation materials are permissible with the same R-Values. Assembly values include interior and exterior air films.

In 1994, R-11 was the most commonly used cavity insulation and this was reflected in the assemblies that were tested in the Barbour study. By 2006, the minimum cavity insulation had increased to R-13 throughout most of the United States. Table 9 shows data from more recent studies of assemblies that are closer to today's construction practices.

The information in Table 9, and in some cases, Table 8, can be useful to designers or builders in meeting code requirements following the U-Factor Prescriptive Method.

At this time there is a lack of test data on assemblies with R-19 or greater insulation, except for the clear wall tests conducted in 1994 by Barbour. For designs requiring higher levels of performance, the reader is referred to the U-Factors in Table 6 or to the calculation methods in Equation 1 and Appendix B.

Instructions for Using the Prescriptive Options in Codes

Prescriptive Option Based on R-Values of Insulation (applicable to the IECC and IRC codes)

1. Determine your climate zone based on the location of the building. Often times the local building code will identify the jurisdiction's climate zone. An example of a climate zone map used in the IECC and IRC codes is reproduced in Figure 1. Note that California has unique climate zones (see Figure 2).
2. Select the appropriate R-Value(s). Each code has a set of R-Values. These are typically expressed in terms of cavity insulation R-Value but may also include exterior continuous insulation. Requirements have changed over the years, so be sure to use the most current code in your jurisdiction. Many states and local organizations follow the IECC or IRC. An example from the 2006 IECC (also applicable to the 2006 IRC) is shown in Table 10.

Table 10: 2006 IECC Code Requirements for Residential Cold-Formed Steel Walls

Climate Zone	Wood Wall R-Value Requirements	Equivalent Steel Requirement	U-Factor Requirement (for all framed wall types)
1 – 4 (except Marine 4)	R-13	R-13+5, R-15+4 or R-21+3	0.082
5 – 6, and Marine 4	R-19 or 13+5	R-13+9, R-19+8, or R-25+7	0.060
7 – 8	R-21	R-13+10, R-19+9, or R-25+8	0.057

When a value in the table only requires cavity insulation, only one number is shown. Whenever continuous exterior insulation is required, a “+” sign followed by a second value is listed in the table. The first value is for cavity insulation and the second is for continuous insulation. As an example, a single-family detached home in New Orleans would fall in Climate Zone 2. Thus, a CFS wall with R-13 in the cavity and R-5 continuous insulation on the exterior would comply.

The R-13 cavity insulation could be batt or spray-in insulation. One inch of XPS will provide the R-5 continuous insulation although other types of insulation could be used in appropriate thicknesses. Note that details around doors and windows need to account for a thicker wall when continuous insulation is used. Builders and designers should also check with local officials and manufacturers when using more than ½ inch of exterior foam insulation with heavy materials like 3-coat stucco.

Most codes have separate requirements for commercial buildings that usually include multi-family buildings over three stories in height. Table 11 summarizes the requirements for commercial buildings from the 2006 IECC.

Table 11: 2006 IECC Code Requirements for Commercial Wood and Cold-Formed Steel Walls

Climate Zone	Wood Frame	CFS Frame
1 – 4 (except Marine 4)	R-13	R-13
5 – 6, and Marine 4	R-13	R-13+3.8
7	R-13	R-13+7.5
8	R-13+7.5	R-13+7.5

Prescriptive Option Based on Assembly U-Factors
Under this approach the designer must show how a wall assembly is equal to or lower than the code-required U-Factor.

1. Identify your climate zone using the map in Figure 1 or from consulting your local code. Figure 2 shows the climate zone designations for California.
2. Select the U-Factor required by your code. U-Factors from the 2006 IECC are shown in Tables 10 and 11. The IECC residential values in Table 10 are the same values used in the 2006 IRC. California has its own U-Factor requirements. Tables 12 and 13 show U-Factors derived from the Title 24 requirements for California.
3. Consult data or provide calculations to show that your design is equal to <u>or less</u> than the required U-Factor. Test data or U-Factors from this report are appropriate sources of data. Be certain that the building official approves the use of the data and calculation method before proceeding with design or construction. For steel framing, California only permits the

use of the Zone Method calculations to determine the actual U-Factor of an assembly. As an alternative to performing zone calculations, U-Factors adopted in the 2008 California Title 24 provisions are reproduced in Appendix C.

Table 12: California Title 24 Requirements for Low-Rise Residential Buildings
Note: Includes single-family and multi-family buildings of three stories or less.

Climate Zone	**All Electric Homes**		**Gas and Electric Homes**		**Lower Performance Window Trade-Off**	
	2005[a]	**2008***	**2005**	**2008***	**2005**	**2008***
1	0.055	No Change from 2005	0.069	No Change from 2005	Not existent in 2005	0.069
2	0.055		0.102			0.074
3	0.057		0.102			0.074
4	0.057		0.102			0.074
5	0.057		0.102			0.074
6	0.069		0.102			0.074
7	0.069		0.102			0.074
8	0.069		0.102			0.074
9	0.069		0.102			0.074
10	0.057		0.102			0.074
11	0.055		0.074			0.074
12	0.055		0.074			0.074
13	0.055		0.074			0.074
14	0.055		0.069			0.069
15	0.055		0.069			0.069
16	0.055		0.069			0.069

*The 2008 provisions have been approved as of publication of this document but will not be implemented until 2009. The 2008 prescriptive provisions provide an option for higher U-Factors (lower R-Values) if the windows are upgraded to a maximum U-Factors of 0.50 in climate zone 1, 0.57 in zones 2 -15, and 0.45 in zone 16. The SGHC must be a maximum of 0.25 in climate zones 4, 7, 11, 12, 14, and 15; 0.30 in zone 13; and 0.40 in zones 2, 3, 5,, 6, 8, 9, and 10. In addition use of the window trade-off option is limited to homes with less than 20% window area. If more than 5% of window area faces west, there are additional limitations in certain climate zones. Check with your building department for these and other requirements.

Table 13: California Requirements for Selected Commercial Building Types				
Climate Zone	High-Rise Residential & Guest Rooms of Hotels/Motels		All Other Nonresidential Buildings (except relocatable schools)	
	2005	**2008**	**2005**	**2008[a]**
1	0.183	0.105	0.217	0.098
2	0.217	0.105	0.217	0.062
3	0.224	0.105	0.224	0.082
4	0.224	0.105	0.224	0.062
5	0.224	0.105	0.224	0.062
6	0.224	0.105	0.224	0.098
7	0.224	0.105	0.224	0.098
8	0.224	0.105	0.224	0.062
9	0.224	0.105	0.224	0.062
10	0.217	0.105	0.217	0.062
11	0.217	0.105	0.217	0.062
12	0.217	0.105	0.217	0.062
13	0.217	0.105	0.217	0.062
14	0.217	0.105	0.217	0.062
15	0.217	0.105	0.217	0.062
16	0.183	0.105	0.217	0.062

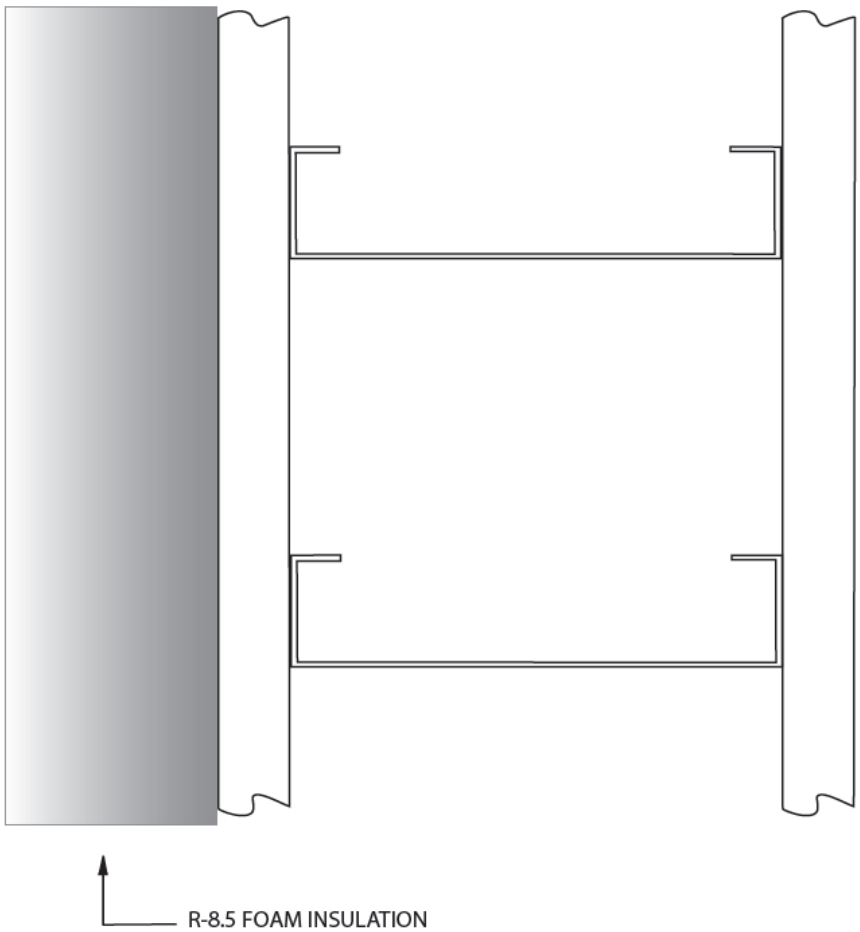
*The 2008 provisions have been approved as publication of this document but will not be implemented until 2009.

SECTION 5
INNOVATIVE SYSTEMS

One innovative approach for code compliance is the warm wall design (see Figure 2). In this approach, no cavity insulation is used. Instead, all of the insulation is moved to the exterior of the wall in the form of continuous foam sheathing. The foam can be applied directly to studs or over any code-required structural sheathing.

There are multiple benefits to the warm wall design. Continuous exterior insulation will usually perform better than cavity insulation. The approach tends to minimize the impact of framing and provides a better quality thermal envelope than stuffing insulation between framing members, sometimes into spaces that are nearly impossible to reach.

Figure 3: Warm Wall Design with Continuous Exterior Insulation and No Cavity Insulation



One possible issue with warm wall designs is that some siding manufacturers limit the thickness of insulation under their product. Generally, the limits are in the range of 1-1/2 to 2 inches. In addition, a few communities in California restrict stucco to walls with no more than one inch of foam insulation over concerns about the fasteners not being capable of supporting the weight of the stucco, eventually leading to cracks.

Because a warm wall eliminates the framing's influence on the insulation, a home can have less overall insulation than a cavity-only wall design and still provide equivalent or better thermal performance. To date, there is no available test data on warm walls without cavity insulation. Thus, the amount of insulation necessary for a warm wall design must be determined by calculation or by following prescriptive code requirements.

The IRC and IECC will for the first time contain prescriptive requirements for warm wall designs for a steel wall assembly in their 2009 editions. A builder or designer will be able to comply with these codes by installing R-10 continuous insulation without any cavity insulation for CFS walls and it will be considered equivalent to R-13 cavity plus R-5 continuous exterior insulation. Although technically limited to the residential section of the codes, this solution sets a precedent that will likely be acceptable to a building official for commercial buildings as well.

There are also innovative systems that have been developed by various manufacturers that are not otherwise described in the code. For example, some manufactures have developed wall panel products with a built-in thermal barrier. In order to use an innovative system, you must have either test results showing the U-Factor or R-Value or be able to calculate the U-Factor using one of the described methods in this report.

Many manufacturers produce evaluation reports that local officials often consider to be equivalent to code text. An evaluation report will likely include thermal test results or calculations. The most comprehensive list of evaluation reports is available from the ICC Evaluation Service. The ICC reports can be viewed at www.icc-es.org. Other reports can be obtained directly from specific manufacturers.

Once the whole-wall U-Factor or R-Value is obtained for a given innovative system, it can be applied in the U-Factor or performance compliance options.

REFERENCE

Barbour-1994: E. Barbour, J. Goodrow, J. Kosny, and J. Christian, "Thermal Performance of Steel-Framed Walls," NAHB Research Center, November 21, 1994.

APPENDIX A

CONTACT INFORMATION FOR COMPLIANCE SOFTWARE

REM/Design
Architectural Energy Corporation
2540 Frontier Avenue, Suite 201
Boulder, CO 80301
Phone: (303) 444-4149
Purchase information available at:
www.archenergy.com

REScheck (Residential)
and **COMcheck** (Commercial)
U.S. Department of Energy
Washington, DC
Download from the Energy Efficiency and Renewable Energy website at:
www.energycodes.gov

Energy 10
Sustainable Buildings Industry Council
1112 16th Street, NW, Suite 240
Washington, DC 20036
Phone: (202) 628-7400
Purchase information available at:
www.sbicouncil.org/storeindex.cfm

Energy Gauge USA (Residential) and
Energy Gauge Summit Premier (Commercial)
Florida Solar Energy Center, University of Central Florida
1679 Clearlake Road
Cocoa, FL 32922-5703
Phone: (321) 638-1492
Purchase information available at:
www.energygauge.com

EnergyPro
EnergySoft LLC
1025 5th Street, Suite A
Novato, CA 94945
Phone: (415) 897-6400
Purchase information available at:
www.energysoft.com

APPENDIX B
ALTERNATIVE CALCULATION METHODS

Zone Method - The Zone Method is a variation on the Parallel Path Method designed to account for steel's impact on adjacent insulation. The Parallel Path Method sums the R-Values for the various components in a wall assembly through two paths – one through the CFS stud and one through the center of the cavity. The sum of the R-Values through each path are inverted to obtain a U-Factor for the path and then weighted based on the area of the wall the paths represent.

In the Zone Method, the CFS flange width is increased by two times the total thickness of all finish material layers on the thicker side of the CFS member. This has the effect of increasing the amount of area that is assumed to be influenced by the steel member. The result is a whole-wall U-Factor that can be inverted to yield an effective R-Value for the assembly, although from a code compliance perspective, the main interest is in the U-Factor.

The Zone Method tends to <u>underestimate</u> the effective R-Value of a steel assembly, or overestimate the U-Factor. Thus it should be acceptable for code compliance but may unnecessarily penalize a steel assembly. It is currently the only method permitted for calculation of U-Factors for CFS walls in California. The Zone Method is described in more detail in the *2004 ASHRAE Handbook of Fundamentals*.

Modified Zone Method - The Modified Zone Method was developed by Oak Ridge National Laboratory as a follow up to a test program funded by AISI in the early 1990s. The Modified Zone Method is sometimes called the ORNL Method because of this fact. With this calculation method, the flange width is widened by increasing its dimension by a term called "zf" that is defined as a ratio of thermal resistivity of finish material to cavity insulation. Thus, the Modified Zone Method is similar to the Zone Method in that it widens the assumed width of the flange, but the width size is smaller than in the Zone Method.

The Modified Zone Method calculation again breaks the assembly into two paths (framed and non-framed) and performs the path calculations on each. The Modified Zone Method is believed to be the most accurate calculation method based on comparison to test results and finite element analysis conducted by ORNL. It is the method recommended in the *ASHRAE Handbook of Fundamentals* for metal framing. This calculation method is limited to C-shaped steel members and should not be applied to other shapes. It is also limited to clear wall assemblies, which can be a significant issue given that many walls are not clear wall assemblies.

Despite its limitations, there are valid applications of the Modified Zone Method including:

- Walls in buildings with few openings, such as side walls. These are similar to a clear wall assembly and could be designed using the Modified Zone Method.
- When advanced or optimum valued wall stud design is used. For walls with a 24 inch on center design and a relatively small amount of openings, the framing factor is not very different from a clear wall assembly.

There is also no common agreement on the acceptable framing factors because some building departments are comfortable with clear wall assumptions.

Oak Ridge National Laboratory maintains an on-line calculator that can be used to determine the thermal characteristics of CFS walls using the Modified Zone Method. The following link will take you to the Oak Ridge calculator: http://www.ornl.gov/sci/roofs+walls/calculators/modzone/modzone2.html.

APPENDIX C
U-FACTORS IN THE 2008 CALIFORNIA TITLE 24 ENERGY PROVISIONS

The information in this appendix is taken from *Appendix JA4 – U-Factor, C-Factor, and Thermal Mass Data* published by the California Energy Commission in May 2008. No interpolation is permitted within the tables.

Table C1: Non-Residential Cold-Formed Steel Walls

				Rated R-value of Continuous Insulation [2]							
	Cavity Insulation R-Value:	Nominal Framing Size		R-0	R-2	R-4	R-6	R-7	R-8	R-10	R-14
Spacing				A	B	C	D	E	F	G	H
16 in. OC	None	Any	1	0.458	0.239	0.162	0.122	0.109	0.098	0.082	0.062
	R-11	2x4	2	0.244	0.155	0.118	0.096	0.087	0.080	0.069	0.054
	R-13	2x4	3	0.217	0.151	0.116	0.094	0.086	0.079	0.068	0.054
	R-15	2x4	4	0.211	0.148	0.114	0.093	0.085	0.078	0.068	0.053
	R-19	2x6	5	0.183	0.134	0.106	0.087	0.080	0.074	0.065	0.051
	R-21[1]	2x6	6	0.178	0.131	0.104	0.086	0.079	0.073	0.064	0.051
	R-19	2x8	7	0.164	0.123	0.099	0.083	0.076	0.071	0.062	0.050
	R-22	2x8	8	0.160	0.121	0.098	0.082	0.075	0.070	0.062	0.049
	R-25	2x8	9	0.158	0.120	0.097	0.081	0.075	0.070	0.061	0.049
	R-30[1]	2x8	10	0.157	0.119	0.096	0.081	0.075	0.070	0.061	0.049
	R-30	2x10	11	0.140	0.109	0.090	0.076	0.071	0.066	0.058	0.047
	R-38[1]	2x10	12	0.139	0.109	0.089	0.076	0.070	0.066	0.058	0.047
	R-38	2 x 12	13	0.124	0.099	0.083	0.071	0.066	0.062	0.055	0.045
	Foamed Plastic or Cellulose Insulation[3]	2 x 4	14	0.218	0.152	0.116	0.094	0.086	0.079	0.069	0.054
		2 x 6	15	0.179	0.132	0.104	0.086	0.079	0.074	0.064	0.051
		2 x 8	16	0.157	0.119	0.096	0.081	0.075	0.070	0.061	0.049
		2 x 10	17	0.138	0.108	0.089	0.075	0.070	0.066	0.058	0.047
		2 x 12	18	0.123	0.099	0.082	0.071	0.066	0.062	0.055	0.045
24 in. OC	None	Any	24	0.455	0.238	0.161	0.122	0.109	0.098	0.082	0.062
	R-11	2x4	25	0.210	0.148	0.114	0.093	0.085	0.078	0.068	0.053
	R-13	2x4	26	0.203	0.144	0.112	0.092	0.084	0.077	0.067	0.053
	R-15	2x4	27	0.197	0.141	0.110	0.090	0.083	0.076	0.066	0.052
	R-19	2x6	28	0.164	0.123	0.099	0.083	0.076	0.071	0.062	0.050
	R-21[1]	2x6	29	0.161	0.122	0.098	0.082	0.076	0.070	0.062	0.049
	R-19	2x8	30	0.153	0.117	0.095	0.080	0.074	0.069	0.060	0.049
	R-22	2x8	21	0.149	0.115	0.093	0.079	0.073	0.068	0.060	0.048
	R-25	2x8	32	0.147	0.114	0.093	0.078	0.072	0.068	0.060	0.048
	R-30[1]	2x8	33	0.146	0.113	0.092	0.078	0.072	0.067	0.059	0.048
	R-30	2x10	34	0.130	0.103	0.086	0.073	0.068	0.064	0.057	0.046
	R-38[1]	2x10	35	0.128	0.102	0.085	0.072	0.068	0.063	0.056	0.046
	R-38	2 x 12	36	0.115	0.093	0.079	0.068	0.064	0.060	0.053	0.044
	Foamed Plastic or Cellulose Insulation[3]	2 x 4	37	0.204	0.145	0.112	0.092	0.084	0.078	0.067	0.053
		2 x 6	38	0.167	0.125	0.100	0.083	0.077	0.071	0.063	0.050
		2 x 8	39	0.146	0.113	0.092	0.078	0.072	0.067	0.059	0.048
		2 x 10	40	0.128	0.102	0.085	0.072	0.068	0.063	0.056	0.046
		2 x 12	41	0.114	0.093	0.078	0.068	0.063	0.060	0.053	0.044

Notes

1. Higher density fiberglass batt is required in these cases.
2. Continuous insulation may be installed on either the inside or the exterior of the wall, or both.
3. Foamed plastic and cellulose shall fill the entire cavity. Cellulose shall have a binder to prevent sagging.

This table contains U-Factors for steel or metal-framed walls, which are typical of nonresidential buildings. The table may be used for any construction assembly where the primary insulation is installed in a metal-framed wall, e.g. uninsulated curtain walls with metal furring on the inside.

Assumptions: Values in this table were calculated using the Zone Calculation Method. The construction assembly assumes an exterior air film of R-0.17, a 7/8 inch layer of stucco of R-0.18, building paper of R-0.06 (BP01), continuous insulation (if any), the insulation/framing layer, ½ inch gypsum of R-0.45 gypsum board (GP01), and an interior air film 0.68. The steel framing is assumed to be 0.0747 inch thick with a 15 percent knock out. The framing factor is assumed to be 25 percent for 16 inch stud spacing and 22 percent for 24 inch spacing. The EZ Frame internal default framing percentages are 15 percent for 16 inch stud spacing and 12 percent for 24 inch spacing. To account for the increased wall framing percentage the frame spacing input to the EZ Frame program is reduced to 13.218 inches for 16 inch stud spacing and 15.231 inches for 24 inch stud spacing. Foam plastic and cellulose are assumed to entirely fill the cavity and have a thermal resistance of R-3.6 per inch. Actual cavity depth is 3.5 inch for 2x4, 5.5 inch for 2x6, 7.25 inch for 2x8, 9.25 inch for 2x10, and 11.25 inch for 2x12. High density R-30 insulation is assumed to be 8.5 inch thick batt and R-38 is assumed to be 10.5 inch thick.

Table C2: Residential Cold-Formed Steel Walls

Spacing	Cavity Insulation R-Value:	Nominal Framing Size		R-0 A	R-2 B	R-4 C	R-5 D	R-6 E	R-7 F
16 in. OC	None	Any	1	0.455	0.238	0.161	0.139	0.122	0.109
	R-11	2x4	2	0.200	0.137	0.107	0.097	0.088	0.081
	R-13	2x4	3	0.192	0.132	0.105	0.095	0.087	0.080
	R-15	2x4	4	0.186	0.129	0.102	0.093	0.085	0.078
	R-19	2x6	5	0.154	0.112	0.092	0.084	0.077	0.072
	R-21[1]	2x6	6	0.151	0.110	0.090	0.083	0.076	0.071
	R-19	2x8	7	0.134	0.102	0.085	0.078	0.072	0.067
	R-22	2x8	8	0.129	0.099	0.082	0.076	0.071	0.066
	R-25	2x8	9	0.125	0.096	0.081	0.075	0.069	0.065
	R-30[1]	2x8	10	0.120	0.093	0.078	0.073	0.068	0.063
	R-30	2x10	11	0.109	0.086	0.073	0.068	0.064	0.060
	R-38[1]	2x10	12	0.104	0.082	0.071	0.066	0.062	0.058
	R-38	2 x 12	13	0.095	0.077	0.067	0.062	0.059	0.055
	Foamed Plastic or Cellulose Insulation[3]	2 x 4	14	0.177	0.131	0.104	0.094	0.086	0.079
		2 x 6	15	0.152	0.119	0.095	0.087	0.080	0.074
		2 x 8	16	0.121	0.098	0.082	0.076	0.070	0.066
		2 x 10	17	0.105	0.0.87	0.074	0.069	0.064	0.060
		2 x 12	18	0.092	0.077	0.067	0.063	0.059	0.056
24 in. OC	None	Any	24	0.449	0.236	0.161	0.138	0.121	0.108
	R-11	2x4	25	0.189	0.131	0.104	0.094	0.086	0.079
	R-13	2x4	26	0.181	0.127	0.101	0.092	0.084	0.078
	R-15	2x4	27	0.175	0.123	0.099	0.090	0.082	0.076
	R-19	2x6	28	0.144	0.107	0.088	0.081	0.075	0.070
	R-21[1]	2x6	29	0.141	0.105	0.086	0.080	0.074	0.069
	R-19	2x8	30	0.126	0.097	0.081	0.075	0.070	0.065
	R-22	2x8	31	0.121	0.094	0.079	0.073	0.068	0.064
	R-25	2x8	32	0.117	0.091	0.077	0.071	0.067	0.063
	R-30[1]	2x8	33	0.112	0.088	0.075	0.069	0.065	0.061
	R-30	2x10	34	0.102	0.081	0.070	0.065	0.061	0.058
	R-38[1]	2x10	35	0.096	0.077	0.067	0063	0.059	0.056
	R-38	2 x 12	36	0.088	0.072	0.063	0.059	0.056	0.053
	Foamed Plastic or Cellulose Insulation[3]	2 x 4	37	0.182	0.133	0.105	0.095	0.087	0.080
		2 x 6	38	0.146	0.112	0.092	0.084	0.078	0.072
		2 x 8	39	0.121	0.097	0.081	0.075	0.070	0.066
		2 x 10	40	0.101	0.084	0.072	0.067	0.063	0.059
		2 x 12	41	0.087	0.074	0.064	0.060	0.057	0.054

Table applies to CFS of 43 mil or thinner material

Assumptions: Values in this table were calculated using the Zone Calculation Method. The construction assembly assumes an exterior air film of R-0.17, a 7/8 inch layer of siding or stucco averaging R-0.18, building paper of R-0.06 (BP01), continuous insulation (if any), the insulation/framing insulation layer, ½ inch gypsum or R-0.45 gypsum board (GP01), and an interior air film 0.68. The framing factor is assumed to be 25 percent for 16 inch stud spacing and 22 percent for 24 inch spacing. To account for the increased wall framing percentage, the frame spacing input to the EZ Frame program is reduced to 13.218 inches for 16 inch stud spacing and 15.231 inches for 24 inch stud spacing. The stud web thickness is assumed to be 0.038 inches, which is a 50/50 mix of 18 gauge and 20 gauge C-channel studs. This value was confirmed to be representative of low-rise residential construction by polling several California-based light-gauge steel structural engineers and light-gauge steel framers. Foam plastic and cellulose are assumed to entirely fill the cavity and have a thermal resistance of R-3.6 inch. Actual cavity depth is 3.5 inch for 2x4, 5.5 inch for 2x6, 8 inch for 2x8, 10 inch for 2x10, and 12 inches for 2x12. High density R-30 insulation is assumed to be 8.5 inch thick batt and R-38 is assumed to be 10.5 inches thick.