research report

Development of a U-factor Calculation Procedure for Cold-Formed Steel C-shaped Clear Wall Assemblies

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DISCLAIMER

Development of a U-factor Calculation Procedure for Cold-Formed Steel C-shape Clear Wall Assemblies

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EXECUTIVE SUMMARY

The American Iron and Steel Institute (AISI) goal is to develop an ANSI approved standard that can be used to calculate the U-factors for cold-formed steel C-shape clear wall assemblies that would be acceptable for energy code analysis and compliance. The current procedures available are: (1) a series path procedure to correct for parallel path thermal bridging which has limited lookup, (2) the modified zone method which is restricted in scope and (3) sophisticated two- and three-dimensional computer simulation programs which require technical expertise to use. None of these procedures meet the intended scope of the desired ANSI standard. The objective of this project was to develop a simplified calculation procedure for an ANSI standard that could easily be used by architects, engineers and building owners to evaluate building envelope designs which could demonstrate compliance with the energy codes such as ASHRAE Standard 90.1, the International Energy Conservation Code, as well as state and local adopted energy codes.

The scope of this project was to expand the current available information by specifically addressing the following five key constructions: nominal stud dimensions (2x4, 2x6, 2x8, 2x10 and 2x12), stud spacings (6 in. oc, 12 in. oc, 16 in. oc and 24 in. oc), designation thicknesses (33, 43, 54 and 68 mils), cavity insulation (R-0 to R-38) and insulated sheathings (R-0 to R-20). Collectively there were 2,128 separate cases to be analyzed. For purposes of this study the following items were not included in the analysis: the thermal contact resistances between adjoining surfaces, the screws to assemble the wall assemblies and temperature dependent thermal properties for the materials.

The technical approach was to first model each case using the THERM 7.6 two-dimensional heat transfer computer program to determine the U-factors. Individual sensitivity studies were completed on two major variables to quantify their impact on the modeling approaches utilized in the THERM 7.6 program. Specifically, the modeling of the various thicknesses of the steel was completed by changing the thermal conductivity of the base 43 mils model rather than developing separate models with different steel dimensions. Also, the thermal impact of excluding the lip on the flange was quantified. These two simplified modeling procedures were shown to have minimal thermal impacts.

The second step was to apply the parallel path calculation procedure for the C-shape and cavity insulation paths. The third step was to calculate the "effective" thermal width of the C-shape path which for this project was defined as the "overall thermal zone" or OTZ. For the fourth step a series of regression equations were developed utilizing MINTAB to correlate the OTZ with the five key construction variables. The fifth step was to develop an EXCEL spreadsheet which integrated the regression equations with the parallel path procedure and served as an easy to use tool to calculate U-factors. The final step was to use the EXCEL program and calculate the U-factors for the 2,128 cases.

The results from the EXCEL spreadsheet were then compared to the original THERM 7.6 U-factors for all 2,128 cases. The average U-factor difference was 0.27% with a standard deviation of 3.11. Based on these results the U-factor calculation procedure was deemed an acceptable basis for the development of an ANSI standard.

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1 - INTRODUCTION

The American Iron and Steel Institute (AISI) goal is to develop an ANSI approved standard that can be used to calculate the U-factors for cold-formed steel C-shape clear wall assemblies. The goal is to provide a simplified calculation procedure that could easily be used by architects, engineers, design professionals and code officials to evaluate alternative thermal designs and demonstrate compliance for energy codes such as ASHRAE Standard 90.1 (ASHRAE), the International Energy Conservation Code (IECC) (ICC) and local jurisdictions or states. There are multiple thermal modeling tools available to calculate the U-factors for cold-formed C-shape clear walls but they are limited in scope and none are an ANSI standard.

2 - BACKGROUND

Currently there are three calculation procedures available to determine code compliance U-factors for cold-formed steel C-shape clear walls. The series path procedure was developed to account for the parallel path thermal bridging using correction factors such as in the International Energy Conservation Code (ICC 2018). This procedure is limited to just ten constructions in a simplified lookup table. The modified zone method as presented in the ASHRAE Handbook-Fundamentals (ASHRAE 2020) is restricted in scope to only address 2x4 and 2x6 walls. Sophisticated two- and three-dimensional computer simulation programs are available but require technical expertise to use.

3 - SCOPE

The scope of this project was to expand beyond the current available information by specifically addressing the following five key construction variables: nominal stud dimensions (2x4, 2x6, 2x8, 2x10 and 2x12), stud spacings (6 in. oc, 12 in. oc, 16 in. oc and 24 in. oc), designation thicknesses (33, 43, 54 and 68 mils), cavity insulation (R-0 to R-38) and insulated sheathings (R-0 to R-20). Collectively there were 2,128 separate cases to be analyzed. For purposes of this study thermal contact resistances between adjoining surfaces, screws to assemble the wall assemblies and temperature dependent material properties were not included in the analysis.

4 - DEFINITIONS, ABBREVIATIONS and ACRONYMS

4.1 - General

Selected terms unique to this report are defined in this section.

4.2 - Definitions

C-Shape: A cold-formed steel shape used for structural members and nonstructural members consisting of a web, two flanges and two lips.

Clear Wall: A wall area containing only insulation and necessary studs with no windows, doors, corners, tracks or other connections with envelope elements.

Clear Wall Stud Spacing: The dimension of the clear wall on center stud spacing.

Designation Thickness: The minimum base steel thickness expressed in mils and rounded to a whole number.

Framing Factor: The fraction of the total area that is framing.

Framing Factor, C-shape (FF_{cs}): The thickness of the cold-formed framing member divided by the width of the flange.

Framing Factor, OTZ (FF_{OTZ}): The Overall Thermal Zone (OTZ) divided by the on-center spacing of the framing members.

Overall Thermal Zone (OTZ): The resultant effective area based on an analysis procedure that is designed to account for the thermal impact of cold-formed steel framing members in the resultant overall U-factor of the wall assembly.

Track: A structural member or nonstructural member consisting of only a web and two flanges.

4.3 - Abbreviations and Acronyms

AISI	- American Iron and Steel Institute
ANSI	- American National Standards Institute
ASHRAE	- American Society of Heating, Refrigerating and Air-Conditioning Engineers
Btu	- British thermal unit
Btu/h-ft^2-^{o}F	- British thermal unit per hour per square foot per degree Fahrenheit
CV	- Coefficient of Variation - dimensionless
CZ	- Climate Zone number in ASHRAE Standard 90.1-2019
ft	- foot
Ga	- Gauge
IECC	- International Energy Conservation Code
IES	- Illuminating Engineering Society
In.	- inch
k	- Thermal Conductivity – (Btu/h-ft-^{o}F)
k_a	- Adjusted Thermal Conductivity – (Btu/h-ft-^{o}F)
L	- thickness – (ft)
Mils	- Thickness (thousands of an inch)
MINITAB	- A Statistical Package for Developing Predictive Equations with Significant Variables - (command-and menu-driven software package for statistical analysis)
oc	- On Center – (inches)
Q	- heat flux – (Btu/hr)
R_c	- R-value of the Cavity Insulation Path – (h-ft^2-^{o}F/Btu)
R_s	- R-value of the Steel C-shape Path – (h-ft^2-^{o}F/Btu)
R-value	- Thermal Resistance – (h-ft^2-^{o}F/Btu)
Rcav	- Thermal Resistance of the Cavity Insulation and/or Air Space - (h-ft^2-^{o}F/Btu)
Rshe	- Thermal Resistance of the Rigid Foam Board Sheathing - (h-ft^2-^{o}F/Btu)
Std. Dev.	- Standard Deviation - dimensionless
Stud	- Nominal Size of the Cold-Formed Steel C-shape - inches
THERM 7.6	- A PC Program for Analyzing the Two-Dimensional Heat Transfer Through Building Assemblies
U-factor	- Thermal Transmittance - (Btu/h-ft^2-^{o}F)

5 - TECHNICAL OBJECTIVE

The objective was to develop the technical basis for an ANSI/AISI consensus based standard that contains a U-factor calculation procedure to analyze cold-formed steel C-shape clear wall assemblies that would be acceptable for energy code analysis and compliance.

6 - TECHNICAL APPROACH

The technical approach was defined by six major procedures. The first was to calculate the U-factor for 2,128 cold-formed steel C-shape clear wall assemblies using the two-dimensional conduction heat transfer program THERM 7.6 (LBNL 2017). The second was to apply the parallel path calculation procedure for the steel C-shape and cavity insulation paths. The third was to calculate the "effective" thermal width of the C-shape path which for this project was defined as the "overall thermal zone" or OTZ. The fourth was to utilize MINITAB (Minitab 2010) to develop a series of regression equations that correlate the OTZ with the five key construction variables. The fifth was the development of an EXCEL spreadsheet which integrated the regression equations with the parallel path procedure and served as an easy to use tool to calculate U-factors. The sixth was to use the EXCEL program and calculate the U-factors for the 2,128 cases. The results of the EXCEL spreadsheet were compared to the original THERM U-factors to determine the accuracy. Each of the major procedures will be discussed in detail.

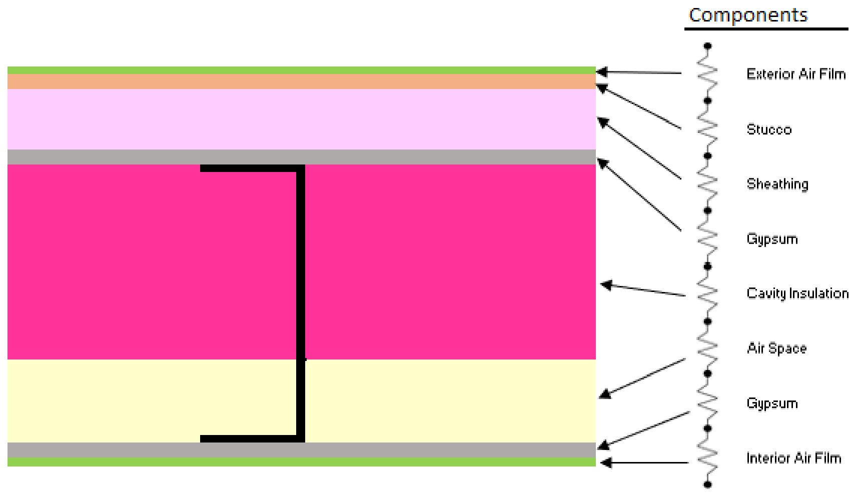
6.1 - THERM 7.6 Analysis

Use THERM 7.6 as the two-dimensional conduction heat transfer modeling software to calculate the U-factors for the 2,128 cold-formed steel C-shape clear wall assemblies to serve as a data base for development of a simplified and easy to use calculation procedure. Initially the project was limited to two stud spacings (16 in. oc and 24 in. oc), 43 mil steel C-shape and five nominal stud dimensions which were represented by ten THERM 7.6 models. Over time the project scope was expanded to also include 6 in. oc and 12 in. oc spacings and a total of four designation thicknesses. The THERM 7.6 program requires the specific geometry plus the materials and their properties to represent the construction of the assemblies to be modeled.

6.1.1 - Geometry

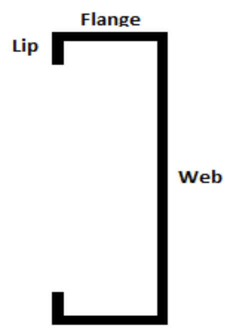
A typical THERM 7.6 model is shown in Fig. 6.1. This construction shows the exterior air film, stucco, exterior sheathing, exterior gypsum, cavity insulation, steel C-shape, air space, interior gypsum and the interior air film.

Fig. 6.1 - 2x8 C-shape with R-19 Cavity Insulation and R-5 Sheathing



Individual sensitivity studies were completed on two major variables to quantify their impact on the modeling approaches utilized in the THERM 7.6 program. It is important to note that the THERM 7.6 models did not include the stiffening lip (0.5 in.) at the end of the flange (1.5 in.) on the C-shape, see Fig. 6.2. A sensitivity analysis was completed to quantify the thermal impact of excluding the lip.

Fig. 6.2 - Typical C-shape



Also, the modeling of the four steel C-shape thicknesses was completed by changing the thermal conductivity of the base 43 mils model rather than developing separate THERM 7.6 models with different steel dimensions. A sensitivity analysis was completed to quantify the thermal impact of this modeling approach.

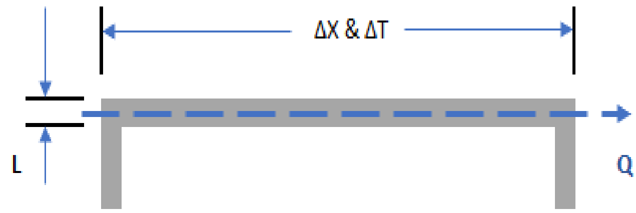
6.1.2 - Material Properties

The THERM 7.6 model required specifications for all of the material properties including the steel C-shape, cavity insulation, insulated sheathing, air spaces, gypsum, stucco, interior and exterior air film coefficients and boundary air temperature conditions.

6.1.2.1 - Steel C-shape

The thermal modeling of the steel C-shape in THERM 7.6 were based on 43 mil steel, see Fig. 6.3.

Fig. 6.3 - Conduction Heat Transfer Through the Web



Instead of changing the designation thicknesses in the THERM 7.6 models the thermal conductivity was adjusted. Apply the basic conduction heat transfer equation to the geometry in Fig. 6.3 for the base case (0.0428 in., k=495) and then again for the adjusted cases, see Eq. 6.1.

$$Q = -k_o*L_o*(\Delta T/\Delta X) = -k_a*L_a*(\Delta T/\Delta X) \quad (6.1)$$

Where:

- Q = heat flux - Btu/h
- k_o = base thermal conductivity - Btu/h-ft^2-^{o}F
- L_o = base steel thicknesses - ft
- k_a = adjusted thermal conductivity - Btu/h-ft^2-^{o}F
- L_a = adjusted steel thicknesses - ft
- ΔT = temperature difference - ^{o}F
- ΔX = web - ft

Solving Eq. 6.1 for k_a yields:

$$k_a = k_o*L_o/L_a \quad (6.2)$$

Apply Eq. 6.2 to determine the adjusted k for each of the other designation thicknesses. The results are presented in Table 6.1. Using these steel properties a sensitivity analysis was completed to quantify the thermal impact of the adjusted k approach.

Table 6.1 - Steel C-shape Properties

Ga	Thickness Mils	Thickness inches	k_a Btu/h-ft^2-^{o}F
20	33	0.0329	381
18	43	0.0428	495
16	54	0.0538	622
14	68	0.0677	783

6.1.2.2 - Cavity Insulation

Cavity insulation was modeled as fiberglass batts with the properties as shown in Table 6.2.

Table 6.2 - Properties of Fiberglass Batt Insulation

Cavity Insulation R-value	Thickness inches	k Btu/h-ft-°F	k Btu-in/h-ft^2-°F	R-value h-ft^2-°F/Btu
11	3.5	0.027	0.324	10.8
13	3.5	0.022	0.264	13.3
15	3.5	0.019	0.228	15.4
19	6.25	0.027	0.324	19.3
21	5.5	0.022	0.264	20.8
25	8	0.026	0.312	25.6
30	9.5	0.026	0.312	30.4
38	12	0.026	0.312	38.5

6.1.2.3 - Insulated Sheathing

Insulated sheathing was modeled as rigid foam boards with the properties as shown in Table 6.3.

Table 6.3 - Properties of Rigid Foam Board Insulated Sheathing

Material	Thickness inches	k Btu/h-ft-°F	k Btu-in/h-ft^2-°F	R-value h-ft^2-°F/Btu
Foam Sheathing	0.5	0.017	0.204	2.45

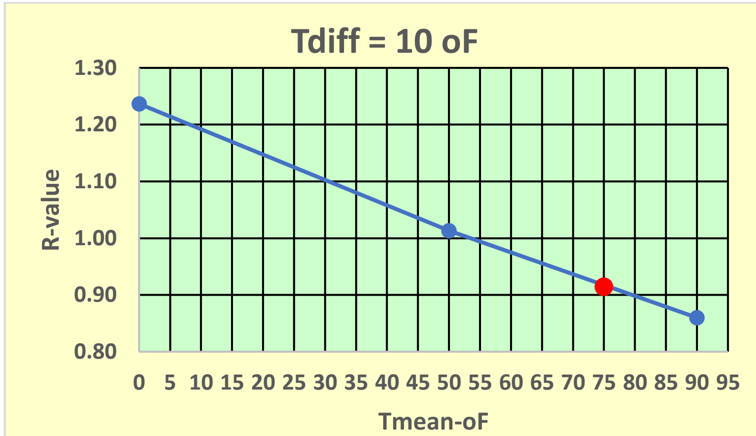
6.1.2.4 - Air Spaces

The basis for the R-value of the air spaces was extracted from published data, ASHRAE (2020), see Table 6.4.

Table 6.4 - R-value of Plane Air Spaces

		Air Space - inches					AVG.
Tmean-°F	**Tdiff-°F**	**0.5**	**0.75**	**1.5**	**3.5**	**5.5**	**1.5-5.5**
90	**10**	0.77	0.84	0.87	0.85	0.86	0.860
50	**30**	0.90	0.94	0.90	0.91	0.93	0.913
50	**10**	0.91	1.01	1.02	1.01	1.01	1.013
0	**20**	1.13	1.18	1.12	1.14	1.17	1.143
0	**10**	1.15	1.26	1.23	1.23	1.25	1.237

Fig. 6.4 - R-value of plane air space for Tdiff = 10 °F and an average of 1.5-5.5 inches



For the purpose of this study air spaces of any thickness were assumed to be at a mean temperature of 75°F which resulted in a nominal R-value of 0.91 for the THERM 7.6 models, see Fig. 6.4. It was recognized that in an actual application the air space temperature would not always be 75°F so the thermal resistance will vary depending upon the particular assembly and boundary conditions that would exist. Air spaces were modeled using the properties as shown in Table 6.5.

Table 6.5 - Properties of Air Spaces

Air Spaces C-shape	Thickness Inches	k Btu/h-ft-°F	k Btu-in/h-ft²-°F	R-value h-ft²-°F/Btu
2x4	3.625	0.333	3.996	0.91
2x6	6	0.556	6.672	0.90
2x8	8	0.741	8.892	0.90
2x10	10	0.925	11.100	0.90
2x12	12	1.108	13.296	0.90
Air Spaces Inches				
0.50	0.50	0.047	0.564	0.89
1.75	1.75	0.162	1.944	0.90
2.50	2.50	0.232	2.784	0.90
3.75	3.75	0.348	4.176	0.90
5.75	5.75	0.532	6.384	0.90

6.1.2.5 - Gypsum

The properties of the interior and exterior gypsum are shown in Table 6.6.

Table 6.6 - Properties of Gypsum

Material	Thickness inches	k Btu/h-ft-°F	k Btu-in/h-ft^2-°F	R-value h-ft^2-°F/Btu
Gypsum	0.5	0.107	1.284	0.39

6.1.2.6 - Stucco

The properties of stucco are presented in Table 6.7.

Table 6.7 - Properties of Stucco

Material	Thickness inches	k Btu/h-ft-°F	k Btu-in/h-ft^2-°F	R-value h-ft^2-°F/Btu
Stucco	0.619	0.781	9.372	0.07

6.1.2.7 - Air Film Coefficients

The air film coefficients used for all of the analysis are shown in Table 6.8.

Table 6.8 - Air Film Coefficients

Surface Location	R-value h-ft^2-°F/Btu
Exterior	0.17
Interior	0.68

6.1.2.8 - Surface Temperatures

Surface temperatures used for all of the analyses are shown in Table 6.9.

Table 6.9 - Surface Temperatures

Surface Location	Temperature °F
Exterior	50
Interior	100

6.2 - Develop a Simplified Analysis Procedure

A simplified analysis procedure was used to account for the thermal impact of the steel C-shape framing in the overall wall assembly. The procedure was to use the parallel path approach. The basic parallel path calculation procedure is presented in Eq. 6.3.

$$U_o = (1 - FF)/R_{LCP} + FF/R_{HCP} \qquad (6.3)$$

Where:

U_o - Thermal Transmittance of Parallel Paths - Btu/h-ft^2-°F

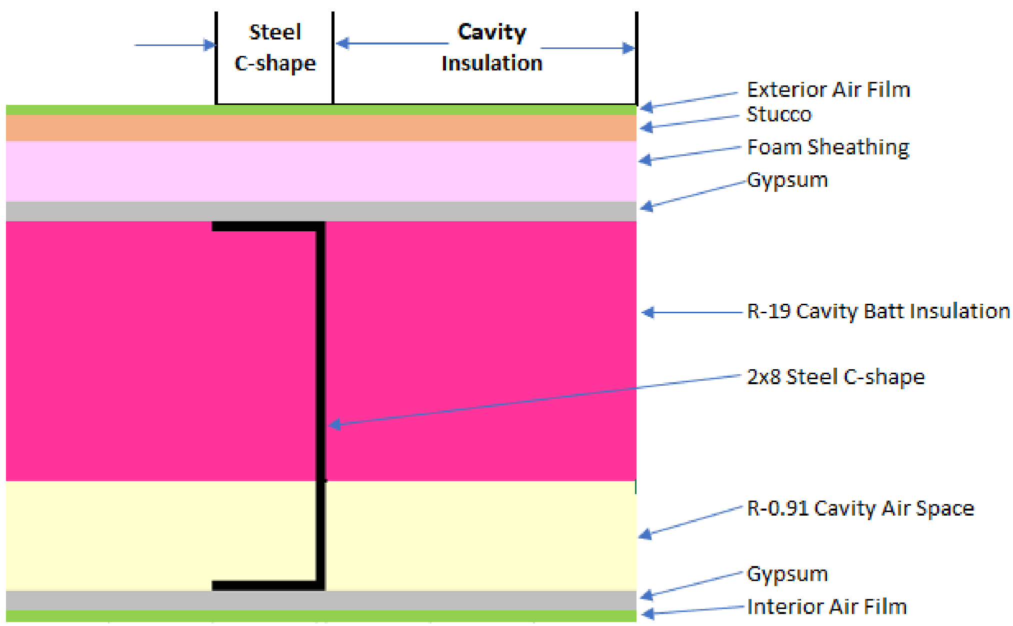
FF - Framing Factor – Area Fraction of Higher Conductive Path - dimensionless

R_{LCP} - R-value of the Lower Conductive Path - h-ft^2-°F/Btu

R_{HCP} - R-value of the Higher Conductive Path - h-ft^2-°F/Btu

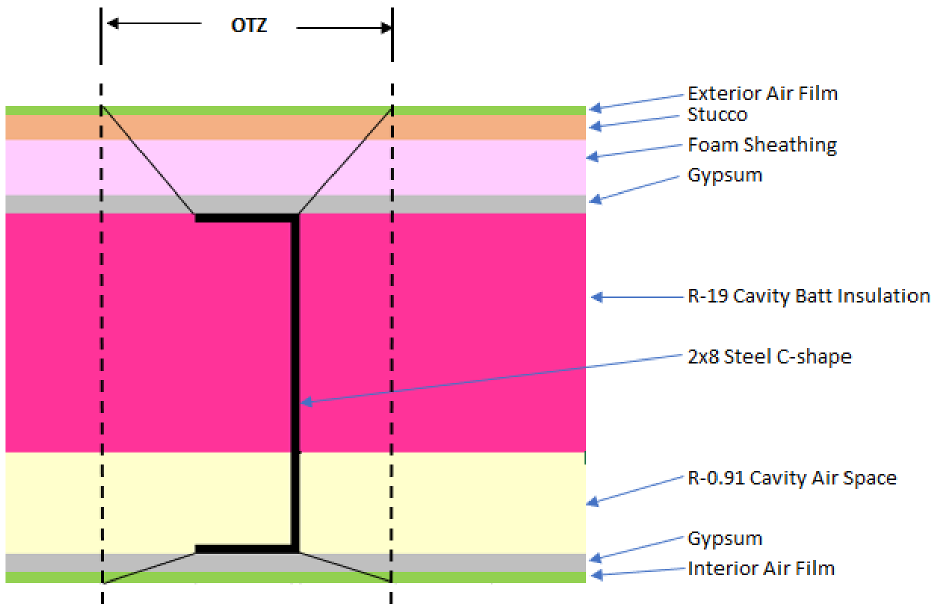
There are multiple parallel paths to analyze in a steel C-shape clear wall assembly. The primary parallel paths are the Steel C-shape and the Cavity Insulation, see Fig. 6.5. Also, there can be two secondary parallel paths within the Steel C-shape path. The steel web and insulation adjacent to the steel web is one. In those cases where the insulation does not completely fill the cavity of the Steel C-shape, an air space was modeled as another secondary parallel path. Then the resulting R-values for the cavity insulation adjacent to the web and the air space adjacent to the web were added together.

Fig. 6.5 – Primary Parallel Paths of Steel C-shape and Cavity Insulation



The flanges of the steel C-shape are in series with the C-shape web, but they were not directly modeled. These flanges create a two-dimensional thermal impact which was accounted for in the determination of the thermal zone due to the steel framing. For purposes of this project this was defined as the Overall Thermal Zone (OTZ), see Fig. 6.6. The dimension of the OTZ is primarily a function of the thermal resistances of the cavity insulation and the rigid foam board sheathing.

Fig. 6.6 - Overall Thermal Zone (OTZ)



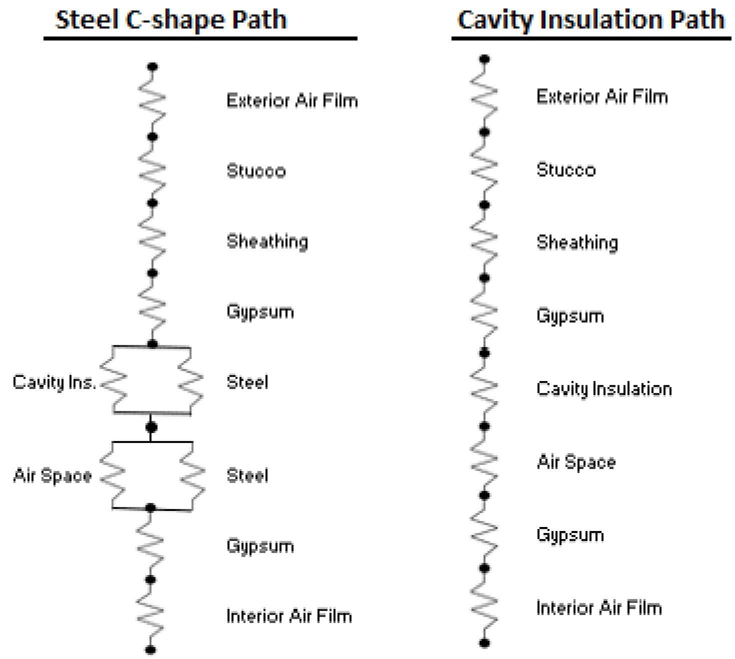
6.2.1 - Parallel Path Calculations

A circuit representation of parallel paths for the construction in Fig. 6.6 is shown in Fig. 6.7. The primary parallel paths are the Steel C-shape and the Cavity Insulation. There are also two secondary parallel paths within the Steel C-shape path, one is the cavity insulation and the steel web while the other is the air space and steel web.

As a general note it is important to understand the secondary parallel paths. There are three cases, (1) the steel C-shape member is completely filled with insulation so there is no air space, (2) the steel C-shape member is only partially filled with insulation so there is also an air space and (3) the steel C-shape member has no insulation so there is only an air space. Thus, option (2) is the only case in which there are two secondary parallel paths.

In order to distinguish among these multiple parallel paths the following nomenclature will be utilized. The primary parallel path will have a subscript with "$_{pp}$", when the steel C-shape member of the secondary parallel path is entirely filled with insulation or is just an air space it will have a subscript with "$_{s1}$" and when the steel C-shape member of the secondary air space parallel path contains insulation and an air space it will have a subscript with "$_{s2}$".

Fig. 6.7 - Circuit Representation of the Parallel Paths



The primary parallel path calculation uses the basic procedure in Eq. 6.3 and is presented as Eq. 6.4.

$$U_{opp} = (1 - FF_{pp})/R_{cpp} + FF_{pp}/R_{spp} \quad (6.4)$$

Where:

U_{opp} - Thermal Transmittance, Primary Parallel Paths - Btu/h-ft^2-^{o}F
FF_{pp} - Framing Factor – Area Fraction of Steel C-shape Path - dimensionless
R_{cpp} - R-value of the Cavity Insulation Path - h-ft^2-^{o}F/Btu
R_{spp} - R-value of the Steel C-shape Path - h-ft^2-^{o}F/Btu

As an example of the parallel path calculations the geometry and construction materials shown in the THERM 7.6 model of Fig. 6-6 will be used. The overall construction is a 2x8 steel C-shape (16 in. oc), stucco (0.5 in.), exterior gypsum (0.5 in.), R-5 rigid foam insulation (1.0 in.), R-19 cavity batt insulation (6.25 in.), R-0.91 air space (1.75 in.), designation thickness (43 Mils), web (8 in.), flange (1.5 in.), interior gypsum (0.5 in.) and the air film coefficients listed in Table 6.8.

The secondary parallel path calculations begin with the cavity insulation beneath the flange and adjacent to the web.

Step 1 - Determine the Framing Factor, Steel C-shape.

The framing factor for the steel C-shape (FF_s) is the width of the higher conductive path divided by the width of the entire path, see Eq. 6.5.

$$FF_s = \text{steel C-shape thickness/ width of flange} \quad (6.5)$$

The steel C-shape thickness is 0.0428 in. and the 1.5 inch flange defines the overall width of the parallel path for this calculation. The framing factor calculation is shown in Eq. 6.6.

$$FF_s = 0.0428/1.5 = 0.02853 \quad (6.6)$$

Step 2 – Secondary parallel path (s1) calculation of the cavity insulation and web.

The thermal resistance of the steel C-shape web (R_{ss1}) is determined by Eq. 6.7.

$$R_{ss1} = \text{depth of insulation next to steel/ steel thermal conductivity} \quad (6.7)$$

The depth of the insulation in contact with the steel is 6.25 inches and the steel thermal conductivity is 495 Btu-in/h-ft^2-^{o}F, see Eq. 6.8.

$$R_{ss1} = 6.25/495 = 0.01263 \quad (6.8)$$

The secondary parallel path ($_{s1}$) U-factor is calculated using Eq. 6.9.

$$U_{os1} = (1\text{-}FF_s)/R_{is1} + FF_s/R_{ss1} \quad (6.9)$$

The thermal resistance of the cavity insulation is R_{is1} = 19 and used in Eq. 6.10.

$$U_{os1} = (1\text{-}0.02853)/19 + 0.02853/0.01263 = 2.31097 \quad (6.10)$$

The effective R-value of the cavity with insulation is computed using Eq. 6.11.

$$R_{s1} = 1/U_{os1} \quad (6.11)$$

The secondary parallel path ($_{s1}$) thermal resistance is calculated using Eq. 6.11 as shown in Eq. 6.12.

$$R_{s1} = 1/2.31097 = 0.43272 \quad (6.12)$$

Step 3 – Secondary parallel path (s2) calculation of the air space and web.

The thermal resistance of the steel C-shape web (R_{ss2}) is determined by Eq. 6.13.

R_{ss2} = depth of air space next to steel/ thermal conductivity of the steel (6.13)

The depth of the air space in contact with the steel is 1.75 inches and the steel thermal conductivity is 495 Btu-in/h-ft^2-^{o}F, using Eq. 6.13 the results are presented in Eq. 6.14.

$$R_{ss2} = 1.75/495 = 0.00354 \quad (6.14)$$

The secondary parallel path (s2) U-factor is calculated using Eq. 6.15.

$$U_{os2} = (1\text{-}FF_s)/R_{as2} + FF_s/R_{ss2} \quad (6.15)$$

The thermal resistance of the cavity air space is R_{as2} = 0.91 and used in Eq. 6.16.

$$U_{os2} = (1\text{-}0.02867)/0.91 + 0.02867/0.00354 = 9.13840 \quad (6.16)$$

The effective R-value of the cavity with an air spaec is computed using Eq. 6.17.

$$R_{s2} = 1/U_{os2} \quad (6.17)$$

The secondary parallel path thermal resistance is calculated using Eq. 6.17 as shown in Eq. 6.18.

$$R_{s1} = 1/9.13840 = 0.10943 \quad (6.18)$$

Step 4 – Add the R-values of the two secondary parallel path C-shape sections in series that are adjacent to the web.

The total R-value of the secondary parallel path C-shape sections is R3 and it is calculated using Eq. 6.19.

$$R_3 = R_{s1} + R_{s2} \quad (6.19)$$

Using Eq. 6.19 the sum of the secondary parallel paths is calculated in Eq. 6.20.

$$R_3 = 0.43272 + 0.10943 = 0.54215 \quad (6.20)$$

Step 5 – Add the R-values of all the components in series for the Steel C-shape path to obtain R_s.

The sum of all the components in the steel C-shape path is shown as Eq. 6.21.

Component	R-value
Exterior Air Film	0.17
Stucco	0.07
Foam Sheathing	5.00
Gypsum	0.39
C-shape (R_3)	0.54
Gypsum	0.39
Interior Air Film	0.68
	R_s = 7.24

(6.21)

Step 6 – Add the R-values of all the components in series for the Cavity Insulation path to obtain R_c.

The sum of all the components in the cavity insulation path is shown as Eq. 6.22

Component	R-value
Exterior Air Film	0.17
Stucco	0.07
Foam Sheathing	5.00
Gypsum	0.39
Cavity Insulation	19.00
Air Space	0.91
Gypsum	0.39
Interior Air Film	0.68
	R_c = 26.61

(6.22)

Step 7 – Calculate the overall U-factor by area weighting the steel C-shape and cavity insulation parallel paths.

The framing factor (effective) is calculated using the framing factor definition as shown in Eq. 6.23.

$$FF_{OTZ} = OTZ/\text{on center spacing} \tag{6.23}$$

The OTZ for this case as derived from the MINITAB model is 3.94 inches. Using the 16 in. on center spacing and Eq. 6.23 the results are shown in Eq. 6.24.

$$FF_{OTZ} = 3.94/16 = 0.24625 \tag{6.24}$$

The overall U-factor is calculated using Eq. 6.25.

$$U_o = (1\text{-}FF_{OTZ})/R_C + FF_{OTZ}/R_S \quad (6.25)$$

Where:

U_o - Overall U-factor – Btu/h-ft^2-^{o}F

R_c - Thermal resistance of the Cavity Insulation Path - h-ft^2-^{o}F/Btu

R_s - Thermal resistance of the Steel C-shape Path - h-ft^2-^{o}F/Btu

Using Eq. 6.25 the overall thermal transmittance is shown in Eq. 6.26.

$$U_o = (1 - 0.24625)/26.61 + 0.24625/7.24 = 0.06233 \quad (6.26)$$

6.3 - Calculate the Overall Thermal Zone (OTZ)

A separate calculation was completed for each of the 2,128 cases to determine the OTZ due to the steel framing using the THERM 7.6 modeling results. The overall U-factor for each of the specific construction was determined by the THERM 7.6 model.

The overall thermal transmittance was presented as Eq. 6.25 and has the FF_{OTZ} from Eq. 6.23 to produce Eq. 6.26.

$$U_o = (1\text{-}OTZ/\text{oc spacing})/R_c + (OTZ/\text{oc spacing})/R_s \quad (6.26)$$

The OTZ is derived from Eq. 6.26 and is shown as Eq. 6.27.

$$OTZ = (\text{oc spacing} \times Rs \times (U_o \times Rc - 1))/(Rc - Rs) \quad (6.27)$$

6.4 - Develop Regression Equations to Calculate OTZ

A statistical approach was taken because the OTZ data can be readily compiled and analyzed in existing statistical software packages. First, the OTZ data were compiled in EXCEL and then inputted into a MINITAB worksheet. Next, the powerful algorithms within the MINITAB® 17 software were deployed to develop key variables in the predictive equations. Regression coefficients developed for each of the sixteen separate regression models account for the four framing spacing categories (oc), four designation thicknesses, cavity insulation and the rigid foam sheathing insulation.

The regression equations that were developed predict OTZ by minimizing the residual error between the predicted value from the equations and the values derived from the THERM 7.6 model. The residual error as defined in Eq. 6.28

Residual error = OTZ derived from THERM model – Statistically Predicted OTZ value (6.28)

The “Backward Elimination” feature was used to eliminate variables from the final equation that do not show a statistically significant signal over the noise in the data at a given “Alpha” level of 0.05. The 95% alpha confidence level is a signal over and above the noise in the data. Variables that are not statistically significant were automatically eliminated from the predictive equation.

6.5 - Develop an EXCEL Spreadsheet Model to Calculate U-factors

Once the MINITAB models were developed to calculate the OTZ they were then integrated into an EXCEL spreadsheet that calculates the overall wall assembly U-factor using the simplified calculation procedure presented in Step 2.

6.6 - Accuracy Check of EXCEL Spreadsheet Models

After the EXCEL spreadsheet model was developed it was then used to calculate the overall U-factor for each of the 2,128 cases to ensure that the programming of the spreadsheet was working correctly.

7 - RESULTS

The results are aligned with each of the major items presented in the Technical Approach. The THERM 7.6 results were based on specific assumptions regarding the thickness of the steel which was modeled by changing the thermal conductivity of the steel and the exclusion of the lip on the flange. These assumptions were analyzed in detail to quantify their thermal impact. Calculations of the OTZ based on the THERM 7.6 results identified specific cases that were outliers so they were excluded from the analysis. The EXCEL spreadsheet that was developed to calculate the U-factors was thoroughly checked and the final results were compared to those from ASHRAE Std. 90.1-2019.

7.1 - THERM 7.6 Analysis

Development of the THERM 7.6 models required considerable time and accuracy considering that there were 2,128 cases. Two simplifying assumptions were made to reduce the amount of time required to develop these models. First, the stiffening lip on the flange was not modeled since it did not demonstrate having any influence on the results. Second, instead of modeling the four thicknesses of the C-shape steel framing (33, 43, 54 and 68 mils) all of the models were set at 43 mils and the thermal conductivity of the steel was adjusted to model the thermal impact of the various thicknesses. However, to validate these two assumptions specific cases were modeled in detail to quantify their thermal impact.

7.1.1 - Thermal Impact of Excluding the Stiffening Lip on the Flange

Exclusion of the ½ inch stiffening lip on the flange was investigated using a sensitivity analysis in order to quantify the thermal impact on the overall U-factor of the entire assembly. A separate THERM 7.6 model for the 2x4, 16 inches on center C-shape was created which included the stiffening lip and then individual cases of cavity and sheathing insulation were analyzed. The 2x4 construction was selected since it would represent a limiting case in order to highlight the thermal impact of the stiffening lip.

The graphical results of the THERM 7.6 analyses are presented in Appendix A and show minimal changes in the isotherms due to the stiffening lip. It is important to note that the insulation completely surrounds the stiffening lip which is an ideal case that would be representative of spray foam or loose fill cavity insulation. In reality a batt insulation product may leave minor air gaps adjacent to the junction of the stiffening lip and flange which would not influence the results.

The change in the overall U-factor due to the presence of the stiffening lip is presented in Table 7.1. The largest U-factor difference (0.0003) occurs for those cases with no cavity or sheathing insulation. Once there is cavity insulation the U-factor differences decrease to 0.0002 and when there are both cavity and sheathing present the U-factor differences become smaller (0.0001). The average U-factor difference for all of the cases due to the presence of the stiffening lip was 0.11%. Based on these sensitivity results the U-factors which excluded the stiffening lip were deemed acceptable.

Table 7.1 - Thermal Impact of Excluding the Stiffening Lip on the Flange

R-values Rcav-Rshe	U-factor w/Lip	% Error Energy Norm	U-factor w/o Lip	% Error Energy Norm	U-factor Difference	U-factor Diff. %
0-0	0.4041	1.71	0.4038	1.60	0.0003	0.07
11-0	0.1409	1.61	0.1407	1.65	0.0002	0.14
13-0	0.1308	1.73	0.1306	1.77	0.0002	0.15
15-0	0.1238	1.83	0.1236	1.87	0.0002	0.16
0-2.5	0.2010	1.61	0.2009	1.49	0.0001	0.05
11-2.5	0.0956	1.76	0.0955	1.82	0.0001	0.10
13-2.5	0.0891	1.90	0.0890	1.95	0.0001	0.11
15-2.5	0.0843	1.56	0.0842	1.59	0.0001	0.12
AVG					**0.0002**	**0.11**

7.1.2 - Modeling the Thermal Conductivity of the Steel C-shape

An analysis was completed to determine the sensitivity of adjusting the thermal conductivity (k_a) of the C-shape steel rather than changing the thickness of the steel (Mils) to use in the development of the THERM 7.6 models. This approach was explored to significantly reduce the number of THERM 7.6 models that would need to be developed since it was a simple process to change the steel thermal conductivity rather than create separate models for each thickness of the steel. However, to quantify the acceptability of this process specific cases were analyzed.

A specific construction was selected that would maximize the steel involved and cover a broad range of cavity and sheathing insulation options. The actual construction was 16 oc, 2x12 framing, cavity insulation of R-0 and R-38 in conjunction with sheathing of R-0 and R-2.5. The results are presented in Table 7.2. The average U-factor difference is 0.00015 (-0.062%) with a standard deviation of 0.00016 (0.162%). These significantly small differences justified using the adjusted k approach in the development of the THERM 7.6 models.

Table 7.2 - THERM 7.6 U-factors Using Steel Properties of k_a and Mils

	16 oc, 2x12		ka, Mils			
	Rcav	Rshe	381, 33	495, 43	622, 54	783, 68
ka	0	0	0.3922	0.3945	0.3969	0.3997
Mils	0	0	0.3922	0.3945	0.3968	0.3995
Diff.			0.0000	0.0000	0.0001	0.0002
Diff. %			0.0000	0.0000	-0.03	-0.05
ka	0	2.5	0.1985	0.1991	0.1997	0.2003
Mils	0	2.5	0.1982	0.1991	0.1994	0.2004
Diff.			0.0003	0.0000	0.0003	0.0001
Diff. %			-0.15	0.00	-0.15	0.05
ka	38	0	0.0691	0.0761	0.0822	0.0884
Mils	38	0	0.0687	0.0761	0.0822	0.0881
Diff.			0.0004	0.0000	0.0000	0.0003
Diff. %			-0.58	0.00	0.00	-0.34
ka	38	2.5	0.0541	0.0578	0.0608	0.0636
Mils	38	2.5	0.0541	0.0578	0.0608	0.0636
Diff.			0.0000	0.0000	0.0000	0.0000
Diff. %			0.00	0.00	0.00	0.00

7.1.3 - THERM 7.6 U-factor Modeling

The THERM 7.6 U-factors for 2,128 cases are presented in Appendix C. For each case the THERM 7.6 program not only lists the calculated U-factor for the entire assembly but also the % Error Energy Norm. The program makes error estimates, refines regions of the model that are troublesome and recalculates until all local regions show error levels that are less than what is prescribed. In order to characterize the magnitude of the % Error Energy Norm a series of 112 THERM 7.6 cases were selected as representative of all the cases. The key variables were the on center spacings, size of steel C-shape, R-value of the cavity insulation plus the R-value of an air space if one is present and the R-value of the exterior rigid foam board sheathing. The results are presented in Table 7.3.

Table 7.3 - % Error Energy Norm

		Sheathing R-value							
		0		2.5		7.5		20	
oc	Stud-Rcav	U	%	U	%	U	%	U	%
6	2x4-0	0.4361	1.79	0.2085	1.60	0.1022	1.23	0.0449	1.45
6	2x6-0	0.4282	2.00	0.2070	1.47	0.1018	1.61	0.0449	1.08
6	2x8-0	0.4221	1.92	0.2052	1.98	0.1022	1.54	0.0448	1.12
6	2x10-0	0.0417	1.53	0.2042	1.08	0.1012	1.31	0.0447	1.00
6	2x4-11	0.2472	1.62	0.1454	1.67	0.0839	1.90	0.0409	1.47
6	2x8-25	0.1898	1.62	0.1227	1.96	0.0757	1.83	0.0389	1.81
6	2x12-38	0.1584	1.81	0.1087	1.93	0.0701	1.72	0.0375	1.89
12	2x4-0	0.4104	1.42	0.2025	1.94	0.1008	1.29	0.0445	1.35
12	2x6-0	0.4071	1.43	0.2019	1.40	0.1006	1.61	0.0446	1.04
12	2x8-0	0.4040	1.62	0.2012	1.73	0.1006	1.16	0.0446	0.76
12	2x10-0	0.4013	1.37	0.2000	1.48	0.1002	0.89	0.0446	0.61
12	2x4-11	0.1622	1.87	0.1060	1.60	0.0677	1.69	0.0366	1.63
12	2x8-25	0.1145	1.72	0.0807	1.60	0.0561	1.81	0.0329	1.97
12	2x12-38	0.0929	1.73	0.0689	1.83	0.0502	1.92	0.0307	1.54
16	2x4-0	0.4038	1.60	0.2009	1.49	0.1003	1.79	0.0446	1.16
16	2x6-0	0.4017	1.65	0.2005	1.86	0.1002	1.25	0.0445	0.81
16	2x8-0	0.3993	1.31	0.2000	1.47	0.1001	0.99	0.0445	0.64
16	2x10-0	0.3972	1.20	0.1995	1.42	0.1000	0.95	0.0445	0.62
16	2x4-11	0.1407	1.65	0.0955	1.82	0.0633	1.98	0.0352	1.97
16	2x8-25	0.0952	1.64	0.0691	1.93	0.0497	1.72	0.0304	1.76
16	2x12-38	0.0761	2.00	0.0578	1.86	0.0433	1.72	0.0279	1.56
24	2x4-0	0.3968	1.45	0.1992	1.32	0.0998	1.42	0.0444	1.50
24	2x6-0	0.3961	1.51	0.1942	1.38	0.1001	1.63	0.0445	1.06
24	2x8-0	0.3945	1.82	0.1989	1.13	0.0998	1.35	0.0445	0.88
24	2x10-0	0.3934	1.34	0.1985	1.67	0.0997	1.12	0.0444	0.73
24	2x4-11	0.1192	1.99	0.0850	1.59	0.0583	1.74	0.0335	1.73
24	2x8-25	0.0758	1.50	0.0574	1.76	0.0429	1.56	0.0276	1.63
24	2x12-38	0.0591	1.88	0.0464	1.73	0.0359	1.59	0.0244	1.71

A statistical summary of those results is presented in Table 7.4. The averages and standard deviations are relatively consistent across the on center spacings of all the steel C-shape. The significance of the %Error Energy Norm became evident when the U-factors were used to calculate the Overall Thermal Zone (OTZ).

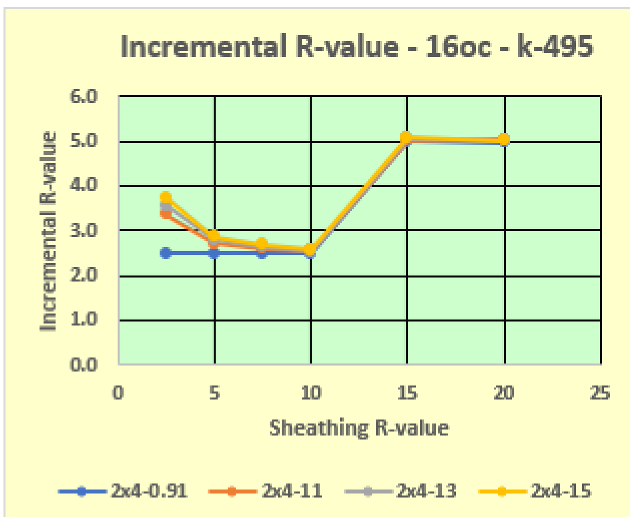
Table 7.4 - Summary Statistics for % Error Energy Norm

	6oc	12oc	16oc	24oc	Avg.
Average	1.61	1.50	1.49	1.49	1.52
Std. Dev.	0.30	0.35	0.41	0.30	0.34
Minimum	1.00	0.61	0.62	0.73	0.61
Maximum	2.00	1.97	2.00	1.99	2.00

7.1.4 - Impact of Adding Exterior Foam Board Sheathing

Once the U-factors were calculated the impact of adding exterior foam board sheathing was investigated. The analysis was to determine the increase in the overall R-value of the assembly due to the addition of incremental R-values of the rigid foam board sheathing. All of the results are shown in Appendix D. The graphical results for one of the assemblies are shown in Fig. 7.1. These results are representative regardless of the designation thicknesses.

Fig. 7.1 - Incremental R-values due to Sheathing

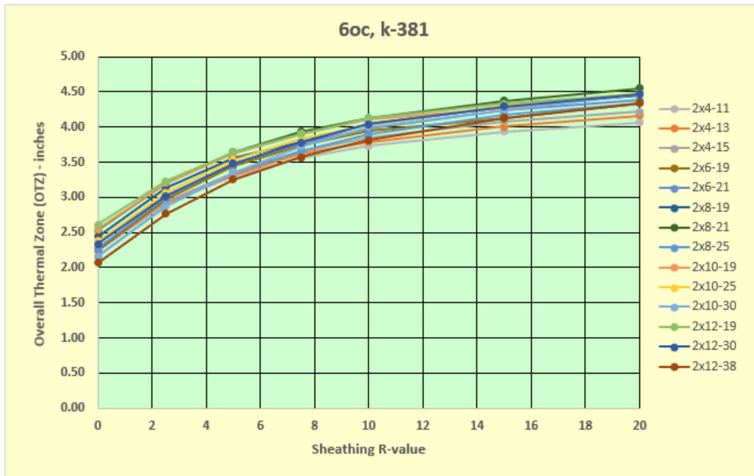


There are several key observations. The incremental R-value due to the added sheathing depends upon the R-value of the cavity insulation and the R-value of any prior sheathing that was installed. This applies to all of the spacings (6, 12, 16 and 24 oc) and all of the steel designation thicknesses (33, 43, 54 and 68 mils). The initial case is no cavity insulation and no sheathing which results in the first increment of sheathing to just equal the R-value of the sheathing. However, once there is any insulation present in the cavity the first increment of R-2.5 sheathing results in an incremental R-value improvement of the entire assembly of R-3.5 or more. The second addition of R-2.5 results in an additional incremental improvement of nearly R-3. Once the addition of sheathing increases from R-7.5 to R-10 the incremental improvement is just equal to the R-2.5 that was added. Then, any further addition of R-5 sheathing from R-10 to R-15 and R-15 to R-20 just increases the entire assembly by the added R-5 value.

7.2 - Overall Thermal Zone (OTZ) Analysis

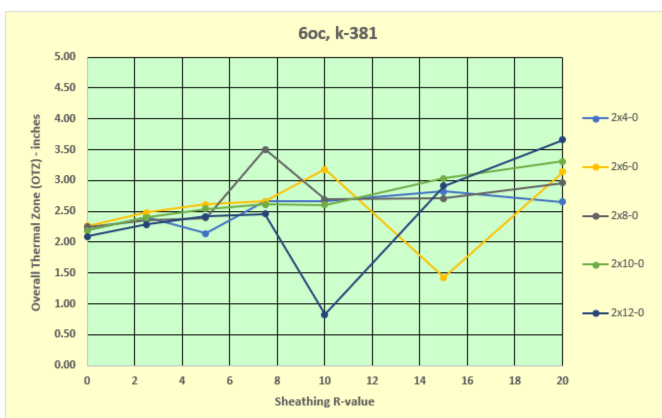
Once the 2,128 U-factors were modeled with the THERM 7.6 program the next step was to calculate the Overall Thermal Zone (OTZ) using Eq. 6.27. The results for the 6oc, k_a-381 with insulated cavities are shown in Fig. 7.2. All of these results are consistent, uniform and represent 74% of all the cases.

Fig. 7.2 - Overall Thermal Zone (OTZ) for Insulated Cavities



However, this was not always the case. Particularly when there was no cavity insulation the OTZ results were not always consistent, see Fig. 7.3. Clearly this was a concern. The remaining 26% of the cases do not have any cavity insulation and some of those results were not consistent nor uniform, see Fig. 7.3.

Fig. 7.3 - Overall Thermal Zone (OTZ) for Uninsulated Cavities



A detailed analysis of these selected cases was completed. The numerical values are presented in Table 7.5 which lists the results from the original THERM 7.6 analysis and the results when the same cases were replicated with the THERM 7.6 program. No changes were made to the THERM 7.6 input files but the program calculated slightly different results. The average difference between the original U-factors and the replicated

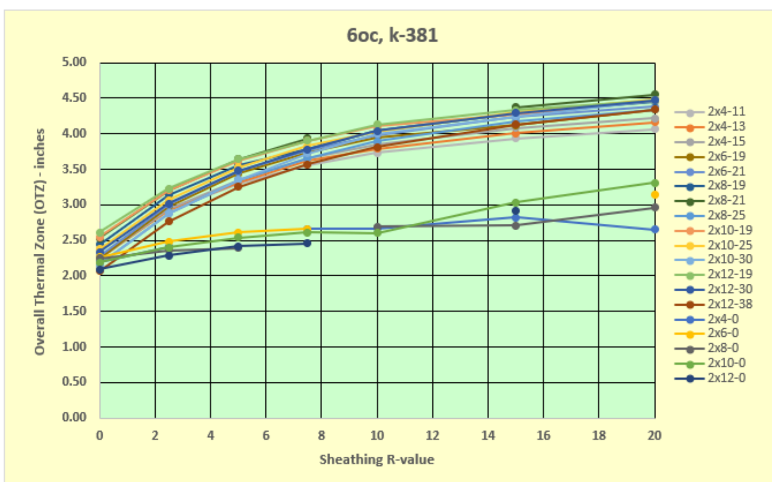
U-factors was only 0.0003 or 0.31%. The average % Error Energy Norm was 1.41% for the replicated analysis. This illustrates the sensitivity of the OTZ due to changes in the THERM 7.6 U-factors. The average OTZ difference of 0.46 inches (23.1%) occurs just due to the variability of the THERM 7.6 U-factor calculation procedure.

Table 7.5 - Overall Thermal Zone (OTZ) Analysis (6oc, ka-381)

		Original Analysis				Cavity/	Replicated Analysis			DIFFERENCES			
	Stud -	U-factor			OTZ	THERM	Uo		OTZ	ΔUo	Uo	ΔOTZ	OTZ
Case	Rcav-Rshe	Cavity	Web	THERM	inches	%	THERM	%Error	inches	THERM	%	inches	%
1	2x4-0-5	0.1312	0.1438	0.1357	2.14	96.7	0.1363	1.42	2.42	0.0006	0.44	0.28	13.1
2	2x6-0-10	0.0792	0.0829	0.0812	3.18	97.5	0.0815	1.58	3.66	0.0003	0.37	0.48	15.1
3	2x6-0-15	0.0568	0.0586	0.0572	1.43	99.3	0.0573	1.84	1.75	0.0001	0.17	0.32	22.4
4	2x8-0-7.5	0.0988	0.1039	0.1018	3.50	97.1	0.1022	1.54	3.96	0.0004	0.39	0.46	13.1
5	2x12-0-10	0.0792	0.0819	0.0796	0.83	99.5	0.0798	1.11	1.28	0.0002	0.25	0.45	54.2
6	2x12-0-20	0.0442	0.0450	0.0447	3.66	98.9	0.0448	0.99	4.41	0.0001	0.22	0.75	20.5
	Average					**98.2**		**1.41**		**0.0003**	**0.31**	**0.46**	**23.1**

Based on this analysis the decision was made to eliminate the OTZ values that appeared to be inconsistent with the adjacent results. Thus, the final OTZ values that were used are presented in Fig. 7.4.

Fig. 7.4 - Final Overall Thermal Zone (OTZ)



The Overall Thermal Zone (OTZ) was calculated for the 2,128 cases and those results are presented in Appendix E where the specific cases that were eliminated are highlighted and the values were deleted. A summary of the cases that were eliminated by the specific nominal stud dimensions is presented in Table 7.6. Based on the 2,128 cases that were analyzed a total of 163 cases (7.7%) were eliminated. The majority (128 or 6.0%) of the total cases eliminated were those with no exterior foam board sheathing

Table 7.6 - OTZ Cases Eliminated

Stud	Rshe=0	Others	Total	%
2x4	24	3	27	16.6
2x6	30	7	37	22.7
2x8	14	10	24	14.7
2x10	23	10	33	20.2
2x12	37	5	42	25.8
SUM	**128**	**35**	**163**	100.0
% Cut	**79**	**21**		
% Total	**6.0**	**1.6**	**7.7**	

7.3 - MINITAB Statistical Analysis

The MINITAB program provides tools that are able to discern statistically significant variables ($P < 0.05$) into predictive equations and discards variables that are not statistically significant. The MINITAB program used the Overall Thermal Zone (OTZ) values from Appendix E to perform a statistical analysis in the development of a multi-variable regression equation, see Eq. 7.1.

$$OTZ = C_0 + C_1 \times Rcav + C_2 \times Rshe + C_3 \times (Rcav)^2 + C_4 \times (Rshe)^2 + C_5 \times Rcav \times Rshe \quad (7.1)$$

Where:

C_0 thru C_5 = MINITAB Regression Coefficients

Rcav = Thermal Resistance of Insulation and/or Air Space that fills the steel C-shape space, h-ft^2-°F/Btu

Rshe = Thermal Resistance of Exterior Foam Board Sheathing, h-ft^2-°F/Btu

It is important to clarify that Rcav will be one of the following: (1) insulation that totally fills the steel C-shape space, (2) the sum of the insulation and an air space that totally fills the steel C-shape space or (3) an air space that totally fills the steel C-shape space.

The MINITAB regression coefficients which were used to predict the OTZ values in Eq. 7.1 are presented in Table 7.7.

Table 7.7 - MINITAB Regression Coefficients Used to Predict OTZ

oc-mils	C0	C1	C2	C3	C4	C5
6-33	1.8583	0.07478	0.1488	-0.001859	-0.005103	0.002013
6-43	1.9826	0.07360	0.1501	-0.001816	-0.005314	0.002149
6-54	2.0814	0.07131	0.1522	-0.001713	-0.005295	0.002050
6-68	2.2110	0.06816	0.1508	-0.001652	-0.005576	0.002300
12-33	2.1584	0.05118	0.2079	-0.001348	-0.005367	0.002253
12-43	2.2077	0.06381	0.1992	-0.001713	-0.006235	0.003499
12-54	2.2974	0.06439	0.2043	-0.001686	-0.006908	0.003943
12-68	2.4136	0.05185	0.2166	-0.001216	-0.006840	0.003748
16-33	2.2771	0.03843	0.1964	-0.001141	-0.005237	0.003197
16-43	2.3769	0.04037	0.2011	-0.001195	-0.005677	0.003714
16-54	2.4945	0.04089	0.1996	-0.001161	-0.005719	0.003927
16-68	2.5917	0.04614	0.1922	-0.001391	-0.005884	0.004606
24-33	3.1820	-0.02946	0.2432	0.000000	-0.007520	0.003572
24-43	2.7510	0.01280	0.1965	-0.000740	-0.006709	0.005169
24-54	2.5720	0.00426	0.2285	0.000000	-0.006100	0.003509
24-68	2.9360	-0.00324	0.2256	0.000000	-0.006430	0.004190

The statistical results of the MINITAB analysis that predict the OTZ values are presented in Table 7.8.

Table 7.8 - OTZ Statistical Results

	Average	Std. Dev.	CV	Uncertainty
oc-mils	inches	inches	%	(+/- %)
6-33	3.353	0.157	4.7	9.2
6-43	3.477	0.157	4.5	8.9
6-54	3.583	0.166	4.7	9.2
6-68	3.677	0.171	4.7	9.2
12-33	3.946	0.274	6.9	13.7
12-43	4.085	0.269	6.6	13.0
12-54	4.238	0.284	6.7	13.2
12-68	4.392	0.299	6.8	13.4
16-33	3.973	0.243	6.1	12.1
16-43	4.174	0.269	6.4	12.7
16-54	4.322	0.298	6.9	13.6
16-68	4.396	0.324	7.4	14.6
24-33	4.363	0.571	13.1	25.8
24-43	4.342	0.364	8.4	16.5
24-54	4.389	0.449	10.2	20.2
24-68	4.692	0.432	9.2	18.2
Std. Dev. = Standard Deviation of Residuals CV = Coefficient of Variation = Std. Dev./Average Uncertainty Interval = 1.975 x CV				

Graphical displays of the MINITAB regression analysis results are presented in Appendix F.

7.4 - Calculation of U-factors in EXCEL Spreadsheet

Once the MINITAB regression equations and coefficients were developed an EXCEL spreadsheet was created that implemented the procedure presented in Section 6-2 to calculate U-factors for the 2,128 cases. The results are presented in Appendix G.

7.5 - Accuracy of EXCEL U-factors

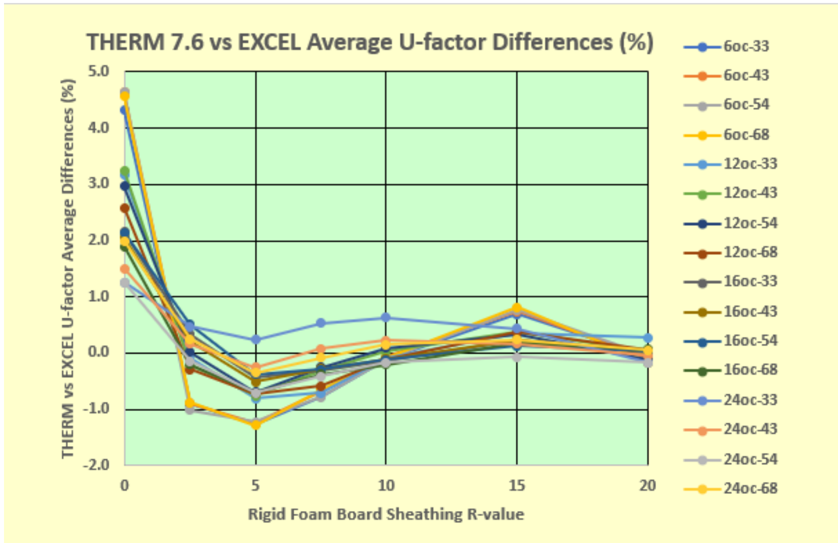
The accuracy of the EXCEL U-factors was determined by calculating the difference with the U-factors from the THERM 7.6 program. Appendix H presents the individual results for each of the 2,128 cases. The average of the differences for the 19 cavity insulation options and for each R-value of the exterior sheathing is presented in Table 7.9. The average difference for the 2,128 cases was 0.43%. The average U-factor differences ranged from a -0.06% to 0.49% depending upon the on center spacing and the thickness of the steel. The most notable observation is that the largest differences occur for the cases with no exterior sheathing which have an average U-factor difference of 2.77% and range from 1.26% to 4.63%.

Table 7.9 - THERM 7.6 vs EXCEL U-factor Average Differences (%)

	Average Differences (%)							
	Rigid Foam Board Sheathing - R-value							
oc-Mils	0	2.5	5	7.5	10	15	20	AVG.
6-33	4.32	-0.90	-1.26	-0.77	-0.12	0.69	-0.07	0.27
6-43	4.63	-0.89	-1.25	-0.67	-0.07	0.74	-0.09	0.34
6-54	4.63	-1.01	-1.22	-0.78	-0.12	0.77	-0.05	0.32
6-68	4.56	-0.89	-1.29	-0.66	-0.09	0.82	-0.16	0.33
12-33	3.16	-0.09	-0.81	-0.71	-0.09	0.35	0.27	0.30
12-43	3.25	-0.21	-0.75	-0.30	0.03	0.37	0.05	0.35
12-54	2.97	0.02	-0.69	-0.25	0.10	0.34	-0.10	0.34
12-68	2.59	-0.29	-0.72	-0.58	-0.12	0.37	0.05	0.19
16-33	2.15	0.33	-0.42	-0.31	-0.13	0.22	0.04	0.27
16-43	2.05	0.20	-0.51	-0.28	-0.11	0.23	0.02	0.23
16-54	2.14	0.50	-0.38	-0.29	-0.12	0.12	0.03	0.29
16-68	1.90	-0.20	-0.71	-0.38	-0.20	0.17	0.07	0.09
24-33	1.26	0.47	0.24	0.53	0.63	0.43	-0.16	0.49
24-43	1.50	0.17	-0.25	0.08	0.23	0.16	-0.05	0.26
24-54	1.26	-0.15	-0.71	-0.41	-0.17	-0.08	-0.16	-0.06
24-68	2.00	0.26	-0.35	-0.09	0.15	0.23	0.05	0.32
Average	**2.77**	**-0.17**	**-0.69**	**-0.37**	**-0.01**	**0.37**	**-0.02**	**0.27**

A graphical representation of the average U-factor differences is presented in Fig. 7.5 which illustrates the largest U-factor differences occur for the cases without any exterior sheathing. The average U-factor differences decrease markedly once there is any exterior foam board insulation in the assembly.

Fig. 7.5 - THERM 7.6 vs EXCEL U-factor Average Differences (%)

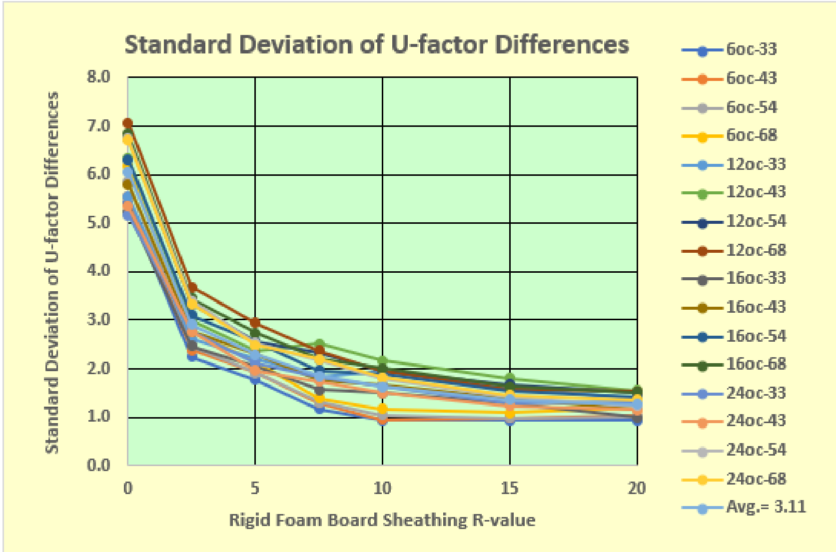


The standard deviations of the differences between THERM 7.6 and the EXCEL U-factors were also determined and they are presented in Table 7.10. The standard deviation for all 2,128 cases was 3.11 and ranged from 2.60 to 3.59 depending upon the on center spacings and the thickness of the steel. Again the most notable observations are the cases without any exterior sheathing which have a standard deviation of 6.05 and a range from a minimum of 5.17 to a maximum of 7.08, see Fig. 7.6.

Table 7.10 - Standard Deviation of U-factor Average Differences in %

	Standard Deviations							
	Rigid Foam Board Sheathing - R-value							
oc-Mils	0	2.5	5	7.5	10	15	20	AVG.
6-33	5.42	2.24	1.77	1.17	0.94	0.93	0.94	2.96
6-43	5.54	2.39	1.93	1.30	0.94	0.99	1.03	3.09
6-54	5.85	2.46	1.92	1.32	1.04	0.99	1.01	3.19
6-68	6.17	2.77	2.13	1.39	1.17	1.10	1.18	3.33
12-33	5.55	2.62	2.21	1.84	1.97	1.62	1.39	2.99
12-43	6.33	2.99	2.38	2.52	2.17	1.80	1.55	3.35
12-54	6.76	3.33	2.56	2.33	1.96	1.68	1.50	3.44
12-68	7.08	3.68	2.95	2.38	1.96	1.59	1.53	3.59
16-33	5.24	2.47	2.06	1.57	1.50	1.28	1.00	2.61
16-43	5.80	2.78	2.30	1.77	1.67	1.39	1.18	2.87
16-54	6.31	3.10	2.54	1.96	1.89	1.53	1.41	3.14
16-68	6.83	3.45	2.73	2.20	2.01	1.62	1.51	3.39
24-33	5.17	2.79	2.12	1.84	1.64	1.28	1.31	2.60
24-43	5.35	2.76	1.97	1.74	1.50	1.24	1.16	2.62
24-54	6.75	3.40	2.52	2.19	1.81	1.42	1.23	3.25
24-68	6.71	3.34	2.48	2.20	1.83	1.46	1.36	3.27
Std. Dev.	**6.05**	**2.91**	**2.29**	**1.88**	**1.64**	**1.38**	**1.26**	**3.11**

Fig. 7.6 - Standard Deviation of U-factor Average Differences in %



Another approach to characterize the accuracy was to determine the number of EXCEL U-factors with a difference that was greater than 5% from the THERM 7.6 U-factors, see Table 7.11. The total number of cases was 173 or 4.7% of the 2,128 cases of which 134 or 3.6% of all the cases were those with no exterior sheathing.

Table 7.11 - Number of EXCEL U-factors with a Difference Greater than 5%

U-factors Greater than 5% Difference than THERM Results								
	Sheathing R-value							No.
oc-Mils	0	2.5	5	7.5	10	15	20	Cases
6-33	9	1	1	0	0	0	0	**11**
6-43	7	1	0	0	0	0	0	**8**
6-54	7	0	0	0	0	0	0	**7**
6-68	7	0	0	0	0	0	0	**7**
12-33	8	1	1	0	1	1	0	**12**
12-43	8	1	1	1	1	1	0	**13**
12-54	7	0	1	0	0	0	0	**8**
12-68	9	0	1	0	0	0	0	**10**
16-33	9	0	1	0	0	0	0	**10**
16-43	10	1	1	0	0	0	0	**12**
16-54	9	2	1	0	0	0	0	**12**
16-68	10	3	2	1	0	0	0	**16**
24-33	6	3	0	0	0	0	0	**9**
24-43	8	1	0	0	0	0	0	**9**
24-54	9	4	1	0	0	0	0	**14**
24-68	11	3	1	0	0	0	0	**15**
SUM	**134**	**21**	**12**	**2**	**2**	**2**	**0**	**173**
%Total	**6.3**	**1.0**	**0.6**	**0.1**	**0.1**	**0.1**	**0.0**	**8.1**

A further breakdown of the U-factor differences was to identify those that were greater than 10%, see Table 7.12. All 54 of those cases had no exterior sheathing. Three cases had negative differences while the remaining 51 cases had positive differences that averaged 12.0% with a standard deviation of 1.4.

Table 7.12 - Number of EXCEL U-factors with a Difference Greater than 10%

Rshe	5%-10%	>10%	Total
0	80	54	134
2.5	21	0	21
5	12	0	12
7.5	2	0	2
10	2	0	2
15	2	0	2
20	0	0	0
Sum	119	54	173
%Cases	**5.6**	**2.5**	**8.1**

7.6 - Comparisons to ASHRAE Standard 90.1-2019 U-factors

The major application of the U-factors exists in specifying the thermal performance of the envelope criteria in energy codes and standards. Currently the ASHRAE energy standards are limited to 2x4 and 2x6 assemblies while the IECC also has 2x8 assemblies. Therefore, a comparison of the existing U-factors to those developed in this project was desired. The construction details specified in Standard 90.1-2019 to use for calculating the U-factors are presented in Table 7.13.

Table 7.13 - Standard 90.1 Construction Details for Calculating U-factors

Component	R-value
Exterior Air Film	0.17
Stucco	0.08
Exterior Gypsum	0.625
Interior Gypsum	0.625
Interior Air Film	0.68

The ASHRAE Standard 90.1-2019 envelope criteria (R-values and U-factors) and the U-factors from this project are presented in Table 7.14 by climate zones. Without any exterior board sheathing the U-factors match. However, when the exterior board sheathing requirement is added the U-factors from this project exhibit lower values than those from the ASHRAE Standard 90.1-2019 which is directly attributed to what was observed and reported in Section 7.1.4 Impact of Adding Exterior Foam Board Sheathing.

Table 7.14 - Comparison to Std. 90.1-2019 U-factors

Standard 90.1-2019 Criteria			EXCEL
CZ	R-value	U-factor	U-factor
0,1	0	0.352	0.354
1	13	0.124	0.124
2	13+3.8	0.084	0.077
2,4	13+7.5	0.064	0.059
3	13+5	0.077	0.070
5	13+10	0.055	0.052
6,7	13+12.5	0.049	0.046
7	13+15.8	0.042	0.040
8	13+18.8	0.037	0.035

Another comparison is the U-factors from ASHRAE Standard 90.1-2019, Appendix A, Table A3.3.3.1 Assembly U-factors for Steel-Framed Walls which are represented by the solid lines and the EXCEL U-factors are represented by the dash lines, see Fig. 7.7 thru 7.10. Again, the EXCEL U-factors are lower as was previously explained.

Fig. 7.7 - Steel-Framed Walls - 2x4, 16oc

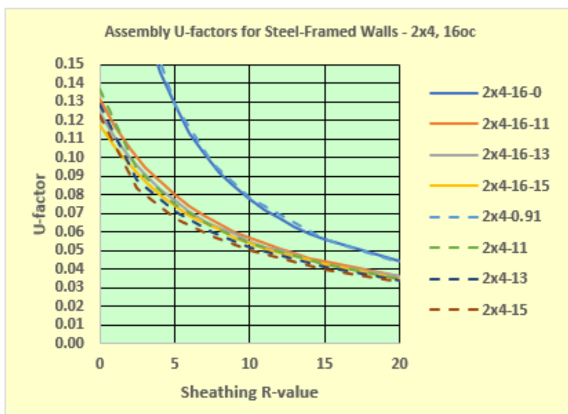


Fig. 7.8 - Steel-Framed Walls - 2x4, 24oc

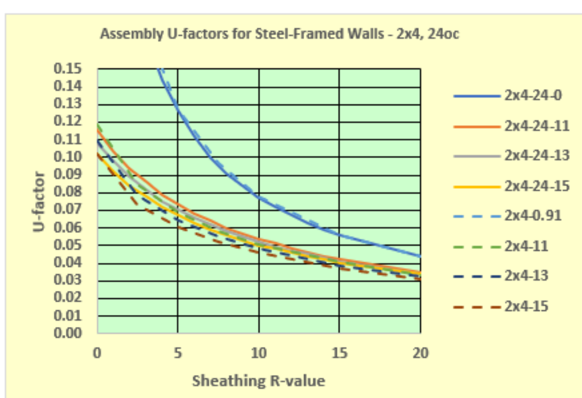


Fig. 7.9 - Steel-Framed Walls - 2x6, 16oc

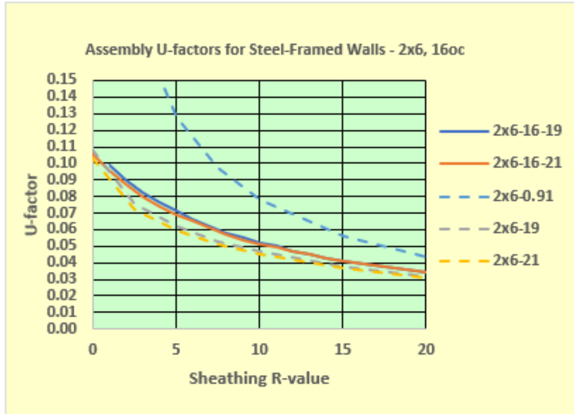
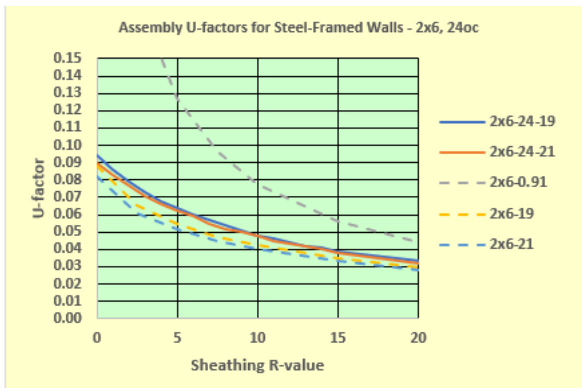


Fig. 7.10 - Steel-Framed Walls - 2x6, 24oc



8 - DISCUSSION OF RESULTS

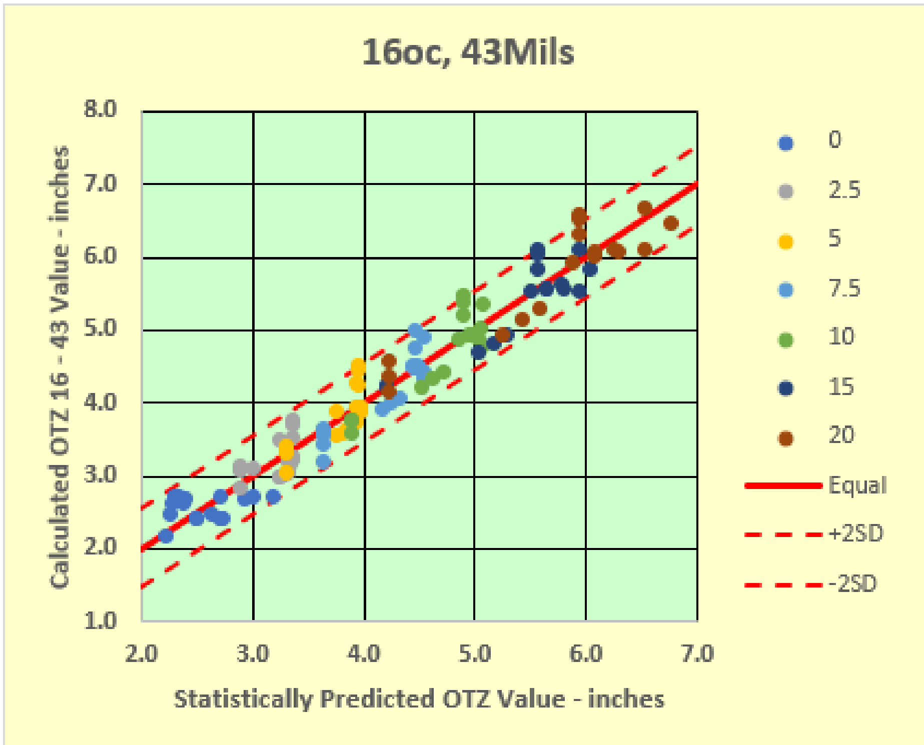
The purpose of this project was to develop an acceptable U-factor calculation procedure to analyze cold-formed steel C-shape clear wall assemblies. The technical analysis and results have been presented in detail. It is also important to thoroughly understand the underlying assumptions and methodology associated with the development of the regression equations used to calculate the Overall Thermal Zones since they have a direct impact on the overall accuracy of the U-factors. The regression equation was presented in Section 7.3 as Eq. 7.1 and is shown again below.

$$OTZ = C_0 + C_1 \text{ x } Rcav + C_2 \text{ x } Rshe + C_3 \text{ x } (Rcav)^2 + C_4 \text{ x } (Rshe)^2 + C_5 \text{ x } Rcav \text{ x } Rshe$$

There are sixteen sets of coefficients to account for the four on center spacings and the four steel thermal conductivities. The accuracy of each of the sixteen equations depends upon two key variables, the residuals and the OTZ that apply to specific cases. Each will be reviewed in detail.

The residuals can best be understood by examining the statistical scatter plots presented in Appendix F. As a typical example the 16oc and 43 Mils case has been recreated to color code the exterior foam board sheathing R-values, see Fig. 8.1.

Fig. 8.1 - Scatter Plot of Calculated vs Predicted Overall Thermal Zones



The underlying statistical process is to minimize the standard deviation of the residuals and this has a profound impact on the resulting U-factor calculations. The average OTZ is 4.174 inches and the standard deviation of the residuals is 0.269 inches which equates to a confidence interval (CI) of +/- two standard deviations (95%) or 1.08 inches. In Fig. 8.1 the CI is represented by the two red dashed parallel lines. Although the residuals are well defined and uniform the key issue is that the U-factor accuracy is sensitive to the OTZ. The same residual in the OTZ has a reduced impact on the U-factors accuracy as the OTZ increases with higher R-values of the exterior foam board sheathing. Fig. 8.1 shows the OTZ values for no exterior foam board sheathing to be between two and three inches so a residual of 1.08 inches is significant. This impact can be represented by showing the dependence of what a change in the OTZ has on the change in the U-factor, see Fig. 8.2. Those cases with no exterior sheathing (blue squares) exhibit the largest changes in U-factors. A summary of these cases is presented in Table 8.1.

Fig. 8.2 - Difference in U-factors vs Difference in OTZ

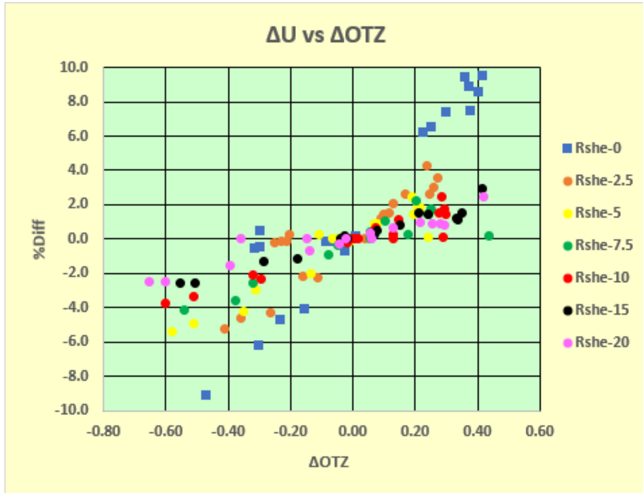


Table 8.1 - U-factor Differences - %

Rshe	AVG. OTZ-in.	U-factor Diff. (%) MIN.	MAX.
0	2.52	-9.08	9.55
2.5	3.22	-5.23	4.23
5	3.79	-5.38	2.50
7.5	4.19	-4.16	2.20
10	4.71	-3.72	2.46
15	5.39	-2.58	2.98
20	5.73	-2.46	2.43

The second key item that impacts the accuracy of the U-factor calculations is the terms in the regression equations which are comprised of the variables Rcav and Rshe. When there is no exterior foam board sheathing (Rshe = 0) three of the terms become zero which reduces the ability of the remaining terms to capture all of the dependence on the U-factors.

As a final observation on the overall accuracy of the U-factor calculation graphs of all the results are presented in Fig. 8-3 to 8-9. Note that the scale on the vertical axis can change from one figure to the next. Each graph has an index which describes the actual wall construction by the case number. Those cases highlighted in yellow (1, 5, 8, 12 and 16) are unique in that there is no cavity or sheathing insulation and the U-factors are all generally centered around a value of zero differences in the U-factors.

Fig. 8.3 - THERM 7.6 vs EXCEL U-factor Differences for Rshe = 0

Stud-R-cav	Case
2x4-0.91	1
2x4-11	2
2x4-13	3
2x4-15	4
2x6-0.91	5
2x6-19	6
2x6-21	7
2x8-0.91	8
2x8-19	9
2x8-21	10
2x8-25	11
2x10-0.91	12
2x10-19	13
2x10-25	14
2x10-30	15
2x12-0.91	16
2x12-19	17
2x12-30	18
2x12-38	19

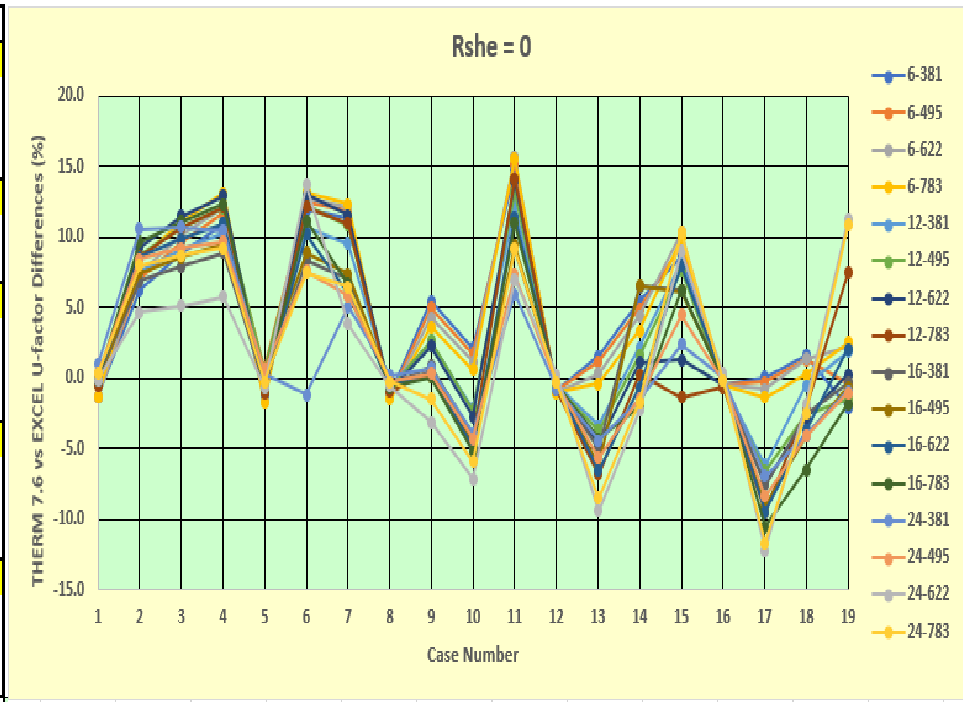


Fig. 8.4 - THERM 7.6 vs EXCEL U-factor Differences for Rshe = 2.5

Stud-R-cav	Case
2x4-0.91	1
2x4-11	2
2x4-13	3
2x4-15	4
2x6-0.91	5
2x6-19	6
2x6-21	7
2x8-0.91	8
2x8-19	9
2x8-21	10
2x8-25	11
2x10-0.91	12
2x10-19	13
2x10-25	14
2x10-30	15
2x12-0.91	16
2x12-19	17
2x12-30	18
2x12-38	19

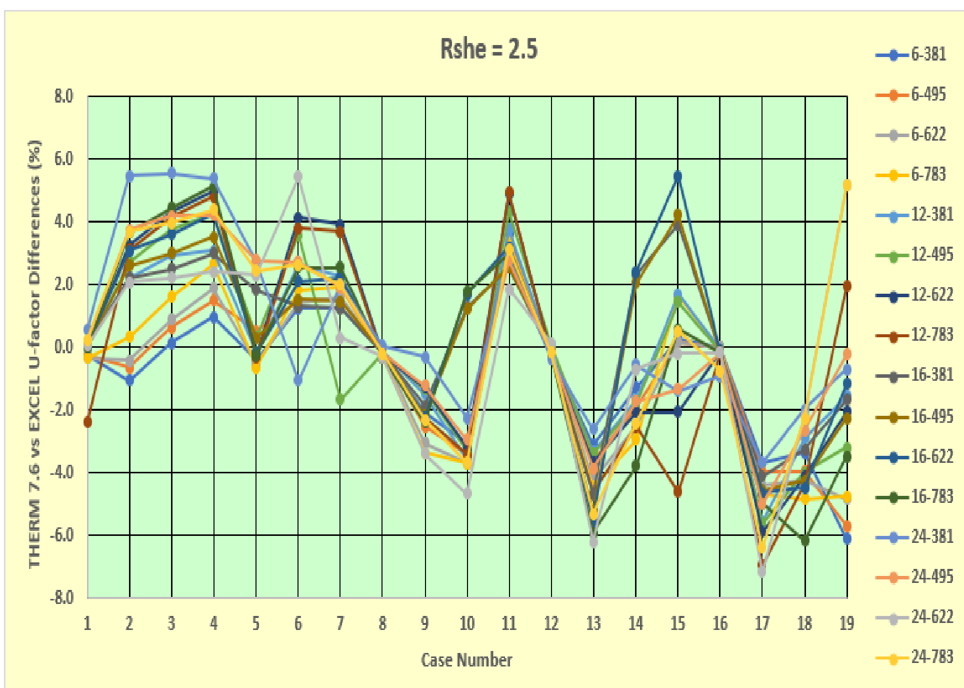


Fig. 8.5 - THERM 7.6 vs EXCEL U-factor Differences for Rshe = 5

Stud-R-cav	Case
2x4-0.91	1
2x4-11	2
2x4-13	3
2x4-15	4
2x6-0.91	5
2x6-19	6
2x6-21	7
2x8-0.91	8
2x8-19	9
2x8-21	10
2x8-25	11
2x10-0.91	12
2x10-19	13
2x10-25	14
2x10-30	15
2x12-0.91	16
2x12-19	17
2x12-30	18
2x12-38	19

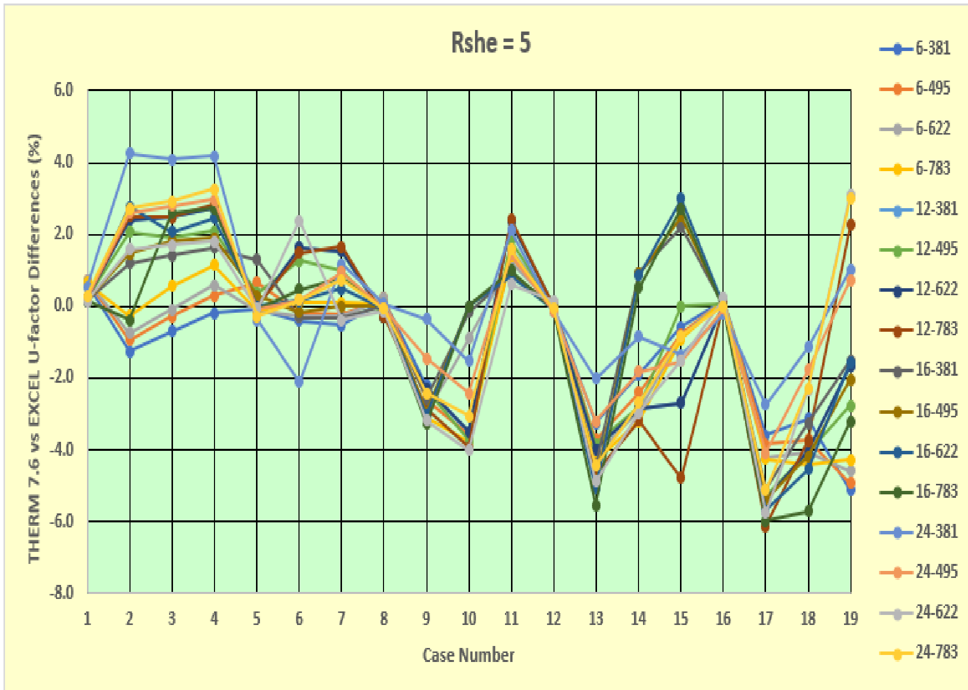


Fig. 8.6 - THERM 7.6 vs EXCEL U-factor Differences for Rshe = 7.5

Stud-R-cav	Case
2x4-0.91	1
2x4-11	2
2x4-13	3
2x4-15	4
2x6-0.91	5
2x6-19	6
2x6-21	7
2x8-0.91	8
2x8-19	9
2x8-21	10
2x8-25	11
2x10-0.91	12
2x10-19	13
2x10-25	14
2x10-30	15
2x12-0.91	16
2x12-19	17
2x12-30	18
2x12-38	19

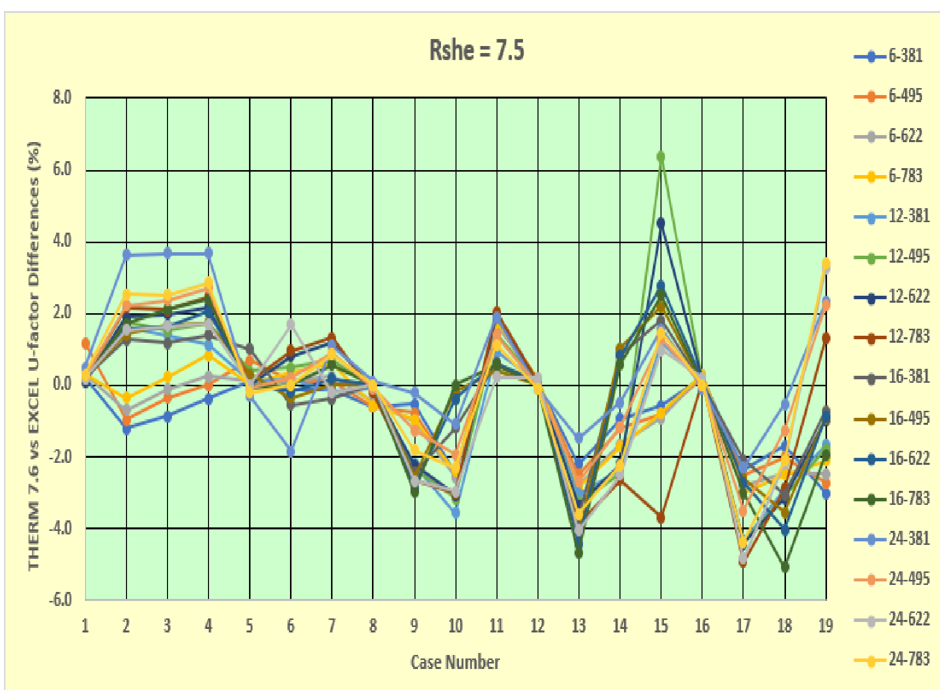


Fig. 8.7 - THERM 7.6 vs EXCEL U-factor Differences for Rshe = 10

Stud-R-cav	Case
2x4-0.91	1
2x4-11	2
2x4-13	3
2x4-15	4
2x6-0.91	5
2x6-19	6
2x6-21	7
2x8-0.91	8
2x8-19	9
2x8-21	10
2x8-25	11
2x10-0.91	12
2x10-19	13
2x10-25	14
2x10-30	15
2x12-0.91	16
2x12-19	17
2x12-30	18
2x12-38	19

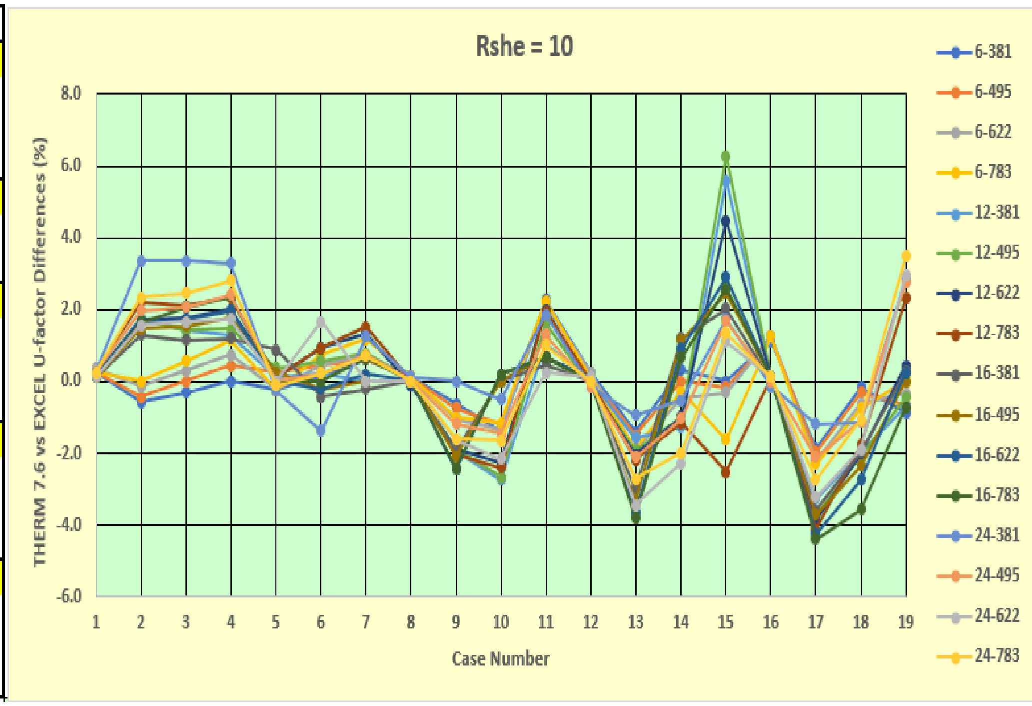


Fig. 8.8 - THERM 7.6 vs EXCEL U-factor Differences for Rshe = 15

Stud-R-cav	Case
2x4-0.91	1
2x4-11	2
2x4-13	3
2x4-15	4
2x6-0.91	5
2x6-19	6
2x6-21	7
2x8-0.91	8
2x8-19	9
2x8-21	10
2x8-25	11
2x10-0.91	12
2x10-19	13
2x10-25	14
2x10-30	15
2x12-0.91	16
2x12-19	17
2x12-30	18
2x12-38	19

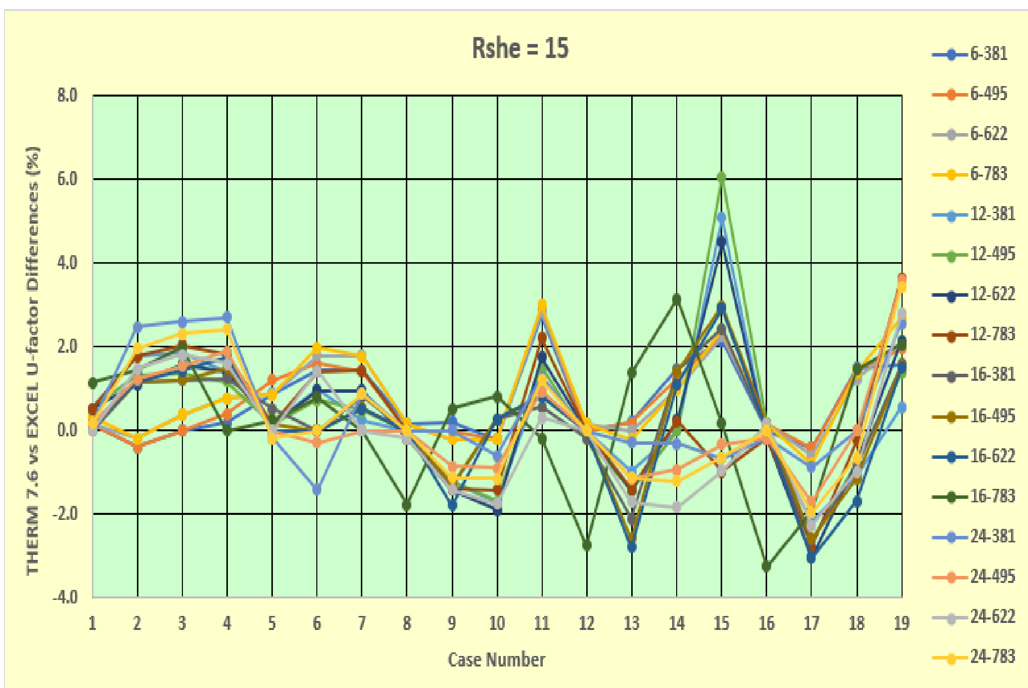
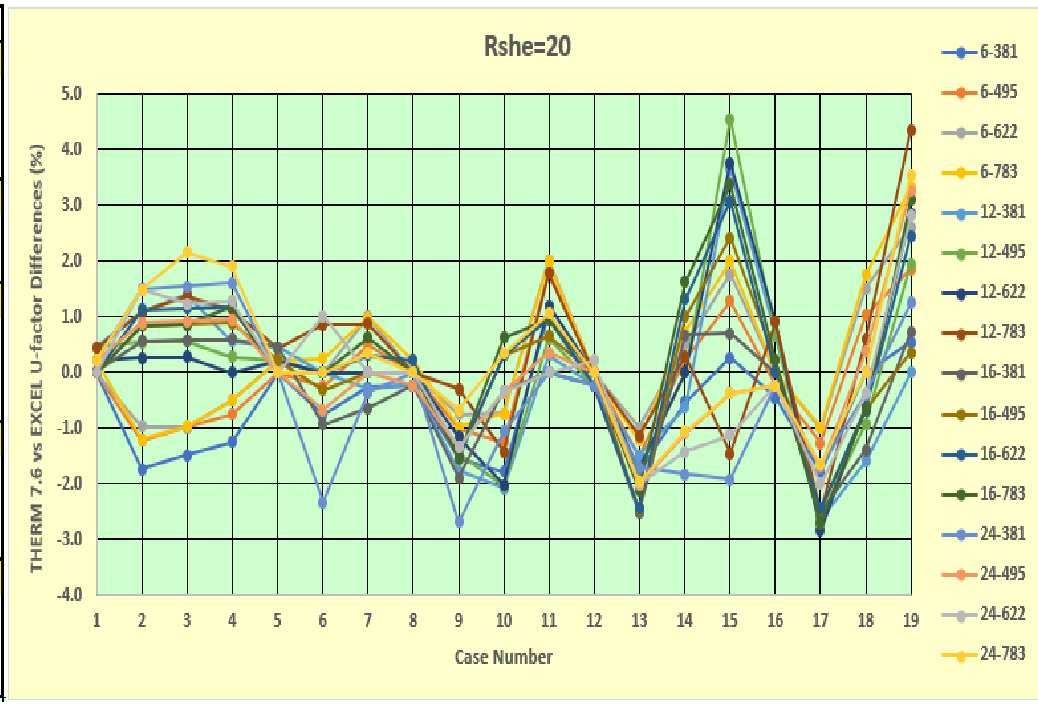


Fig. 8.9 - THERM 7.6 vs EXCEL U-factor Differences for Rshe = 20

Stud-R-cav	Case
2x4-0.91	1
2x4-11	2
2x4-13	3
2x4-15	4
2x6-0.91	5
2x6-19	6
2x6-21	7
2x8-0.91	8
2x8-19	9
2x8-21	10
2x8-25	11
2x10-0.91	12
2x10-19	13
2x10-25	14
2x10-30	15
2x12-0.91	16
2x12-19	17
2x12-30	18
2x12-38	19



9 - CONCLUSIONS

The objective of this project has been met with the development of a U-factor calculation procedure to analyze cold-formed steel C-shape clear wall assemblies that would be acceptable for energy code analysis and compliance. The calculation method encompasses the five key construction variables: five nominal stud dimensions, four on center spacings, four designation thicknesses, nineteen cavity insulation options and seven exterior sheathing options which cover an R-value range from R-0 to to R-20 for a total of 2,128 cases. This represents as significant expansion of the existing construction variables available in the IECC which is limited to three nominal stud dimensions, two on center spacings, one designation thicknesses, ten cavity insulation options and user defined exterior sheathing options.

Simplifying modeling assumptions regarding the exclusion of the lip on the flange and adjusting the thermal conductivity of the steel to address varying the actual metal thickness were analyzed to verify their applicability. Using both assumptions the THERM 7.6 program was executed to model the 2,128 cases. The THERM 7.6 results were first used to quantify the magnitude of the incremental increases in the overall R-value that exceeded the nominal product R-values due to the application of the exterior sheathing. Then the THERM 7.6 results served as a data base for the development of a simplified U-factor calculation procedure.

The parallel path concept was the basic calculation approach utilized with the introduction of the overall thermal zone (OTZ) as the mechanism to account for the thermal anomaly caused by the cold-formed steel C-shape framing members. The OTZ results were critically investigated and selective cases identified as outliers were excluded from the data base for the application of the MINTAB software program to develop simplified statistical regression equations.

The regression equations were then embedded into an EXCEL spreadsheet which was then checked by comparing those U-factors with those from the THERM 7.6 analysis. An exhaustive analysis of the EXCEL spreadsheet results was completed to understand the basis for the observed U-factor differences. The overall U-factor results for the 2,128 cases had an average difference of 0.27% with a standard deviation of 3.11. Further investigations quantified the differences by on center spacings, designation thicknesses and the R-values of the exterior sheathing. Those cases with no exterior sheathing exhibited the largest U-factor differences with an average 2.77% and a standard deviation of 6.05.

A final assessment of the U-factor calculation procedure was completed by making comparisons to the published values contained in ASHRAE Std. 90.1-2019. Overall, the U-factors from this project were lower due to the impact of the incremental increase in the R-values of the exterior sheathings that were identified.

Based on the analysis completed in this project the U-factor calculation procedure was deemed an acceptable basis for the development of an ANSI standard.

10 - RECOMMENDATIONS

This project developed the technical basis for a U-factor calculation procedure to analyze cold-formed steel C-shape clear wall assemblies that would be acceptable for energy code analysis and compliance. The U-factor calculation procedure developed in this project was deemed acceptable and is therefore recommended to be the basis for the development of an ANSI standard.

11 - REFERENCES

ASHRAE Standard 90.1, “ANSI/ASHRAE/IES Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings,” ASHRAE International, Atlanta, GA, 2019.

ASHRAE HOF, “Handbook of Fundamentals,” ASHRAE International, Atlanta, GA, 2017.

IECC, “International Energy Conservation Code,” International Code Council, Country Club Hills, IL, 2018.

THERM 7.6, “A PC Program for Analyzing Two-Dimensional Heat Transfer Through Building Products,” Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA, 2017.

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12 - APPENDICIES

Appendix A - Thermal Impact of Excluding Stiffening Lip on Flange

Figures A-1 through A-8 show the THERM 7.6 isotherms for the C-shape flange without and with the stiffening lip.

Fig. A-1 - 16 oc, 2x4, Rcav-0, Rshe-0

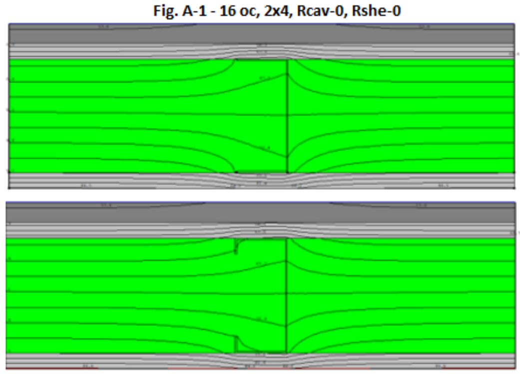


Fig. A-2 - 16 oc, 2x4, Rcav-11, Rshe-0

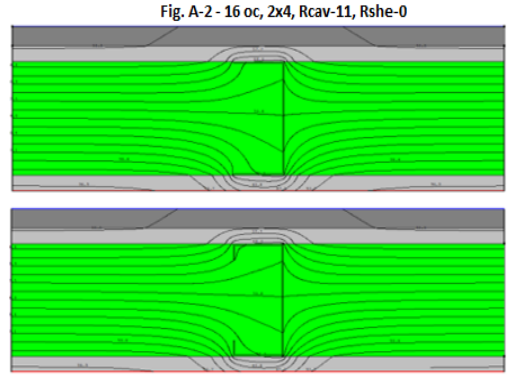


Fig. A-3 - 16 oc, 2x4, Rcav-13, Rshe-0

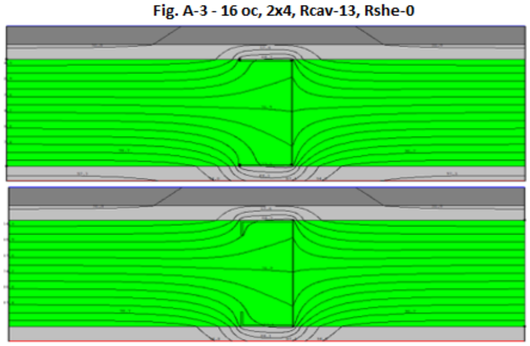


Fig. A-4 - 16 oc, 2x4, Rcav-15, Rshe-0

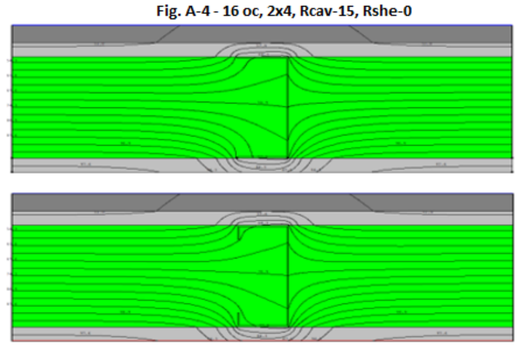


Fig. A-5 - 16 oc, 2x4, Rcav-0, Rshe-2.5

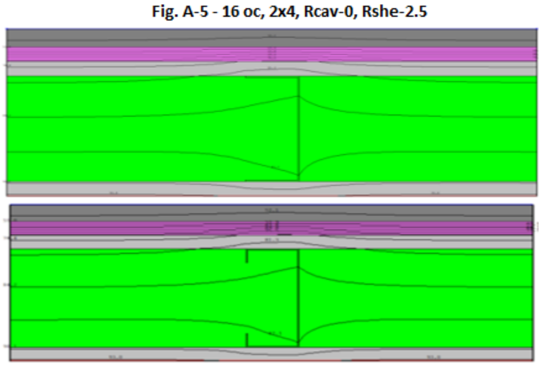


Fig. A-6 - 16 oc, 2x4, Rcav-11, Rshe-2.5

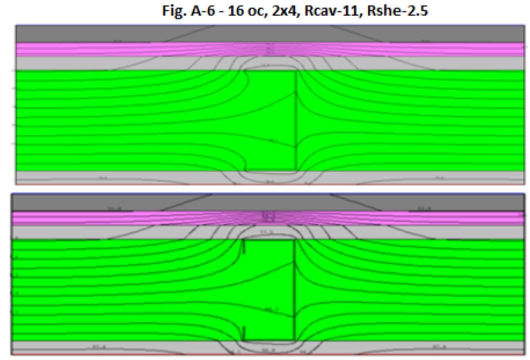


Fig. A-7 - 16 oc, 2x4, Rcav-13, Rshe-2.5

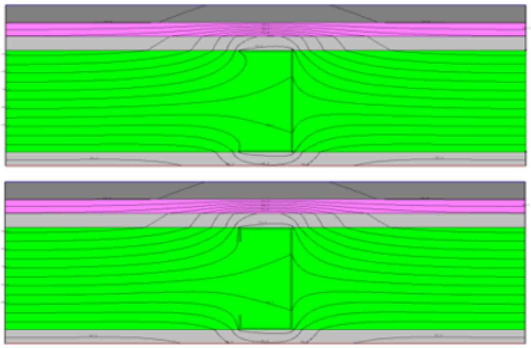
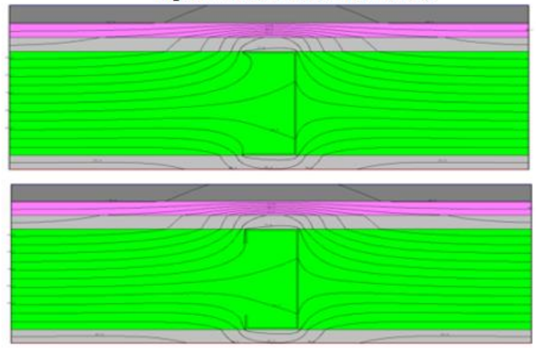
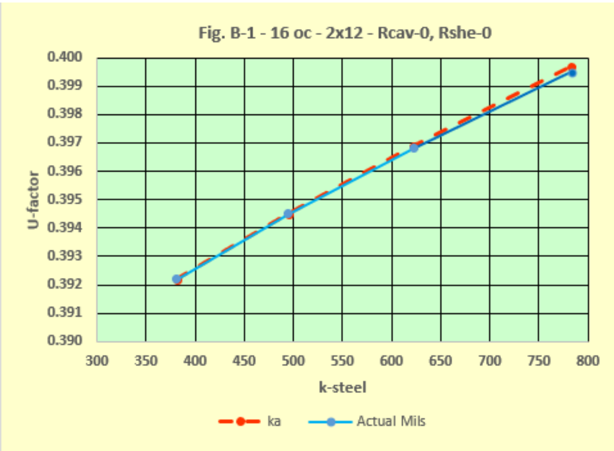


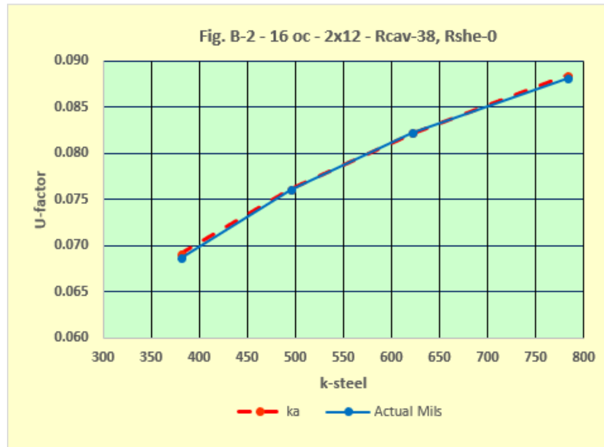
Fig. A-8 - 16 oc, 2x4, Rcav-15, Rshe-2.5

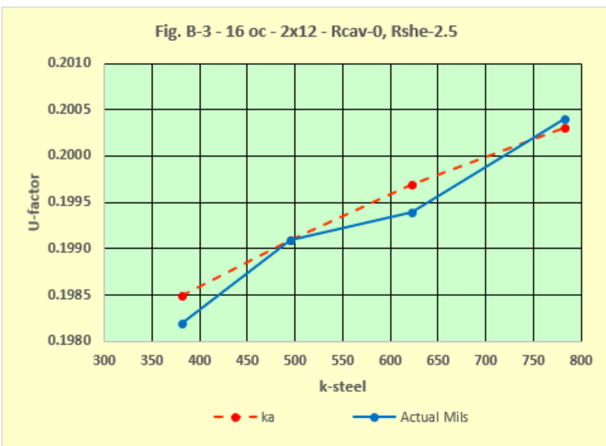


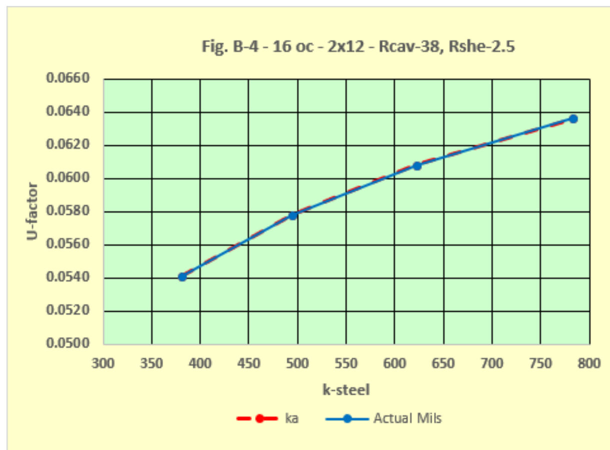
Appendix B - Modeling the Thermal Conductivity of the Steel

Figures B-1 through B-4 below compare the U-factors for modeling the actual thickness of the C-shape steel versus a model that uses a constant thickness (43 mils) and adjusts the thermal conductivity (k_a).









Appendix C - THERM 7.6 U-factors

Tables C-1 through C-16 present the THERM 7.6 U-factors for the 2,182 cases which address the five nominal stud dimensions, four thermal conductivities of the steel, nineteen cavity insulation options and seven sheathing insulation options.

Table C-1 THERM U-factors for 6oc, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-values						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4293	0.2070	0.1357	0.1019	0.0812	0.0578	0.0448
2x4-11	0.2342	0.1411	0.1034	0.0824	0.0683	0.0509	0.0406
2x4-13	0.2265	0.1373	0.1013	0.0811	0.0674	0.0504	0.0403
2x4-15	0.2211	0.1346	0.0997	0.0800	0.0667	0.0500	0.0400
2x6-0.91	0.4211	0.2053	0.1358	0.1014	0.0812	0.0572	0.0448
2x6-19	0.1972	0.1265	0.0957	0.0772	0.0649	0.0486	0.0393
2x6-21	0.1949	0.1244	0.0945	0.0764	0.0642	0.0485	0.0390
2x8-0.91	0.4154	0.2036	0.1349	0.1018	0.0807	0.0575	0.0447
2x8-19	0.1964	0.1266	0.0954	0.0763	0.0646	0.0488	0.0393
2x8-21	0.2014	0.1269	0.0959	0.0773	0.0648	0.0489	0.0394
2x8-25	0.1724	0.1154	0.0892	0.0729	0.0618	0.0472	0.0382
2x10-0.91	0.4104	0.2028	0.1347	0.1008	0.0805	0.0575	0.0447
2x10-19	0.1957	0.1256	0.0952	0.0769	0.0646	0.0485	0.0392
2x10-25	0.1760	0.1171	0.0902	0.0736	0.0621	0.0474	0.0384
2x10-30	0.1580	0.1088	0.0852	0.0709	0.0607	0.0463	0.0378
2x12-0.91	0.4059	0.2017	0.1342	0.1005	0.0796	0.0574	0.0447
2x12-19	0.1930	0.1246	0.0946	0.0764	0.0645	0.0486	0.0391
2x12-30	0.1613	0.1103	0.0861	0.0708	0.0602	0.0463	0.0376
2x12-38	0.1404	0.1001	0.0798	0.0665	0.0570	0.0444	0.0364

Table C-2 THERM U-factors for 6oc, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-values						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4361	0.2085	0.1363	0.1022	0.0814	0.0579	0.0449
2x4-11	0.2472	0.1454	0.1057	0.0839	0.0693	0.0515	0.0409
2x4-13	0.2396	0.1417	0.1036	0.0825	0.0684	0.0510	0.0406
2x4-15	0.2343	0.1391	0.1021	0.0816	0.0677	0.0506	0.0404
2x6-0.91	0.4283	0.2070	0.1365	0.1018	0.0815	0.0573	0.0449
2x6-19	0.2134	0.1326	0.0991	0.0794	0.0664	0.0495	0.0399
2x6-21	0.2116	0.1307	0.0980	0.0787	0.0659	0.0495	0.0396
2x8-0.91	0.4221	0.2052	0.1356	0.1022	0.0810	0.0577	0.0448
2x8-19	0.2165	0.1344	0.0997	0.0790	0.0665	0.0499	0.0400
2x8-21	0.2219	0.1345	0.1001	0.0800	0.0666	0.0500	0.0401
2x8-25	0.1898	0.1227	0.0935	0.0757	0.0638	0.0483	0.0389
2x10-0.91	0.4165	0.2042	0.1353	0.1012	0.0808	0.0576	0.0447
2x10-19	0.2165	0.1336	0.0997	0.0798	0.0666	0.0496	0.0400
2x10-25	0.1970	0.1257	0.0952	0.0768	0.0645	0.0488	0.0393
2x10-30	0.1765	0.1170	0.0901	0.0743	0.0632	0.0477	0.0387
2x12-0.91	0.4115	0.2031	0.1348	0.1009	0.0798	0.0575	0.0448
2x12-19	0.2133	0.1323	0.0990	0.0793	0.0665	0.0497	0.0398
2x12-30	0.1826	0.1195	0.0916	0.0745	0.0628	0.0478	0.0386
2x12-38	0.1584	0.1087	0.0851	0.0701	0.0597	0.0460	0.0375

Table C-3 THERM U-factors for 6oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4422	0.2099	0.1369	0.1025	0.0816	0.0580	0.0450
2x4-11	0.2575	0.1487	0.1074	0.0849	0.0700	0.0519	0.0412
2x4-13	0.2499	0.1450	0.1054	0.0836	0.0691	0.0514	0.0409
2x4-15	0.2446	0.1424	0.1039	0.0827	0.0685	0.0510	0.0407
2x6-0.91	0.4349	0.2085	0.1372	0.1022	0.0817	0.0575	0.0449
2x6-19	0.2267	0.1374	0.1018	0.0811	0.0676	0.0501	0.0403
2x6-21	0.2254	0.1356	0.1008	0.0804	0.0671	0.0501	0.0400
2x8-0.91	0.4286	0.2066	0.1362	0.1025	0.0812	0.0578	0.0449
2x8-19	0.2339	0.1406	0.1031	0.0811	0.0680	0.0508	0.0405
2x8-21	0.2396	0.1405	0.1003	0.0820	0.0681	0.0508	0.0406
2x8-25	0.2044	0.1284	0.0967	0.0778	0.0653	0.0492	0.0395
2x10-0.91	0.4226	0.2057	0.1360	0.1015	0.0810	0.0577	0.0448
2x10-19	0.2349	0.1401	0.1033	0.0820	0.0682	0.0505	0.0405
2x10-25	0.2155	0.1328	0.0992	0.0794	0.0663	0.0498	0.0400
2x10-30	0.1925	0.1237	0.0940	0.0769	0.0651	0.0488	0.0394
2x12-0.91	0.4172	0.2044	0.1354	0.1012	0.0800	0.0576	0.0448
2x12-19	0.2312	0.1387	0.1025	0.0815	0.0681	0.0506	0.0404
2x12-30	0.2017	0.1272	0.0960	0.0774	0.0648	0.0490	0.0394
2x12-38	0.1743	0.1158	0.0894	0.0730	0.0617	0.0472	0.0383

Table C-4 THERM U-factors for 6oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-values						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4482	0.2112	0.1375	0.1028	0.0818	0.0581	0.0450
2x4-11	0.2667	0.1515	0.1088	0.0858	0.0706	0.0522	0.0414
2x4-13	0.2591	0.1479	0.1068	0.0846	0.0698	0.0517	0.0411
2x4-15	0.2538	0.1453	0.1054	0.0836	0.0691	0.0514	0.0409
2x6-0.91	0.4421	0.2101	0.1379	0.1026	0.0820	0.0576	0.0450
2x6-19	0.2390	0.1416	0.1040	0.0825	0.0686	0.0506	0.0406
2x6-21	0.2382	0.1399	0.1031	0.0819	0.0681	0.0507	0.0404
2x8-0.91	0.4358	0.2083	0.1370	0.1029	0.0815	0.0579	0.0449
2x8-19	0.2508	0.1463	0.1061	0.0829	0.0693	0.0515	0.0410
2x8-21	0.2567	0.1459	0.1062	0.0838	0.0693	0.0515	0.0410
2x8-25	0.2184	0.1336	0.0996	0.0797	0.0666	0.0499	0.0400
2x10-0.91	0.4296	0.2073	0.1367	0.1019	0.0813	0.0578	0.0449
2x10-19	0.2531	0.1461	0.1065	0.0840	0.0696	0.0513	0.0410
2x10-25	0.2339	0.1393	0.1028	0.0817	0.0678	0.0507	0.0405
2x10-30	0.2083	0.1277	0.0975	0.0792	0.0677	0.0497	0.0400
2x12-0.91	0.4238	0.2060	0.1361	0.1016	0.0803	0.0577	0.0449
2x12-19	0.2492	0.1448	0.1057	0.0836	0.0695	0.0514	0.0409
2x12-30	0.2210	0.1344	0.1001	0.0800	0.0667	0.0500	0.0400
2x12-38	0.1901	0.1224	0.0933	0.0756	0.0636	0.0483	0.0390

Table C-5 THERM U-factors for 12oc, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4070	0.2017	0.1342	0.1007	0.0805	0.0572	0.0445
2x4-11	0.1556	0.1037	0.0808	0.0669	0.0572	0.0444	0.0364
2x4-13	0.1467	0.0981	0.0775	0.0645	0.0554	0.0432	0.0354
2x4-15	0.1402	0.0941	0.0747	0.0625	0.0539	0.0424	0.0350
2x6-0.91	0.4034	0.2010	0.1339	0.1004	0.0803	0.0573	0.0445
2x6-19	0.1226	0.0860	0.0686	0.0590	0.0513	0.0406	0.0338
2x6-21	0.1193	0.0830	0.0673	0.0572	0.0499	0.0399	0.0332
2x8-0.91	0.4004	0.2003	0.1340	0.1004	0.0803	0.0573	0.0446
2x8-19	0.1246	0.0866	0.0699	0.0592	0.0515	0.0409	0.0340
2x8-21	0.1276	0.0863	0.0694	0.0587	0.0510	0.0405	0.0337
2x8-25	0.1056	0.0767	0.0632	0.0542	0.0476	0.0384	0.0322
2x10-0.91	0.3980	0.1997	0.1333	0.1000	0.0802	0.0573	0.0446
2x10-19	0.1278	0.0870	0.0702	0.0593	0.0511	0.0407	0.0338
2x10-25	0.1094	0.0783	0.0643	0.0550	0.0479	0.0384	0.0322
2x10-30	0.0951	0.0707	0.0590	0.0504	0.0429	0.0353	0.0300
2x12-0.91	0.3961	0.1992	0.1331	0.0999	0.0800	0.0573	0.0442
2x12-19	0.1285	0.0881	0.0708	0.0598	0.0518	0.0411	0.0341
2x12-30	0.0994	0.0727	0.0604	0.0521	0.0459	0.0373	0.0314
2x12-38	0.0837	0.0641	0.0543	0.0477	0.0425	0.0350	0.0298

Table C-6 THERM U-factors for 12oc, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4104	0.2025	0.1345	0.1008	0.0806	0.0572	0.0445
2x4-11	0.1622	0.1060	0.0820	0.0677	0.0578	0.0448	0.0366
2x4-13	0.1533	0.1004	0.0788	0.0655	0.0561	0.0436	0.0358
2x4-15	0.1468	0.0964	0.0761	0.0634	0.0546	0.0428	0.0353
2x6-0.91	0.4071	0.2019	0.1343	0.1006	0.0804	0.0574	0.0446
2x6-19	0.1308	0.0893	0.0716	0.0605	0.0524	0.0413	0.0342
2x6-21	0.1278	0.0907	0.0694	0.0587	0.0510	0.0406	0.0337
2x8-0.91	0.4040	0.2012	0.1343	0.1006	0.0804	0.0574	0.0446
2x8-19	0.1355	0.0910	0.0726	0.0611	0.0529	0.0417	0.0344
2x8-21	0.1392	0.0907	0.0721	0.0605	0.0524	0.0414	0.0343
2x8-25	0.1145	0.0807	0.0658	0.0561	0.0490	0.0393	0.0329
2x10-0.91	0.4013	0.2000	0.1337	0.1002	0.0804	0.0574	0.0446
2x10-19	0.1401	0.0917	0.0731	0.0613	0.0526	0.0416	0.0344
2x10-25	0.1208	0.0833	0.0675	0.0573	0.0496	0.0395	0.0329
2x10-30	0.1045	0.0753	0.0621	0.0502	0.0445	0.0363	0.0308
2x12-0.91	0.3990	0.2000	0.1334	0.1001	0.0801	0.0572	0.0442
2x12-19	0.1409	0.0929	0.0737	0.0618	0.0534	0.0420	0.0347
2x12-30	0.1113	0.0782	0.0640	0.0547	0.0480	0.0386	0.0324
2x12-38	0.0929	0.0689	0.0576	0.0502	0.0445	0.0363	0.0307

Table C-7 THERM U-factors for 12oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4135	0.2032	0.1348	0.1010	0.0807	0.0573	0.0446
2x4-11	0.1674	0.1077	0.0830	0.0684	0.0583	0.0451	0.0368
2x4-13	0.1584	0.1022	0.0798	0.0661	0.0566	0.0439	0.0360
2x4-15	0.1520	0.0982	0.0771	0.0641	0.0551	0.0431	0.0355
2x6-0.91	0.4107	0.2027	0.1346	0.1008	0.0805	0.0574	0.0446
2x6-19	0.1376	0.0919	0.0732	0.0616	0.0532	0.0418	0.0346
2x6-21	0.1348	0.0891	0.0711	0.0598	0.0518	0.0411	0.0341
2x8-0.91	0.4075	0.2020	0.1347	0.1008	0.0806	0.0575	0.0446
2x8-19	0.1449	0.0945	0.0747	0.0626	0.0540	0.0424	0.0347
2x8-21	0.1493	0.0942	0.0742	0.0620	0.0534	0.0421	0.0347
2x8-25	0.1220	0.0839	0.0678	0.0575	0.0501	0.0400	0.0333
2x10-0.91	0.4047	0.2013	0.1340	0.1004	0.0805	0.0574	0.0446
2x10-19	0.1510	0.0956	0.0754	0.0629	0.0538	0.0423	0.0349
2x10-25	0.1310	0.0875	0.0701	0.0591	0.0510	0.0403	0.0335
2x10-30	0.1209	0.0824	0.0667	0.0531	0.0468	0.0378	0.0318
2x12-0.91	0.4021	0.2007	0.1337	0.1003	0.0802	0.0574	0.0442
2x12-19	0.1520	0.0969	0.0761	0.0634	0.0546	0.0428	0.0352
2x12-30	0.1220	0.0829	0.0670	0.0569	0.0496	0.0397	0.0331
2x12-38	0.1012	0.0729	0.0603	0.0522	0.0460	0.0373	0.0314

Table C-8 THERM U-factors for 12oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4166	0.2089	0.1351	0.1012	0.0808	0.0574	0.0446
2x4-11	0.1720	0.1092	0.0838	0.0689	0.0586	0.0453	0.0369
2x4-13	0.1631	0.1037	0.0807	0.0667	0.0570	0.0441	0.0361
2x4-15	0.1566	0.0997	0.0780	0.0647	0.0555	0.0434	0.0356
2x6-0.91	0.4145	0.2036	0.1350	0.1010	0.0807	0.0575	0.0446
2x6-19	0.1438	0.0942	0.0746	0.0625	0.0539	0.0422	0.0348
2x6-21	0.1415	0.0915	0.0725	0.0608	0.0526	0.0415	0.0344
2x8-0.91	0.4115	0.2029	0.1351	0.1011	0.0807	0.0575	0.0447
2x8-19	0.1541	0.0978	0.0766	0.0639	0.0549	0.0430	0.0350
2x8-21	0.1592	0.0971	0.0761	0.0632	0.0544	0.0426	0.0351
2x8-25	0.1292	0.0867	0.0696	0.0588	0.0511	0.0406	0.0337
2x10-0.91	0.4085	0.2023	0.1344	0.1007	0.0806	0.0575	0.0447
2x10-19	0.1620	0.0992	0.0775	0.0644	0.0548	0.0429	0.0353
2x10-25	0.1413	0.0914	0.0725	0.0608	0.0522	0.0411	0.0341
2x10-30	0.1358	0.0892	0.0710	0.0597	0.0517	0.0410	0.0344
2x12-0.91	0.4058	0.2016	0.1341	0.1005	0.0804	0.0575	0.0443
2x12-19	0.1633	0.1007	0.0783	0.0649	0.0557	0.0434	0.0357
2x12-30	0.1331	0.0878	0.0697	0.0588	0.0511	0.0406	0.0337
2x12-38	0.1093	0.0766	0.0620	0.0540	0.0474	0.0383	0.0321

Table C-9 THERM U-factors for 16oc, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4012	0.2003	0.1336	0.1002	0.0802	0.0573	0.0445
2x4-11	0.1358	0.0938	0.0748	0.0626	0.0540	0.0425	0.0350
2x4-13	0.1267	0.0879	0.0706	0.0596	0.0517	0.0410	0.0340
2x4-15	0.1196	0.0831	0.0672	0.0570	0.0497	0.0397	0.0331
2x6-0.91	0.3988	0.1959	0.1316	0.0991	0.0794	0.0569	0.0443
2x6-19	0.1040	0.0757	0.0623	0.0535	0.0470	0.0379	0.0319
2x6-21	0.1000	0.0719	0.0594	0.0512	0.0451	0.0364	0.0310
2x8-0.91	0.3966	0.1993	0.1331	0.0999	0.0800	0.0572	0.0445
2x8-19	0.1052	0.0754	0.0621	0.0533	0.0468	0.0378	0.0318
2x8-21	0.1071	0.0707	0.0587	0.0512	0.0448	0.0364	0.0308
2x8-25	0.0885	0.0661	0.0554	0.0482	0.0429	0.0352	0.0299
2x10-0.91	0.3947	0.1989	0.1329	0.0998	0.0799	0.0572	0.0445
2x10-19	0.1084	0.0767	0.0628	0.0537	0.0471	0.0380	0.0319
2x10-25	0.0857	0.0642	0.0540	0.0471	0.0419	0.0345	0.0294
2x10-30	0.0782	0.0584	0.0499	0.0440	0.0394	0.0328	0.0284
2x12-0.91	0.3922	0.1985	0.1327	0.0997	0.0799	0.0571	0.0444
2x12-19	0.1092	0.0755	0.0628	0.0526	0.0472	0.0381	0.0319
2x12-30	0.0823	0.0617	0.0521	0.0458	0.0408	0.0337	0.0288
2x12-38	0.0691	0.0541	0.0466	0.0414	0.0373	0.0313	0.0271

Table C-10 THERM U-factors for 16oc, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4038	0.2009	0.1338	0.1003	0.0803	0.0573	0.0446
2x4-11	0.1407	0.0955	0.0758	0.0633	0.0545	0.0428	0.0352
2x4-13	0.1316	0.0896	0.0716	0.0602	0.0522	0.0413	0.0342
2x4-15	0.1246	0.0849	0.0683	0.0577	0.0502	0.0400	0.0333
2x6-0.91	0.4017	0.2005	0.1337	0.1002	0.0802	0.0573	0.0445
2x6-19	0.1101	0.0782	0.0639	0.0546	0.0478	0.0385	0.0322
2x6-21	0.1064	0.0745	0.0610	0.0523	0.0460	0.0372	0.0314
2x8-0.91	0.3993	0.2000	0.1334	0.1001	0.0801	0.0572	0.0445
2x8-19	0.1134	0.0787	0.0642	0.0547	0.0479	0.0385	0.0323
2x8-21	0.1156	0.0736	0.0605	0.0520	0.0458	0.0371	0.0312
2x8-25	0.0952	0.0691	0.0574	0.0497	0.0440	0.0359	0.0304
2x10-0.91	0.3972	0.1995	0.1332	0.1000	0.0800	0.0572	0.0445
2x10-19	0.1178	0.0803	0.0650	0.0553	0.0483	0.0388	0.0325
2x10-25	0.0929	0.0675	0.0561	0.0486	0.0431	0.0353	0.0300
2x10-30	0.0853	0.0614	0.0519	0.0455	0.0406	0.0336	0.0288
2x12-0.91	0.3945	0.1991	0.1330	0.0999	0.0799	0.0571	0.0444
2x12-19	0.1190	0.0790	0.0650	0.0542	0.0484	0.0388	0.0325
2x12-30	0.0913	0.0659	0.0550	0.0479	0.0424	0.0348	0.0296
2x12-38	0.0761	0.0578	0.0492	0.0433	0.0389	0.0324	0.0279

Table C-11 THERM U-factors for 16oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4062	0.2015	0.1341	0.1005	0.0803	0.0573	0.0446
2x4-11	0.1446	0.0968	0.0758	0.0638	0.0548	0.0430	0.0353
2x4-13	0.1355	0.0909	0.0724	0.0608	0.0525	0.0415	0.0343
2x4-15	0.1285	0.0862	0.0690	0.0582	0.0506	0.0402	0.0335
2x6-0.91	0.4043	0.2011	0.1339	0.1004	0.0803	0.0573	0.0446
2x6-19	0.1152	0.0802	0.0651	0.0554	0.0485	0.0389	0.0325
2x6-21	0.1147	0.0765	0.0622	0.0532	0.0467	0.0376	0.0317
2x8-0.91	0.4020	0.2007	0.1337	0.1003	0.0802	0.0573	0.0445
2x8-19	0.1205	0.0814	0.0658	0.0559	0.0488	0.0391	0.0327
2x8-21	0.1237	0.0759	0.0620	0.0532	0.0465	0.0376	0.0316
2x8-25	0.1005	0.0715	0.0590	0.0508	0.0448	0.0365	0.0308
2x10-0.91	0.3997	0.2001	0.1335	0.1001	0.0801	0.0573	0.0446
2x10-19	0.1263	0.0833	0.0668	0.0566	0.0493	0.0394	0.0329
2x10-25	0.1076	0.0702	0.0579	0.0499	0.0441	0.0360	0.0304
2x10-30	0.0915	0.0637	0.0535	0.0466	0.0415	0.0343	0.0292
2x12-0.91	0.3969	0.1997	0.1333	0.1000	0.0800	0.0572	0.0445
2x12-19	0.1277	0.0819	0.0668	0.0554	0.0494	0.0394	0.0329
2x12-30	0.0995	0.0695	0.0573	0.0496	0.0437	0.0357	0.0302
2x12-38	0.0822	0.0608	0.0513	0.0449	0.0401	0.0333	0.0285

Table C-12 THERM U-factors for 16oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4085	0.2020	0.1343	0.1006	0.0804	0.0574	0.0446
2x4-11	0.1481	0.0979	0.0791	0.0642	0.0551	0.0432	0.0355
2x4-13	0.1390	0.0920	0.0730	0.0612	0.0528	0.0417	0.0345
2x4-15	0.1320	0.0873	0.0699	0.0587	0.0509	0.0404	0.0336
2x6-0.91	0.4072	0.2018	0.1342	0.1006	0.0804	0.0574	0.0446
2x6-19	0.1199	0.0819	0.0661	0.0562	0.0490	0.0392	0.0328
2x6-21	0.1195	0.0783	0.0633	0.0539	0.0472	0.0380	0.0319
2x8-0.91	0.4049	0.2014	0.1340	0.1004	0.0803	0.0573	0.0446
2x8-19	0.1275	0.0839	0.0673	0.0569	0.0495	0.0395	0.0330
2x8-21	0.1308	0.0780	0.0633	0.0539	0.0472	0.0380	0.0319
2x8-25	0.1062	0.0737	0.0603	0.0518	0.0456	0.0370	0.0312
2x10-0.91	0.4027	0.2008	0.1338	0.1003	0.0802	0.0574	0.0446
2x10-19	0.1303	0.0862	0.0685	0.0577	0.0501	0.0399	0.0332
2x10-25	0.1153	0.0770	0.0595	0.0510	0.0450	0.0365	0.0308
2x10-30	0.0976	0.0688	0.0549	0.0477	0.0424	0.0348	0.0296
2x12-0.91	0.3997	0.2003	0.1336	0.1002	0.0801	0.0572	0.0445
2x12-19	0.1367	0.0847	0.0685	0.0565	0.0502	0.0400	0.0333
2x12-30	0.1080	0.0729	0.0594	0.0512	0.0449	0.0365	0.0308
2x12-38	0.0884	0.0636	0.0532	0.0463	0.0413	0.0340	0.0290

Table C-13 THERM U-factors for oc24, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.3951	0.1988	0.1328	0.0997	0.0799	0.0571	0.0444
2x4-11	0.1159	0.0839	0.0682	0.0579	0.0504	0.0402	0.0334
2x4-13	0.1063	0.0774	0.0636	0.0544	0.0477	0.0384	0.0321
2x4-15	0.0990	0.0723	0.0598	0.0515	0.0454	0.0368	0.0310
2x6-0.91	0.3942	0.1938	0.1336	0.1002	0.0802	0.0573	0.0445
2x6-19	0.0928	0.0672	0.0566	0.0490	0.0434	0.0355	0.0301
2x6-21	0.0808	0.0607	0.0513	0.0449	0.0401	0.0332	0.0284
2x8-0.91	0.3927	0.1985	0.1327	0.0997	0.0798	0.0571	0.0444
2x8-19	0.0856	0.0642	0.0539	0.0470	0.0418	0.0344	0.0298
2x8-21	0.0854	0.0625	0.0523	0.0456	0.0406	0.0336	0.0285
2x8-25	0.0714	0.0554	0.0474	0.0419	0.0377	0.0316	0.0272
2x10-0.91	0.3951	0.1989	0.1329	0.0998	0.0799	0.0571	0.0445
2x10-19	0.0881	0.0651	0.0545	0.0474	0.0421	0.0344	0.0294
2x10-25	0.0728	0.0554	0.0476	0.0420	0.0379	0.0316	0.0273
2x10-30	0.0626	0.0509	0.0440	0.0382	0.0346	0.0300	0.0260
2x12-0.91	0.3936	0.1997	0.1328	0.0997	0.0799	0.0571	0.0445
2x12-19	0.0890	0.0653	0.0546	0.0476	0.0420	0.0345	0.0294
2x12-30	0.0649	0.0505	0.0435	0.0388	0.0355	0.0297	0.0256
2x12-38	0.0544	0.0444	0.0386	0.0346	0.0316	0.0272	0.0238

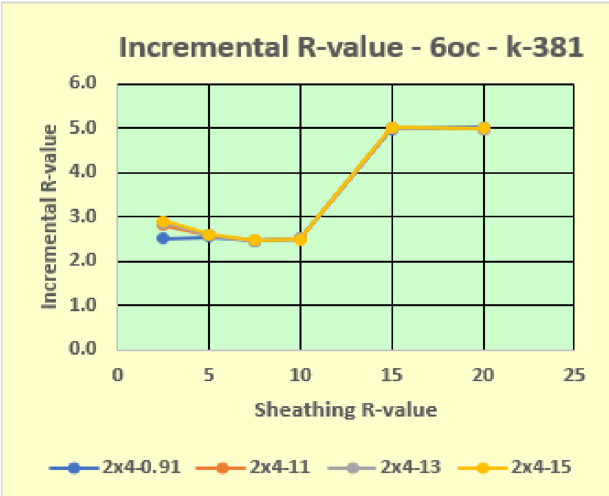
Table C-14 THERM U-factors for oc24, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.3968	0.1992	0.1330	0.0998	0.0799	0.0571	0.0444
2x4-11	0.1192	0.0850	0.0689	0.0583	0.0507	0.0404	0.0335
2x4-13	0.1096	0.0785	0.0642	0.0548	0.0480	0.0386	0.0323
2x4-15	0.1023	0.0735	0.0605	0.0519	0.0457	0.0370	0.0312
2x6-0.91	0.3961	0.1942	0.1334	0.1001	0.0801	0.0572	0.0445
2x6-19	0.0895	0.0660	0.0558	0.0484	0.0429	0.0352	0.0299
2x6-21	0.0851	0.0624	0.0523	0.0456	0.0407	0.0338	0.0287
2x8-0.91	0.3945	0.1989	0.1329	0.0998	0.0799	0.0571	0.0445
2x8-19	0.0910	0.0663	0.0553	0.0480	0.0426	0.0349	0.0297
2x8-21	0.0913	0.0647	0.0537	0.0466	0.0414	0.0340	0.0287
2x8-25	0.0758	0.0574	0.0488	0.0429	0.0385	0.0321	0.0276
2x10-0.91	0.3934	0.1985	0.1328	0.0997	0.0799	0.0571	0.0444
2x10-19	0.0945	0.0675	0.0560	0.0485	0.0429	0.0349	0.0298
2x10-25	0.0786	0.0583	0.0493	0.0432	0.0388	0.0323	0.0277
2x10-30	0.0669	0.0532	0.0456	0.0394	0.0356	0.0306	0.0265
2x12-0.91	0.3920	0.1982	0.1326	0.0996	0.0798	0.0571	0.0445
2x12-19	0.0957	0.0679	0.0562	0.0487	0.0428	0.0350	0.0297
2x12-30	0.0709	0.0533	0.0454	0.0402	0.0364	0.0304	0.0262
2x12-38	0.0591	0.0464	0.0403	0.0359	0.0327	0.0279	0.0244

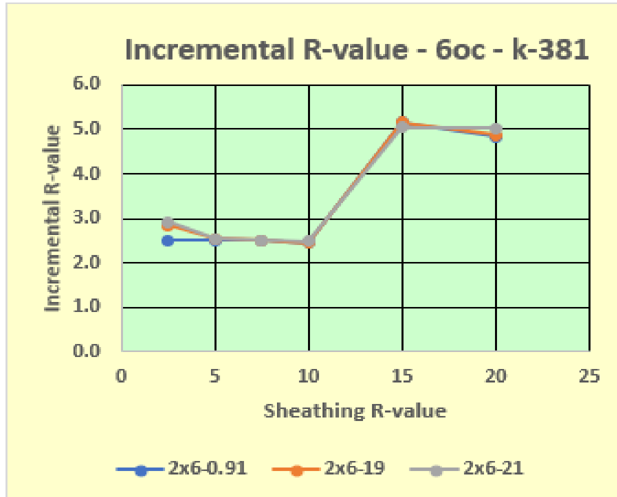
Table C-15 THERM U-factors for 24oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.3984	0.1995	0.1332	0.0999	0.0800	0.0572	0.0445
2x4-11	0.1217	0.0858	0.0694	0.0587	0.0510	0.0405	0.0336
2x4-13	0.1122	0.0794	0.0647	0.0552	0.0483	0.0387	0.0324
2x4-15	0.1049	0.0743	0.0610	0.0523	0.0460	0.0372	0.0313
2x6-0.91	0.3979	0.1946	0.1332	0.1000	0.0800	0.0572	0.0445
2x6-19	0.0854	0.0643	0.0547	0.0477	0.0424	0.0348	0.0296
2x6-21	0.0886	0.0638	0.0532	0.0462	0.0411	0.0339	0.0289
2x8-0.91	0.3963	0.1993	0.1331	0.0999	0.0800	0.0572	0.0445
2x8-19	0.0958	0.0681	0.0564	0.0488	0.0430	0.0353	0.0299
2x8-21	0.0965	0.0664	0.0548	0.0473	0.0419	0.0344	0.0289
2x8-25	0.0714	0.0554	0.0474	0.0419	0.0377	0.0316	0.0272
2x10-0.91	0.3917	0.1981	0.1326	0.0996	0.0798	0.0571	0.0444
2x10-19	0.1002	0.0696	0.0572	0.0493	0.0436	0.0353	0.0301
2x10-25	0.0837	0.0590	0.0506	0.0442	0.0396	0.0328	0.0281
2x10-30	0.0706	0.0551	0.0469	0.0403	0.0363	0.0311	0.0269
2x12-0.91	0.3905	0.1985	0.1324	0.0995	0.0797	0.0570	0.0445
2x12-19	0.1018	0.0699	0.0574	0.0496	0.0434	0.0354	0.0300
2x12-30	0.0764	0.0556	0.0470	0.0414	0.0372	0.0310	0.0267
2x12-38	0.0632	0.0484	0.0418	0.0370	0.0336	0.0286	0.0249

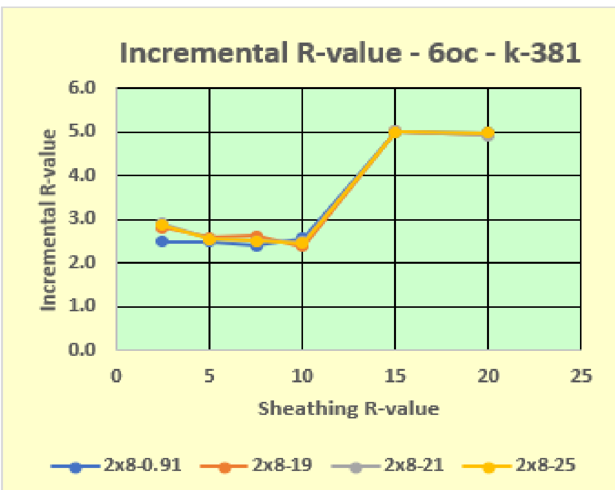
Table C-16 THERM U-factors for 24oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.3999	0.1999	0.1333	0.1000	0.0800	0.0572	0.0445
2x4-11	0.1241	0.0866	0.0698	0.0589	0.0512	0.0406	0.0337
2x4-13	0.1145	0.0802	0.0652	0.0555	0.0485	0.0388	0.0323
2x4-15	0.1073	0.0751	0.0614	0.0526	0.0462	0.0373	0.0314
2x6-0.91	0.3998	0.1950	0.1338	0.1003	0.0802	0.0573	0.0446
2x6-19	0.0960	0.0683	0.0573	0.0495	0.0437	0.0357	0.0302
2x6-21	0.0918	0.0649	0.0539	0.0467	0.0415	0.0341	0.0291
2x8-0.91	0.3982	0.1998	0.1333	0.1000	0.0801	0.0572	0.0445
2x8-19	0.1004	0.0698	0.0574	0.0494	0.0437	0.0356	0.0301
2x8-21	0.1015	0.0681	0.0557	0.0480	0.0424	0.0347	0.0291
2x8-25	0.0831	0.0604	0.0507	0.0443	0.0396	0.0328	0.0281
2x10-0.91	0.3970	0.1994	0.1332	0.1000	0.0800	0.0572	0.0445
2x10-19	0.1060	0.0715	0.0584	0.0501	0.0441	0.0356	0.0304
2x10-25	0.0889	0.0624	0.0519	0.0451	0.0403	0.0332	0.0284
2x10-30	0.0743	0.0568	0.0480	0.0412	0.0370	0.0316	0.0272
2x12-0.91	0.3954	0.2003	0.1330	0.0999	0.0799	0.0571	0.0446
2x12-19	0.1080	0.0719	0.0586	0.0504	0.0440	0.0358	0.0303
2x12-30	0.0821	0.0579	0.0484	0.0425	0.0378	0.0316	0.0271
2x12-38	0.0673	0.0503	0.0431	0.0380	0.0344	0.0291	0.0253

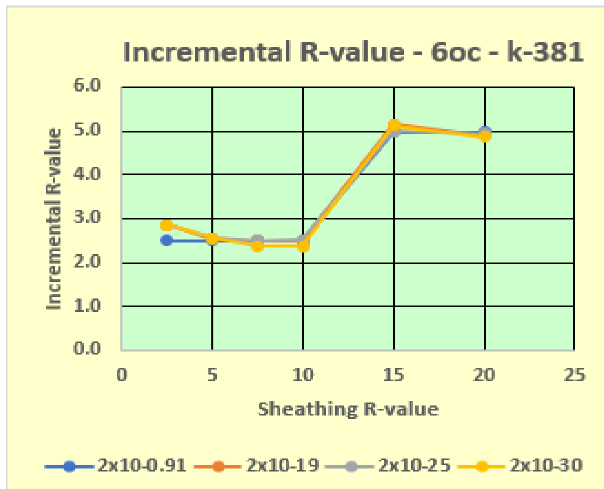
Appendix D - Incremental Thermal Impact of Adding Rigid Foam Board Sheathings

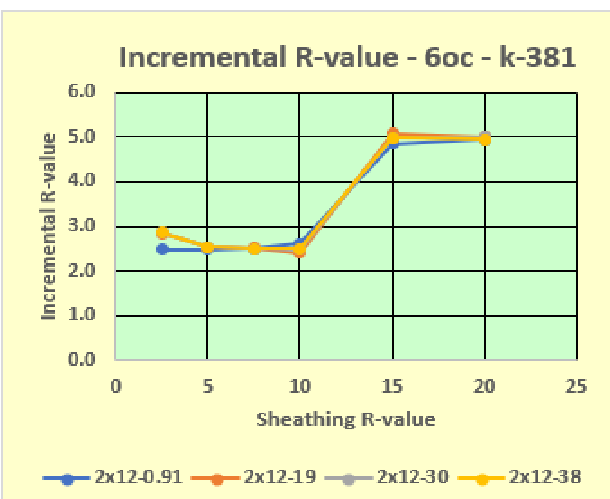
The figures below present the incremental R-values for adding six rigid form board sheathings to all nineteen of the cavity insulations.

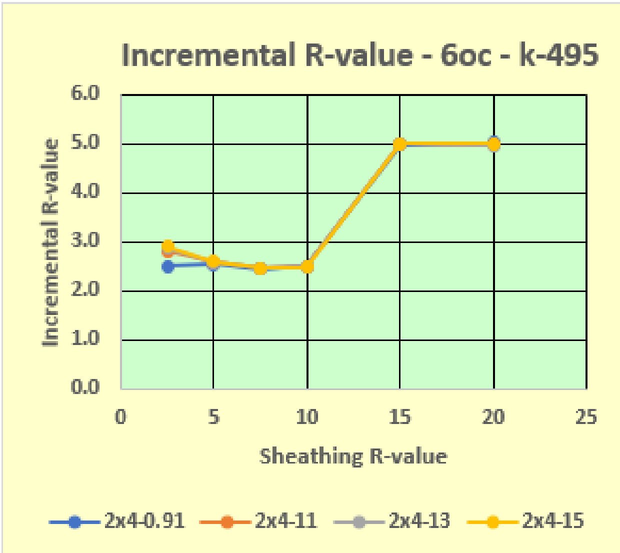


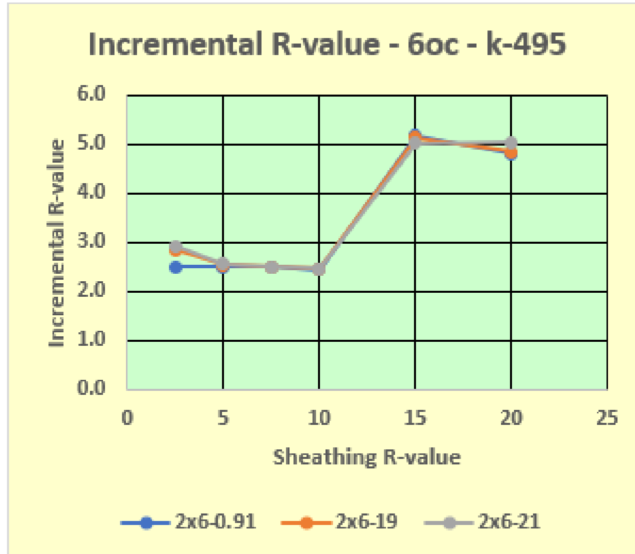


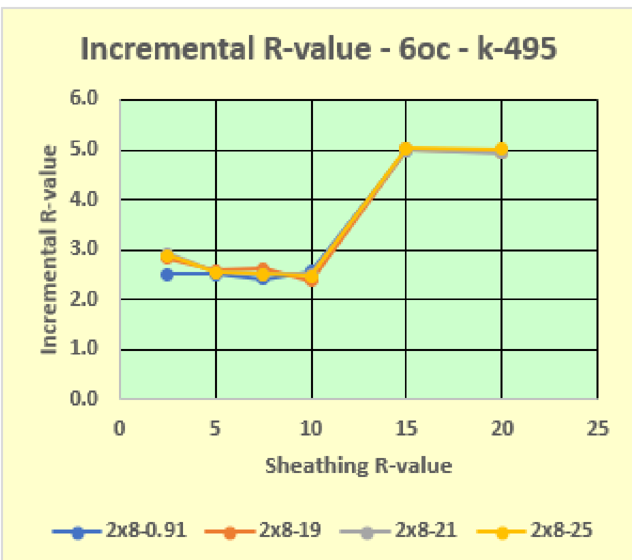


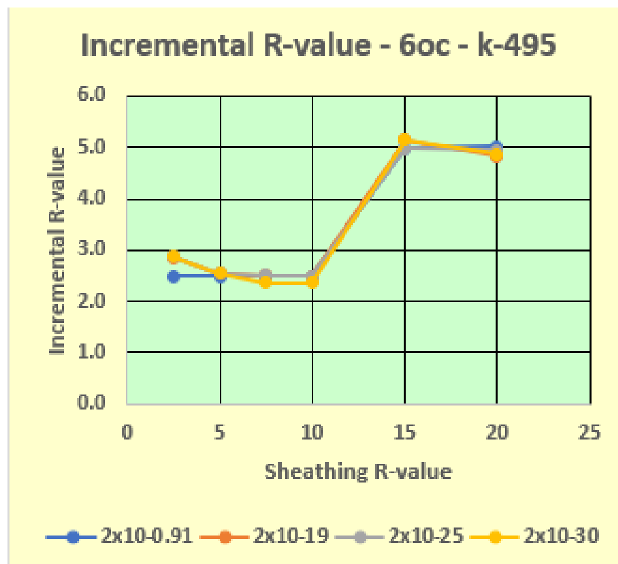


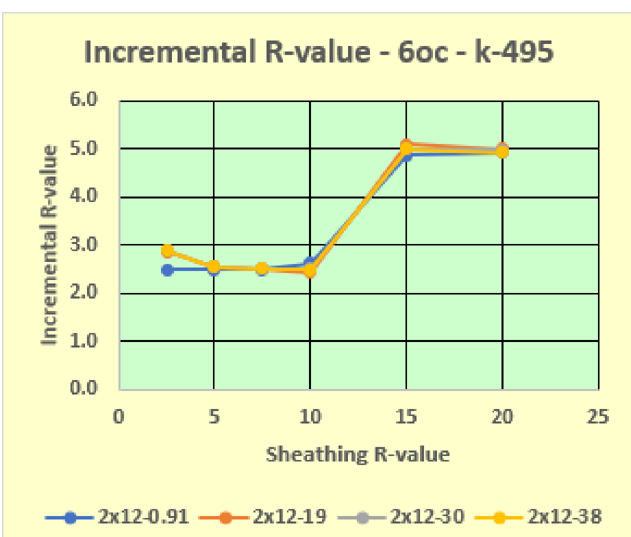


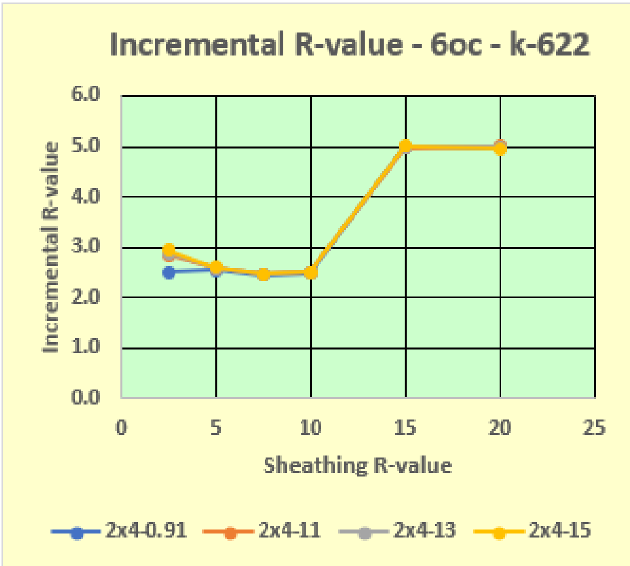

Incremental R-value - 6oc - k-495
Incremental R-value
Sheathing R-value
2x4-0.91
2x4-11
2x4-13
2x4-15


Incremental R-value - 6oc - k-495
Incremental R-value
Sheathing R-value
2x6-0.91
2x6-19
2x6-21


Incremental R-value - 6oc - k-495
Incremental R-value
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25


Incremental R-value - 6oc - k-495
Incremental R-value
Sheathing R-value
2x10-0.91
2x10-19
2x10-25
2x10-30


Incremental R-value - 6oc - k-495
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38


Incremental R-value - 6oc - k-622
Incremental R-value
Sheathing R-value
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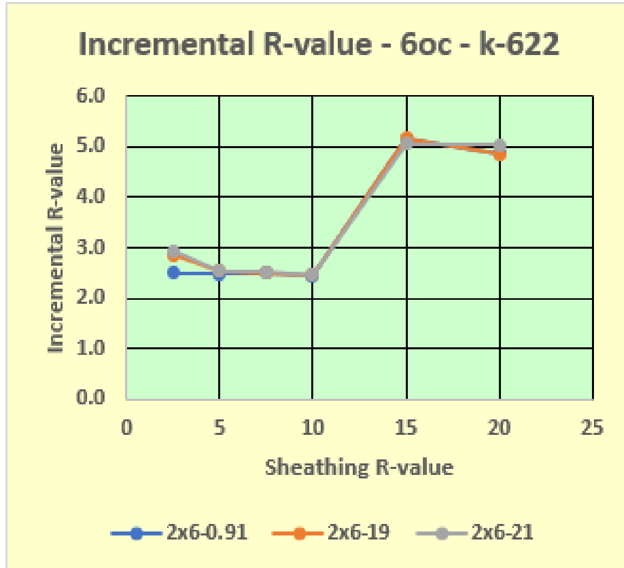
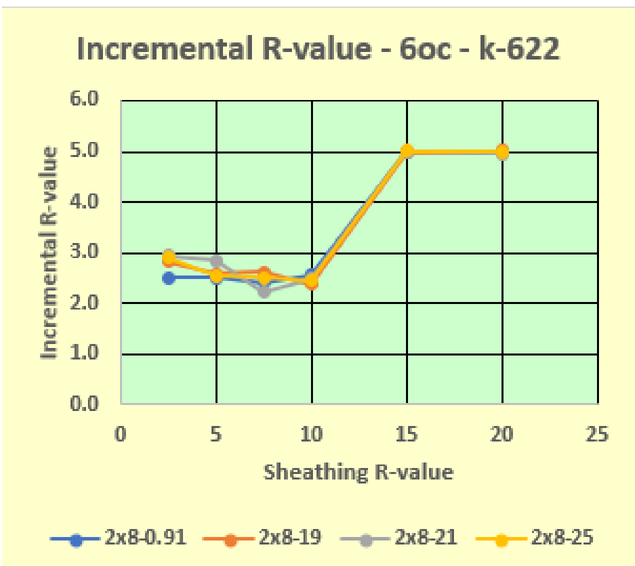
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
2x4-0.91
2x4-11
2x4-13
2x4-15


Incremental R-value - 6oc - k-622
Incremental R-value
Sheathing R-value
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
2x6-0.91
2x6-19
2x6-21


Incremental R-value - 6oc - k-622
Incremental R-value
Sheathing R-value
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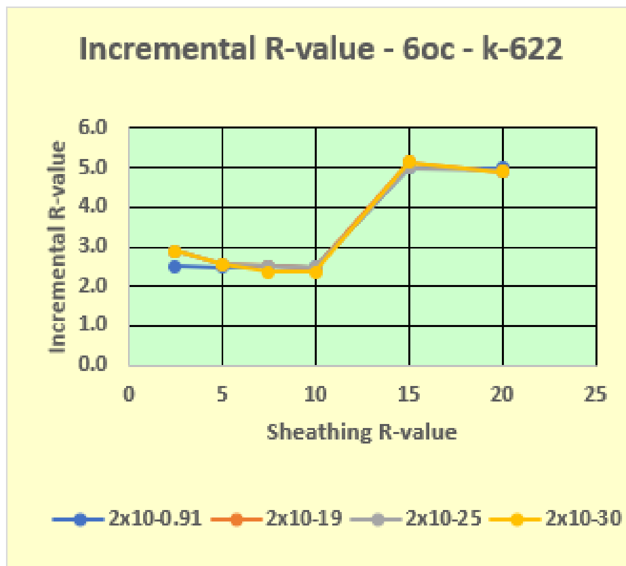
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
2x8-0.91
2x8-19
2x8-21
2x8-25


Incremental R-value - 6oc - k-622
Incremental R-value
Sheathing R-value
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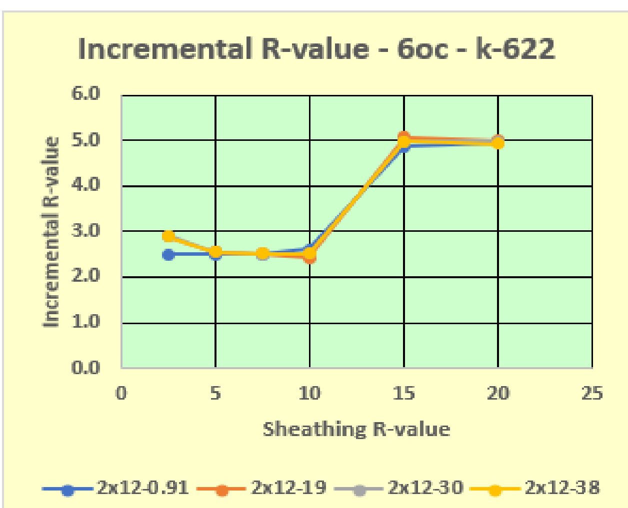
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
2x10-0.91
2x10-19
2x10-25
2x10-30


Incremental R-value - 6oc - k-622
Incremental R-value
Sheathing R-value
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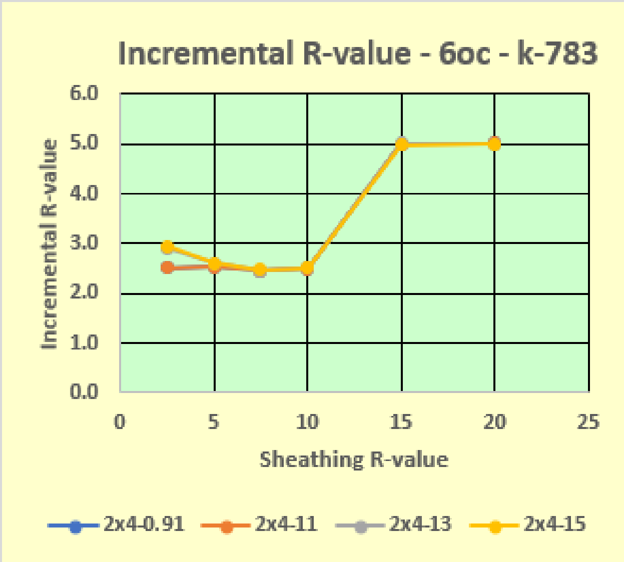
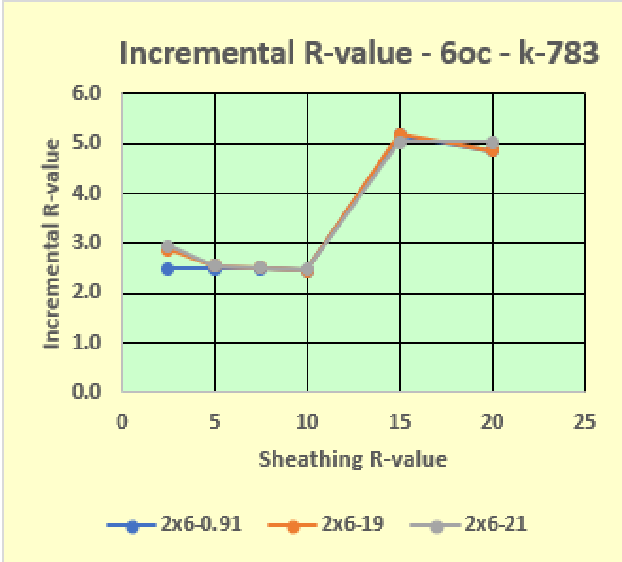
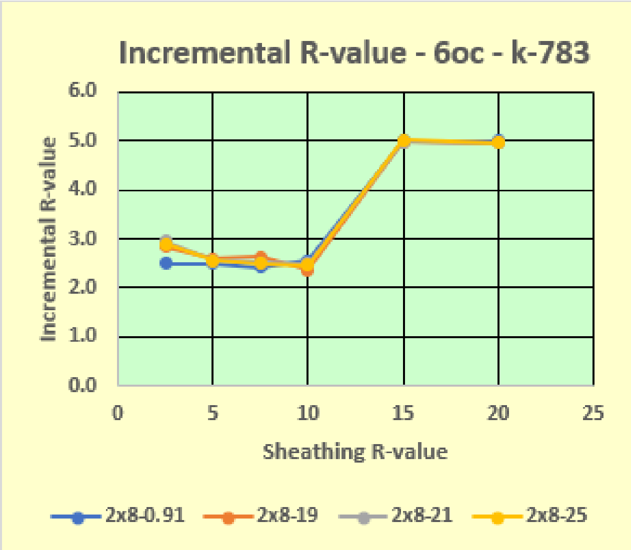
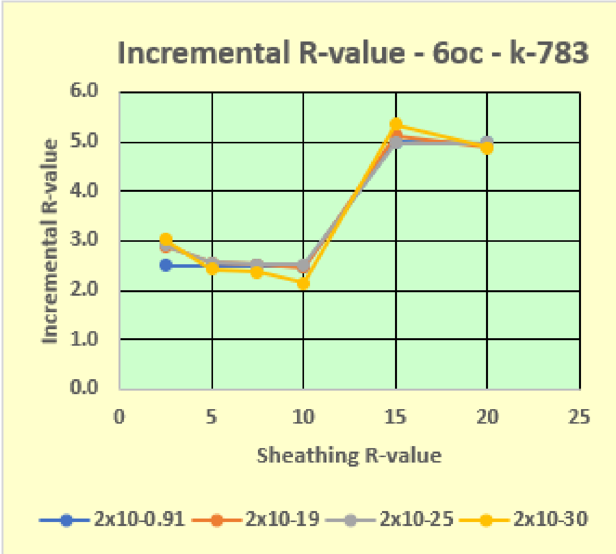
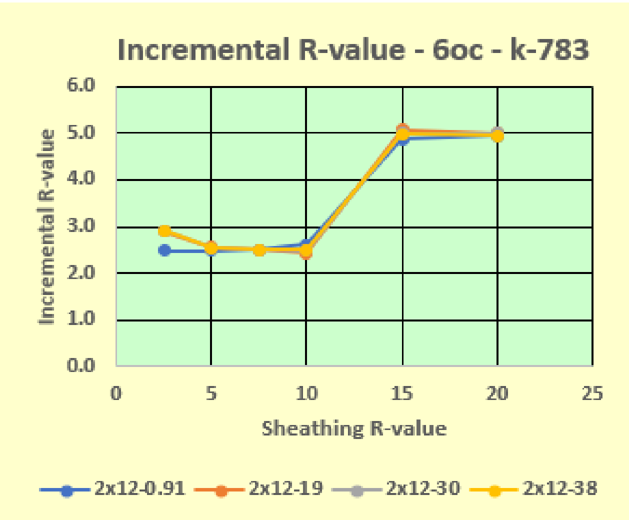
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
2x12-0.91
2x12-19
2x12-30
2x12-38

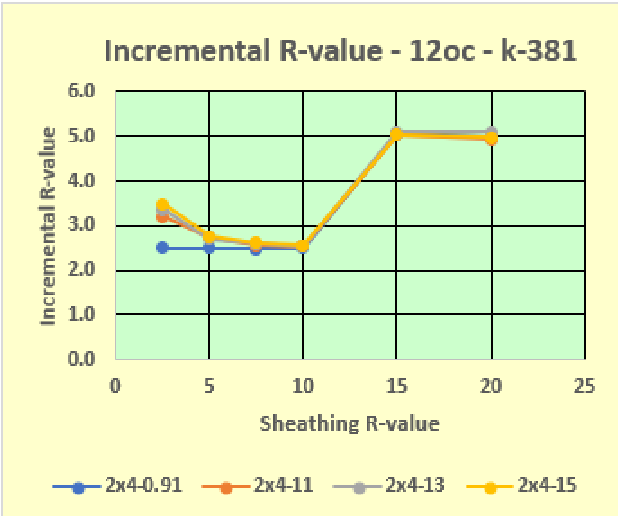

Incremental R-value - 6oc - k-783
Incremental R-value
Sheathing R-value
2x4-0.91
2x4-11
2x4-13
2x4-15

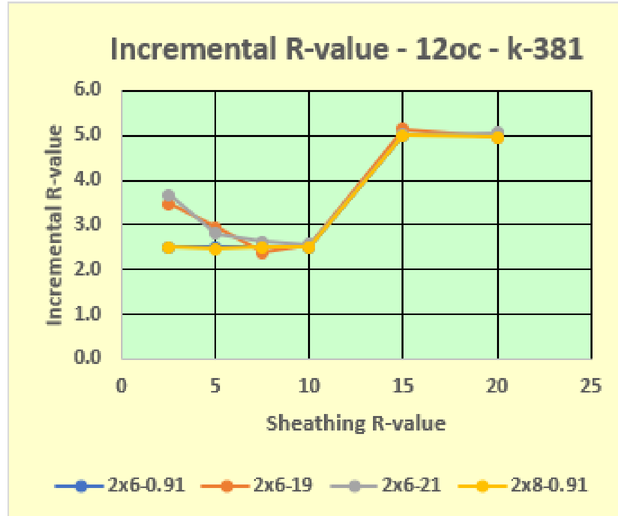

Incremental R-value - 6oc - k-783
Incremental R-value
Sheathing R-value
2x6-0.91
2x6-19
2x6-21

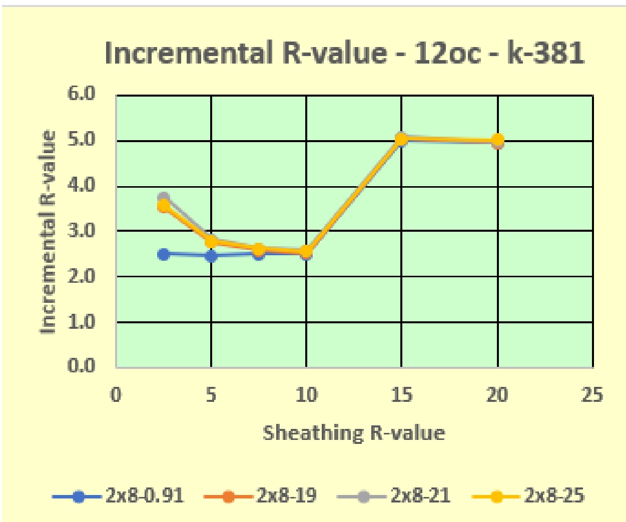

Incremental R-value - 6oc - k-783
Incremental R-value
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25

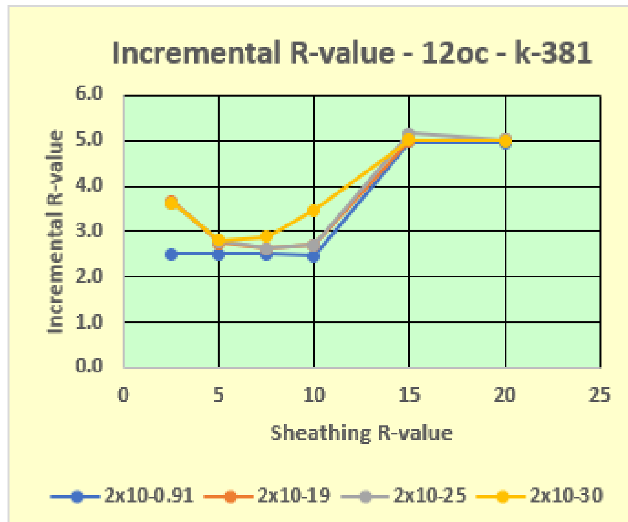

Incremental R-value - 6oc - k-783
Incremental R-value
Sheathing R-value
2x10-0.91
2x10-19
2x10-25
2x10-30

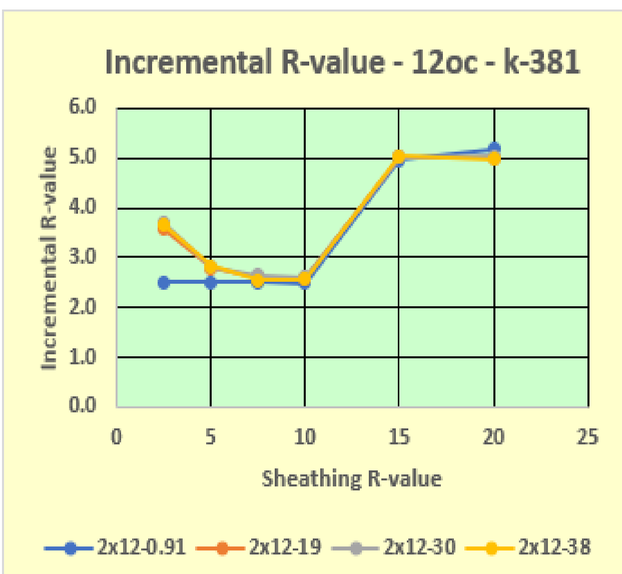

Incremental R-value - 6oc - k-783
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38

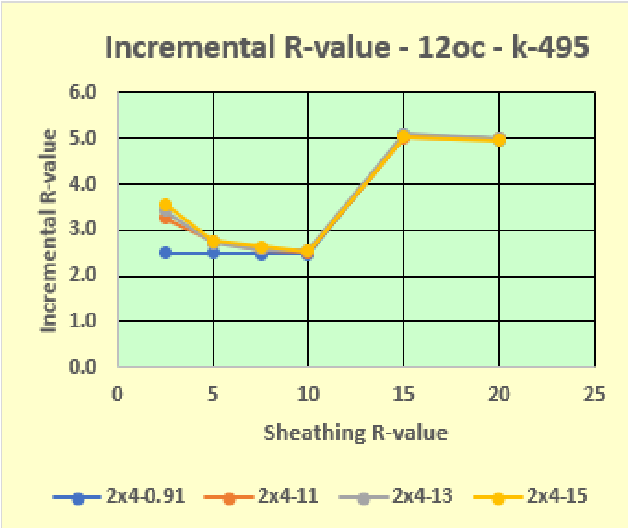

Incremental R-value - 12oc - k-381
Incremental R-value
Sheathing R-value
2x4-0.91
2x4-11
2x4-13
2x4-15

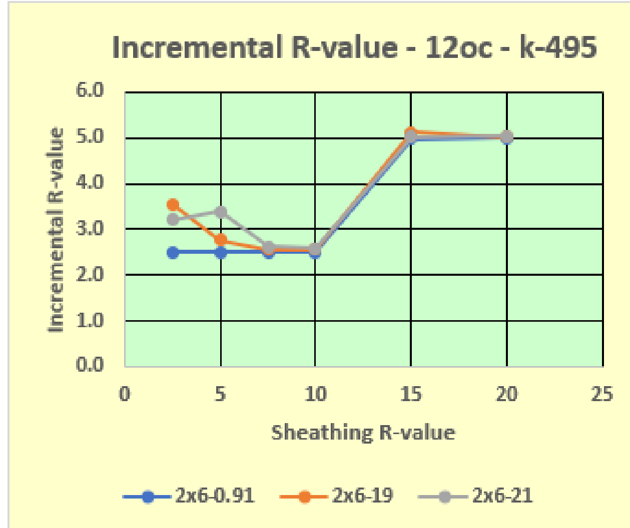

Incremental R-value - 12oc - k-381
Incremental R-value
Sheathing R-value
2x6-0.91
2x6-19
2x6-21
2x8-0.91

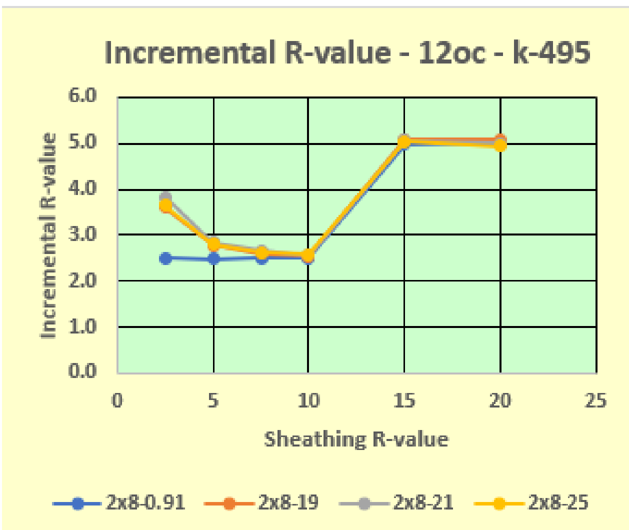

Incremental R-value - 12oc - k-381
Incremental R-value
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25

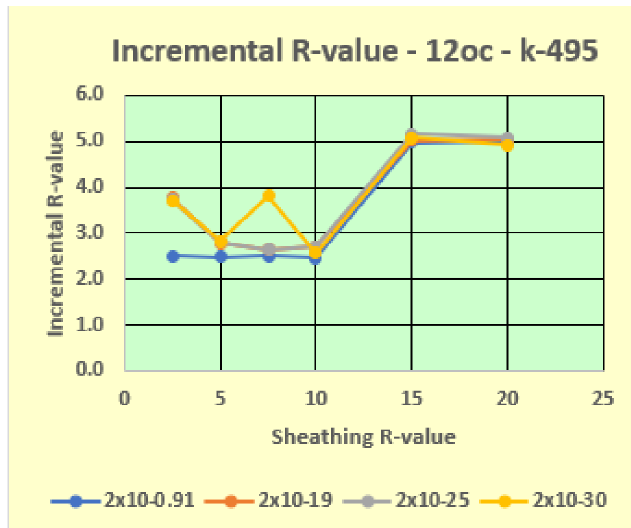

Incremental R-value - 12oc - k-381
Incremental R-value
Sheathing R-value
2x10-0.91
2x10-19
2x10-25
2x10-30

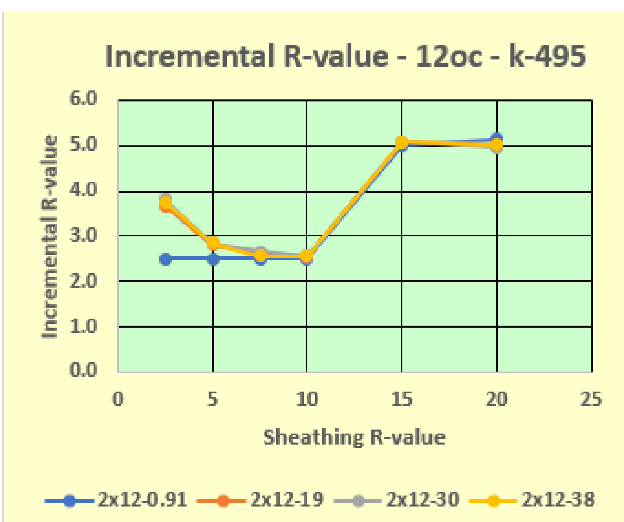

Incremental R-value - 12oc - k-381
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38


Incremental R-value - 12oc - k-495
Incremental R-value
Sheathing R-value
2x4-0.91
2x4-11
2x4-13
2x4-15


Incremental R-value - 12oc - k-495
Incremental R-value
Sheathing R-value
2x6-0.91
2x6-19
2x6-21


Incremental R-value - 12oc - k-495
Incremental R-value
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25


Incremental R-value - 12oc - k-495
Incremental R-value
Sheathing R-value
2x10-0.91
2x10-19
2x10-25
2x10-30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Incremental R-value
Sheathing R-value
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2x12-19
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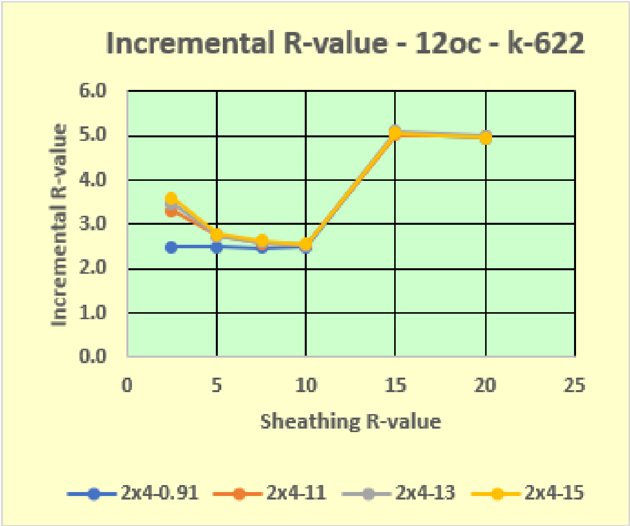
2x12-38


Incremental R-value - 12oc - k-622
Incremental R-value
Sheathing R-value
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2x4-11
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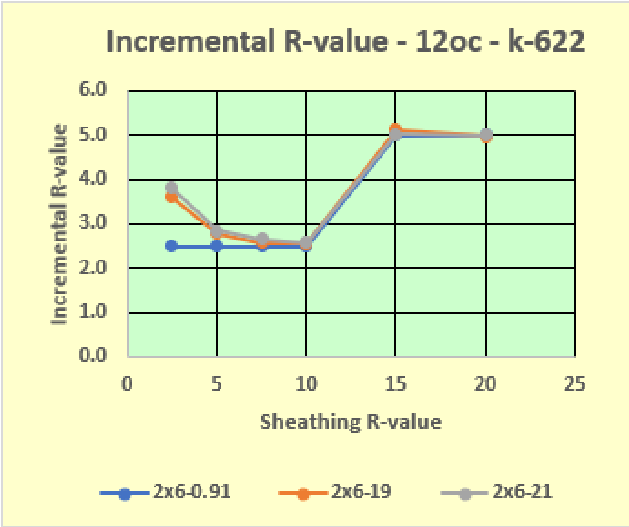
Incremental R-value - 12oc - k-622
Incremental R-value
Sheathing R-value
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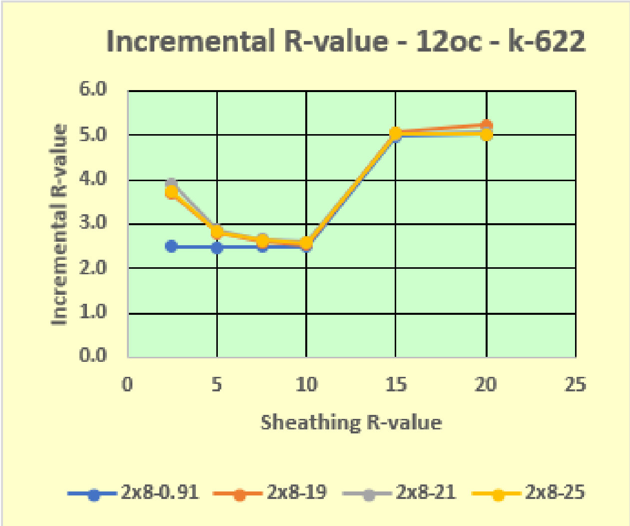
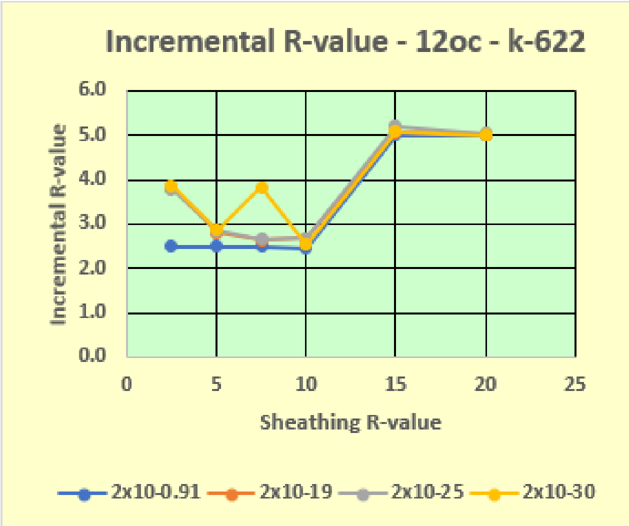
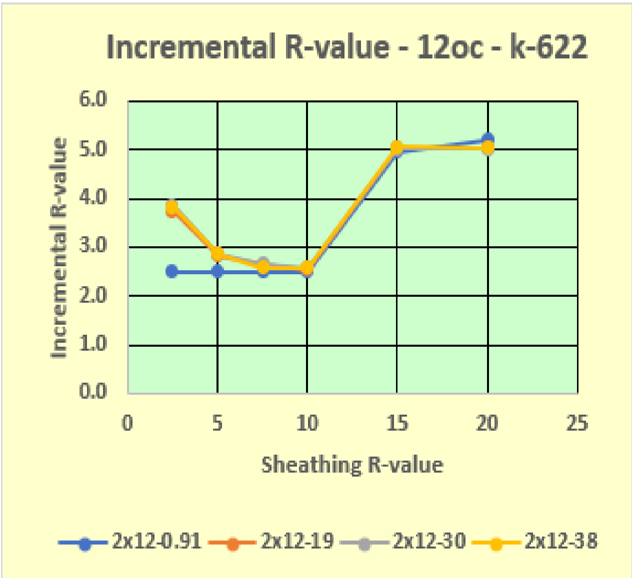
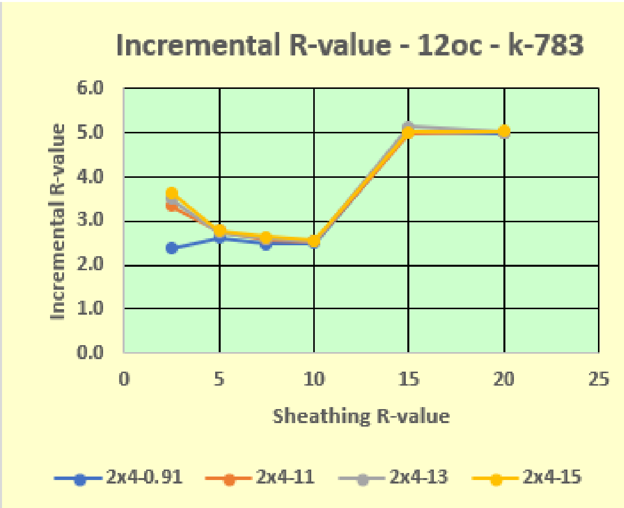
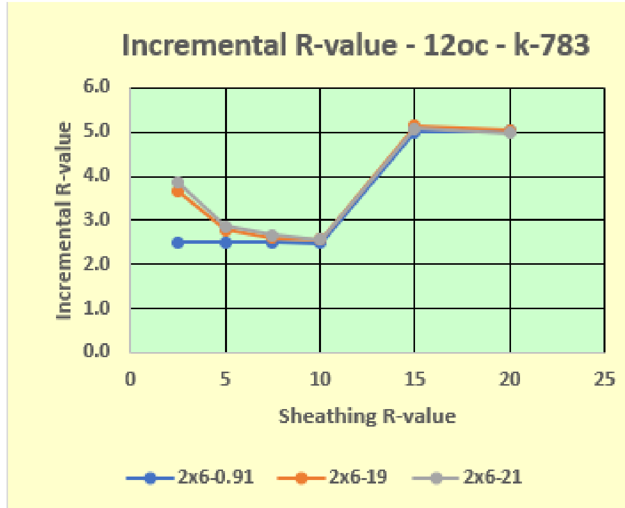
2x6-19
2x6-21


Incremental R-value - 12oc - k-622
Incremental R-value
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25


Incremental R-value - 12oc - k-622
Incremental R-value
Sheathing R-value
2x10-0.91
2x10-19
2x10-25
2x10-30


Incremental R-value - 12oc - k-622
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38


Incremental R-value - 12oc - k-783
Incremental R-value
Sheathing R-value
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
2x4-0.91
2x4-11
2x4-13
2x4-15


Incremental R-value - 12oc - k-783
Incremental R-value
Sheathing R-value
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5.0
4.0
3.0
2.0
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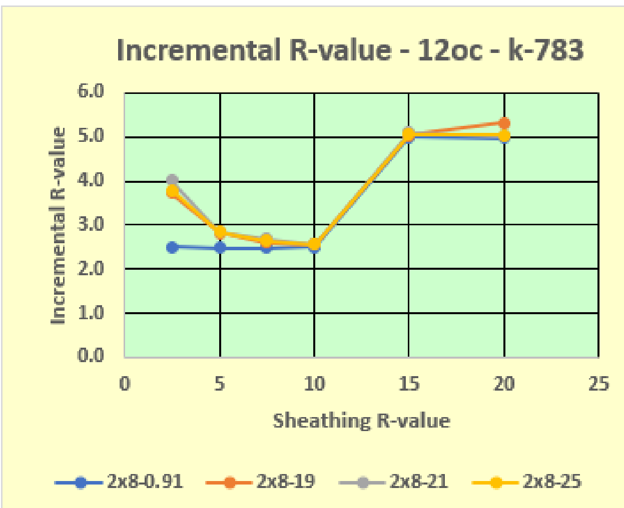
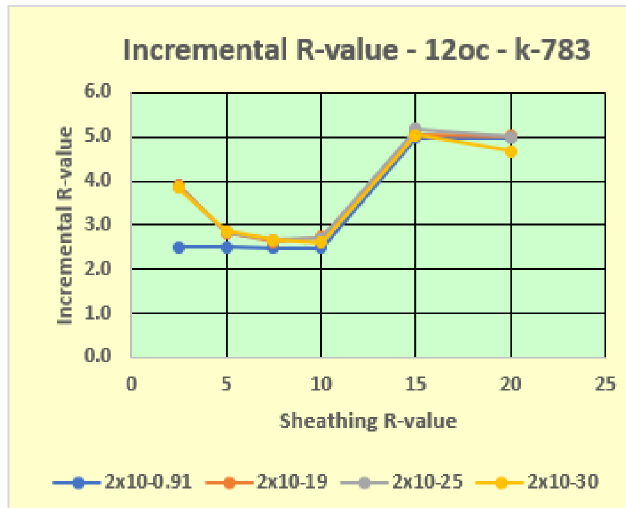
0.0
0
5
10
15
20
25
2x6-0.91
2x6-19
2x6-21


Incremental R-value - 12oc - k-783
Incremental R-value
Sheathing R-value
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
2x8-0.91
2x8-19
2x8-21
2x8-25


Incremental R-value - 12oc - k-783
Incremental R-value
Sheathing R-value
6.0
5.0
4.0
3.0
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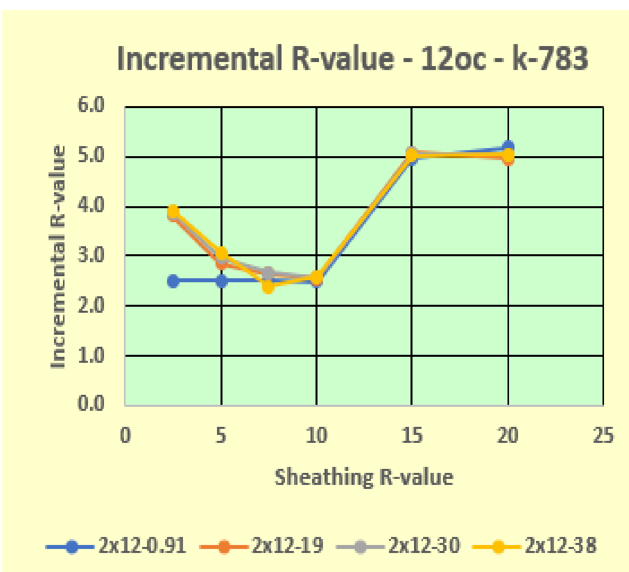
0
5
10
15
20
25
2x10-0.91
2x10-19
2x10-25
2x10-30


Incremental R-value - 12oc - k-783
Incremental R-value
Sheathing R-value
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4.0
3.0
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1.0
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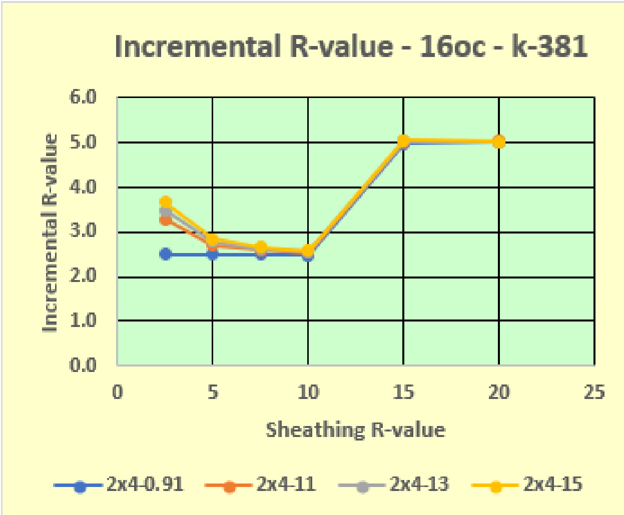
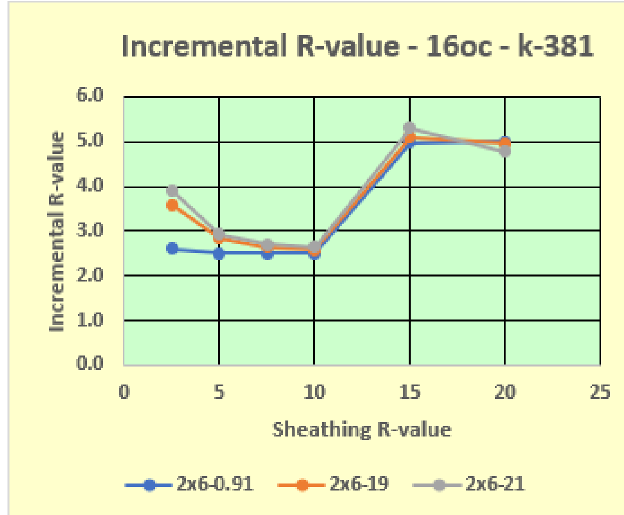
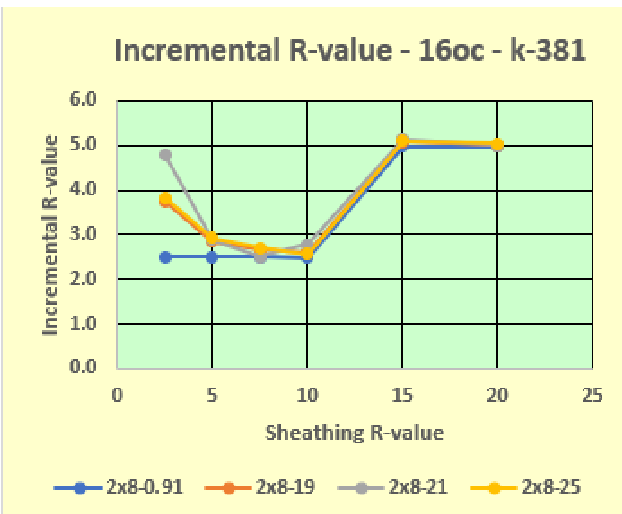
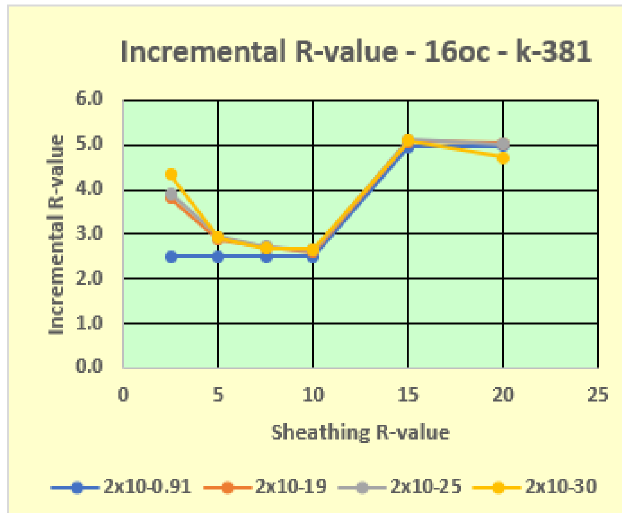
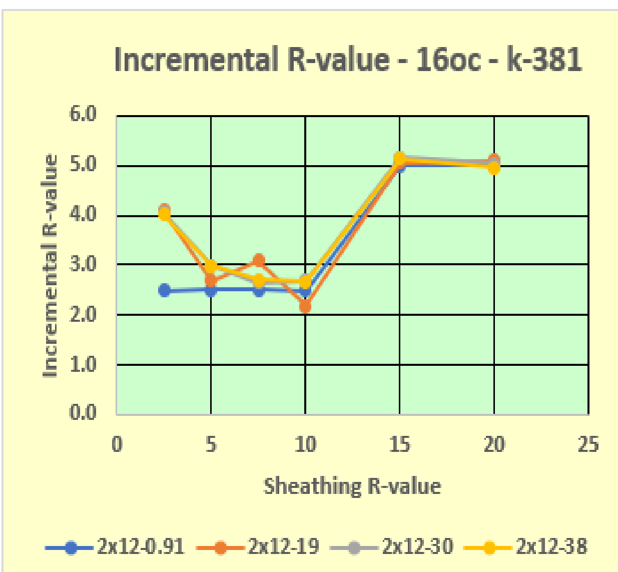
0
5
10
15
20
25
2x12-0.91
2x12-19
2x12-30
2x12-38

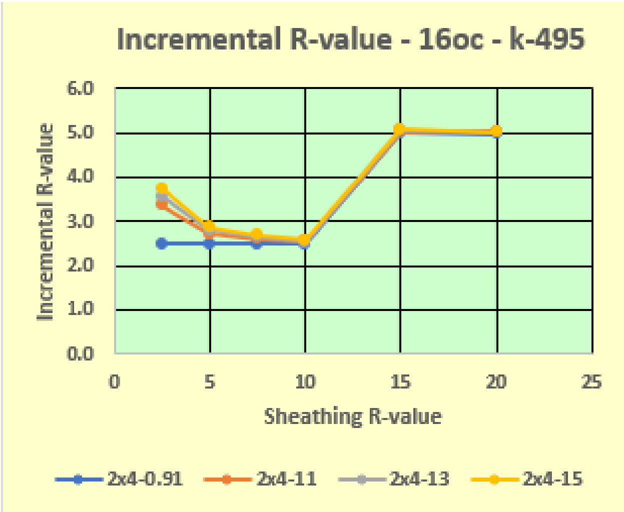

Incremental R-value - 16oc - k-381
Incremental R-value
Sheathing R-value
2x4-0.91
2x4-11
2x4-13
2x4-15

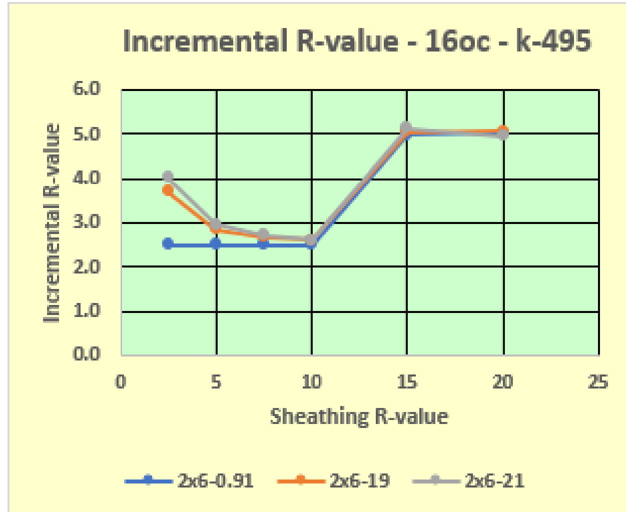

Incremental R-value - 16oc - k-381
Incremental R-value
Sheathing R-value
2x6-0.91
2x6-19
2x6-21

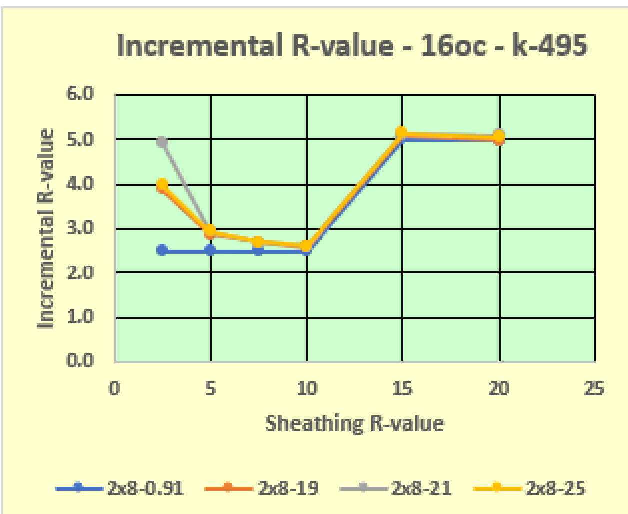

Incremental R-value - 16oc - k-381
Incremental R-value
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25


Incremental R-value - 16oc - k-381
Incremental R-value
Sheathing R-value
2x10-0.91
2x10-19
2x10-25
2x10-30


Incremental R-value - 16oc - k-381
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38


Incremental R-value - 16oc - k-495
Incremental R-value
Sheathing R-value
2x4-0.91
2x4-11
2x4-13
2x4-15


Incremental R-value - 16oc - k-495
Incremental R-value
Sheathing R-value
2x6-0.91
2x6-19
2x6-21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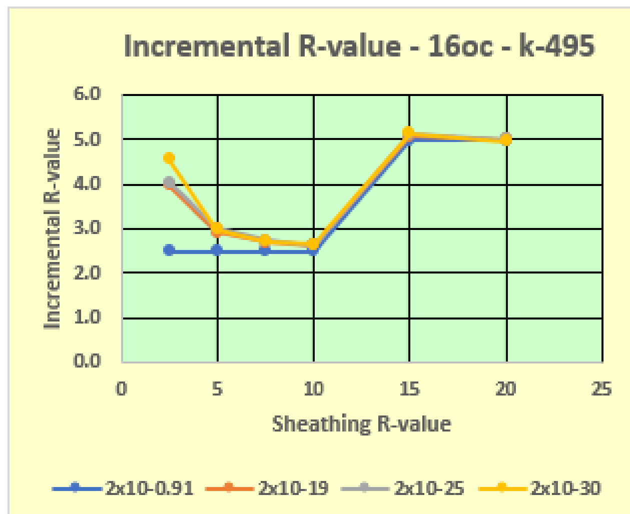
Incremental R-value
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25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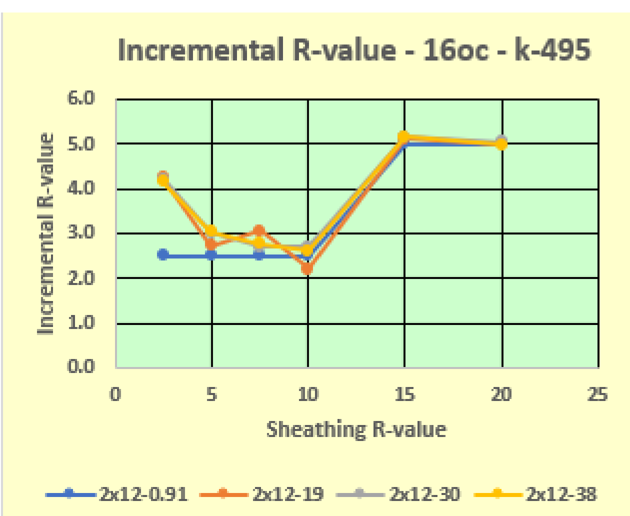
Incremental R-value
Sheathing R-value
2x10-0.91
2x10-19
2x10-25
2x10-30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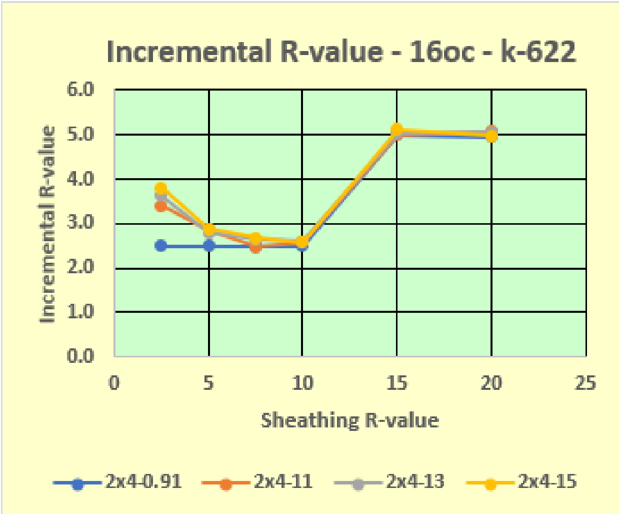
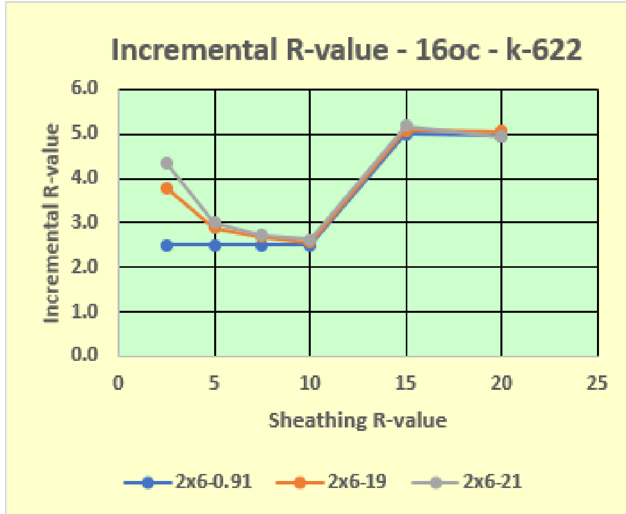
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38


Incremental R-value - 16oc - k-622
Incremental R-value
Sheathing R-value
2x4-0.91
2x4-11
2x4-13
2x4-15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Incremental R-value
Sheathing R-value
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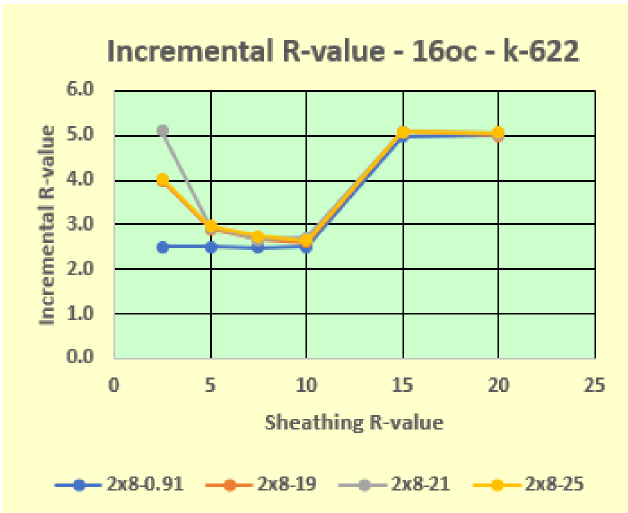
2x6-19
2x6-21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Incremental R-value
Sheathing R-value
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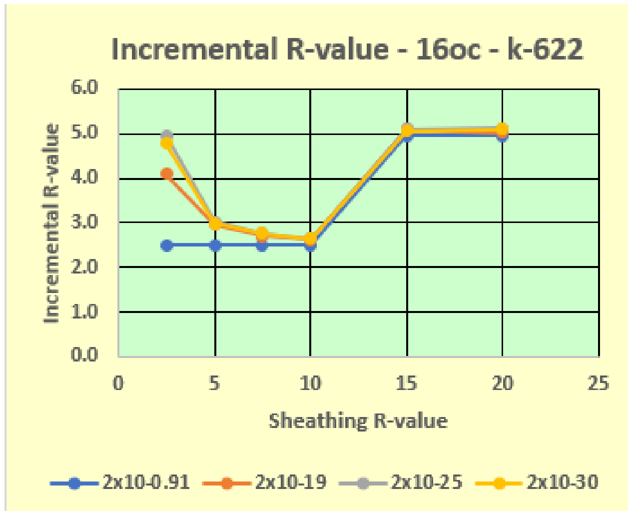
2x8-19
2x8-21
2x8-25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Incremental R-value
Sheathing R-value
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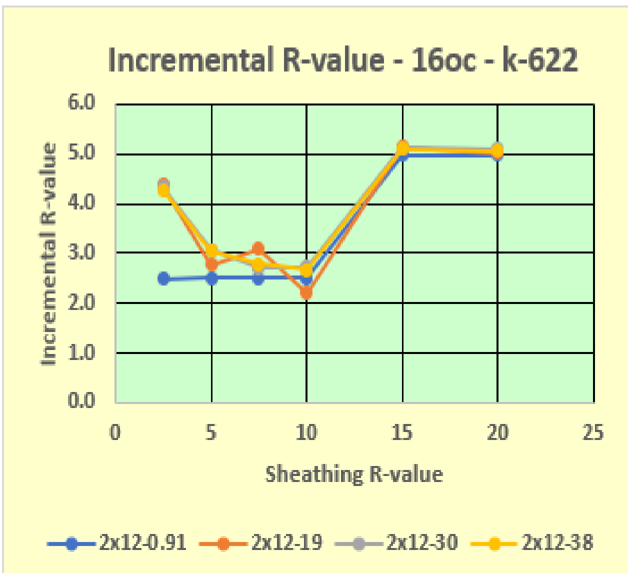
2x10-19
2x10-25
2x10-30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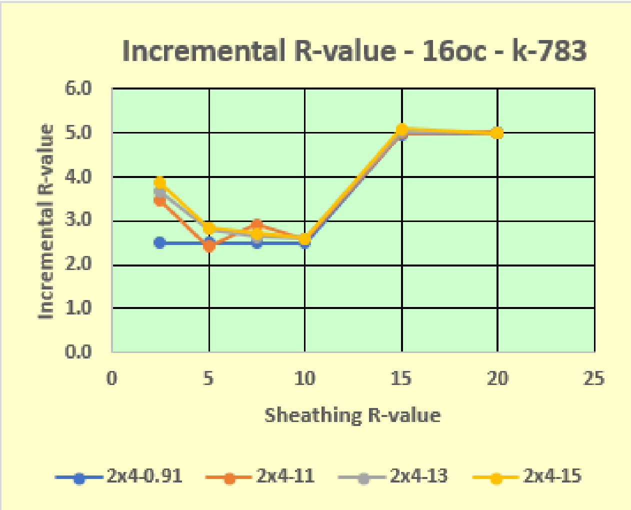
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38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Incremental R-value
Sheathing R-value
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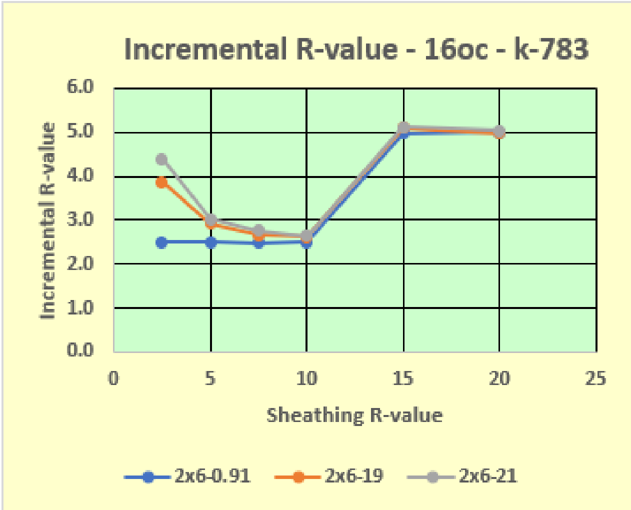
2x4-11
2x4-13
2x4-15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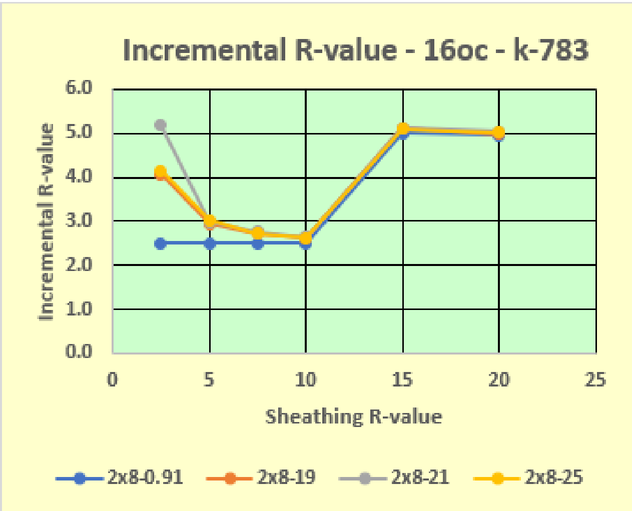
Incremental R-value
Sheathing R-value
2x6-0.91
2x6-19
2x6-21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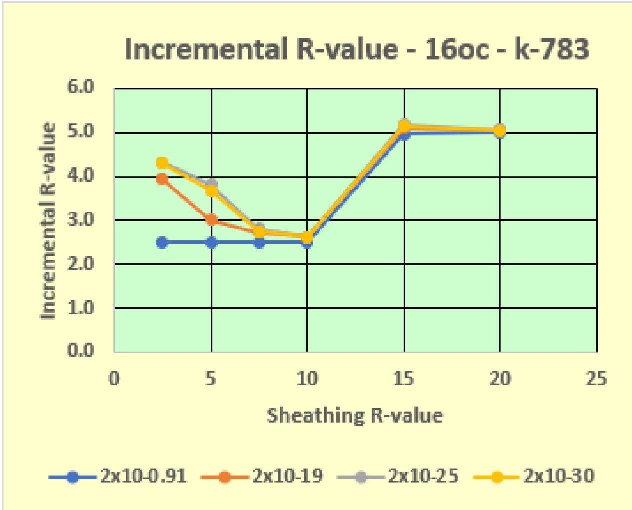
Incremental R-value
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25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Incremental R-value
Sheathing R-value
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2x10-19
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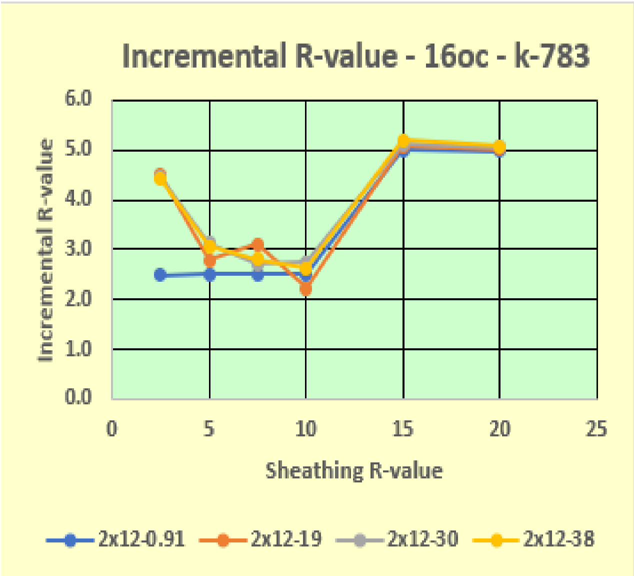
2x10-30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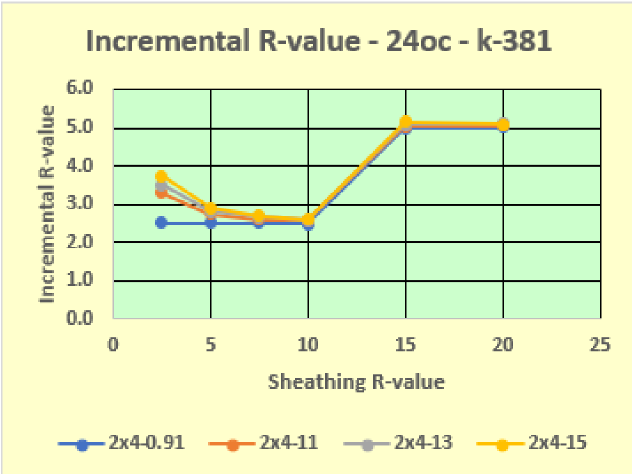
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38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Incremental R-value
Sheathing R-value
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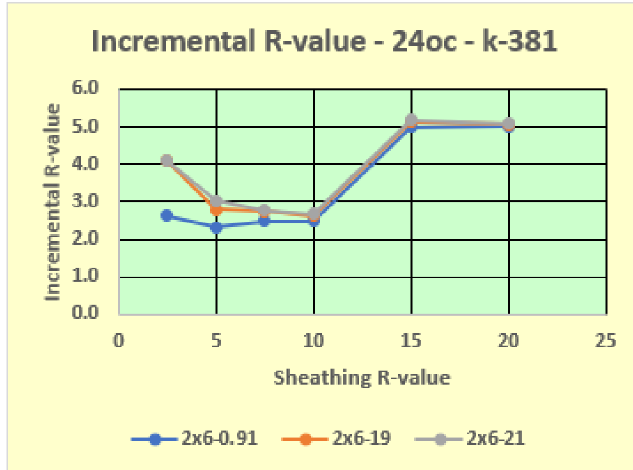
2x4-11
2x4-13
2x4-15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Incremental R-value
Sheathing R-value
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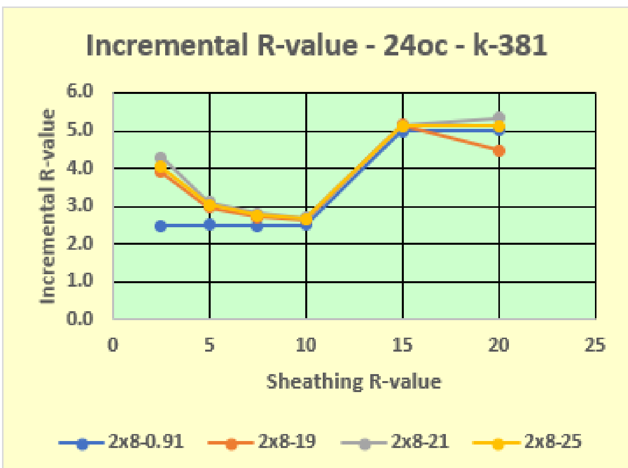
2x6-19
2x6-21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Incremental R-value
Sheathing R-value
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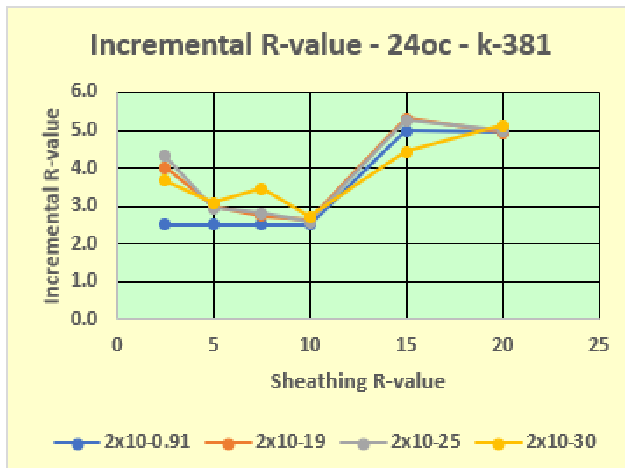
2x8-19
2x8-21
2x8-25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Incremental R-value
Sheathing R-value
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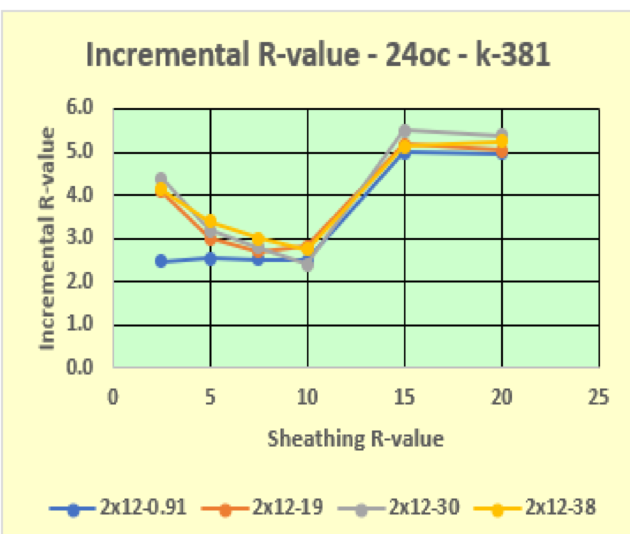
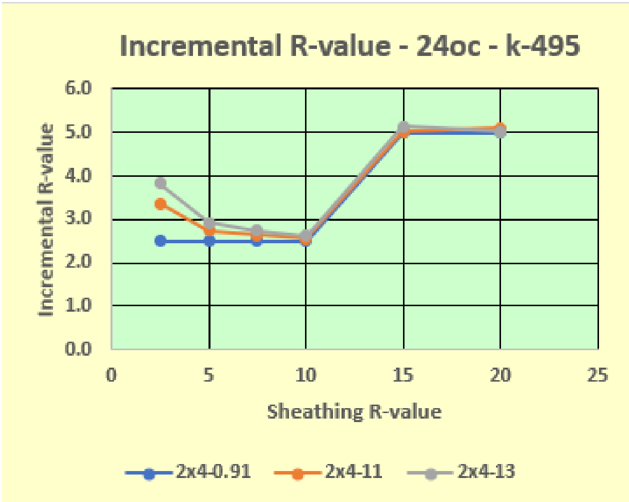
2x10-19
2x10-25
2x10-30


Incremental R-value - 24oc - k-381
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38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Incremental R-value
Sheathing R-value
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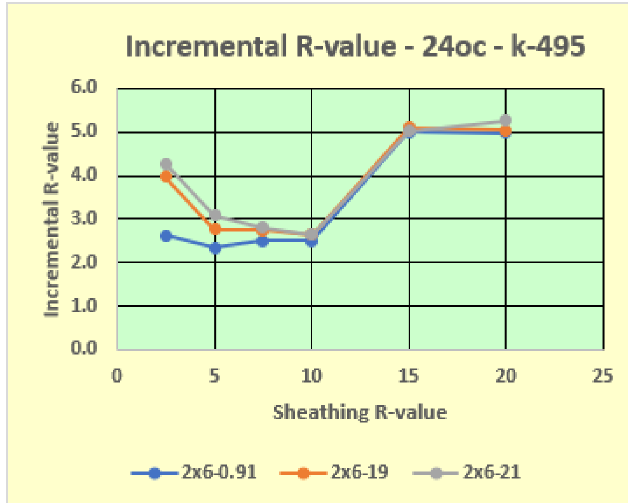
2x4-11
2x4-13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Incremental R-value
Sheathing R-value
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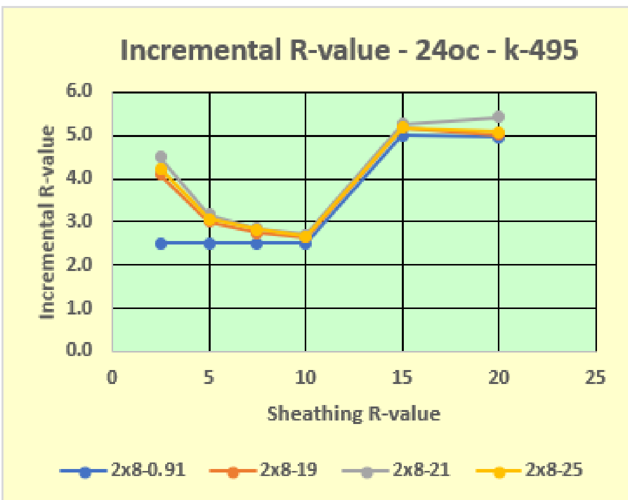
2x6-19
2x6-21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Incremental R-value
Sheathing R-value
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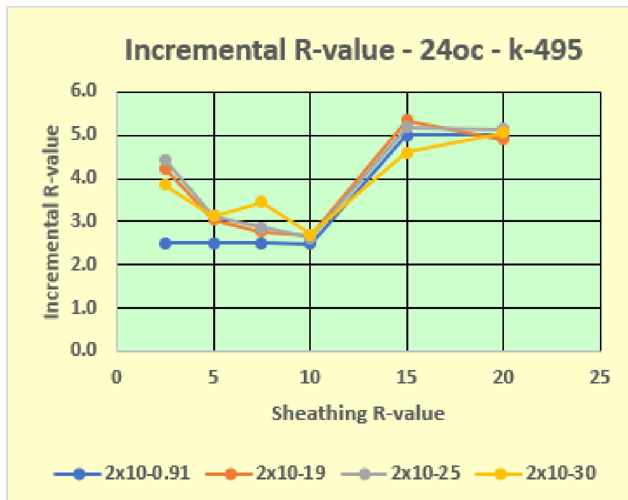
2x8-19
2x8-21
2x8-25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Incremental R-value
Sheathing R-value
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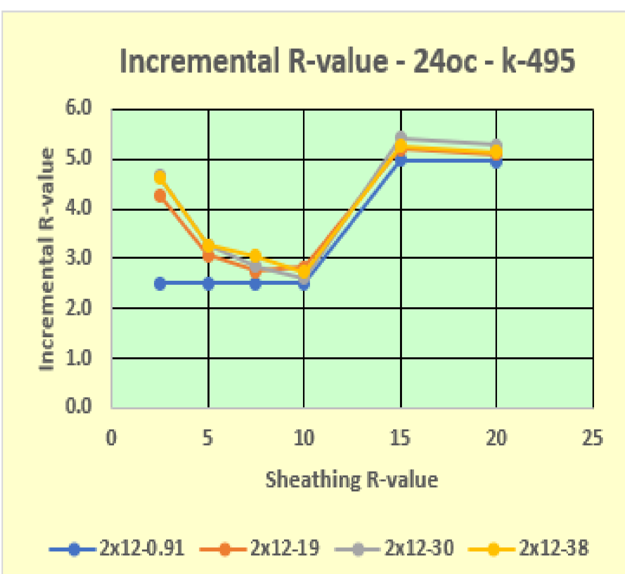
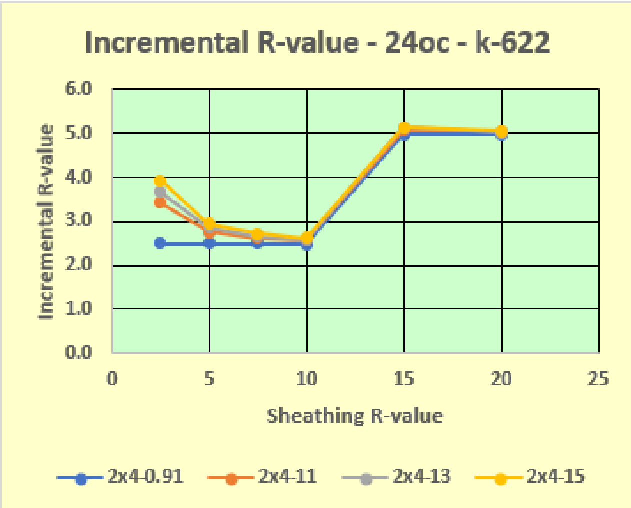
2x10-19
2x10-25
2x10-30


Incremental R-value - 24oc - k-495
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38


Incremental R-value - 24oc - k-622
Incremental R-value
Sheathing R-value
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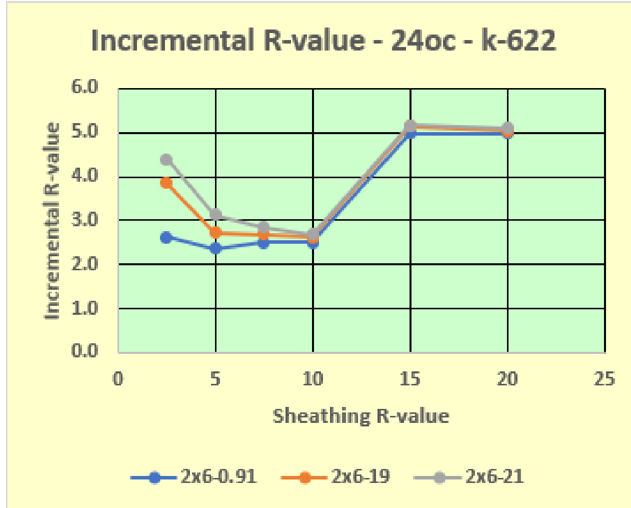
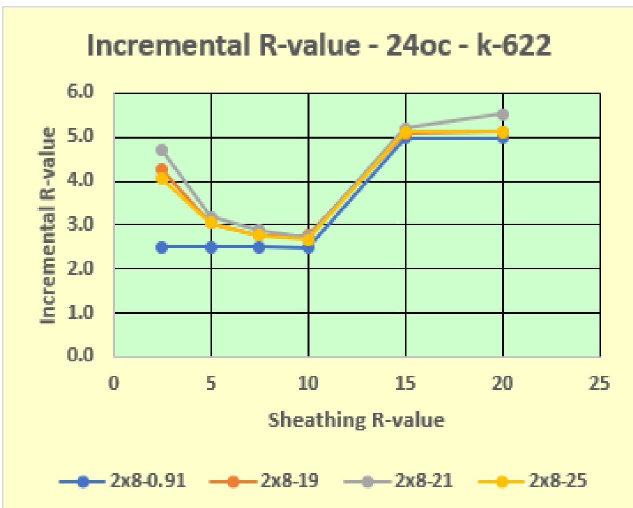
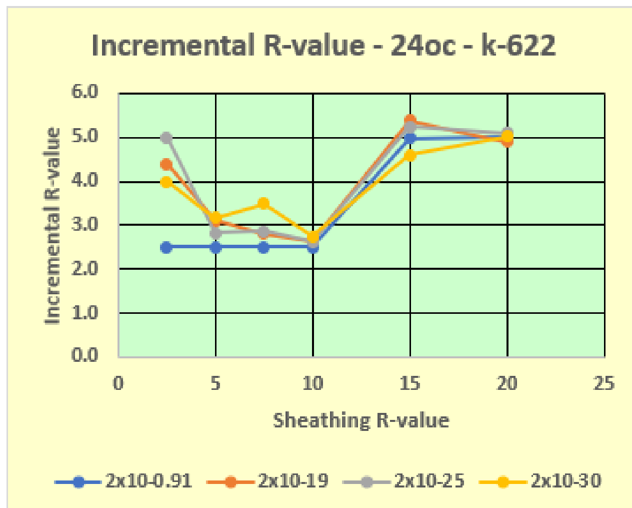
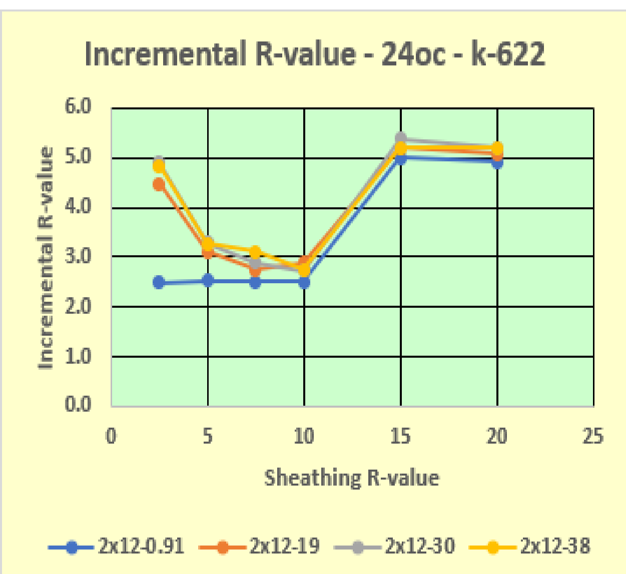
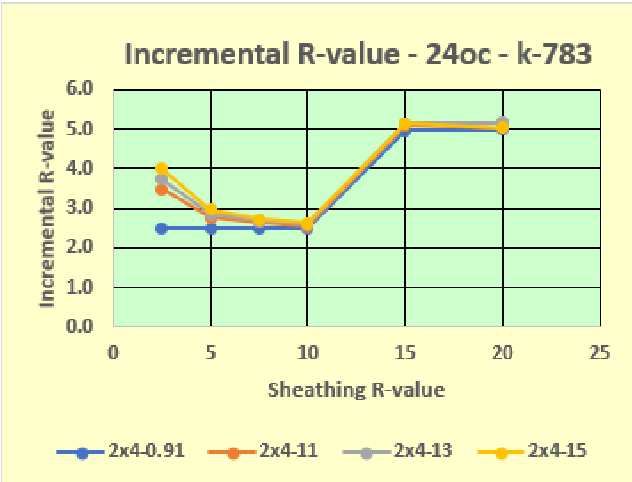
2x4-11
2x4-13
2x4-15

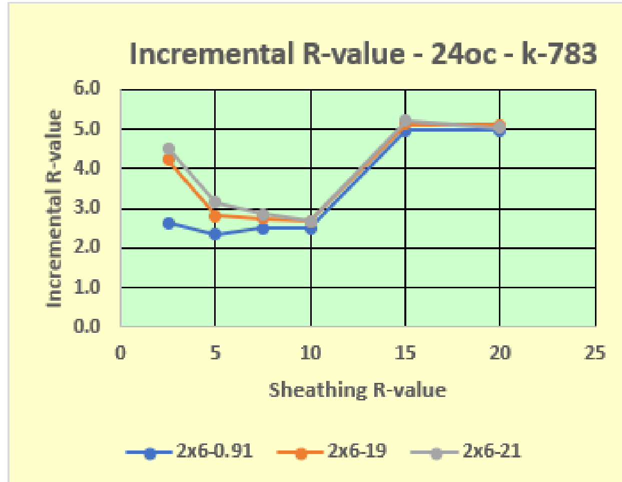

Incremental R-value - 24oc - k-622
Incremental R-value
Sheathing R-value
2x6-0.91
2x6-19
2x6-21


Incremental R-value - 24oc - k-622
Incremental R-value
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25


Incremental R-value - 24oc - k-622
Incremental R-value
Sheathing R-value
2x10-0.91
2x10-19
2x10-25
2x10-30


Incremental R-value - 24oc - k-622
Incremental R-value
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38


Incremental R-value - 24oc - k-783
Incremental R-value
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
Sheathing R-value
2x4-0.91
2x4-11
2x4-13
2x4-15


Incremental R-value - 24oc - k-783
Incremental R-value
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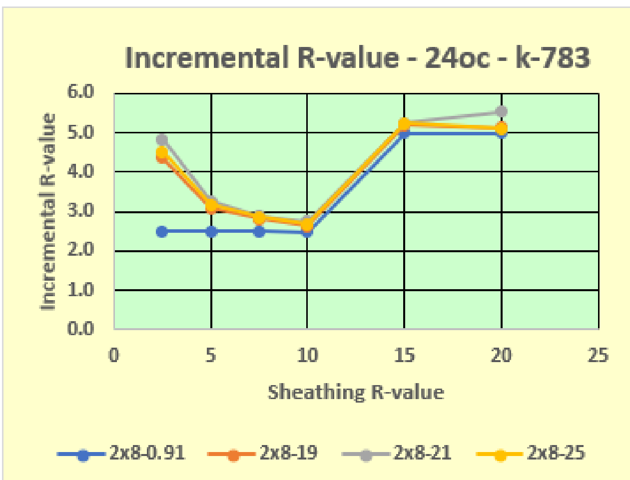
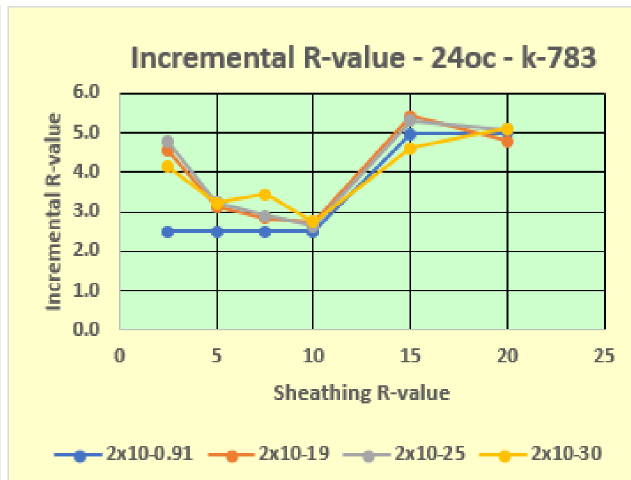
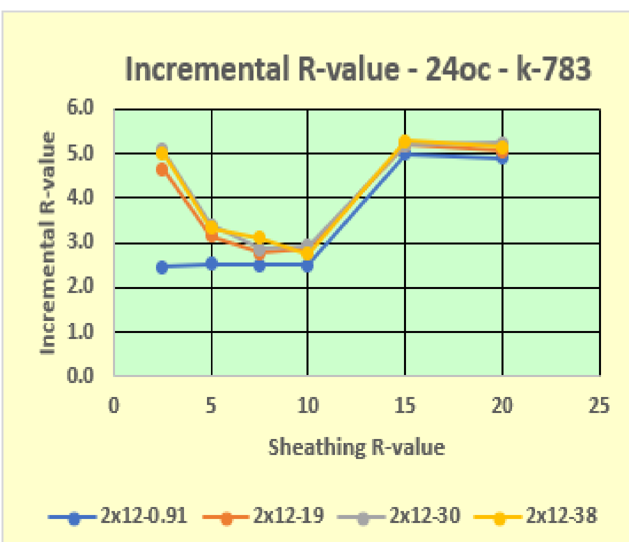
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
Sheathing R-value
2x6-0.91
2x6-19
2x6-21


Incremental R-value - 24oc - k-783
Incremental R-value
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
Sheathing R-value
2x8-0.91
2x8-19
2x8-21
2x8-25


Incremental R-value - 24oc - k-783
Incremental R-value
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
Sheathing R-value
2x10-0.91
2x10-19
2x10-25
2x10-30


Incremental R-value - 24oc - k-783
Incremental R-value
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
Sheathing R-value
2x12-0.91
2x12-19
2x12-30
2x12-38

Appendix E - Overall Thermal Zone (OTZ) Calculated Values

The Overall Thermal Zone (OTZ) value was calculated for each of the 2,182 cases to serve as a data base for statistical analysis. Individual cells that are highlighted in the tables below were eliminated since they were evaluated and found to be out of line with the adjoining cells. Each of the tables below are identified by the cell in the top left corner which lists the on center (oc) spacing and the Mils. The first table is for 6-33.

6-33	2x4				2x6			2x8				2x10				2x12			
Rshe	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.20	2.26	2.25	2.24		2.25	2.27	2.25	2.44	2.53	2.16	2.19	2.55	2.38	2.16	2.09	2.61	2.34	2.07
2.5	2.41	2.92	2.93	2.94	2.48	2.98	3.00	2.36	3.14	3.20	2.88	2.40	3.20	3.07	2.88	2.29	3.23	3.02	2.77
5.0		3.29	3.32	3.35	2.61	3.44	3.47	2.39	3.56	3.64	3.35	2.54	3.62	3.53	3.35	2.42	3.64	3.48	3.25
7.5	2.66	3.56	3.62	3.65	2.66	3.73	3.77		3.78	3.93	3.66	2.61	3.90	3.83	3.72	2.46	3.90	3.78	3.57
10	2.67	3.73	3.79	3.85		3.95	3.98	2.69	4.04		3.89	2.60	4.10	4.03	4.00		4.13	4.04	3.81
15	2.82	3.93	4.01	4.08		4.12	4.23	2.71	4.28	4.37	4.17	3.03	4.27	4.30	4.24	2.91	4.33	4.29	4.13
20	2.65	4.06	4.16	4.22	3.14	4.34	4.38	2.96	4.45	4.55	4.34	3.31	4.47	4.48	4.47		4.47	4.47	4.34

6-43	2x4				2x6			2x8				2x10				2x12			
Rshe	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.30	2.34	2.33	2.33	2.37	2.34	2.37	2.35	2.56	2.66	2.26	2.28	2.69	2.52	2.27	2.17	2.74	2.48	2.17
2.5	2.52	3.02	3.02	3.03	2.61	3.10	3.12	2.48	3.30	3.34	3.02	2.48	3.35	3.24	3.02	2.39	3.37	3.19	2.92
5		3.39	3.41	3.45	2.72	3.56	3.59	2.53	3.71	3.79	3.50	2.60	3.78	3.70	3.51	2.51	3.79	3.66	3.41
7.5	2.73	3.67	3.71	3.75	2.78	3.85	3.89		3.93	4.07	3.81	2.74	4.06	3.99	3.89	2.63	4.06	3.97	3.74
10	2.75	3.83	3.88	3.93		4.07	4.11	2.88	4.18	4.26	4.04	2.82	4.25	4.20	4.17		4.28	4.18	3.98
15	2.89	4.04	4.11	4.17		4.24	4.36	3.06	4.42	4.50	4.30	3.02	4.41	4.46	4.39	2.91	4.47	4.45	4.29
20	2.90	4.14	4.23	4.32	3.34	4.46	4.49	3.17	4.58	4.68	4.46	2.90	4.62	4.64	4.61		4.60	4.63	4.51

6-54	2x4				2x6			2x8				2x10				2x12			
Rshe	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.40	2.41	2.40	2.39	2.47	2.42	2.45	2.45	2.68	2.78	2.34	2.37	2.81	2.64	2.36	2.26	2.85	2.61	2.26
2.5	2.64	3.09	3.09	3.10	2.73	3.19	3.21	2.58	3.42	3.46	3.13	2.60	3.48	3.37	3.15	2.48	3.49	3.34	3.04
5		3.46	3.49	3.52	2.87	3.66	3.69	2.63	3.84	3.73	3.61	2.75	3.91	3.83	3.64	2.61	3.91	3.81	3.55
7.5	2.82	3.74	3.78	3.82	2.94	3.95	3.98		4.04	4.18	3.92	2.79	4.18	4.14	4.02	2.68	4.18	4.11	3.88
10		3.90	3.95	4.01		4.16	4.20	2.94	4.30	4.37	4.15	2.88	4.37	4.33	4.30		4.40	4.32	4.11
15	2.99	4.12	4.18	4.23		4.32	4.43	3.10	4.54	4.60	4.41	3.05	4.53	4.58	4.52	2.95	4.58	4.59	4.42
20	3.16	4.23	4.31	4.39	3.11	4.54	4.56	3.41	4.68	4.77	4.57	3.17	4.71	4.76	4.72	3.42	4.72	4.76	4.63

6-68	2x4				2x6			2x8				2x10				2x12			
Rshe	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.50	2.47	2.46	2.45	2.60	2.50	2.53	2.57	2.79	2.89	2.43	2.49	2.93	2.76	2.45	2.38	2.96	2.73	2.35
2.5	2.75	3.15	3.16	3.16	2.86	3.28	3.29	2.74	3.53	3.56	3.22	2.73	3.59	3.49	3.19	2.62	3.61	3.47	3.16
5		3.52	3.55	3.58	3.00	3.74	3.77	2.82	3.95	4.00	3.71	2.88	4.02	3.96	3.76	2.75	4.02	3.95	3.68
7.5	2.93	3.81	3.85	3.88	3.08	4.03	4.07		4.14	4.27	4.02	2.93	4.28	4.25	4.14	2.84	4.29	4.24	4.04
10	2.97	3.96	4.02	4.06		4.24	4.28	3.14	4.40	4.46	4.24	3.08	4.48	4.43	4.51		4.51	4.45	4.24
15	3.11	4.17	4.23	4.30		4.39	4.51	3.15	4.63	4.69	4.49	3.09	4.63	4.69	4.62	2.99	4.68	4.70	4.53
20	3.04	4.29	4.36	4.43	3.35	4.59	4.64	3.16	4.78	4.84	4.66	3.40	4.81	4.84	4.82		4.81	4.85	4.73

12-33	2x4				2x6			2x8				2x10				2x12			
She	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.34	2.23	2.23	2.23	2.49	2.24	2.29	2.50	2.54		2.18	2.49	2.79	2.49	2.18	2.48	2.92	2.47	2.10
2.5	2.63	2.94	2.95	3.00	2.82	3.07	3.11	2.84	3.33	3.46	3.02	2.82	3.46	3.30	3.02	2.79	3.62	3.27	2.93
5	2.84	3.41	3.51	3.58	3.05	3.60	3.77	3.61	3.98	4.12	3.68		4.10	3.98	3.70	3.05	4.24	3.95	3.61
7.5	3.26	3.77	3.90	4.00	3.26	4.21	4.27	3.71	4.48	4.62	4.19		4.57	4.50	3.77	3.17	4.73	4.48	4.18
10	3.43	4.04	4.20	4.33	3.44	4.58	4.66	3.90	4.87	5.00	4.59	3.96	4.84	4.83	4.17	3.48	5.07	4.89	4.62
15		4.41	4.57	4.80	3.50	5.04	5.24	3.96	5.41	5.54	5.18	4.44	5.40	5.36	4.79		5.61	5.53	5.28
20		4.72		5.13		5.44	5.60		5.81	5.95	5.58	5.27	5.75	5.77	5.23		5.98	5.96	5.77

12-43	2x4				2x6			2x8				2x10				2x12			
She	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.43	2.32	2.32	2.32	2.59	2.34	2.39	2.59	2.69		2.28	2.57	2.96	2.65	2.29	2.52	3.10	2.64	2.20
2.5	2.75	3.05	3.06	3.09	2.94	3.20	3.25	2.96	3.52	3.78	3.17	2.62	3.66	3.50	3.20	2.88	3.82	3.49	3.10
5	2.91	3.51	3.62	3.69	3.17	3.87	3.92	3.55	4.19	4.32	3.87	3.16	4.33	4.22	3.93	3.04	4.46	4.22	3.83
7.5	3.20	3.89	4.05	4.12	3.33	4.39	4.44	3.72	4.71	4.83	4.40	3.19	4.81	4.76	3.99	3.24	4.96	4.77	4.44
10	3.46	4.17	4.35	4.46	3.41	4.77	4.84	3.80	5.10	5.23	4.81		5.10	5.10	4.41	3.40	5.35	5.22	4.91
15		4.57	4.72	4.93	3.76	5.25	5.43	4.18	5.63	5.79	5.42		5.65	5.65	5.03	3.48	5.86	5.85	5.58
20		4.83	5.02	5.29	3.78	5.60	5.81	4.20	5.95	6.19	5.87		6.01	6.00	5.52		6.23	6.33	6.06

12-54	2x4				2x6			2x8				2x10				2x12			
She	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.53	2.39	2.38	2.39	2.70	2.43	2.48	2.69	2.82		2.37	2.67	3.12	2.79	2.63	2.60	3.26	2.78	2.30
2.5	2.86	3.13	3.14	3.17	3.05	3.31	3.35	3.06	3.66	3.78	3.30	3.00	3.82	3.68	3.56	2.94	3.98	3.68	3.25
5	3.02	3.61	3.71	3.78	3.23	3.99	4.05	3.66	4.35	4.48	4.02	3.19	4.50	4.41	4.33	3.09	4.65	4.43	4.02
7.5	3.35	4.00	4.13	4.21	3.44	4.52	4.57	3.78	4.89	5.00	4.56	3.29	5.00	4.96	4.36	3.34	5.15	5.07	4.65
10	3.54	4.29	4.45	4.56	3.45	4.91	4.97	4.08	5.29	5.39	4.98		5.30	5.32	4.82	3.40	5.55	5.46	5.12
15		4.69	4.82	5.03	3.50	5.40	5.57	4.43	5.84	5.99	5.60		5.85	5.86	5.57		6.09	6.13	5.81
20		4.96	5.13	5.39	3.62	5.79	5.97		6.06	6.35	6.00		6.22	6.27	5.58		6.44	6.57	6.29

12-68	2x4				2x6			2x8				2x10				2x12			
She	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.63	2.45	2.44	2.44	2.82	2.50	2.56	2.83	2.94	2.40	2.46	2.79	3.28	2.93	2.90	2.73	3.42	2.94	2.39
2.5		3.20	3.20	3.23	3.20	3.40	3.45	3.20	3.80	3.89	3.40	3.19	3.97	3.83	3.90	3.09	4.13		3.39
5	3.14	3.68	3.79	3.85	3.39	4.10	4.16	3.78	4.50	4.62	4.15	3.34	4.66	4.59	4.70	3.24	4.81	4.63	4.11
7.5	3.51	4.07	4.22	4.29	3.56	4.63	4.69	4.03	5.05	5.14	4.71	3.58	5.19	5.16	5.30	3.43	5.32	5.22	4.83
10	3.63	4.35	4.53	4.63	3.76	5.03	5.10	4.06	5.44	5.56	5.14	4.07	5.47	5.51	5.76	3.72	5.73	5.69	5.31
15		4.77	4.89	5.13	3.80	5.51	5.67	4.11	6.01	6.12	5.76	4.41	6.02	6.07	6.43		6.25	6.35	6.05
20		5.01	5.17	5.43		5.86	6.10	4.50	6.18	6.52	6.17	4.83	6.39	6.51			6.66	6.79	6.53

16-33	2x4				2x6			2x8				2x10				2x12			
She	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.41	2.21	2.22	2.22	2.62	2.24	2.66		2.55	2.75	2.18	2.65	2.83	2.25	2.15	2.42	2.98	2.47	2.10
2.5	2.74	2.90	2.93	2.95		3.11	2.96		3.34	3.12	3.02	3.07	3.57	3.03	2.86	3.05	3.53	3.27	2.94
5	3.02	3.42	3.48	3.52		3.78	3.80	3.25	4.03	3.78	3.70	3.26	4.23	3.69	3.55	3.19	4.30	3.98	3.65
7.5	3.19	3.79	3.90	3.95		4.30	4.33	3.39	4.55	4.42	4.24	3.45	4.73	4.21	4.12	3.45		4.59	4.25
10	3.49	4.08	4.22	4.30			4.73	3.73		4.72	4.70	3.63	5.13		4.56	4.03	5.22	5.04	4.73
15	3.93	4.54	4.69	4.81		5.28	5.24	4.32	5.32	5.32	5.37		5.74	5.28	5.27	4.16	5.85	5.75	5.49
20		4.78	5.01	5.17		5.76		4.68	5.79	5.79	5.86		6.18	5.77			6.23	6.28	6.10

16-43	2x4				2x6			2x8				2x10				2x12			
She	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.50	2.30	2.30	2.30	2.71	2.34	2.39	2.73	2.70	2.92	2.28	2.71		2.37	2.26	2.49	3.18	2.64	2.21
2.5	2.85	3.00	3.03	3.05	3.09	3.24	3.26	3.14	3.52	3.27	3.17	3.12	3.77	3.20	3.00	3.10	3.72	3.50	3.12
5	3.05	3.55	3.59	3.65	3.40	3.94	3.96	3.34	4.25	3.96	3.90	3.36	4.45	3.89	3.73	3.31	4.52	4.27	3.89
7.5	3.19	3.93	4.00	4.07	3.45	4.48	4.50	3.57	4.77	4.51	4.47	3.63	4.99	4.43	4.33	3.65		4.91	4.51
10	3.60	4.23	4.35	4.42	3.76	4.88	4.93	3.76	5.21	4.94	4.94		5.40	4.88	4.79		5.49	5.37	5.04
15		4.69	4.83	4.94	4.23	5.53	5.57		5.84	5.58	5.62	4.24	6.06	5.56	5.53		6.11	6.12	5.83
20	4.38	4.95	5.16	5.30		5.92	6.09	4.17	6.33	6.01	6.12	4.59	6.54	6.08	6.11		6.59	6.67	6.46

16-54	2x4				2x6			2x8				2x10				2x12			
She	2x4-0	2x4-11	2x4-13	2x4-15	2x6-0	2x6-19	2x6-21	2x8-0	2x8-19	2x8-21	2x8-25	2x10-0	2x10-19	2x10-25	2x10-30	2x12-0	2x12-19	2x12-30	2x12-38
0	2.60	2.37	2.37	2.37	2.80	2.42	2.59	2.83	2.83	3.04		2.78	3.18	2.80	2.37	2.59	3.34	2.80	2.30
2.5	2.99	3.09	3.11	3.12	3.19	3.35	3.16	3.28	3.67	3.39	3.30	3.20	3.93	3.34	3.10	3.19	3.87	3.70	3.27
5	3.24	3.51	3.69	3.72	3.41	4.07	4.07	3.48	4.41	4.12	4.06	3.49	4.64	4.06	3.88	3.45	4.70	4.49	4.09
7.5	3.45	4.03	4.12	4.16	3.67	4.60	4.64	3.77	4.97	4.70	4.64		5.20	4.63	4.47			5.16	4.74
10		4.31	4.43	4.53	3.87		5.09	3.84	5.42	5.09	5.10		5.64	5.09	4.97		5.72	5.63	5.27
15		4.80	4.92	5.02		5.68	5.71	4.32	6.08	5.77	5.84		6.29	5.81	5.76	4.15	6.34	6.42	6.12
20	4.17	5.02	5.22	5.44	4.69	6.10			6.57	6.24	6.33		6.77	6.28	6.29	4.50	6.82	6.96	6.73

16-68	2x4				2x6			2x8				2x10				2x12			
She	**2x4-0**	**2x4-11**	**2x4-13**	**2x4-15**	**2x6-0**	**2x6-19**	**2x6-21**	**2x8-0**	**2x8-19**	**2x8-21**	**2x8-25**	**2x10-0**	**2x10-19**	**2x10-25**	**2x10-30**	**2x12-0**	**2x12-19**	**2x12-30**	**2x12-38**
0	2.69	2.43	2.43	2.43	2.92	2.50	2.66	2.94	2.95	3.18	2.46	2.92	3.17	2.94	2.46	2.72	3.52	2.96	2.20
2.5	3.08	3.15	3.18	3.19	3.34	3.44	3.29	3.42	3.81	3.50	3.41	3.34	4.10	3.47	3.21	3.26	4.02	3.88	3.27
5	3.32		3.76	3.83	3.56	4.17	4.18	3.61	4.57	4.25	4.18	3.61	4.82	4.22	4.00	3.57	4.87	4.70	4.14
7.5	3.50	4.11	4.19	4.25	3.88	4.74	4.74	3.73	5.13	4.80	4.79	3.76	5.37	4.79	4.63	3.76		5.40	4.82
10	3.60	4.40	4.51	4.60	3.98		5.19	3.93	5.57	5.25	5.28	3.83	5.81	5.28	5.15		5.89	5.88	5.40
15	3.98	4.91	5.02	5.11	4.39	5.80		4.01	6.23	5.91	6.02		6.48	5.98	5.92		6.58	6.69	6.24
20	4.01	5.20	5.38	5.50	4.42	6.29		4.77	6.74	6.40	6.55		6.93	6.49	6.48		7.05	7.26	6.86

24-33	2x4				2x6			2x8				2x10				2x12			
She	**2x4-0**	**2x4-11**	**2x4-13**	**2x4-15**	**2x6-0**	**2x6-19**	**2x6-21**	**2x8-0**	**2x8-19**	**2x8-21**	**2x8-25**	**2x10-0**	**2x10-19**	**2x10-25**	**2x10-30**	**2x12-0**	**2x12-19**	**2x12-30**	**2x12-38**
0	2.48	2.16	2.17	2.18	2.87	2.69	2.29	2.95	2.55	2.74	2.69	4.10	2.86	2.49	2.17	4.11	3.04	2.46	2.10
2.5	2.87	2.81	2.85	2.88		3.45	3.12	3.63	3.36	3.49	3.52	4.61	3.59	3.25	3.21		3.70	3.26	3.00
5	3.00	3.29	3.38	3.43	5.42	4.29	3.81	3.83	4.02	4.15	4.25	4.89	4.26	4.01	3.98	5.11	4.35	3.96	3.67
7.5		3.65	3.76	3.85	5.71	4.84	4.35	4.15	4.56	4.68	4.85	5.18	4.79	4.59		5.17	4.92	4.58	4.23
10	3.60	3.91	4.07	4.19	6.22	5.30	4.79		4.98	5.11	5.34	5.45	5.21	5.13	5.17		5.22	5.25	4.74
15	3.73	4.36	4.54	4.65	6.99	6.00	5.46	5.03	5.64	5.85	6.12	5.63	5.72	5.84	6.03	6.24	5.85	5.90	5.64
20		4.58	4.76	4.97		6.52	5.97				6.72		6.33	6.49	6.65		6.38	6.34	6.23

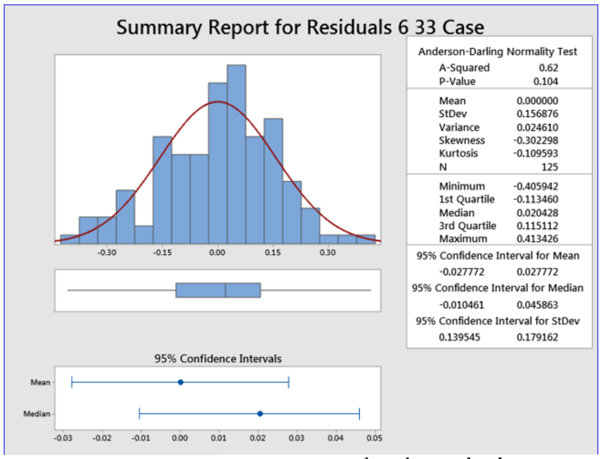
24-43	2x4				2x6			2x8				2x10				2x12			
She	**2x4-0**	**2x4-11**	**2x4-13**	**2x4-15**	**2x6-0**	**2x6-19**	**2x6-21**	**2x8-0**	**2x8-19**	**2x8-21**	**2x8-25**	**2x10-0**	**2x10-19**	**2x10-25**	**2x10-30**	**2x12-0**	**2x12-19**	**2x12-30**	**2x12-38**
0	2.56	2.25	2.26	2.26	2.93	2.34	2.40	2.98	2.70	2.91	2.27	3.07	3.05	2.66	2.25	3.00	3.24	2.63	2.21
2.5	2.97	2.92	2.95	2.99		3.18	3.25	3.60	3.53	3.67	3.16	3.56	3.79	3.39	3.38	3.55	3.93	3.48	3.12
5	3.15	3.42	3.48	3.55		4.00	3.95	3.86	4.24	4.36	3.90	4.01	4.49	4.27	4.20	3.84	4.60	4.24	3.90
7.5		3.76	3.87	3.95		4.54	4.50	4.10	4.80	4.92	4.48		5.06	4.86		3.96	5.19	4.89	4.50
10	3.36	4.04	4.19	4.29		4.97	4.99	4.33	5.27	5.38	4.98	4.77	5.48	5.41	5.43	4.43	5.49	5.50	5.06
15	3.49	4.52	4.69	4.78		5.68	5.84	4.48	5.94	6.06	5.74	4.94	6.01	6.23	6.32		6.14	6.25	5.96
20		4.70	5.01	5.19		6.21	6.22		6.51	6.29	6.32		6.69	6.79	7.02		6.62	6.80	6.65

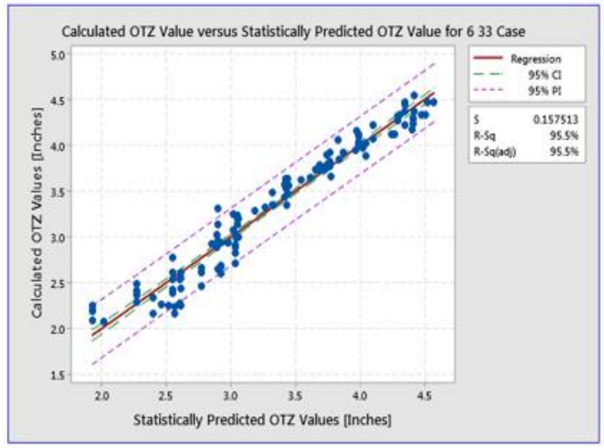
24-54	2x4				2x6			2x8				2x10				2x12			
She	**2x4-0**	**2x4-11**	**2x4-13**	**2x4-15**	**2x6-0**	**2x6-19**	**2x6-21**	**2x8-0**	**2x8-19**	**2x8-21**	**2x8-25**	**2x10-0**	**2x10-19**	**2x10-25**	**2x10-30**	**2x12-0**	**2x12-19**	**2x12-30**	**2x12-38**
0	2.66	2.32	2.33	2.33	3.01	2.02	2.48	3.05	2.83	3.05	1.91	2.32	3.21	2.79	2.33	2.25	3.42	2.79	2.30
2.5	3.03	2.99	3.03	3.06		2.87	3.37	3.65	3.68	3.80	2.81	2.79	3.97	3.49	3.52	3.48	4.08	3.67	3.27
5	3.33	3.52	3.57	3.63	3.78	3.68	4.09	3.95	4.41	4.53	3.52	3.16	4.67	4.46	4.39		4.78	4.48	4.12
7.5		3.90	3.99	4.06	4.11	4.24	4.65	4.14	5.00	5.08	4.09	3.26	5.24	5.10			5.40	5.17	4.40
10	3.68	4.19	4.32	4.42	4.16	4.68	5.11	4.56	5.38	5.54	4.56	3.66	5.73	5.68	5.67		5.68	5.74	5.33
15	4.29	4.59	4.75	4.93	4.83	5.32	5.86	5.29	6.18	6.29	5.33		6.24	6.49	6.56		6.36	6.55	6.31
20	4.66	4.82	5.12	5.30	5.24	5.81	6.39	5.74	6.00		5.86		6.95	7.12	7.31		6.88	7.18	7.00

24-68	2x4				2x6			2x8				2x10				2x12			
She	**2x4-0**	**2x4-11**	**2x4-13**	**2x4-15**	**2x6-0**	**2x6-19**	**2x6-21**	**2x8-0**	**2x8-19**	**2x8-21**	**2x8-25**	**2x10-0**	**2x10-19**	**2x10-25**	**2x10-30**	**2x12-0**	**2x12-19**	**2x12-30**	**2x12-38**
0	2.74	2.39	2.39	2.40	3.11	2.50	2.56	3.14	2.95	3.19	2.45	3.19	3.38	2.94		3.11	3.60	2.95	2.40
2.5	3.17	3.07	3.11	3.13		3.35	3.45	3.78	3.82	3.94	3.39	3.73	4.13		3.64		4.25	3.87	3.41
5	3.35	3.59	3.66	3.70	4.63	4.23	4.20	4.04	4.57	4.66	4.18	4.15	4.87	4.66	4.54	4.00	4.97	4.68	4.30
7.5	3.49	3.95	4.07	4.14	4.84	4.81	4.76	4.18	5.14	5.25		4.50	5.44	5.30		4.42	5.59	5.42	4.95
10		4.28	4.40	4.49	4.94	5.25	5.25		5.65	5.71	5.33		5.89	5.90	5.85		5.89	5.90	5.56
15	4.12	4.67	4.82	4.99	5.57	5.98	5.96	4.91	6.35	6.45	6.11	5.28	6.40	6.70	6.82		6.60	6.87	6.54
20	4.47	4.95		5.40		6.46	6.56	5.33	6.84	6.61	6.71	5.73	7.23	7.35	7.52		7.15	7.48	7.27

Appendix F - MINITAB Statistical Analysis

The figures below represent the results of the MINITAB statistical analysis used to quantify the Overall Thermal Zone (OTZ). The title in each figure identifies the oc spacing and the Mils so the first figure is: 6 33.



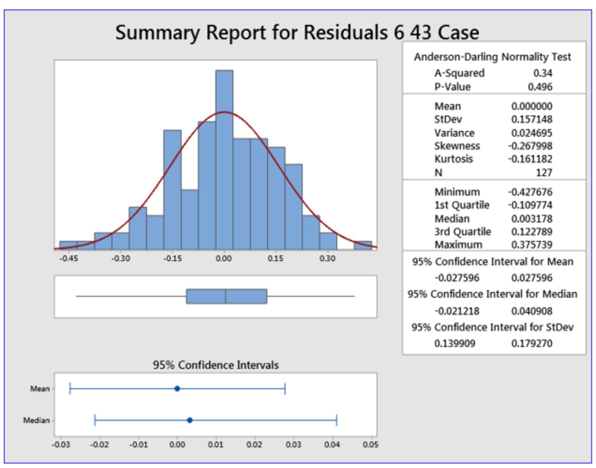


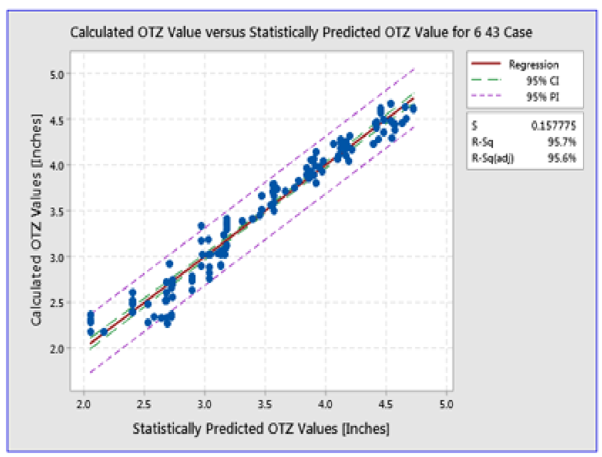
Standard Deviation on OTZ Residuals (Sigma) = 0.157 [Inches]

Average OTZ for this Case (data not shown) = 3.353 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 4.7%

And OTZ uncertainty = 1.975 x 4.7% = +/- 9.2% @ 95% Confidence Interval



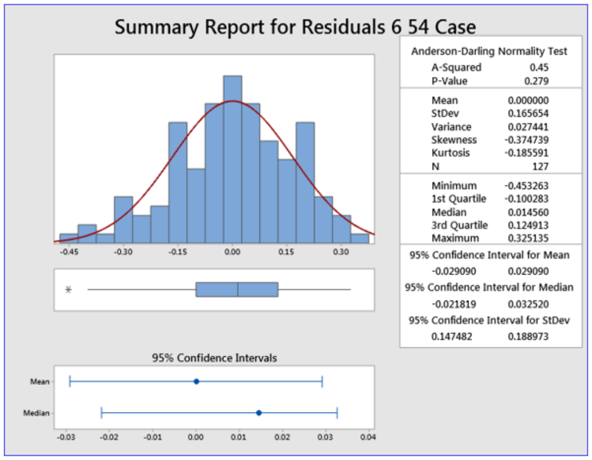


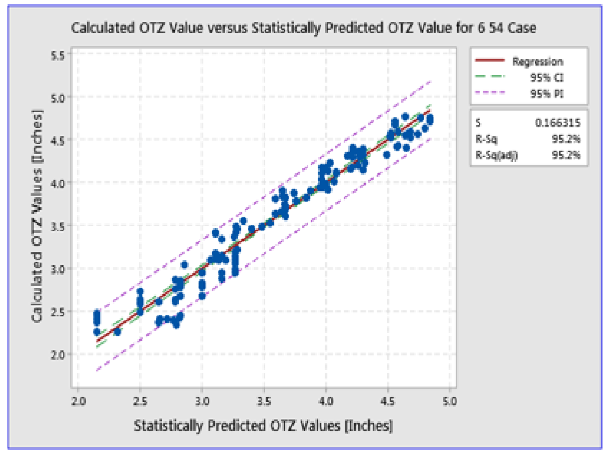
Standard Deviation on OTZ Residuals (Sigma) = 0.157 [Inches]

Average OTZ for this Case (data not shown) = 3.477 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 4.5%

And OTZ uncertainty = 1.975 x 4.5% = +/- 8.9% @ 95% Confidence Interval



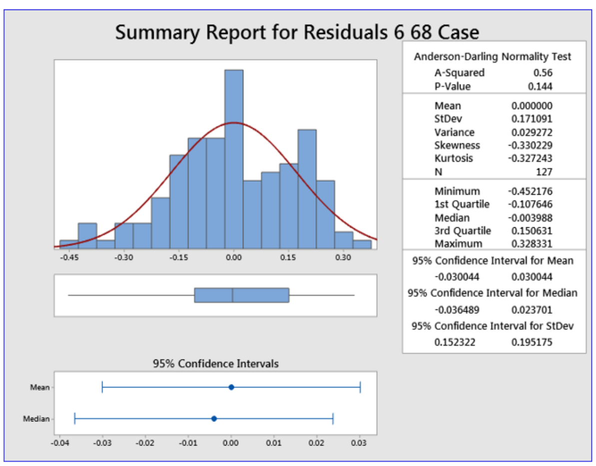


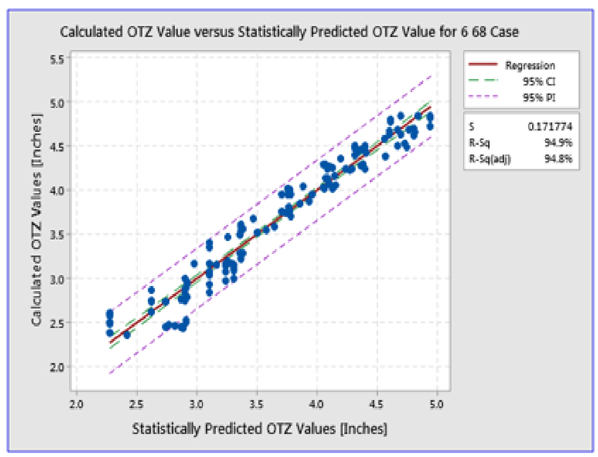
Standard Deviation on OTZ Residuals (Sigma) = 0.166 [Inches]

Average OTZ for this Case (data not shown) = 3.583 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 4.7%

And OTZ uncertainty = 1.975 x 4.7% = +/- 9.2% @ 95% Confidence Interval



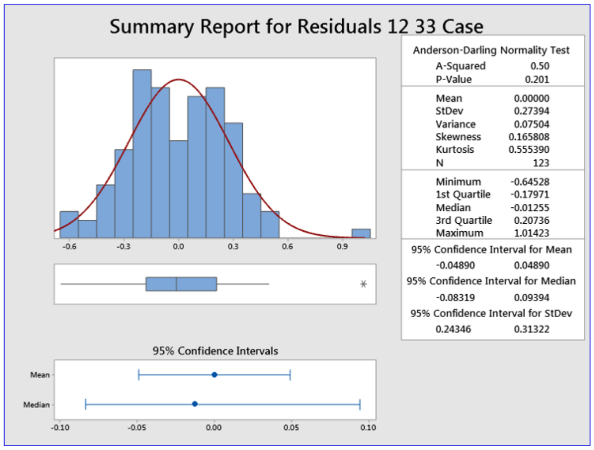


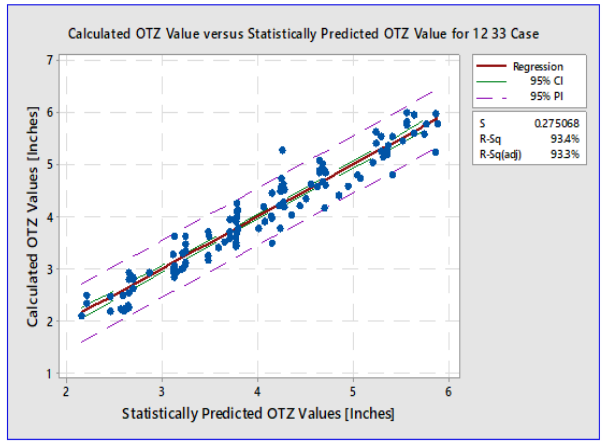
Standard Deviation on OTZ Residuals (Sigma) = 0.171 [Inches]

Average OTZ for this Case (data not shown) = 3.677 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 4.7%

And OTZ uncertainty = 1.975 x 4.7% = +/- 9.2% @ 95% Confidence Interval



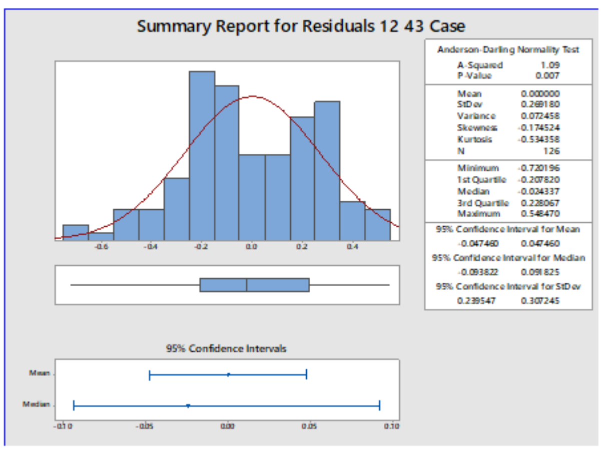


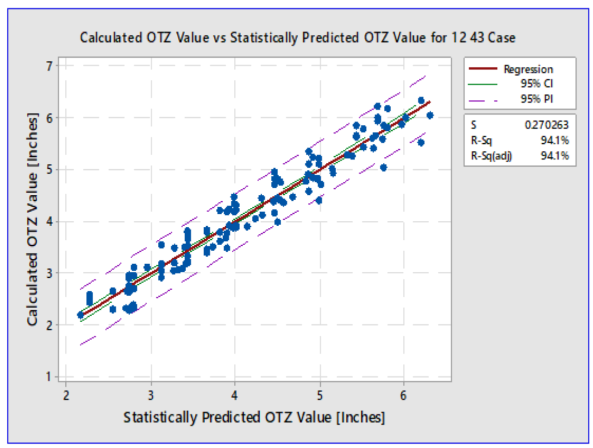
Standard Deviation on OTZ Residuals (Sigma) = 0.274 [Inches]

Average OTZ for this Case (data not shown) = 3.946 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 6.9%

And OTZ uncertainty = 1.975 x 6.9% = +/- 13.7% @ 95% Confidence Interval



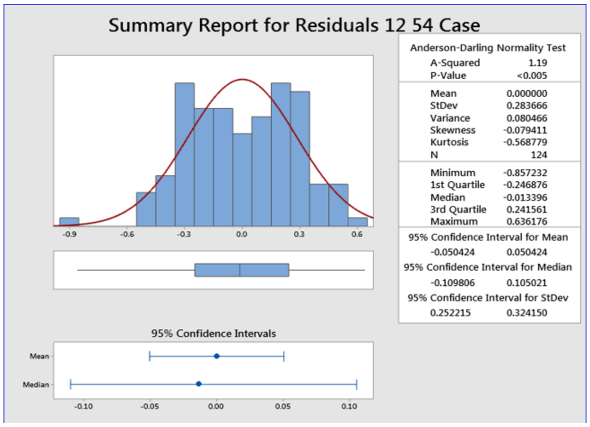


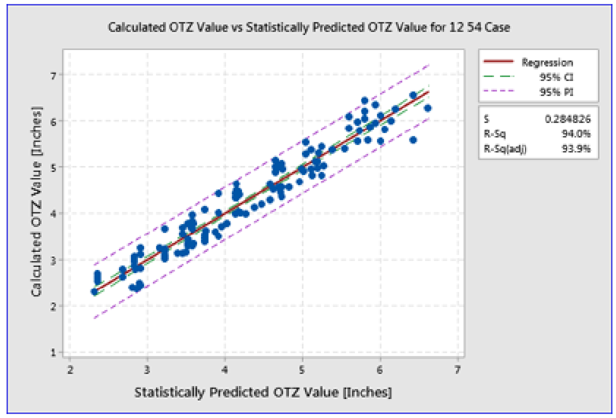
Standard Deviation on OTZ Residuals (Sigma) = 0.269 [Inches]

Average OTZ for this Case (data not shown) = 4.085 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 6.6%

And OTZ uncertainty = 1.975 x 6.6% = +/- 13.0% @ 95% Confidence Interval



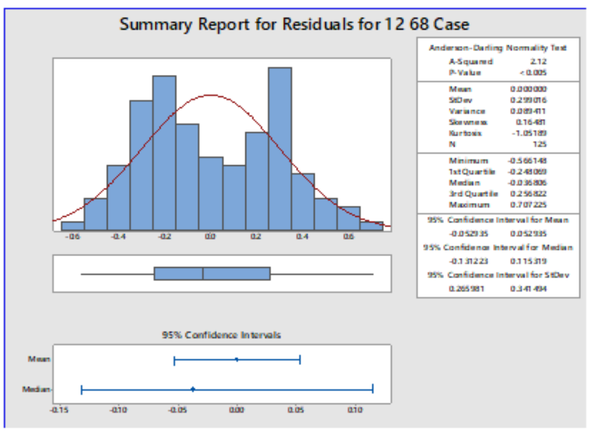


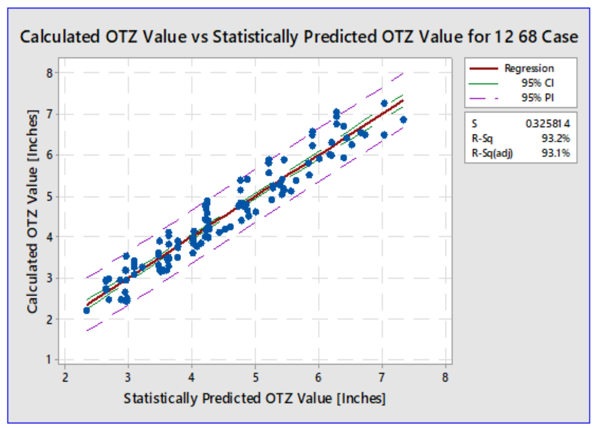
Standard Deviation on OTZ Residuals (Sigma) = 0.284 [Inches]

Average OTZ for this Case (data not shown) = 4.238 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 6.7%

And OTZ uncertainty = 1.975 x 6.7% = +/- 13.2% @ 95% Confidence Interval



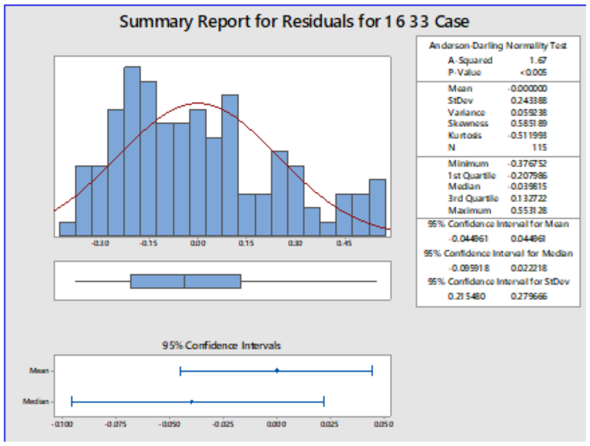


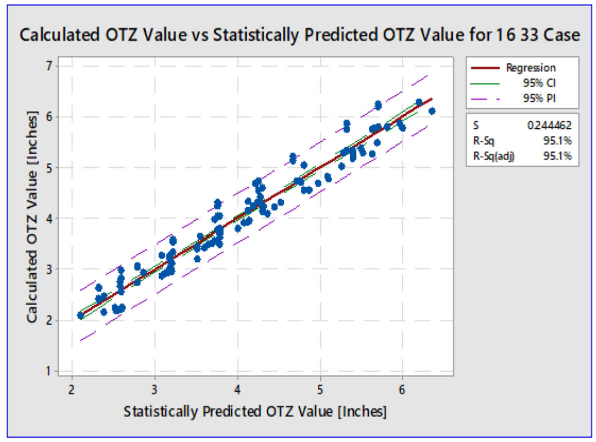
Standard Deviation on OTZ Residuals (Sigma) = 0.299 [Inches]

Average OTZ for this Case (data not shown) = 4.392 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 6.8%

And OTZ uncertainty = 1.975 x 6.8% = +/- 13.4% @ 95% Confidence Interval



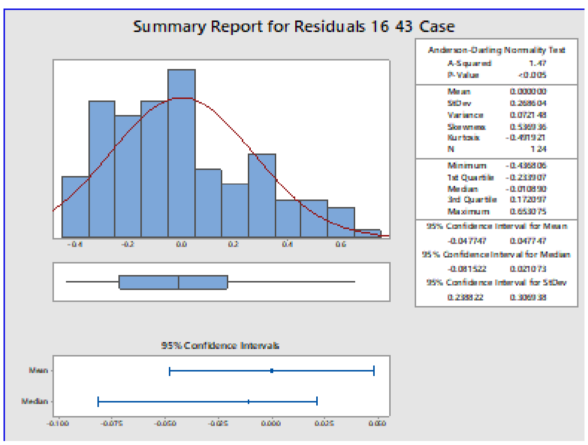


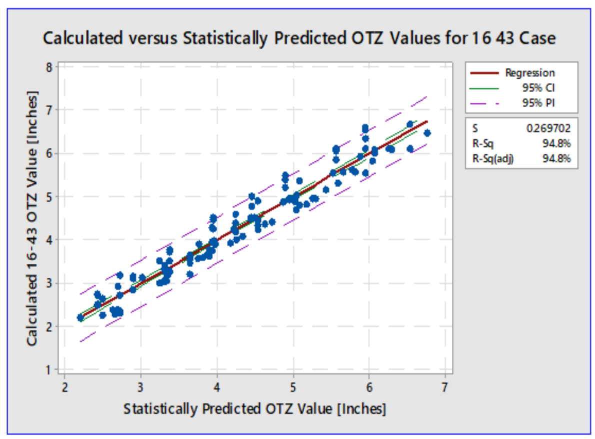
Standard Deviation on OTZ Residuals (Sigma) = 0.243 [Inches]

Average OTZ for this Case (data not shown) = 3.973 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 6.1%

And OTZ uncertainty = 1.975 x 6.1% = +/- 12.1% @ 95% Confidence Interval



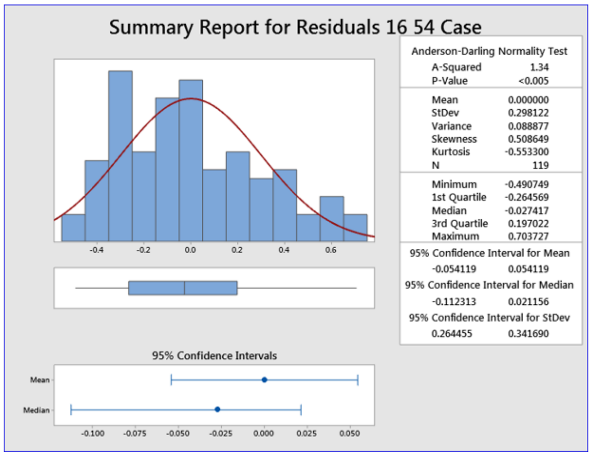


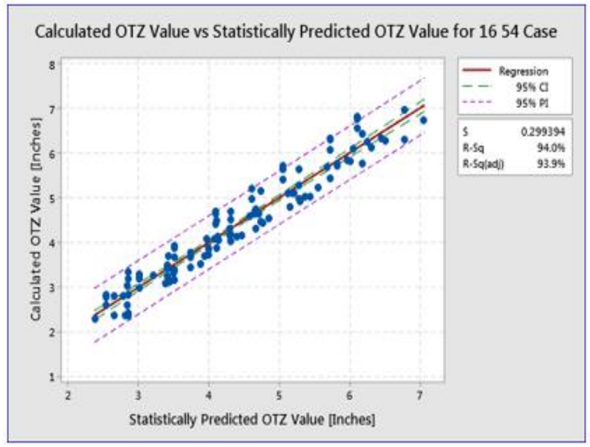
Standard Deviation on OTZ Residuals (Sigma) = 0.269 [Inches]

Average OTZ for this Case (data not shown) = 4.174 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 6.4%

And OTZ uncertainty = 1.975 x 6.4% = +/- 12.7% @ 95% Confidence Interval



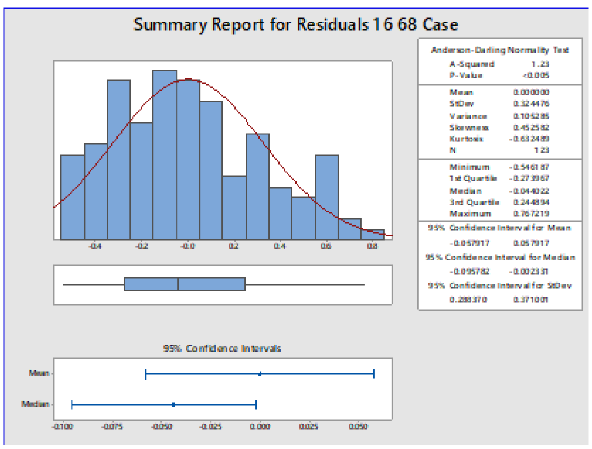


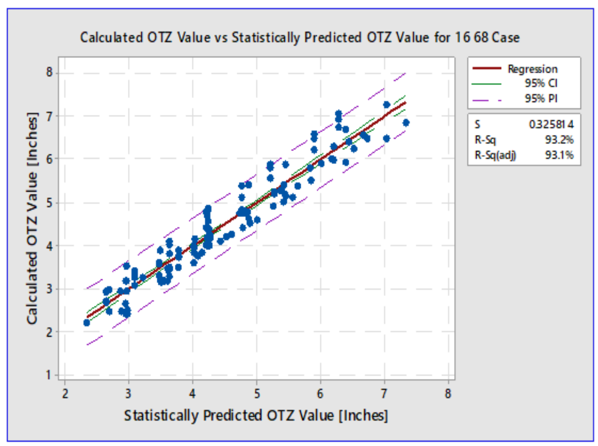
Standard Deviation on OTZ Residuals (Sigma) = 0.298 [Inches]

Average OTZ for this Case (data not shown) = 4.322 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 6.9%

And OTZ uncertainty = 1.975 x 6.9% = +/- 13.6% @ 95% Confidence Interval



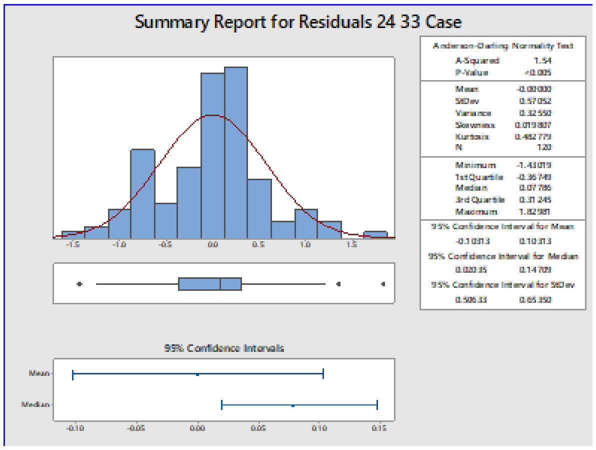


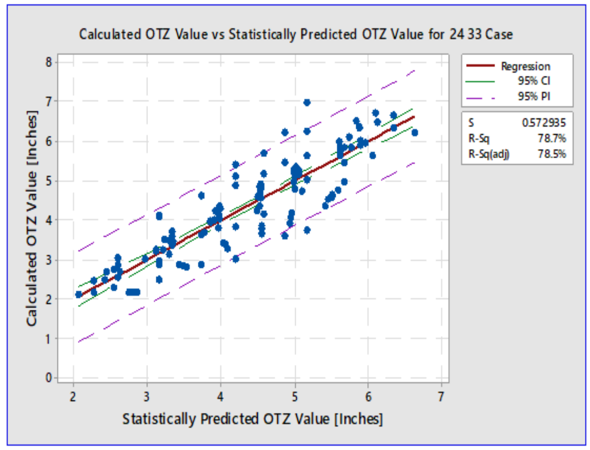
Standard Deviation on OTZ Residuals (Sigma) = 0.324 [Inches]

Average OTZ for this Case (data not shown) = 4.396 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 7.4%

And OTZ uncertainty = 1.975 x 7.4% = +/- 14.6% @ 95% Confidence Interval



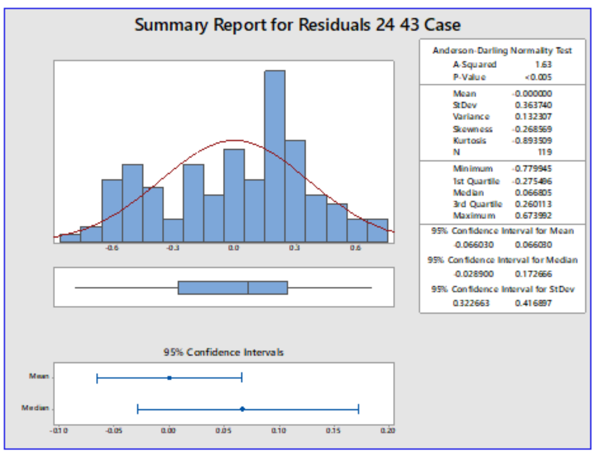


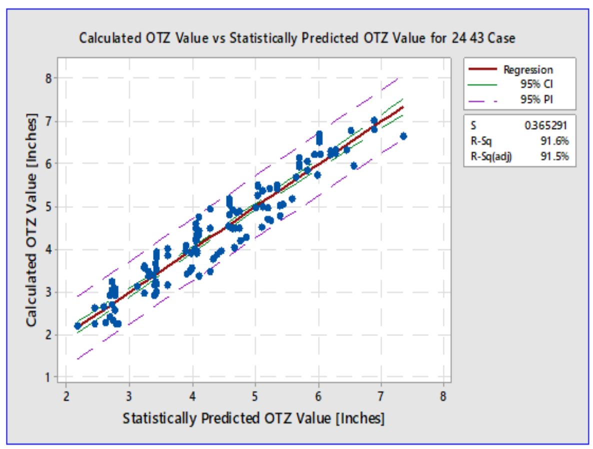
Standard Deviation on OTZ Residuals (Sigma) = 0.571 [Inches]

Average OTZ for this Case (data not shown) = 4.363 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 13.1%

And OTZ uncertainty = 1.975 x 13.1% = +/- 25.8% @ 95% Confidence Interval



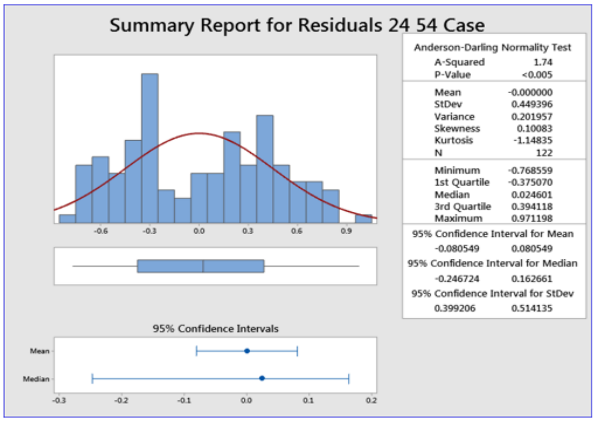


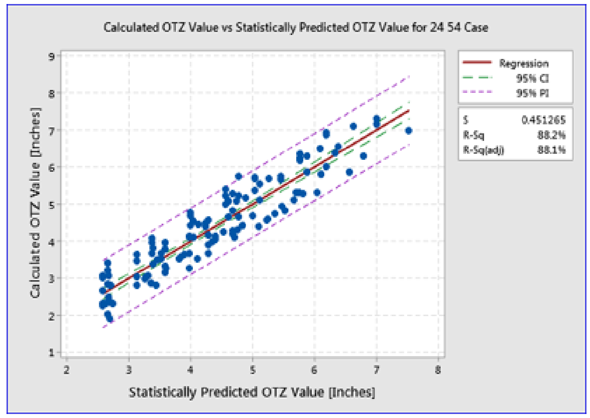
Standard Deviation on OTZ Residuals (Sigma) = 0.364 [Inches]

Average OTZ for this Case (data not shown) = 4.342 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 8.4%

And OTZ uncertainty = 1.975 x 8.4% = +/- 16.5% @ 95% Confidence Interval



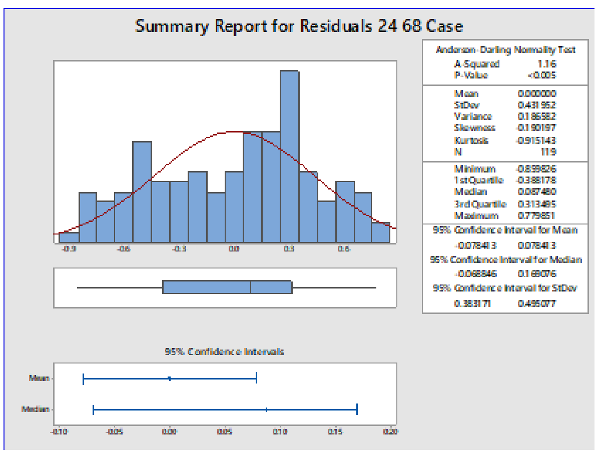


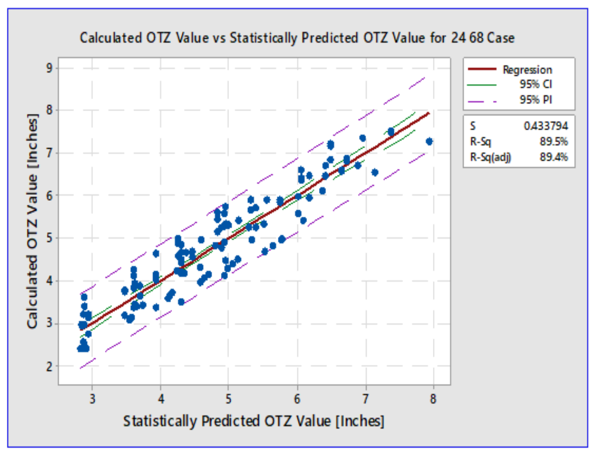
Standard Deviation on OTZ Residuals (Sigma) = 0.449 [Inches]

Average OTZ for this Case (data not shown) = 4.389 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 10.2%

And OTZ uncertainty = 1.975 x 10.2% = +/- 20.2% @ 95% Confidence Interval





Standard Deviation on OTZ Residuals (Sigma) = 0.432 [Inches]

Average OTZ for this Case (data not shown) = 4.692 [Inches]

Therefore Coefficient of Variation = CV = Sigma/Average x 100% = 9.2%

And OTZ uncertainty = 1.975 x 9.2% = +/- 18.2% @ 95% Confidence Interval

Appendix G - EXCEL U-factors

Tables G-1 through G-16 present the EXCEL U-factors for the 2,182 cases which address the five nominal stud dimensions, four thermal conductivities of the steel, nineteen cavity insulation options and seven sheathing insulation options.

Table G-1 EXCEL U-factors for 6oc, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-values						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4293	0.2070	0.1357	0.1019	0.0812	0.0578	0.0448
2x4-11	0.2342	0.1411	0.1034	0.0824	0.0683	0.0509	0.0406
2x4-13	0.2265	0.1373	0.1013	0.0811	0.0674	0.0504	0.0403
2x4-15	0.2211	0.1346	0.0997	0.0800	0.0667	0.0500	0.0400
2x6-0.91	0.4211	0.2053	0.1358	0.1014	0.0812	0.0572	0.0448
2x6-19	0.1972	0.1265	0.0957	0.0772	0.0649	0.0486	0.0393
2x6-21	0.1949	0.1244	0.0945	0.0764	0.0642	0.0485	0.0390
2x8-0.91	0.4154	0.2036	0.1349	0.1018	0.0807	0.0575	0.0447
2x8-19	0.1964	0.1266	0.0954	0.0763	0.0646	0.0488	0.0393
2x8-21	0.2014	0.1269	0.0959	0.0773	0.0648	0.0489	0.0394
2x8-25	0.1724	0.1154	0.0892	0.0729	0.0618	0.0472	0.0382
2x10-0.91	0.4104	0.2028	0.1347	0.1008	0.0805	0.0575	0.0447
2x10-19	0.1957	0.1256	0.0952	0.0769	0.0646	0.0485	0.0392
2x10-25	0.1760	0.1171	0.0902	0.0736	0.0621	0.0474	0.0384
2x10-30	0.1580	0.1088	0.0852	0.0709	0.0607	0.0463	0.0378
2x12-0.91	0.4059	0.2017	0.1342	0.1005	0.0796	0.0574	0.0447
2x12-19	0.1930	0.1246	0.0946	0.0764	0.0645	0.0486	0.0391
2x12-30	0.1613	0.1103	0.0861	0.0708	0.0602	0.0463	0.0376
2x12-38	0.1404	0.1001	0.0798	0.0665	0.0570	0.0444	0.0364

Table G-2 EXCEL U-factors for 6oc, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-values						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4306	0.2080	0.1373	0.1034	0.0816	0.0580	0.0449
2x4-11	0.2647	0.1445	0.1047	0.0831	0.0690	0.0513	0.0404
2x4-13	0.2629	0.1426	0.1033	0.0822	0.0684	0.0510	0.0402
2x4-15	0.2617	0.1412	0.1024	0.0816	0.0680	0.0508	0.0401
2x6-0.91	0.4314	0.2081	0.1374	0.1025	0.0817	0.0580	0.0449
2x6-19	0.2402	0.1346	0.0989	0.0795	0.0667	0.0503	0.0398
2x6-21	0.2367	0.1327	0.0978	0.0788	0.0663	0.0502	0.0398
2x8-0.91	0.4169	0.2048	0.1359	0.1016	0.0811	0.0577	0.0448
2x8-19	0.2273	0.1310	0.0971	0.0784	0.0660	0.0499	0.0396
2x8-21	0.2258	0.1299	0.0965	0.0780	0.0658	0.0499	0.0396
2x8-25	0.2187	0.1269	0.0948	0.0770	0.0652	0.0497	0.0396
2x10-0.91	0.4130	0.2039	0.1354	0.1013	0.0809	0.0576	0.0447
2x10-19	0.2190	0.1288	0.0960	0.0778	0.0656	0.0497	0.0394
2x10-25	0.2068	0.1233	0.0929	0.0759	0.0645	0.0494	0.0394
2x10-30	0.1930	0.1172	0.0894	0.0737	0.0631	0.0488	0.0392
2x12-0.91	0.4098	0.2031	0.1350	0.1011	0.0808	0.0576	0.0447
2x12-19	0.2128	0.1271	0.0952	0.0773	0.0652	0.0495	0.0393
2x12-30	0.1850	0.1148	0.0882	0.0730	0.0626	0.0485	0.0390
2x12-38	0.1578	0.1025	0.0809	0.0682	0.0593	0.0469	0.0382

Table G-3 EXCEL U-factors for 6oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4361	0.2092	0.1379	0.1028	0.0819	0.0581	0.0450
2x4-11	0.2766	0.1481	0.1066	0.0843	0.0699	0.0518	0.0407
2x4-13	0.2752	0.1463	0.1053	0.0835	0.0693	0.0516	0.0405
2x4-15	0.2744	0.1451	0.1045	0.0829	0.0690	0.0514	0.0405
2x6-0.91	0.4278	0.2074	0.1370	0.1023	0.0815	0.0580	0.0449
2x6-19	0.2557	0.1394	0.1015	0.0812	0.0679	0.0510	0.0402
2x6-21	0.2528	0.1378	0.1005	0.0806	0.0676	0.0510	0.0403
2x8-0.91	0.4227	0.2062	0.1365	0.1020	0.0813	0.0579	0.0448
2x8-19	0.2439	0.1363	0.1000	0.0803	0.0673	0.0507	0.0401
2x8-21	0.2425	0.1353	0.0994	0.0799	0.0672	0.0507	0.0402
2x8-25	0.2364	0.1327	0.0979	0.0791	0.0667	0.0506	0.0402
2x10-0.91	0.4186	0.2053	0.1360	0.1017	0.0812	0.0578	0.0448
2x10-19	0.2357	0.1342	0.0990	0.0797	0.0669	0.0505	0.0400
2x10-25	0.2251	0.1295	0.0963	0.0781	0.0660	0.0503	0.0400
2x10-30	0.2124	0.1239	0.0932	0.0762	0.0649	0.0499	0.0399
2x12-0.91	0.4152	0.2044	0.1357	0.1015	0.0810	0.0577	0.0447
2x12-19	0.2294	0.1326	0.0982	0.0792	0.0666	0.0503	0.0399
2x12-30	0.2045	0.1218	0.0921	0.0755	0.0644	0.0496	0.0398
2x12-38	0.1783	0.1102	0.0853	0.0712	0.0615	0.0482	0.0391

Table G-4 EXCEL U-factors for 6oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-values						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4425	0.2105	0.1384	0.1031	0.0820	0.0583	0.0450
2x4-11	0.2893	0.1520	0.1085	0.0855	0.0706	0.0521	0.0408
2x4-13	0.2880	0.1503	0.1074	0.0848	0.0702	0.0519	0.0407
2x4-15	0.2871	0.1492	0.1066	0.0843	0.0699	0.0518	0.0406
2x6-0.91	0.4345	0.2088	0.1377	0.1026	0.0818	0.0581	0.0449
2x6-19	0.2706	0.1442	0.1041	0.0828	0.0691	0.0516	0.0405
2x6-21	0.2676	0.1426	0.1032	0.0824	0.0689	0.0516	0.0406
2x8-0.91	0.4294	0.2077	0.1371	0.1023	0.0816	0.0580	0.0449
2x8-19	0.2599	0.1414	0.1028	0.0821	0.0686	0.0514	0.0404
2x8-21	0.2582	0.1405	0.1022	0.0818	0.0685	0.0514	0.0405
2x8-25	0.2525	0.1381	0.1010	0.0811	0.0681	0.0514	0.0406
2x10-0.91	0.4252	0.2068	0.1367	0.1021	0.0814	0.0579	0.0448
2x10-19	0.2521	0.1396	0.1019	0.0816	0.0683	0.0512	0.0403
2x10-25	0.2419	0.1352	0.0995	0.0803	0.0676	0.0512	0.0405
2x10-30	0.2291	0.1298	0.0966	0.0786	0.0666	0.0509	0.0406
2x12-0.91	0.4216	0.2059	0.1363	0.1019	0.0813	0.0578	0.0448
2x12-19	0.2458	0.1380	0.1012	0.0811	0.0679	0.0510	0.0402
2x12-30	0.2216	0.1279	0.0957	0.0780	0.0662	0.0507	0.0404
2x12-38	0.1950	0.1166	0.0893	0.0740	0.0636	0.0496	0.0400

Table G-5 EXCEL U-factors for 12oc, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4058	0.2019	0.1345	0.1008	0.0806	0.0575	0.0447
2x4-11	0.1673	0.1060	0.0822	0.0680	0.0582	0.0452	0.0368
2x4-13	0.1602	0.1010	0.0786	0.0654	0.0562	0.0440	0.0360
2x4-15	0.1547	0.0970	0.0757	0.0632	0.0546	0.0430	0.0353
2x6-0.91	0.4009	0.2007	0.1340	0.1005	0.0804	0.0574	0.0446
2x6-19	0.1358	0.0883	0.0700	0.0591	0.0514	0.0410	0.0339
2x6-21	0.1307	0.0849	0.0674	0.0571	0.0499	0.0400	0.0333
2x8-0.91	0.3982	0.2001	0.1336	0.1003	0.0803	0.0573	0.0446
2x8-19	0.1277	0.0853	0.0682	0.0579	0.0505	0.0404	0.0336
2x8-21	0.1249	0.0832	0.0666	0.0566	0.0496	0.0398	0.0331
2x8-25	0.1186	0.0796	0.0641	0.0547	0.0481	0.0389	0.0325
2x10-0.91	0.3961	0.1995	0.1334	0.1001	0.0802	0.0573	0.0445
2x10-19	0.1235	0.0841	0.0676	0.0575	0.0503	0.0403	0.0335
2x10-25	0.1118	0.0770	0.0625	0.0537	0.0473	0.0384	0.0322
2x10-30	0.1029	0.0719	0.0590	0.0510	0.0453	0.0371	0.0313
2x12-0.91	0.3945	0.1991	0.1332	0.1000	0.0801	0.0572	0.0445
2x12-19	0.1206	0.0832	0.0671	0.0572	0.0501	0.0402	0.0334
2x12-30	0.0989	0.0706	0.0583	0.0506	0.0450	0.0369	0.0312
2x12-38	0.0853	0.0631	0.0532	0.0469	0.0422	0.0352	0.0301

Table G-6 EXCEL U-factors for 12oc, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4087	0.2025	0.1348	0.1010	0.0807	0.0575	0.0447
2x4-11	0.1764	0.1089	0.0837	0.0689	0.0588	0.0454	0.0368
2x4-13	0.1697	0.1042	0.0803	0.0665	0.0569	0.0442	0.0360
2x4-15	0.1646	0.1005	0.0777	0.0645	0.0554	0.0433	0.0354
2x6-0.91	0.4092	0.2026	0.1348	0.1010	0.0807	0.0575	0.0447
2x6-19	0.1469	0.0925	0.0725	0.0608	0.0527	0.0416	0.0342
2x6-21	0.1417	0.0892	0.0701	0.0591	0.0514	0.0408	0.0337
2x8-0.91	0.4012	0.2008	0.1339	0.1005	0.0804	0.0574	0.0446
2x8-19	0.1391	0.0898	0.0709	0.0597	0.0519	0.0412	0.0339
2x8-21	0.1361	0.0877	0.0694	0.0586	0.0510	0.0407	0.0336
2x8-25	0.1296	0.0842	0.0670	0.0569	0.0498	0.0399	0.0331
2x10-0.91	0.3990	0.2002	0.1337	0.1003	0.0803	0.0573	0.0445
2x10-19	0.1349	0.0886	0.0703	0.0593	0.0516	0.0410	0.0338
2x10-25	0.1228	0.0818	0.0656	0.0559	0.0491	0.0395	0.0329
2x10-30	0.1125	0.0764	0.0621	0.0534	0.0473	0.0385	0.0322
2x12-0.91	0.3972	0.1998	0.1335	0.1002	0.0802	0.0573	0.0445
2x12-19	0.1317	0.0877	0.0698	0.0591	0.0514	0.0409	0.0338
2x12-30	0.1085	0.0751	0.0614	0.0530	0.0470	0.0383	0.0321
2x12-38	0.0915	0.0667	0.0560	0.0493	0.0443	0.0368	0.0313

Table G-7 EXCEL U-factors for 12oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4116	0.2032	0.1351	0.1011	0.0808	0.0576	0.0447
2x4-11	0.1830	0.1112	0.0850	0.0697	0.0593	0.0456	0.0368
2x4-13	0.1766	0.1066	0.0818	0.0674	0.0576	0.0446	0.0361
2x4-15	0.1717	0.1031	0.0792	0.0655	0.0562	0.0437	0.0355
2x6-0.91	0.4070	0.2022	0.1346	0.1008	0.0806	0.0575	0.0446
2x6-19	0.1555	0.0957	0.0744	0.0621	0.0537	0.0422	0.0345
2x6-21	0.1504	0.0926	0.0722	0.0605	0.0525	0.0415	0.0341
2x8-0.91	0.4042	0.2015	0.1343	0.1007	0.0805	0.0574	0.0446
2x8-19	0.1482	0.0933	0.0730	0.0612	0.0530	0.0418	0.0342
2x8-21	0.1452	0.0912	0.0716	0.0601	0.0522	0.0413	0.0340
2x8-25	0.1391	0.0880	0.0694	0.0586	0.0511	0.0407	0.0336
2x10-0.91	0.4019	0.2009	0.1340	0.1005	0.0804	0.0574	0.0446
2x10-19	0.1440	0.0921	0.0724	0.0608	0.0527	0.0417	0.0342
2x10-25	0.1325	0.0857	0.0681	0.0578	0.0505	0.0404	0.0334
2x10-30	0.1225	0.0807	0.0649	0.0555	0.0489	0.0395	0.0329
2x12-0.91	0.4001	0.2005	0.1338	0.1004	0.0803	0.0573	0.0445
2x12-19	0.1407	0.0912	0.0720	0.0606	0.0525	0.0415	0.0341
2x12-30	0.1185	0.0795	0.0643	0.0551	0.0486	0.0394	0.0328
2x12-38	0.1015	0.0714	0.0593	0.0517	0.0462	0.0381	0.0322

Table G-8 EXCEL U-factors for 12oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4146	0.2039	0.1354	0.1014	0.0810	0.0577	0.0447
2x4-11	0.1869	0.1126	0.0859	0.0704	0.0599	0.0461	0.0372
2x4-13	0.1805	0.1080	0.0827	0.0681	0.0582	0.0450	0.0365
2x4-15	0.1757	0.1045	0.0802	0.0663	0.0568	0.0442	0.0359
2x6-0.91	0.4103	0.2030	0.1350	0.1011	0.0808	0.0576	0.0447
2x6-19	0.1613	0.0978	0.0757	0.0631	0.0544	0.0428	0.0350
2x6-21	0.1571	0.0949	0.0737	0.0616	0.0534	0.0421	0.0346
2x8-0.91	0.4075	0.2023	0.1347	0.1009	0.0807	0.0575	0.0447
2x8-19	0.1549	0.0956	0.0744	0.0622	0.0538	0.0424	0.0348
2x8-21	0.1523	0.0938	0.0731	0.0613	0.0531	0.0420	0.0345
2x8-25	0.1475	0.0910	0.0713	0.0600	0.0521	0.0415	0.0342
2x10-0.91	0.4052	0.2018	0.1344	0.1008	0.0806	0.0575	0.0446
2x10-19	0.1510	0.0946	0.0739	0.0619	0.0536	0.0423	0.0347
2x10-25	0.1417	0.0891	0.0702	0.0592	0.0516	0.0412	0.0340
2x10-30	0.1340	0.0851	0.0676	0.0575	0.0504	0.0406	0.0337
2x12-0.91	0.4033	0.2013	0.1342	0.1006	0.0805	0.0574	0.0446
2x12-19	0.1478	0.0937	0.0735	0.0617	0.0534	0.0422	0.0346
2x12-30	0.1302	0.0840	0.0671	0.0571	0.0502	0.0405	0.0337
2x12-38	0.1175	0.0781	0.0634	0.0547	0.0485	0.0397	0.0334

Table G-9 EXCEL U-factors for 16oc, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4007	0.2004	0.1338	0.1004	0.0803	0.0573	0.0446
2x4-11	0.1452	0.0959	0.0757	0.0634	0.0547	0.0430	0.0353
2x4-13	0.1368	0.0901	0.0716	0.0603	0.0523	0.0415	0.0343
2x4-15	0.1303	0.0856	0.0683	0.0578	0.0503	0.0402	0.0334
2x6-0.91	0.3968	0.1995	0.1333	0.1001	0.0801	0.0572	0.0445
2x6-19	0.1127	0.0767	0.0621	0.0532	0.0468	0.0379	0.0318
2x6-21	0.1070	0.0728	0.0592	0.0510	0.0450	0.0367	0.0309
2x8-0.91	0.3947	0.1990	0.1331	0.0999	0.0800	0.0572	0.0445
2x8-19	0.1061	0.0740	0.0605	0.0520	0.0459	0.0373	0.0314
2x8-21	0.1028	0.0716	0.0586	0.0506	0.0448	0.0365	0.0308
2x8-25	0.0966	0.0678	0.0559	0.0485	0.0431	0.0354	0.0300
2x10-0.91	0.3930	0.1986	0.1329	0.0998	0.0799	0.0571	0.0444
2x10-19	0.1030	0.0731	0.0600	0.0517	0.0457	0.0372	0.0313
2x10-25	0.0913	0.0657	0.0545	0.0475	0.0424	0.0350	0.0297
2x10-30	0.0831	0.0607	0.0510	0.0448	0.0402	0.0336	0.0288
2x12-0.91	0.3918	0.1982	0.1327	0.0997	0.0799	0.0571	0.0444
2x12-19	0.1009	0.0724	0.0596	0.0515	0.0455	0.0371	0.0312
2x12-30	0.0802	0.0597	0.0504	0.0444	0.0400	0.0334	0.0287
2x12-38	0.0689	0.0532	0.0459	0.0411	0.0374	0.0318	0.0275

Table G-10 EXCEL U-factors for 16oc, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4033	0.2010	0.1340	0.1005	0.0804	0.0574	0.0446
2x4-11	0.1512	0.0980	0.0769	0.0642	0.0553	0.0433	0.0355
2x4-13	0.1429	0.0923	0.0729	0.0612	0.0530	0.0418	0.0345
2x4-15	0.1365	0.0879	0.0696	0.0587	0.0511	0.0406	0.0336
2x6-0.91	0.4036	0.2011	0.1341	0.1005	0.0804	0.0574	0.0446
2x6-19	0.1199	0.0794	0.0638	0.0544	0.0477	0.0385	0.0321
2x6-21	0.1143	0.0756	0.0610	0.0523	0.0460	0.0374	0.0314
2x8-0.91	0.3973	0.1996	0.1334	0.1001	0.0801	0.0572	0.0445
2x8-19	0.1136	0.0770	0.0623	0.0533	0.0469	0.0380	0.0318
2x8-21	0.1102	0.0745	0.0605	0.0519	0.0458	0.0372	0.0313
2x8-25	0.1042	0.0709	0.0579	0.0499	0.0443	0.0362	0.0306
2x10-0.91	0.3955	0.1992	0.1332	0.1000	0.0800	0.0572	0.0445
2x10-19	0.1105	0.0761	0.0618	0.0530	0.0467	0.0378	0.0317
2x10-25	0.0990	0.0689	0.0566	0.0491	0.0436	0.0358	0.0303
2x10-30	0.0906	0.0640	0.0532	0.0465	0.0416	0.0346	0.0295
2x12-0.91	0.3941	0.1988	0.1330	0.0999	0.0800	0.0572	0.0445
2x12-19	0.1082	0.0754	0.0615	0.0528	0.0466	0.0378	0.0317
2x12-30	0.0876	0.0631	0.0527	0.0462	0.0414	0.0344	0.0294
2x12-38	0.0756	0.0565	0.0482	0.0429	0.0389	0.0329	0.0280

Table G-11 EXCEL U-factors for 16oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4058	0.2016	0.1343	0.1007	0.0805	0.0574	0.0446
2x4-11	0.1570	0.0998	0.0779	0.0648	0.0557	0.0435	0.0356
2x4-13	0.1489	0.0942	0.0739	0.0618	0.0534	0.0421	0.0347
2x4-15	0.1426	0.0899	0.0707	0.0594	0.0516	0.0409	0.0338
2x6-0.91	0.4021	0.2008	0.1339	0.1004	0.0803	0.0573	0.0446
2x6-19	0.1270	0.0819	0.0652	0.0553	0.0484	0.0389	0.0324
2x6-21	0.1216	0.0782	0.0625	0.0533	0.0468	0.0378	0.0317
2x8-0.91	0.3998	0.2002	0.1336	0.1003	0.0802	0.0573	0.0445
2x8-19	0.1211	0.0796	0.0638	0.0543	0.0476	0.0384	0.0321
2x8-21	0.1177	0.0772	0.0620	0.0530	0.0466	0.0377	0.0316
2x8-25	0.1120	0.0738	0.0595	0.0511	0.0451	0.0368	0.0310
2x10-0.91	0.3980	0.1998	0.1334	0.1002	0.0802	0.0573	0.0445
2x10-19	0.1180	0.0787	0.0634	0.0541	0.0475	0.0383	0.0320
2x10-25	0.1069	0.0719	0.0584	0.0503	0.0445	0.0364	0.0307
2x10-30	0.0988	0.0672	0.0551	0.0479	0.0427	0.0353	0.0300
2x12-0.91	0.3965	0.1994	0.1333	0.1001	0.0801	0.0572	0.0445
2x12-19	0.1156	0.0781	0.0630	0.0539	0.0473	0.0382	0.0320
2x12-30	0.0958	0.0664	0.0547	0.0476	0.0425	0.0351	0.0299
2x12-38	0.0839	0.0601	0.0505	0.0445	0.0402	0.0338	0.0291

Table G-12 EXCEL U-factors for 16oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.4081	0.2020	0.1345	0.1008	0.0805	0.0574	0.0446
2x4-11	0.1625	0.1015	0.0788	0.0653	0.0560	0.0437	0.0357
2x4-13	0.1545	0.0961	0.0749	0.0625	0.0539	0.0423	0.0348
2x4-15	0.1483	0.0918	0.0718	0.0601	0.0521	0.0412	0.0340
2x6-0.91	0.4046	0.2013	0.1341	0.1005	0.0804	0.0574	0.0446
2x6-19	0.1333	0.0840	0.0664	0.0562	0.0490	0.0393	0.0327
2x6-21	0.1275	0.0803	0.0638	0.0542	0.0475	0.0383	0.0320
2x8-0.91	0.4024	0.2008	0.1339	0.1004	0.0803	0.0573	0.0446
2x8-19	0.1276	0.0819	0.0651	0.0552	0.0483	0.0388	0.0324
2x8-21	0.1240	0.0794	0.0633	0.0539	0.0473	0.0382	0.0320
2x8-25	0.1179	0.0759	0.0609	0.0521	0.0459	0.0373	0.0314
2x10-0.91	0.4006	0.2004	0.1337	0.1003	0.0802	0.0573	0.0445
2x10-19	0.1247	0.0811	0.0647	0.0550	0.0482	0.0388	0.0323
2x10-25	0.1130	0.0741	0.0598	0.0513	0.0453	0.0370	0.0312
2x10-30	0.1037	0.0692	0.0564	0.0489	0.0435	0.0359	0.0305
2x12-0.91	0.3990	0.2000	0.1335	0.1002	0.0802	0.0573	0.0445
2x12-19	0.1223	0.0805	0.0644	0.0548	0.0480	0.0387	0.0323
2x12-30	0.1010	0.0684	0.0560	0.0486	0.0433	0.0358	0.0304
2x12-38	0.0868	0.0614	0.0515	0.0454	0.0410	0.0345	0.0297

Table G-13 EXCEL U-factors for oc24, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.3990	0.1999	0.1335	0.1002	0.0801	0.0572	0.0445
2x4-11	0.1282	0.0885	0.0711	0.0600	0.0521	0.0412	0.0340
2x4-13	0.1177	0.0817	0.0662	0.0564	0.0493	0.0394	0.0327
2x4-15	0.1094	0.0762	0.0623	0.0534	0.0469	0.0378	0.0315
2x6-0.91	0.3954	0.1991	0.1331	0.0999	0.0800	0.0572	0.0444
2x6-19	0.0917	0.0665	0.0554	0.0481	0.0428	0.0350	0.0295
2x6-21	0.0849	0.0619	0.0519	0.0454	0.0406	0.0335	0.0284
2x8-0.91	0.3935	0.1986	0.1328	0.0998	0.0799	0.0571	0.0444
2x8-19	0.0862	0.0640	0.0537	0.0469	0.0418	0.0344	0.0291
2x8-21	0.0821	0.0611	0.0515	0.0451	0.0404	0.0334	0.0283
2x8-25	0.0757	0.0570	0.0484	0.0427	0.0384	0.0320	0.0273
2x10-0.91	0.3920	0.1982	0.1327	0.0997	0.0798	0.0571	0.0444
2x10-19	0.0842	0.0634	0.0534	0.0467	0.0417	0.0343	0.0290
2x10-25	0.0717	0.0551	0.0472	0.0418	0.0377	0.0315	0.0269
2x10-30	0.0641	0.0502	0.0434	0.0388	0.0352	0.0298	0.0257
2x12-0.91	0.3909	0.1979	0.1325	0.0996	0.0798	0.0570	0.0444
2x12-19	0.0828	0.0629	0.0531	0.0465	0.0415	0.0342	0.0290
2x12-30	0.0623	0.0495	0.0430	0.0386	0.0351	0.0297	0.0256
2x12-38	0.0539	0.0441	0.0390	0.0354	0.0325	0.0279	0.0243

Table G-14 EXCEL U-factors for oc24, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.3982	0.1996	0.1333	0.1000	0.0801	0.0572	0.0445
2x4-11	0.1293	0.0882	0.0707	0.0596	0.0517	0.0409	0.0338
2x4-13	0.1197	0.0818	0.0660	0.0561	0.0490	0.0392	0.0326
2x4-15	0.1122	0.0766	0.0623	0.0533	0.0468	0.0377	0.0315
2x6-0.91	0.3984	0.1996	0.1333	0.1000	0.0801	0.0572	0.0445
2x6-19	0.0963	0.0678	0.0559	0.0485	0.0430	0.0351	0.0297
2x6-21	0.0901	0.0636	0.0528	0.0460	0.0410	0.0338	0.0287
2x8-0.91	0.3936	0.1985	0.1328	0.0997	0.0799	0.0571	0.0444
2x8-19	0.0913	0.0655	0.0545	0.0474	0.0421	0.0346	0.0293
2x8-21	0.0874	0.0628	0.0524	0.0457	0.0408	0.0337	0.0286
2x8-25	0.0814	0.0590	0.0495	0.0435	0.0390	0.0324	0.0277
2x10-0.91	0.3922	0.1982	0.1326	0.0997	0.0798	0.0571	0.0444
2x10-19	0.0892	0.0649	0.0542	0.0472	0.0420	0.0345	0.0292
2x10-25	0.0775	0.0573	0.0484	0.0427	0.0384	0.0320	0.0274
2x10-30	0.0699	0.0525	0.0449	0.0399	0.0362	0.0305	0.0264
2x12-0.91	0.3912	0.1979	0.1325	0.0996	0.0798	0.0570	0.0444
2x12-19	0.0877	0.0645	0.0539	0.0470	0.0419	0.0344	0.0292
2x12-30	0.0680	0.0519	0.0446	0.0397	0.0360	0.0304	0.0263
2x12-38	0.0585	0.0463	0.0406	0.0367	0.0336	0.0289	0.0252

Table G-15 EXCEL U-factors for 24oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.3980	0.1996	0.1334	0.1001	0.0801	0.0572	0.0445
2x4-11	0.1274	0.0876	0.0705	0.0596	0.0518	0.0411	0.0340
2x4-13	0.1180	0.0812	0.0658	0.0561	0.0491	0.0394	0.0328
2x4-15	0.1110	0.0761	0.0621	0.0532	0.0468	0.0378	0.0317
2x6-0.91	0.3955	0.1991	0.1331	0.1000	0.0800	0.0572	0.0445
2x6-19	0.0971	0.0678	0.0560	0.0485	0.0431	0.0353	0.0299
2x6-21	0.0920	0.0640	0.0530	0.0461	0.0411	0.0339	0.0288
2x8-0.91	0.3940	0.1987	0.1329	0.0999	0.0800	0.0571	0.0445
2x8-19	0.0928	0.0658	0.0546	0.0475	0.0423	0.0348	0.0295
2x8-21	0.0896	0.0633	0.0526	0.0459	0.0410	0.0338	0.0288
2x8-25	0.0851	0.0601	0.0501	0.0438	0.0392	0.0326	0.0279
2x10-0.91	0.3928	0.1984	0.1328	0.0998	0.0799	0.0571	0.0444
2x10-19	0.0908	0.0653	0.0544	0.0473	0.0421	0.0347	0.0294
2x10-25	0.0818	0.0586	0.0491	0.0431	0.0387	0.0322	0.0276
2x10-30	0.0770	0.0550	0.0462	0.0407	0.0367	0.0308	0.0266
2x12-0.91	0.3917	0.1982	0.1327	0.0997	0.0798	0.0571	0.0444
2x12-19	0.0894	0.0649	0.0541	0.0472	0.0420	0.0346	0.0294
2x12-30	0.0750	0.0544	0.0459	0.0405	0.0365	0.0307	0.0265
2x12-38	0.0703	0.0509	0.0431	0.0382	0.0346	0.0294	0.0255

Table G-16 EXCEL U-factors for 24oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	0.4013	0.2004	0.1337	0.1003	0.0802	0.0573	0.0445
2x4-11	0.1340	0.0898	0.0717	0.0604	0.0524	0.0414	0.0342
2x4-13	0.1245	0.0834	0.0671	0.0569	0.0497	0.0397	0.0330
2x4-15	0.1172	0.0784	0.0634	0.0541	0.0475	0.0382	0.0319
2x6-0.91	0.3987	0.1998	0.1334	0.1001	0.0801	0.0572	0.0445
2x6-19	0.1032	0.0701	0.0574	0.0495	0.0438	0.0357	0.0302
2x6-21	0.0978	0.0662	0.0543	0.0471	0.0418	0.0344	0.0292
2x8-0.91	0.3971	0.1994	0.1332	0.1000	0.0801	0.0572	0.0445
2x8-19	0.0989	0.0682	0.0560	0.0485	0.0430	0.0352	0.0298
2x8-21	0.0955	0.0656	0.0540	0.0469	0.0417	0.0343	0.0291
2x8-25	0.0907	0.0623	0.0515	0.0448	0.0400	0.0332	0.0283
2x10-0.91	0.3957	0.1991	0.1331	0.0999	0.0800	0.0572	0.0445
2x10-19	0.0970	0.0677	0.0558	0.0483	0.0429	0.0352	0.0297
2x10-25	0.0874	0.0609	0.0505	0.0441	0.0395	0.0328	0.0280
2x10-30	0.0820	0.0571	0.0476	0.0418	0.0375	0.0314	0.0270
2x12-0.91	0.3946	0.1988	0.1330	0.0999	0.0800	0.0571	0.0444
2x12-19	0.0954	0.0673	0.0556	0.0482	0.0428	0.0351	0.0297
2x12-30	0.0801	0.0566	0.0473	0.0416	0.0374	0.0314	0.0270
2x12-38	0.0746	0.0529	0.0444	0.0393	0.0356	0.0301	0.0261

Appendix H - Overall Accuracy of U-factor Calculations

Tables H-1 through H-16 present the accuracy of the EXCEL U-factors vs. the THERM U-factors for the 2,182 cases which address the five nominal stud dimensions, four thermal conductivities of the steel, nineteen cavity insulation options and seven sheathing insulation options.

Table H-1 Overall U-factor Accuracy for 6oc, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-values						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	-1.28	-0.24	0.66	0.20	0.25	0.17	0.22
2x4-11	6.28	-1.06	-1.26	-1.21	-0.59	-0.39	-1.23
2x4-13	8.92	0.15	-0.69	-0.86	-0.30	0.00	-1.24
2x4-15	10.90	0.97	-0.20	-0.38	0.00	0.20	-0.75
2x6-0.91	-1.38	-0.39	-0.07	0.10	-0.25	0.87	0.00
2x6-19	11.97	1.26	-0.42	-0.13	0.15	1.44	-0.25
2x6-21	11.39	1.29	-0.53	-0.13	0.62	1.44	0.51
2x8-0.91	-1.18	-0.15	0.15	-0.59	0.12	0.17	0.00
2x8-19	5.45	-2.05	-2.20	-0.52	-0.62	0.20	-0.76
2x8-21	2.18	-3.07	-3.55	-2.46	-1.39	-0.20	-1.27
2x8-25	14.73	3.64	1.57	1.78	2.27	2.75	1.57
2x10-0.91	-0.85	-0.20	0.00	0.10	0.25	0.00	-0.22
2x10-19	1.58	-3.11	-3.26	-2.21	-1.39	0.21	-1.02
2x10-25	5.45	-1.28	-1.88	-0.95	0.32	1.48	0.52
2x10-30	8.67	0.28	-0.59	-0.56	0.00	2.16	1.06
2x12-0.91	-0.44	0.00	0.15	0.20	1.13	0.00	-0.22
2x12-19	0.10	-3.69	-3.59	-2.36	-1.86	-0.41	-1.02
2x12-30	1.61	-3.35	-3.14	-1.69	-0.17	1.51	1.06
2x12-38	-2.07	-6.09	-5.14	-3.01	-0.88	1.58	1.65

Table H-2 Overall U-factor Accuracy for 6oc, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-values						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	-1.26	-0.24	0.73	1.17	0.25	0.17	0.00
2x4-11	7.08	-0.62	-0.95	-0.95	-0.43	-0.39	-1.22
2x4-13	9.72	0.64	-0.29	-0.36	0.00	0.00	-0.99
2x4-15	11.69	1.51	0.29	0.00	0.44	0.40	-0.74
2x6-0.91	0.72	0.53	0.66	0.69	0.25	1.22	0.00
2x6-19	12.56	1.51	-0.20	0.13	0.45	1.62	-0.25
2x6-21	11.86	1.53	-0.20	0.13	0.61	1.41	0.51
2x8-0.91	-1.23	-0.19	0.22	-0.59	0.12	0.00	0.00
2x8-19	4.99	-2.53	-2.61	-0.76	-0.75	0.00	-1.00
2x8-21	1.76	-3.42	-3.60	-2.50	-1.20	-0.20	-1.25
2x8-25	15.23	3.42	1.39	1.72	2.19	2.90	1.80
2x10-0.91	-0.84	-0.15	0.07	0.10	0.12	0.00	0.00
2x10-19	1.15	-3.59	-3.71	-2.51	-1.50	0.20	-1.50
2x10-25	4.97	-1.91	-2.42	-1.17	0.00	1.23	0.25
2x10-30	9.35	0.17	-0.78	-0.81	-0.16	2.31	1.29
2x12-0.91	-0.41	0.00	0.15	0.20	1.25	0.17	-0.22
2x12-19	-0.23	-3.93	-3.84	-2.52	-1.95	-0.40	-1.26
2x12-30	1.31	-3.93	-3.71	-2.01	-0.32	1.46	1.04
2x12-38	-0.38	-5.70	-4.94	-2.71	-0.67	1.96	1.87

Table H-3 Overall U-factor Accuracy for 6oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	-1.38	-0.33	0.73	0.29	0.37	0.17	0.00
2x4-11	7.42	-0.40	-0.74	-0.71	-0.14	-0.19	-1.21
2x4-13	10.12	0.90	-0.09	-0.12	0.29	0.39	-0.98
2x4-15	12.18	1.90	0.58	0.24	0.73	0.78	-0.49
2x6-0.91	-1.63	-0.53	-0.15	0.10	-0.24	0.87	0.00
2x6-19	12.79	1.46	-0.29	0.12	0.44	1.80	-0.25
2x6-21	12.16	1.62	-0.30	0.25	0.75	1.80	0.75
2x8-0.91	-1.38	-0.19	0.22	-0.49	0.12	0.17	-0.22
2x8-19	4.28	-3.06	-3.01	-0.99	-1.03	-0.20	-0.99
2x8-21	1.21	-3.70	-0.90	-2.56	-1.32	-0.20	-0.99
2x8-25	15.66	3.35	1.24	1.67	2.14	2.85	1.77
2x10-0.91	-0.95	-0.19	0.00	0.20	0.25	0.17	0.00
2x10-19	0.34	-4.21	-4.16	-2.80	-1.91	0.00	-1.23
2x10-25	4.45	-2.48	-2.92	-1.64	-0.45	1.00	0.00
2x10-30	10.34	0.16	-0.85	-0.91	-0.31	2.25	1.27
2x12-0.91	-0.48	0.00	0.22	0.30	1.25	0.17	-0.22
2x12-19	-0.78	-4.40	-4.20	-2.82	-2.20	-0.59	-1.24
2x12-30	1.39	-4.25	-4.06	-2.45	-0.62	1.22	1.02
2x12-38	2.29	-4.84	-4.59	-2.47	-0.32	2.12	2.09

Table H-4 Overall U-factor Accuracy for 6oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-values						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	-1.27	-0.33	0.65	0.29	0.24	0.34	0.00
2x4-11	8.47	0.33	-0.28	-0.35	0.00	-0.19	-1.45
2x4-13	11.15	1.62	0.56	0.24	0.57	0.39	-0.97
2x4-15	13.12	2.68	1.14	0.84	1.16	0.78	-0.73
2x6-0.91	-1.72	-0.62	-0.15	0.00	-0.24	0.87	-0.22
2x6-19	13.22	1.84	0.10	0.36	0.73	1.98	-0.25
2x6-21	12.34	1.93	0.10	0.61	1.17	1.78	0.50
2x8-0.91	-1.47	-0.29	0.07	-0.58	0.12	0.17	0.00
2x8-19	3.63	-3.35	-3.11	-0.97	-1.01	-0.19	-1.46
2x8-21	0.58	-3.70	-3.77	-2.39	-1.15	-0.19	-1.22
2x8-25	15.61	3.37	1.41	1.76	2.25	3.01	1.50
2x10-0.91	-1.02	-0.24	0.00	0.20	0.12	0.17	-0.22
2x10-19	-0.40	-4.45	-4.32	-2.86	-1.87	-0.19	-1.71
2x10-25	3.42	-2.94	-3.21	-1.71	-0.29	0.99	0.00
2x10-30	9.99	1.64	-0.92	-0.76	-1.62	2.41	1.50
2x12-0.91	-0.52	-0.05	0.15	0.30	1.25	0.17	-0.22
2x12-19	-1.36	-4.70	-4.26	-2.99	-2.30	-0.78	-1.71
2x12-30	0.27	-4.84	-4.40	-2.50	-0.75	1.40	1.00
2x12-38	2.58	-4.74	-4.29	-2.12	0.00	2.69	2.56

Table H-5 Overall U-factor Accuracy for 12oc, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	-0.29	0.10	0.22	0.10	0.12	0.52	0.45
2x4-11	7.52	2.22	1.73	1.64	1.75	1.80	1.10
2x4-13	9.20	2.96	1.42	1.40	1.44	1.85	1.69
2x4-15	10.34	3.08	1.34	1.12	1.30	1.42	0.86
2x6-0.91	-0.62	-0.15	0.07	0.10	0.12	0.17	0.22
2x6-19	10.77	2.67	2.04	0.17	0.19	0.99	0.30
2x6-21	9.56	2.29	0.15	-0.17	0.00	0.25	0.30
2x8-0.91	-0.55	-0.10	-0.30	-0.10	0.00	0.00	0.00
2x8-19	2.49	-1.50	-2.43	-2.20	-1.94	-1.22	-1.18
2x8-21	-2.12	-3.59	-4.03	-3.58	-2.75	-1.73	-1.78
2x8-25	12.31	3.78	1.42	0.92	1.05	1.30	0.93
2x10-0.91	-0.48	-0.10	0.08	0.10	0.00	0.00	-0.22
2x10-19	-3.36	-3.33	-3.70	-3.04	-1.57	-0.98	-0.89
2x10-25	2.19	-1.66	-2.80	-2.36	-1.25	0.00	0.00
2x10-30	8.20	1.70	0.00	1.19	5.59	5.10	4.33
2x12-0.91	-0.40	-0.05	0.08	0.10	0.13	-0.17	0.68
2x12-19	-6.15	-5.56	-5.23	-4.35	-3.28	-2.19	-2.05
2x12-30	-0.50	-2.89	-3.48	-2.88	-1.96	-1.07	-0.64
2x12-38	1.91	-1.56	-2.03	-1.68	-0.71	0.57	1.01

Table H-6 Overall U-factor Accuracy for 12oc, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	-0.41	0.00	0.22	0.20	0.12	0.52	0.45
2x4-11	8.75	2.74	2.07	1.77	1.73	1.34	0.55
2x4-13	10.70	3.78	1.90	1.53	1.43	1.38	0.56
2x4-15	12.13	4.25	2.10	1.74	1.47	1.17	0.28
2x6-0.91	0.52	0.35	0.37	0.40	0.37	0.17	0.22
2x6-19	12.31	3.58	1.26	0.50	0.57	0.73	0.00
2x6-21	10.88	-1.65	1.01	0.68	0.78	0.49	0.00
2x8-0.91	-0.69	-0.20	-0.30	-0.10	0.00	0.00	0.00
2x8-19	2.66	-1.32	-2.34	-2.29	-1.89	-1.20	-1.45
2x8-21	-2.23	-3.31	-3.74	-3.14	-2.67	-1.69	-2.04
2x8-25	13.19	4.34	1.82	1.43	1.63	1.53	0.61
2x10-0.91	-0.57	0.10	0.00	0.10	-0.12	-0.17	-0.22
2x10-19	-3.71	-3.38	-3.83	-3.26	-1.90	-1.44	-1.74
2x10-25	1.66	-1.80	-2.81	-2.44	-1.01	0.00	0.00
2x10-30	7.66	1.46	0.00	6.37	6.29	6.06	4.55
2x12-0.91	-0.45	-0.10	0.07	0.10	0.12	0.17	0.68
2x12-19	-6.53	-5.60	-5.29	-4.37	-3.75	-2.62	-2.59
2x12-30	-2.52	-3.96	-4.06	-3.11	-2.08	-0.78	-0.93
2x12-38	-1.51	-3.19	-2.78	-1.79	-0.45	1.38	1.95

Table H-7 Overall U-factor Accuracy for 12oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	-0.46	0.00	0.22	0.10	0.12	0.52	0.22
2x4-11	9.32	3.25	2.41	1.90	1.72	1.11	0.00
2x4-13	11.49	4.31	2.51	1.97	1.77	1.59	0.28
2x4-15	12.96	4.99	2.72	2.18	2.00	1.39	0.00
2x6-0.91	-0.90	-0.25	0.00	0.00	0.12	0.17	0.00
2x6-19	13.01	4.13	1.64	0.81	0.94	0.96	-0.29
2x6-21	11.57	3.93	1.55	1.17	1.35	0.97	0.00
2x8-0.91	-0.81	-0.25	-0.30	-0.10	-0.12	-0.17	0.00
2x8-19	2.28	-1.27	-2.28	-2.24	-1.85	-1.42	-1.44
2x8-21	-2.75	-3.18	-3.50	-3.06	-2.25	-1.90	-2.02
2x8-25	14.02	4.89	2.36	1.91	2.00	1.75	0.90
2x10-0.91	-0.69	-0.20	0.00	0.10	-0.12	0.00	0.00
2x10-19	-4.64	-3.66	-3.98	-3.34	-2.04	-1.42	-2.01
2x10-25	1.15	-2.06	-2.85	-2.20	-0.98	0.25	-0.30
2x10-30	1.32	-2.06	-2.70	4.52	4.49	4.50	3.46
2x12-0.91	-0.50	-0.10	0.07	0.10	0.12	-0.17	0.68
2x12-19	-7.43	-5.88	-5.39	-4.42	-3.85	-3.04	-3.13
2x12-30	-2.87	-4.10	-4.03	-3.16	-2.02	-0.76	-0.91
2x12-38	0.30	-2.06	-1.66	-0.96	0.43	2.14	2.55

Table H-8 Overall U-factor Accuracy for 12oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	-0.48	-2.39	0.22	0.20	0.25	0.52	0.22
2x4-11	8.66	3.11	2.51	2.18	2.22	1.77	0.81
2x4-13	10.67	4.15	2.48	2.10	2.11	2.04	1.11
2x4-15	12.20	4.81	2.82	2.47	2.34	1.84	0.84
2x6-0.91	-1.01	-0.29	0.00	0.10	0.12	0.17	0.22
2x6-19	12.17	3.82	1.47	0.96	0.93	1.42	0.57
2x6-21	11.02	3.72	1.66	1.32	1.52	1.45	0.58
2x8-0.91	-0.97	-0.30	-0.30	-0.20	0.00	0.00	0.00
2x8-19	0.52	-2.25	-2.87	-2.66	-2.00	-1.40	-0.57
2x8-21	-4.33	-3.40	-3.94	-3.01	-2.39	-1.41	-1.71
2x8-25	14.16	4.96	2.44	2.04	1.96	2.22	1.48
2x10-0.91	-0.81	-0.25	0.00	0.10	0.00	0.00	-0.22
2x10-19	-6.79	-4.64	-4.65	-3.88	-2.19	-1.40	-1.70
2x10-25	0.28	-2.52	-3.17	-2.63	-1.15	0.24	-0.29
2x10-30	-1.33	-4.60	-4.79	-3.69	-2.51	-0.98	-2.03
2x12-0.91	-0.62	-0.15	0.07	0.10	0.12	-0.17	0.68
2x12-19	-9.49	-6.95	-6.13	-4.93	-4.13	-2.76	-3.08
2x12-30	-2.18	-4.33	-3.73	-2.89	-1.76	-0.25	0.00
2x12-38	7.50	1.96	2.26	1.30	2.32	3.66	4.05

Table H-9 Overall U-factor Accuracy for 16oc, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	-0.12	0.05	0.15	0.20	0.12	0.00	0.03
2x4-11	6.92	2.24	1.20	1.28	1.30	1.18	0.86
2x4-13	7.97	2.50	1.42	1.17	1.16	1.22	0.88
2x4-15	8.95	3.01	1.64	1.40	1.21	1.26	0.91
2x6-0.91	-0.50	1.84	1.29	1.01	0.88	0.53	0.45
2x6-19	8.37	1.32	-0.32	-0.56	-0.43	0.00	-0.31
2x6-21	7.00	1.25	-0.34	-0.39	-0.22	0.82	-0.32
2x8-0.91	-0.48	-0.15	0.00	0.00	0.00	0.00	0.00
2x8-19	0.86	-1.86	-2.58	-2.44	-1.92	-1.32	-1.26
2x8-21	-4.01	1.27	-0.17	-1.17	0.00	0.27	0.00
2x8-25	9.15	2.57	0.90	0.62	0.47	0.57	0.33
2x10-0.91	-0.43	-0.15	0.00	0.00	0.00	-0.17	-0.22
2x10-19	-4.98	-4.69	-4.46	-3.72	-2.97	-2.11	-1.88
2x10-25	6.53	2.34	0.93	0.85	1.19	1.45	1.02
2x10-30	6.27	3.94	2.20	1.82	2.03	2.44	1.41
2x12-0.91	-0.10	-0.15	0.00	0.00	0.00	0.00	0.00
2x12-19	-7.60	-4.11	-5.10	-2.09	-3.60	-2.62	-2.19
2x12-30	-2.55	-3.24	-3.26	-3.06	-1.96	-0.89	-0.35
2x12-38	-0.29	-1.66	-1.50	-0.72	0.27	1.60	1.48

Table H-10 Overall U-factor Accuracy for 16oc, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	-0.12	0.05	0.15	0.20	0.12	0.17	0.00
2x4-11	7.46	2.62	1.45	1.42	1.47	1.17	0.85
2x4-13	8.59	3.01	1.82	1.66	1.53	1.21	0.88
2x4-15	9.55	3.53	1.90	1.73	1.79	1.50	0.90
2x6-0.91	0.47	0.30	0.30	0.30	0.25	0.17	0.22
2x6-19	8.90	1.53	-0.16	-0.37	-0.21	0.00	-0.31
2x6-21	7.42	1.48	0.00	0.00	0.00	0.54	0.00
2x8-0.91	-0.50	-0.20	0.00	0.00	0.00	0.00	0.00
2x8-19	0.18	-2.16	-2.96	-2.56	-2.09	-1.30	-1.55
2x8-21	-4.67	1.22	0.00	-0.19	0.00	0.27	0.32
2x8-25	9.45	2.60	0.87	0.40	0.68	0.84	0.66
2x10-0.91	-0.43	-0.15	0.00	0.00	0.00	0.00	0.00
2x10-19	-6.20	-5.23	-4.92	-4.16	-3.31	-2.58	-2.46
2x10-25	6.57	2.07	0.89	1.03	1.16	1.42	1.00
2x10-30	6.21	4.23	2.50	2.20	2.46	2.98	2.43
2x12-0.91	-0.10	-0.15	0.00	0.00	0.13	0.18	0.23
2x12-19	-9.08	-4.56	-5.38	-2.58	-3.72	-2.58	-2.46
2x12-30	-4.05	-4.25	-4.18	-3.55	-2.36	-1.15	-0.68
2x12-38	-0.66	-2.25	-2.03	-0.92	0.00	1.54	0.36

Table H-11 Overall U-factor Accuracy for 16oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	-0.10	0.05	0.15	0.20	0.25	0.17	0.00
2x4-11	8.58	3.10	2.77	1.57	1.64	1.16	0.85
2x4-13	9.89	3.63	2.07	1.64	1.71	1.45	1.17
2x4-15	10.97	4.29	2.46	2.06	1.98	1.74	0.90
2x6-0.91	-0.54	-0.15	0.00	0.00	0.00	0.00	0.00
2x6-19	10.24	2.12	0.15	-0.18	-0.21	0.00	-0.31
2x6-21	6.02	2.22	0.48	0.19	0.21	0.53	0.00
2x8-0.91	-0.55	-0.25	-0.07	0.00	0.00	0.00	0.00
2x8-19	0.50	-2.21	-3.04	-2.86	-2.46	-1.79	-1.83
2x8-21	-4.85	1.71	0.00	-0.38	0.22	0.27	0.00
2x8-25	11.44	3.22	0.85	0.59	0.67	0.82	0.65
2x10-0.91	-0.43	-0.15	-0.07	0.10	0.12	0.00	-0.22
2x10-19	-6.57	-5.52	-5.09	-4.42	-3.65	-2.79	-2.74
2x10-25	-0.65	2.42	0.86	0.80	0.91	1.11	0.99
2x10-30	7.98	5.49	2.99	2.79	2.89	2.92	2.74
2x12-0.91	-0.10	-0.15	0.00	0.10	0.13	0.00	0.00
2x12-19	-9.48	-4.64	-5.69	-2.71	-4.25	-3.05	-2.74
2x12-30	-3.72	-4.46	-4.54	-4.03	-2.75	-1.68	-0.99
2x12-38	2.07	-1.15	-1.56	-0.89	0.25	1.50	2.11

Table H-12 Overall U-factor Accuracy for 16oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	0	2.5	5	7.5	10	15	20
2x4-0.91	-0.10	0.00	0.15	0.20	0.12	0.00	0.00
2x4-11	9.72	3.68	-0.38	1.71	1.63	1.16	0.56
2x4-13	11.15	4.46	2.60	2.12	2.08	1.44	0.87
2x4-15	12.35	5.15	2.72	2.39	2.36	1.98	1.19
2x6-0.91	-0.64	-0.25	-0.07	-0.10	0.00	0.00	0.00
2x6-19	11.18	2.56	0.45	0.00	0.00	0.26	-0.30
2x6-21	6.69	2.55	0.79	0.56	0.64	0.79	0.31
2x8-0.91	-0.62	-0.30	-0.07	0.00	0.00	0.00	0.00
2x8-19	0.08	-2.38	-3.27	-2.99	-2.42	-1.77	-1.82
2x8-21	-5.20	1.79	0.00	0.00	0.21	0.53	0.31
2x8-25	11.02	2.99	1.00	0.58	0.66	0.81	0.64
2x10-0.91	-0.52	-0.20	-0.07	0.00	0.00	-0.17	-0.22
2x10-19	-4.30	-5.92	-5.55	-4.68	-3.79	-2.76	-2.71
2x10-25	-1.99	-3.77	0.50	0.59	0.67	1.37	1.30
2x10-30	6.25	0.58	2.73	2.52	2.59	3.16	3.04
2x12-0.91	-0.18	-0.15	-0.07	0.00	0.12	0.17	0.00
2x12-19	-10.53	-4.96	-5.99	-3.01	-4.38	-3.25	-3.00
2x12-30	-6.48	-6.17	-5.72	-5.08	-3.56	-1.92	-1.30
2x12-38	-1.81	-3.46	-3.20	-1.94	-0.73	1.47	2.41

Table H-13 Overall U-factor Accuracy for oc24, Mils-33, k-381							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.99	0.55	0.53	0.50	0.25	0.18	0.23
2x4-11	10.61	5.48	4.25	3.63	3.37	2.49	1.80
2x4-13	10.72	5.56	4.09	3.68	3.35	2.60	1.87
2x4-15	10.51	5.39	4.18	3.69	3.30	2.72	1.61
2x6-0.91	0.30	2.73	-0.37	-0.30	-0.25	-0.17	-0.22
2x6-19	-1.19	-1.04	-2.12	-1.84	-1.38	-1.41	-1.99
2x6-21	5.07	1.98	1.17	1.11	1.25	0.90	0.00
2x8-0.91	0.20	0.05	0.08	0.10	0.13	0.00	0.00
2x8-19	0.70	-0.31	-0.37	-0.21	0.00	0.00	-2.35
2x8-21	-3.86	-2.24	-1.53	-1.10	-0.49	-0.60	-0.70
2x8-25	6.02	2.89	2.11	1.91	1.86	1.27	0.37
2x10-0.91	-0.78	-0.35	-0.15	-0.10	-0.13	0.00	-0.22
2x10-19	-4.43	-2.61	-2.02	-1.48	-0.95	-0.29	-1.36
2x10-25	-1.51	-0.54	-0.84	-0.48	-0.53	-0.32	-1.47
2x10-30	2.40	-1.38	-1.36	1.57	1.73	-0.67	-1.15
2x12-0.91	0.10	-0.90	-0.23	-0.10	-0.13	-0.18	-0.22
2x12-19	-6.97	-3.68	-2.75	-2.31	-1.19	-0.87	-1.36
2x12-30	-4.01	-1.98	-1.15	-0.52	-1.13	0.00	0.00
2x12-38	-0.92	-0.68	1.04	2.31	2.85	2.57	2.10

Table H-14 Overall U-factor Accuracy for oc24, Mils-43, k-495							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.35	0.20	0.23	0.20	0.25	0.18	0.23
2x4-11	8.47	3.76	2.61	2.23	1.97	1.24	0.90
2x4-13	9.22	4.20	2.80	2.37	2.08	1.55	0.93
2x4-15	9.68	4.22	2.98	2.70	2.41	1.89	0.96
2x6-0.91	0.58	2.78	-0.07	-0.10	0.00	0.00	0.00
2x6-19	7.60	2.73	0.18	0.21	0.23	-0.28	-0.67
2x6-21	5.88	1.92	0.96	0.88	0.74	0.00	0.00
2x8-0.91	-0.23	-0.20	-0.08	-0.10	0.00	0.00	-0.22
2x8-19	0.33	-1.21	-1.45	-1.25	-1.17	-0.86	-1.35
2x8-21	-4.27	-2.94	-2.42	-1.93	-1.45	-0.88	-0.35
2x8-25	7.39	2.79	1.43	1.40	1.30	0.93	0.36
2x10-0.91	-0.31	-0.15	-0.15	0.00	-0.13	0.00	0.00
2x10-19	-5.61	-3.85	-3.21	-2.68	-2.10	-1.15	-2.01
2x10-25	-1.40	-1.72	-1.83	-1.16	-1.03	-0.93	-1.08
2x10-30	4.48	-1.32	-1.54	1.27	1.69	-0.33	-0.38
2x12-0.91	-0.20	-0.15	-0.08	0.00	0.00	-0.18	-0.22
2x12-19	-8.36	-5.01	-4.09	-3.49	-2.10	-1.71	-1.68
2x12-30	-4.09	-2.63	-1.76	-1.24	-1.10	0.00	0.38
2x12-38	-1.02	-0.22	0.74	2.23	2.75	3.58	3.28

Table H-15 Overall U-factor Accuracy for 24oc, Mils-54, k-622							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	-0.10	0.05	0.15	0.20	0.13	0.00	0.00
2x4-11	4.68	2.10	1.59	1.53	1.57	1.48	1.19
2x4-13	5.17	2.23	1.70	1.63	1.66	1.81	1.23
2x4-15	5.82	2.42	1.80	1.72	1.74	1.61	1.28
2x6-0.91	-0.60	2.31	-0.08	0.00	0.00	0.00	0.00
2x6-19	13.70	5.44	2.38	1.68	1.65	1.44	1.01
2x6-21	3.84	0.31	-0.38	-0.22	0.00	0.00	-0.35
2x8-0.91	-0.58	-0.30	-0.15	0.00	0.00	-0.17	0.00
2x8-19	-3.13	-3.38	-3.19	-2.66	-1.63	-1.42	-1.34
2x8-21	-7.15	-4.67	-4.01	-2.96	-2.15	-1.74	-0.35
2x8-25	7.04	1.86	0.60	0.23	0.26	0.31	0.00
2x10-0.91	0.28	0.15	0.15	0.20	0.13	0.00	0.00
2x10-19	-9.38	-6.18	-4.90	-4.06	-3.44	-1.70	-2.33
2x10-25	-2.27	-0.68	-2.96	-2.49	-2.27	-1.83	-1.78
2x10-30	9.07	-0.18	-1.49	0.99	1.10	-0.96	-1.12
2x12-0.91	0.31	-0.15	0.23	0.20	0.13	0.18	-0.22
2x12-19	-12.18	-7.15	-5.75	-4.84	-3.23	-2.26	-2.00
2x12-30	-1.83	-2.16	-2.34	-2.17	-1.88	-0.97	-0.75
2x12-38	11.23	5.17	3.11	3.24	2.98	2.80	2.41

Table H-16 Overall U-factor Accuracy for 24oc, Mils-68, k-783							
	U-factors						
	Rigid Foam Board Sheathing - R-value						
Stud-R-cav	**0**	**2.5**	**5**	**7.5**	**10**	**15**	**20**
2x4-0.91	0.35	0.25	0.30	0.30	0.25	0.17	0.00
2x4-11	7.98	3.70	2.72	2.55	2.34	1.97	1.48
2x4-13	8.73	3.99	2.91	2.52	2.47	2.32	2.17
2x4-15	9.23	4.39	3.26	2.85	2.81	2.41	1.59
2x6-0.91	-0.28	2.46	-0.30	-0.20	-0.12	-0.17	-0.22
2x6-19	7.50	2.64	0.17	0.00	0.23	0.00	0.00
2x6-21	6.54	2.00	0.74	0.86	0.72	0.88	0.34
2x8-0.91	-0.28	-0.20	-0.08	0.00	0.00	0.00	0.00
2x8-19	-1.49	-2.29	-2.44	-1.82	-1.60	-1.12	-1.00
2x8-21	-5.91	-3.67	-3.05	-2.29	-1.65	-1.15	0.00
2x8-25	9.15	3.15	1.58	1.13	1.01	1.22	0.71
2x10-0.91	-0.33	-0.15	-0.08	-0.10	0.00	0.00	0.00
2x10-19	-8.49	-5.31	-4.45	-3.59	-2.72	-1.12	-2.30
2x10-25	-1.69	-2.40	-2.70	-2.22	-1.99	-1.20	-1.41
2x10-30	10.36	0.53	-0.83	1.46	1.35	-0.63	-0.74
2x12-0.91	-0.20	-0.75	0.00	0.00	0.13	0.00	-0.45
2x12-19	-11.67	-6.40	-5.12	-4.37	-2.73	-1.96	-1.98
2x12-30	-2.44	-2.25	-2.27	-2.12	-1.06	-0.63	-0.37
2x12-38	10.85	5.17	3.02	3.42	3.49	3.44	3.16

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