WESTLab Canada
NFRC Accredited Simulation Laboratory

Final
Report

IGMA Spacer Thermal Performance Study

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1. Executive Summary

The National Fenestration Rating Council (NFRC) has been developing a component based calculation procedure for determining the thermal performance of non-residential fenestration products. The original proposal had far reaching consequences for IG unit fabricators, spacer manufacturers, and sealant suppliers in terms of rating and certifying their products with NFRC. Suggested revisions to the NFRC non-residential program proposed by IGMA and others would simplify and streamline the non-residential program.

The original non-residential proposal would have required IG unit manufacturers to calculate and certifying the center-of-glass U-factor and solar heat gain coefficient (SHGC) for every IG unit option they produce. The suggested revision to the program was to include the center-of-glass calculation engine from the Window computer program in the proposed NFRC web based calculation tool and determine the center-of-glass U-factor and SHGC online. This approach would greatly simplify the storage and management of the center-of-glass data for NFRC and remove the burden of calculating and certifying center-of-glass data from IG unit manufacturers.

The original proposal also required IG unit manufacturers to calculate and certify the thermal performance of every spacer system combination they offer. The NFRC has defined spacer to mean the spacer bar and spacer system to mean the spacer bar including any sealants used. This requirement would force IG unit manufacturers to calculate and certify the thermal performance data for a very large numbers of spacer systems. There has been a suggested revision to the proposed NFRC non-residential program to develop a spacer system calculation tool to be included with the proposed web based non-residential calculation tool. The large number of spacer system variables affecting the thermal performance of the spacer system needed to be studied to determine the variables that have a significant impact on the thermal performance of the complete fenestration product.

WESTLab was contracted by IGMA to conduct a study to determine the thermally significant variables in insulating glass spacer systems. This study identified and categorized spacer systems, and performed a parametric study to identify the spacer system variables that result in a significant change in total product thermal performance. Spacer systems were evaluated in a non-residential thermally broken aluminum window wall system and a residential PVC picture window to compare their thermal performance.

The study identified the following spacer system variable that impact the thermal performance of the complete fenestration product:

- Sealant type,
- Overall system height (backing seal height),
- Primary sealant thickness,
- Spacer wall thickness, and
- IG unit placement in the frame.

The study concluded that the any spacer system calculation tool that NFRC may develop needs to be able address the following concerns:

- Allow grouping of aluminum and galvanized-steel spacers to reduce the number of spacer designs that have to be evaluated as design changes in these spacers have very little impact on thermal performance of the complete fenestration product.
- Allow the detail of stainless steel and non-metal spacer system designs to be accounted for as the design of these systems does impact the thermal performance of the complete fenestration product.

- Account for the sealant material used and the overall spacer system height. These two variables affect the spacer system effective conductivity and will impact the total product thermal performance.
- Account for the thickness of the primary sealant. The PIB thickness had a large impact on metal spacer system effective conductivities and a smaller impact on non-metal spacer systems, but will need to be accurately modeled to properly calculate the spacer system effective conductivity.
- Allow spacer wall thickness for aluminum and galvanized-steel spacer systems to be grouped with the changes in aluminum and galvanized-steel spacer designs. The aluminum and galvanized-steel spacer wall thickness did not impact the overall product thermal performance.
- Account for the wall thickness of stainless steel spacer systems. The wall thickness of stainless steel spacer systems did impact the thermal performance.
- Allow the placement of the IG unit in the frame to be simplified by placing the bottom edge fo the spacer system ½" below the sightline of the frame for all spacer systems. The impact of the placement of the IG unit in the fenestration product frame did not impact the thermal performance of the total product.

The conclusions drawn from this study need to be recommended to the NFRC non-residential task group to ensure that the proposed spacer calculation tool addresses these concerns and streamlines the calculation of spacer system thermal performance in the NFRC non-residential program to avoid putting the burden of calculating and certifying spacer system thermal performance on the IG unit manufacturers.

2. Introduction

WESTLab was contracted by IGMA to conduct a parametric study to determine the thermally significant variables in insulating glass spacer systems. This study will identify and categorize spacer systems, perform a parametric study to identify the spacer system variables that result in a significant change in total product thermal performance. Spacer systems will be evaluated in a non-residential thermally broken aluminum window wall system and a PVC residential picture window to compare their thermal performance.

The first phase of the study will identify spacer systems of similar design and geometry in terms of thermal performance. Spacer systems of similar thermal performance and geometry will be grouped to reduce the total number of spacer systems studied in phase 2 of the study. This phase of the study will also identify the spacer system variables that may impact total product thermal performance for each spacer system being grouped in phase 2 of the study.

The second phase of the study will include a parametric analysis of the spacer system groupings identified in phase 1. The variables identified in phase 1 will be analyzed to determine if they result in a significant change in thermal performance of the total fenestration product.

The results of the study will be used to draw conclusion and make recommendations on the spacer system variables that have a significant impact on the total fenestration system thermal performance.

3. Phase 1 – Spacer System Identification and Categorization

The first phase of the study identified as many spacer systems as possible to compare their thermal performance. Figures 1 illustrates the spacer systems that include metal components and Figure 2 illustrates non-metal spacer systems considered in this study. Based on these spacer types 74 unique spacer systems were identified.

This phase of the study limited many of the spacer system variables to allow for a comparison of the spacer systems construction and geometry. The spacer width was set at ½”, the PIB thickness was set at 0.010” on both sides of any dual-seal spacers, the backing seal was defined as polysulphide, and the spacer system height (spacer bar and backing seal) was set to 7/16”. Spacer systems that do not use PIB or a backing seal were modeled as designed at a ½” width. All of these variables will be addressed in phase 2 of the study.

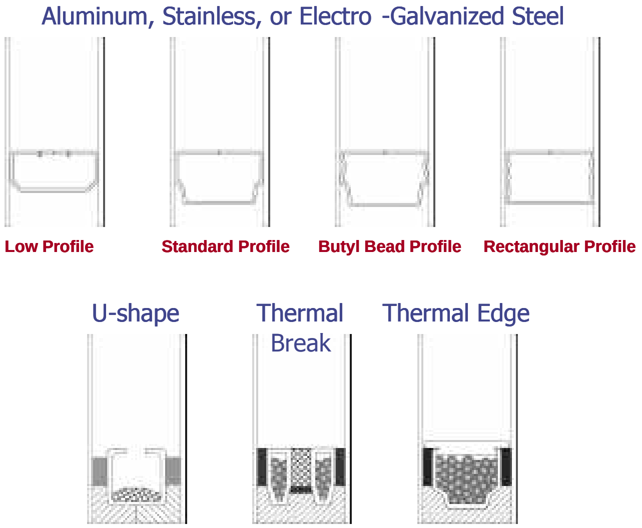


Figure 1 – Spacer Systems that include metal

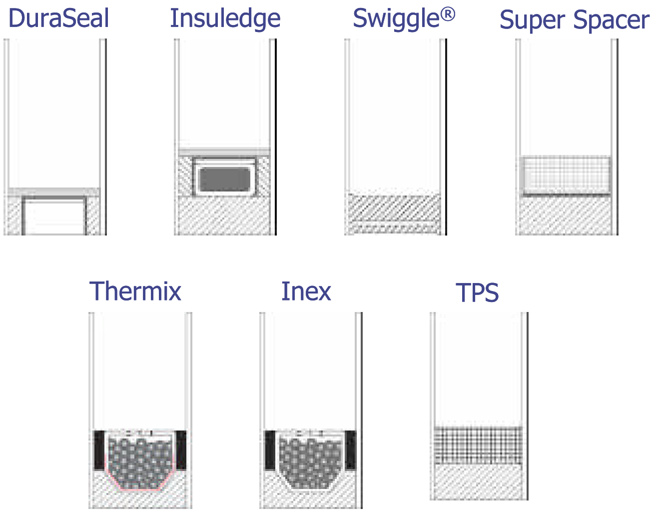


Figure 2 – Non-metal Spacer Systems components

Once all the spacer systems had been identified they were modeled in the Therm computer program as a stand-alone spacer system. This technique is used to determine the spacer system effective thermal conductivity. The spacer system effective thermal conductivity is determined by developing a detailed model of the spacer system in the Therm program and determining the heat flow through the spacer system. The spacer effective conductivity is the thermal conductivity of a single block of homogeneous material the same width and height of the spacer system that results in the same heat flow as that through the spacer system. Figure 3 shows the detailed spacer system model and the single block of homogeneous material used to replace the spacer system.

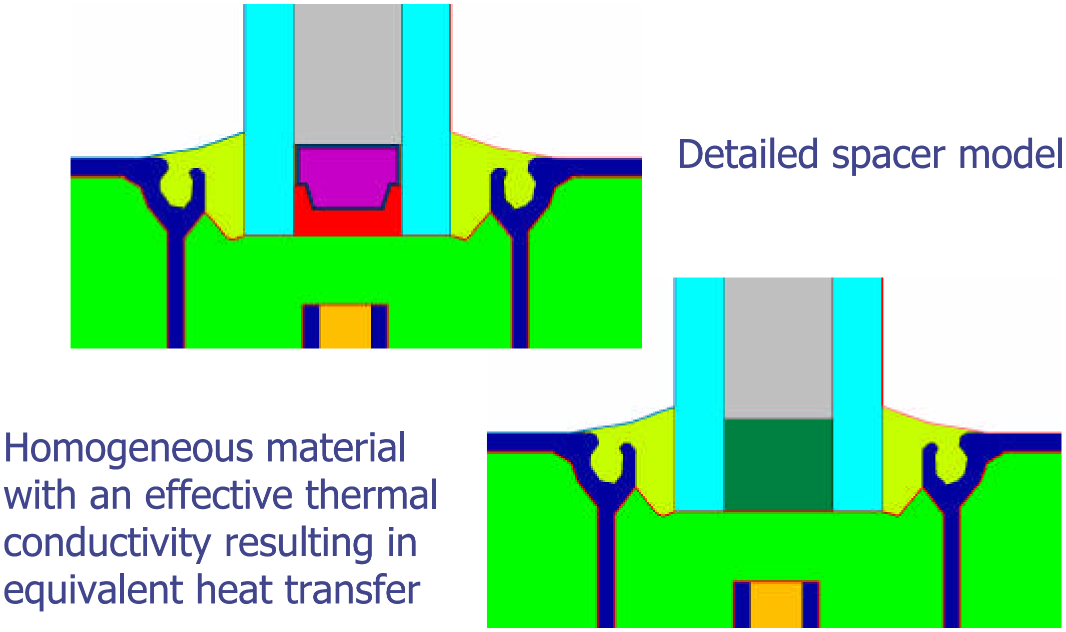


Figure 3 – Spacer System Effective Thermal Conductivity

The effective thermal conductivity of a spacer system can be used in place of a detailed spacer model in the Therm program to calculate the total fenestration product thermal performance. In order to determine the impact of spacer thermal performance on the total fenestration product thermal performance a non-residential aluminum frame window wall system and a residential PVC picture window system were modeled with varying spacer system effective thermal conductivities. Figures 4 and 5 illustrate the impact of spacer system effective thermal conductivity on total product performance. The two framing systems were both modeled with a clear glass air filled IG unit and a low-e glass argon filled IG unit. As the results in the two figures indicate once the spacer system effective thermal conductivity reaches 2.0 W/mK the total product U-factor curve flattens out and increasing the spacer system effective thermal conductivity beyond 2.0 W/mK does not result in an increase in the total product U-factor. This result will be used to judge the impact of various spacer system variables on the total product thermal performance.

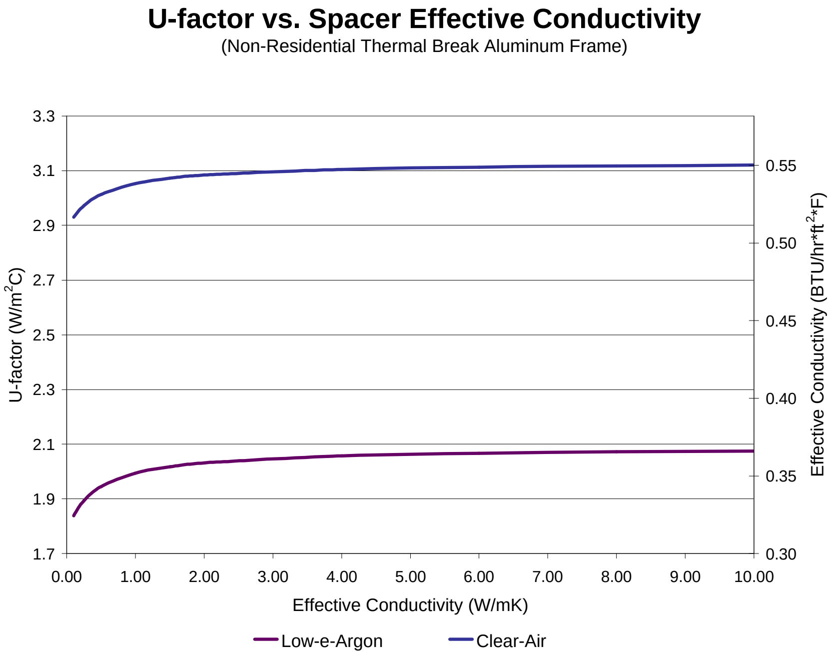


Figure 4 – Total Product U-factor vs. Spacer Effective Conductivity Non-Residential Frame

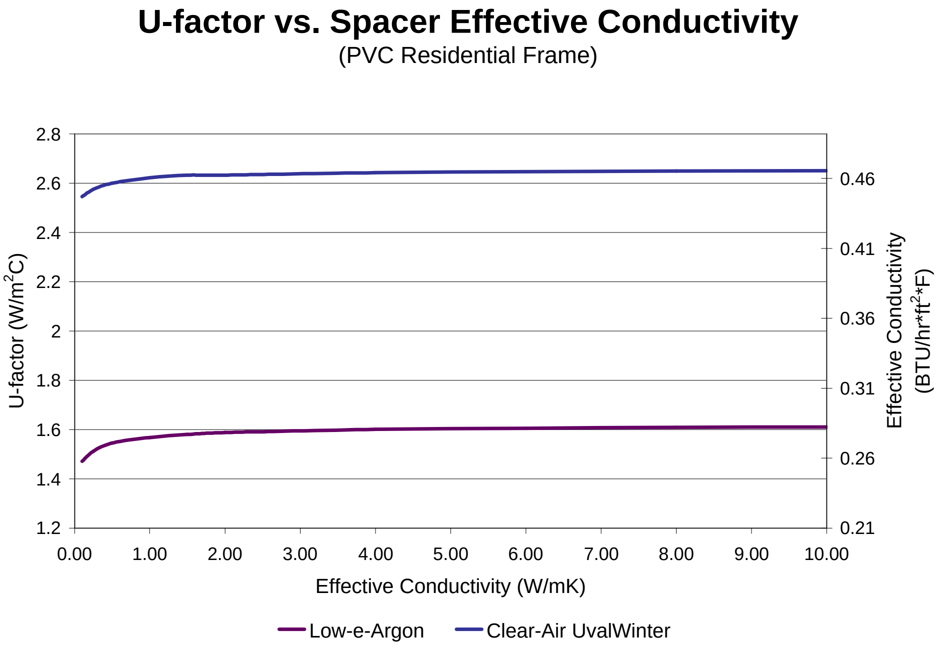


Figure 5 – Total Product U-factor vs. Spacer Effective Conductivity Residential Frame

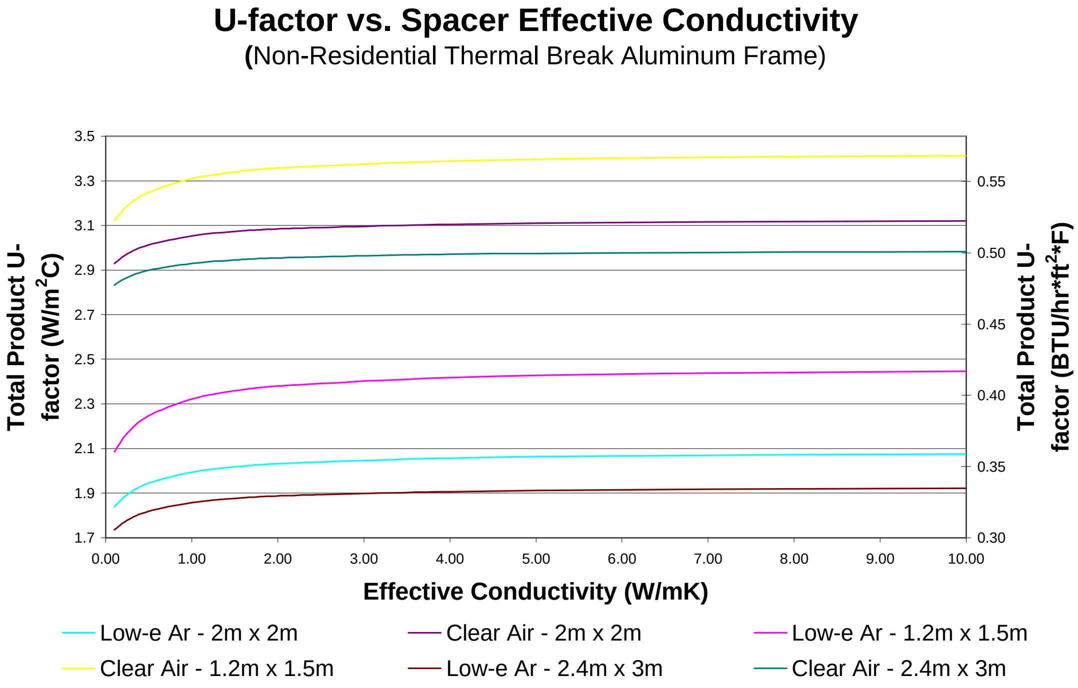


Figure 6 – Total Product U-factor vs. Spacer Effective Conductivity Non-Residential Frame with Total Product Size Variation

The total product U-factor for the non-residential frame was determined as a function of the spacer system effective conductivity for three different total product sizes. The U-factors were determined at total product sizes of 1.2m x 1.5m, 2.0m x 2.0m, and 2.4m x 3.0m. Figure 6 illustrates the results for both the clear glass air filled and low-e glass argon filled IG units. The shape of these curves is the same for the three different product sizes, but the impact of the effective conductivity is greater at the smallest size. Still the variation in the total product U-factor for spacer system effective conductivities greater than 2.0 W/mK is very small, indicating that variation in spacer system variable for spacer systems with effective conductivities greater than 2.0 W/mK will not impact the total product U-factor significantly.

The 74 spacer systems identified in this phase of the study have been numbered and categorized as follows:

- Spacers 1 – 13 are dual-seal aluminum,
- Spacers 14 – 26 are single-seal aluminum,
- Spacers 31 – 35 are dual-seal electro galvanized steel,
- Spacers 36 – 40 are single-seal electro galvanized steel,
- Spacers 45 – 55 are dual-seal stainless-steel,
- Spacers 56 – 66 are single-seal stainless steel, and
- Spacers 27-30, 41-44, and 67-74 are various non-metal spacers.

The spacer system effective conductivity was calculated for each of these spacer systems. Figure 7 plots the effective conductivity for each of these spacer systems. Based on the effective conductivity results 33 spacer systems were selected to represent groups of spacer systems with similar thermal performance and modeled in the non-residential and residential frames with clear glass air filled IG and low-e argon filled IG. Figure 8 through 11 show the total product U-factor and spacer system effective conductivity results for the non-residential frame with a low-e argon filled IG unit. A complete set of these graphs has been included in Appendix A.

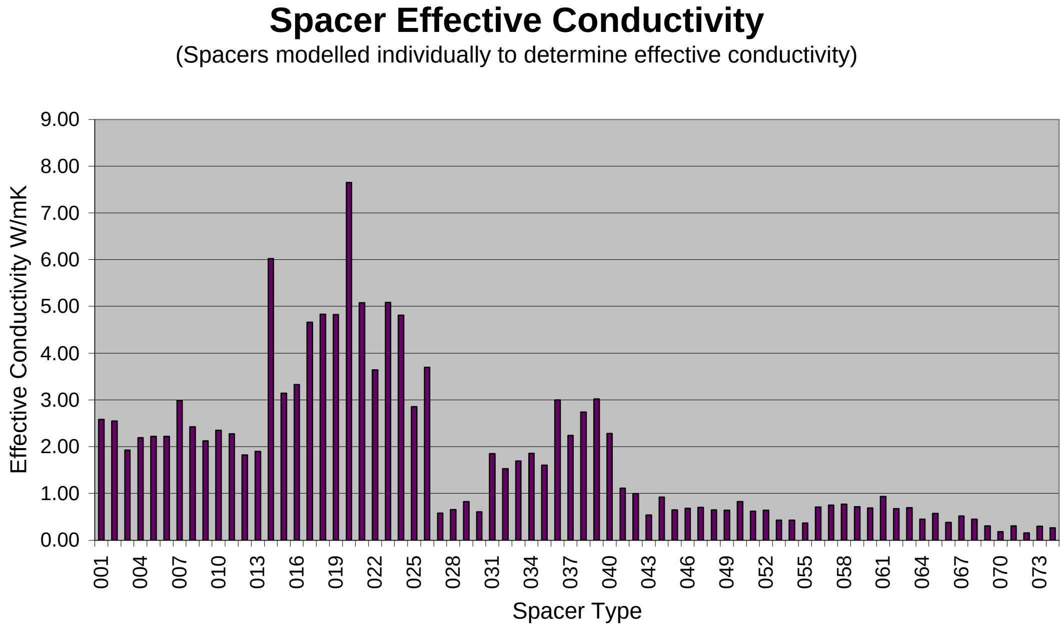


Figure 7 – Spacer System Effective Conductivity

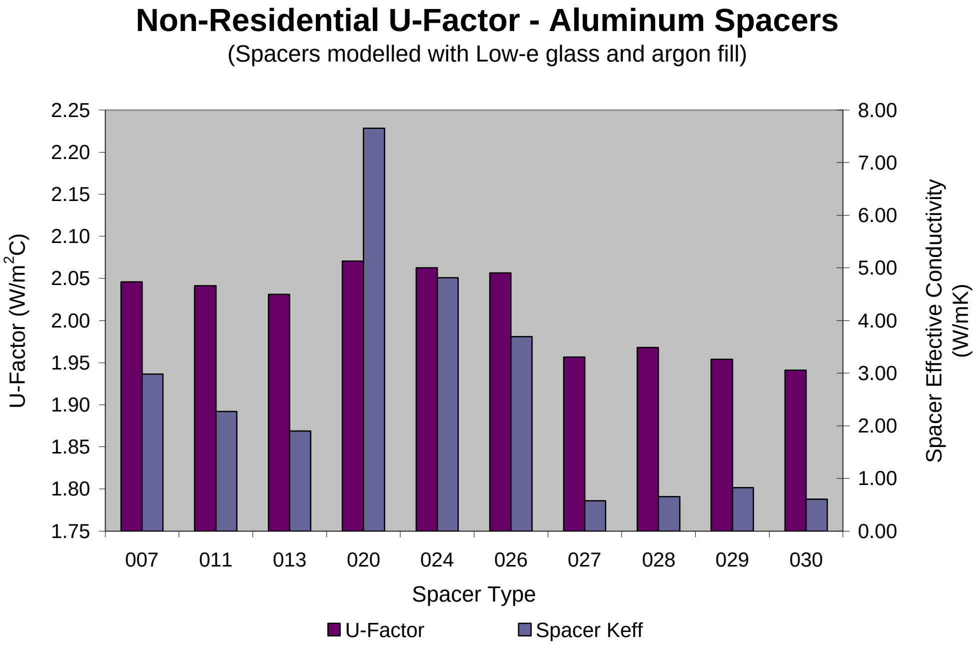


Figure 8 – Total Product U-factor and Spacer System Effective Conductivity Spacer 007 - 030

Figure 8 includes the aluminum spacer systems and shows that for large variation in the spacer system effective conductivity the total product U-factor variation in very small. Simplifying aluminum spacer systems by grouping designs would result in minimal error in the total product U-factor.

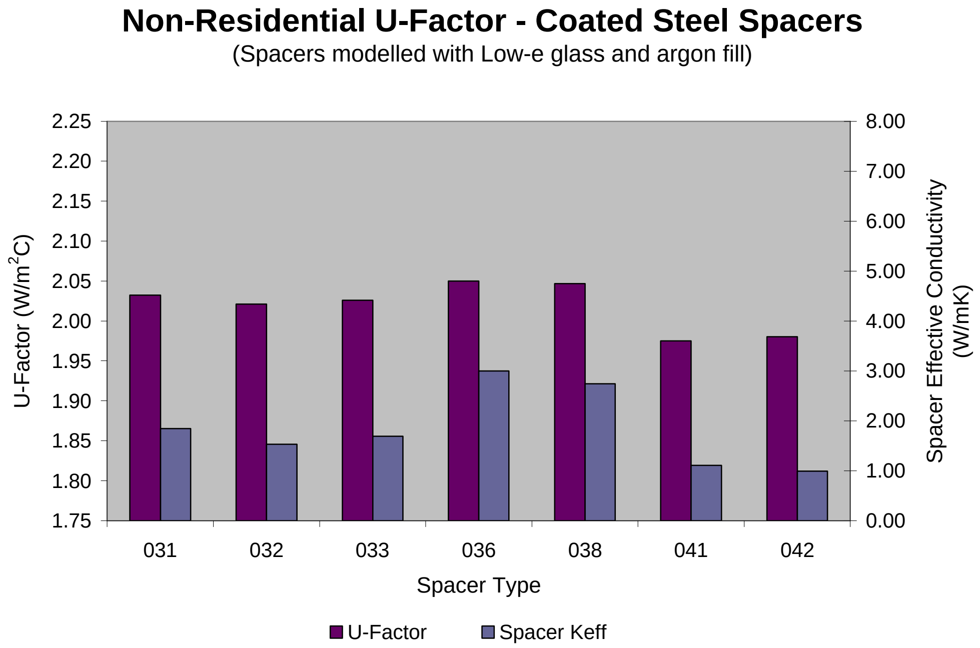


Figure 9 – Total Product U-factor and Spacer System Effective Conductivity Spacer 031 – 042

Figure 9 includes the galvanized-steel spacer systems and shows that for small variations in spacer system effective conductivity there is a very small variation in the total product U-factor again grouping of galvanized-steel spacer designs would result in minimal error in the total product U-factor.

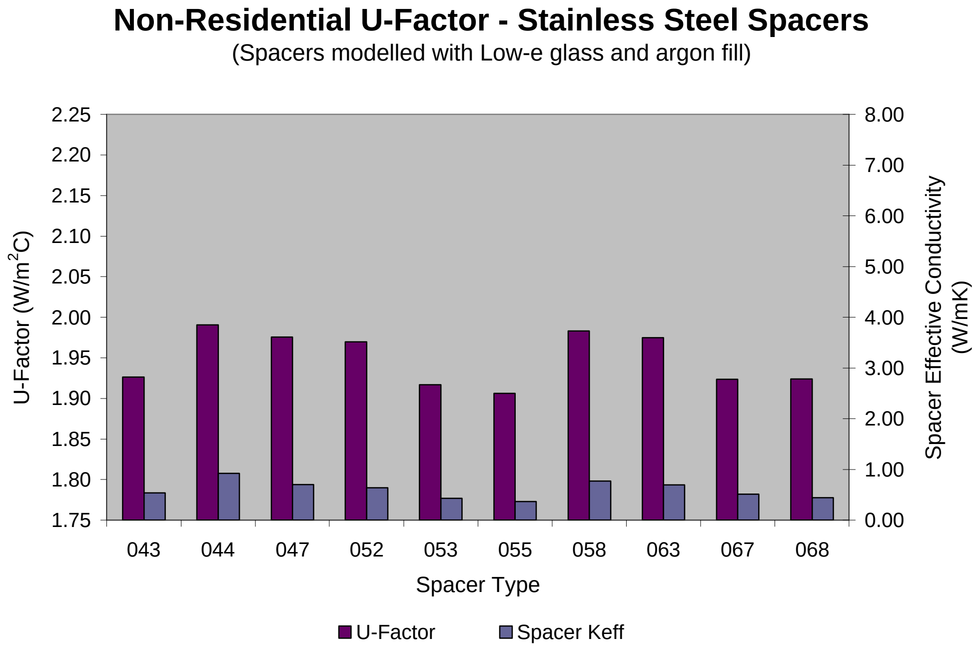


Figure 10 – Total Product U-factor and Spacer System Effective Conductivity Spacer 043 – 068

Figure 10 includes the stainless-steel spacer systems and shows that the total product U-factor tracks very closely to the variation in the spacer system effective conductivity indicating that any simplification in the spacer system modeling will have to capture the variation in the stainless-steel spacer design.

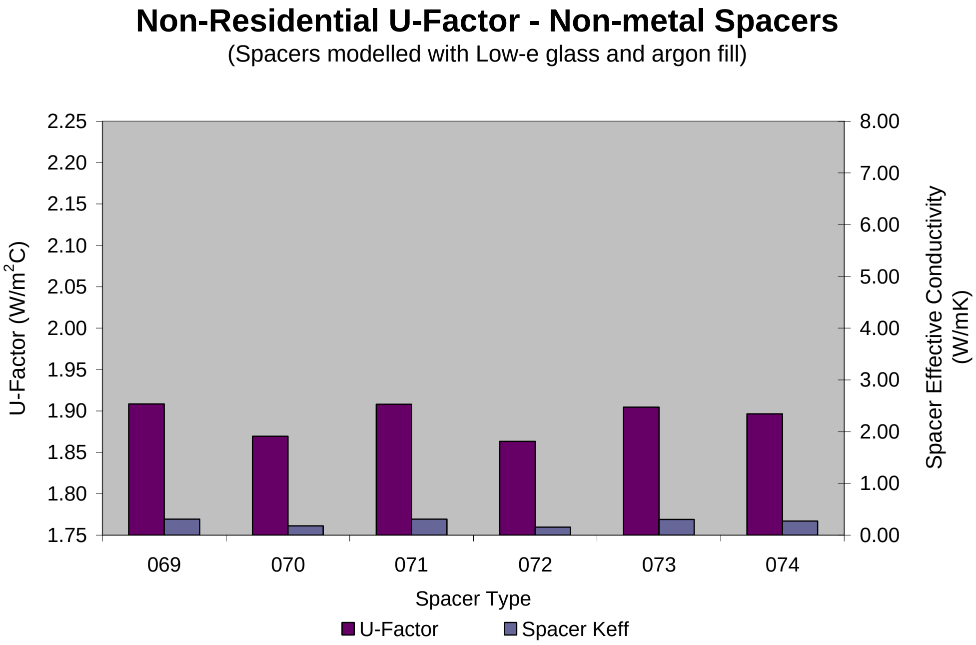


Figure 11 – Total Product U-factor and Spacer System Effective Conductivity Spacer 069 – 074

Figure 11 includes the non-metal spacer systems and also indicates that the total product U-factor tracks very closely to the variation in spacer system effective conductivity. Again any simplification in the non-metal spacer system modeling will have to capture the variation in the non-metal spacer system design.

4. Phase 2 – Spacer System Parametric Analysis

The second phase of this study examined the spacer system variables held constant in the first phase of the study. Based on the results of phase 1 eleven spacer systems were chosen to be used in the second phase of the study. The eleven spacer systems included in this phase of the study were:

- Spacers 7 and 13 dual-seal aluminum,
- Spacers 20 and 26 single-seal aluminum,
- Spacers 31 dual-seal electro galvanized steel,
- Spacers 36 single-seal electro galvanized steel,
- Spacers 47 dual-seal stainless-steel,
- Spacers 58 single-seal stainless steel, and
- Spacers 42, 70, and 73 non-metal spacers.

These 11spacer systems were used to examine the impact of the following spacer system variables on the total fenestration system thermal performance:

- Sealant type,
- Overall system height (backing seal height),
- Primary sealant thickness,
- Spacer wall thickness, and
- IG unit placement in the frame.

Ten of the eleven spacer systems were used to examine the impact of the sealant type on the spacer system effective conductivity. Spacer system 42 does not use a backing seal so it was not included. Four sealant materials were studied, polysulphide, hot-melt butyl, polyurethane, and silicone. Figure 12 shows the effective conductivity for each of the spacer systems with the four sealant types. The results in Figure 12 indicate that the choice of sealant can affect the spacer system effective conductivity. Any variation in the effective conductivity of a spacer system with an effective conductivity below 3.0 W/mK may result in a change in the total product thermal performance. This result indicates that the type of sealant used in the spacer system will need to be addressed in any simplification of the spacer system

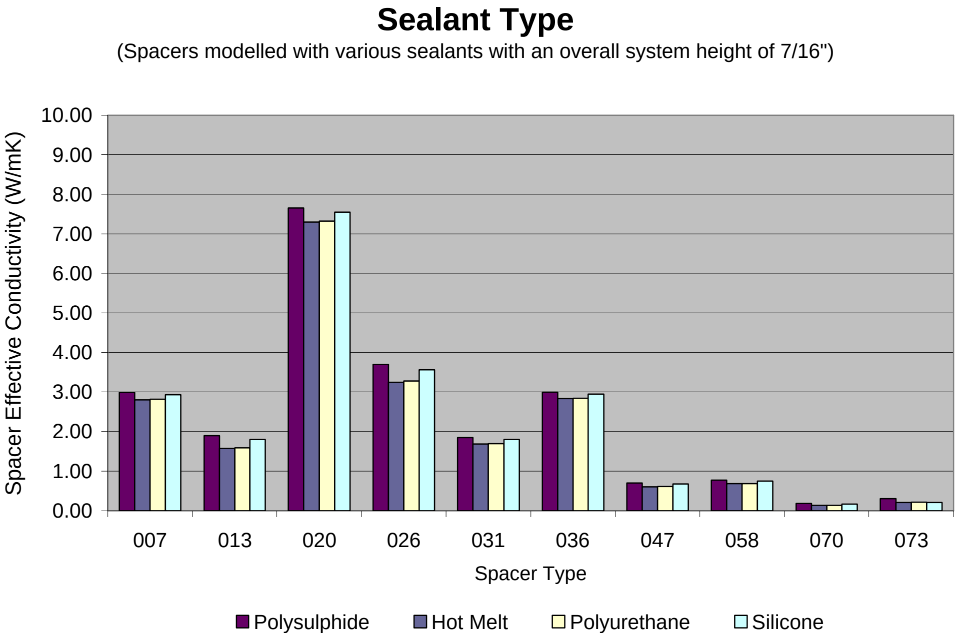


Figure 12 – Spacer System Effective Conductivity vs. Sealant Type

The same ten spacer systems used to study the sealant type were also used to examine the affect of the overall spacer system height, spacer bar and backing seal height. These ten spacer systems were modeled with a polysulphide backing seal with overall system heights of 3/8”, 7/16”, 1/2", and 9/16”. Figure 13 illustrates the results for these ten spacer systems for the four system heights. These results indicate that the overall spacer system height can result in large variations in the spacer system effective conductivity and may result in significant variation in the total product thermal performance. Any simplification in the spacer system will need to address the overall spacer system height.

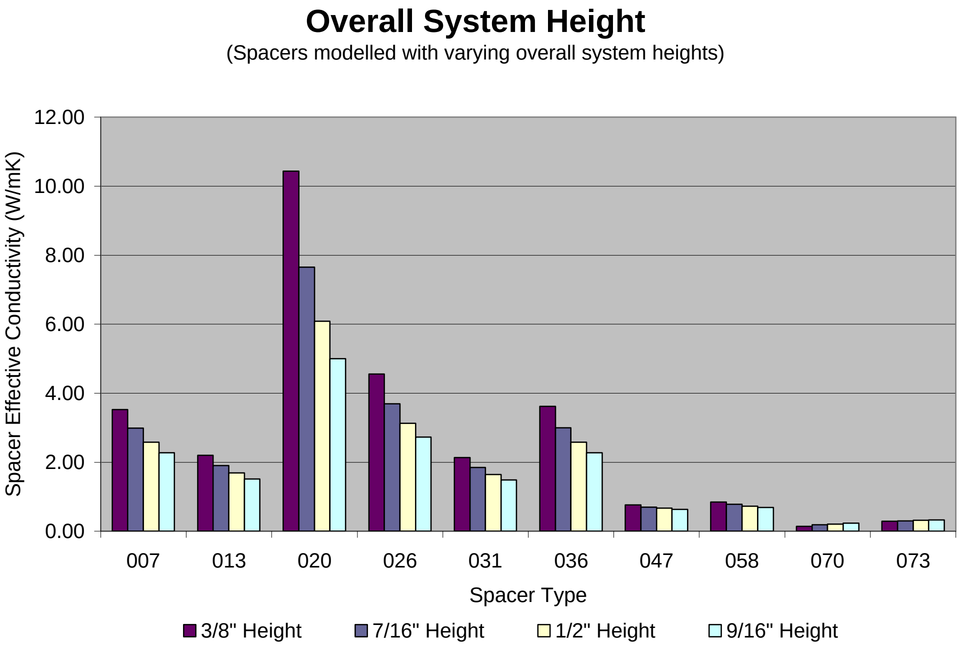


Figure 13 – Spacer System Effective Conductivity vs. Spacer System Height

Spacer systems 7, 31, 47, and 70 are all dual-seal spacer systems that include a PIB primary sealant. The four spacer systems include aluminum, galvanized steel, stainless steel, and non-metal. The impact of the primary sealant thickness was examined in two ways, holding the spacer bar width constant at ½" allowing the overall system width to vary, and holding the overall spacer system width constant and varying the spacer bar width. The thickness of the PIB layer on both sides of the spacer was varied as follows: 0.005", 0.010", 0.015", and 0.020". The effective conductivity values for each spacer system for the eight possible spacer system combinations are illustrated in Figure 14. The aluminum and galvanized-steel spacer show a large variation in effective conductivity based on the primary sealant thickness. The stainless-steel and non-metal spacer systems show small to no variation in the effective conductivity, but the effective conductivities are below 1.0 W/mK and may results in changes in the total product thermal performance. These results also indicate that any simplification in the spacer system will have to include accurate modeling of the primary sealant thickness.

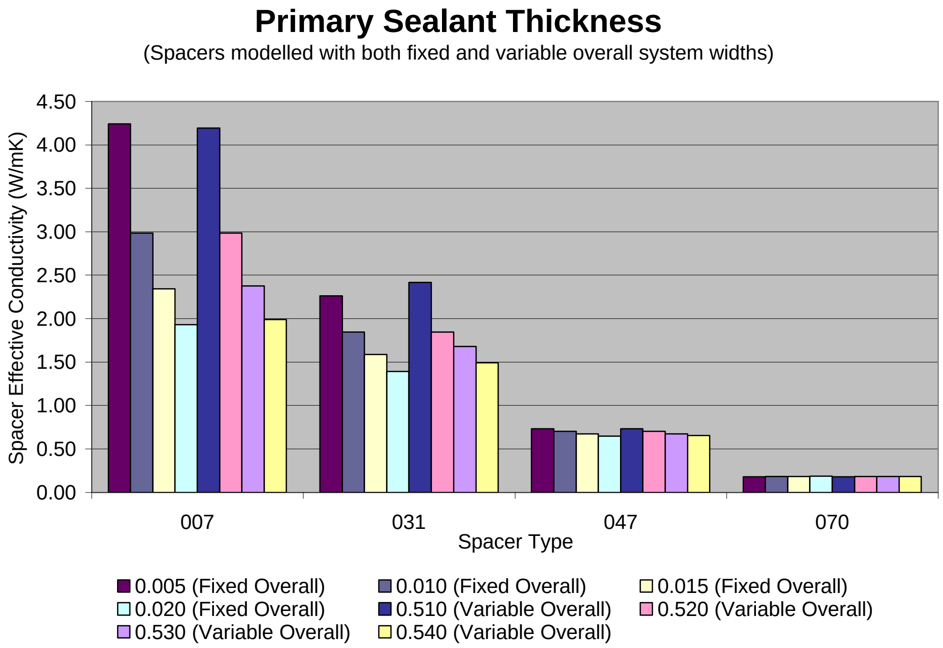
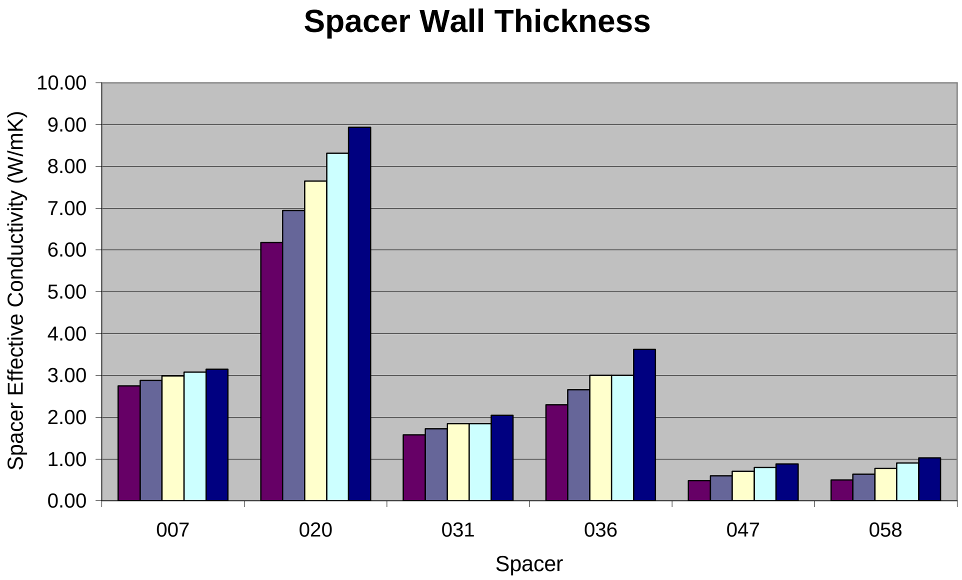


Figure 14 – Spacer System Effective Conductivity vs. Primary Sealant Thickness

The impact of the spacer system wall thickness was examined using spacer systems 7, 20, 31, 36, 47,and 58. The aluminum spacer systems were examined with the following wall thicknesses: 0.012”, 0.014”, 0.016”, 0.018”, and 0.020”. The galvanized-steel spacer systems were examined with the following wall thicknesses: 0.010”, 0.012”, 0.014”, 0.016”, and 0.018”. The stainless-steel spacer systems were examined with the following wall thicknesses: 0.004”, 0.006”, 0.008”, 0.010”, and 0.012”. The effective conductivity results for all six of these spacer systems with varying wall thicknesses are illustrated in Figure 15. The results for the aluminum and galvanized-steel spacer systems show a wide range of variation in the effective conductivity, but all of the spacer systems had effective conductivities of 2.0 W/mK and greater where the variation in the effective conductivity may not result in a change in the total product thermal performance. The results for the stainless-steel spacer system show a small variation in the effective conductivity, but these effective conductivities are all below 1.0 W/mK where the variation in effective conductivity will impact the total product thermal performance.



Aluminum spacer wall thicknesses (007 and 020)	0.012”, 0.014”, 0.016”, 0.018”, and 0.020”
Galvanized-steel spacer wall thicknesses (031 and 036)	0.010”, 0.012”, 0.014”, 0.016”, and 0.018”
Stainless-steel spacer wall thicknesses (047 and 058)	0.004”, 0.006”, 0.008”, 0.010”, and 0.012”

Figure 15– Spacer System Effective Conductivity vs. Spacer Wall Thickness

These results indicate that spacer wall thickness for aluminum and galvanized-steel spacer systems may not need to be accounted for in spacer system simplification, but any spacer systems simplification will have to address the wall thickness of stainless-steel spacer systems to accurately account for the spacer system heat flow.

The impact of IG placement in the frame or the depth of the spacer below the sightline of the frame was analyzed for three spacer system depths: 7/16”, 1/2", and 9/16”. These dimensions represent the eleven spacer systems were modeled in the non-residential aluminum frame and the residential PVC frame with a low-e argon filled IG unit. Figures 16 and 17 shows the results for the two frame types, the three spacer depths, and the eleven spacer systems. The variation in the total product U-factor is very small, less than 0.02 W/m^{2}C or 0.003 BTU/hr*Ft^2*F. These results indicate that if the spacer depth were standardized a ½” below the frame sightline the error introduced in the calculations would be very small.

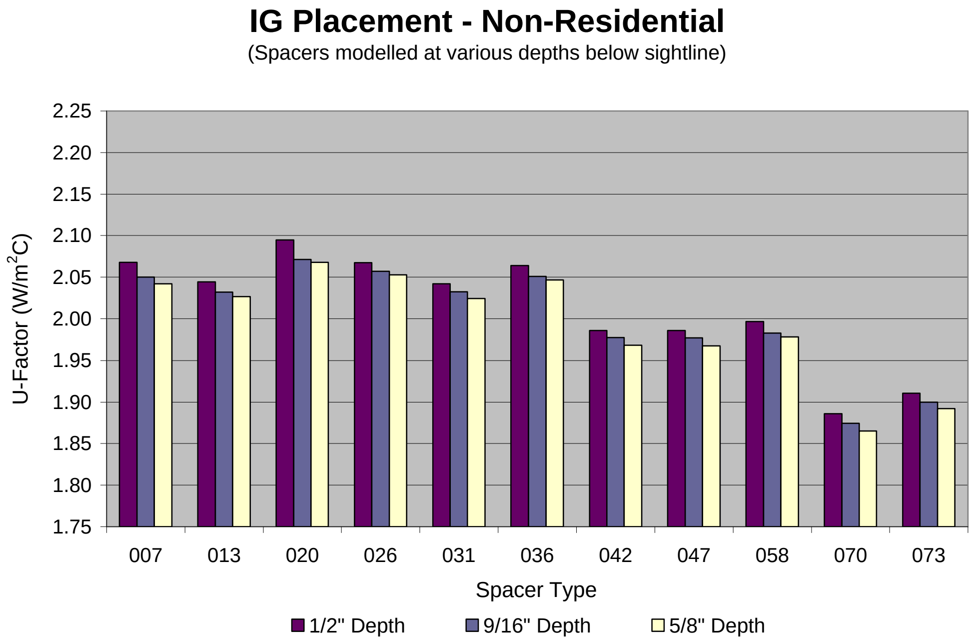


Figure 16– Spacer System Effective Conductivity vs. IG Placement Non-Res Frame

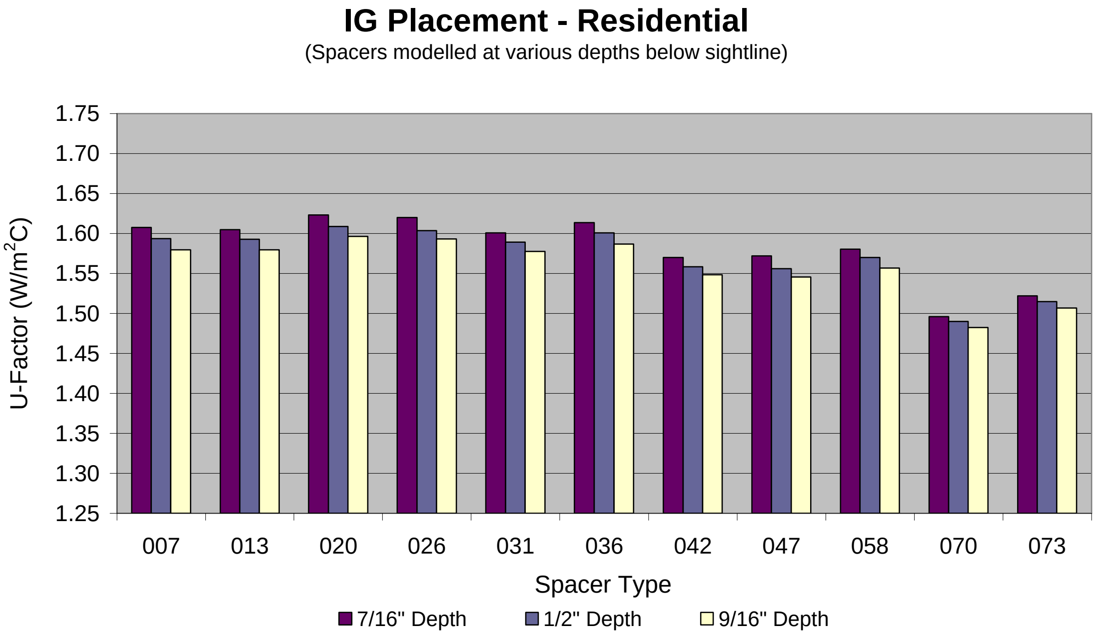


Figure 17 – Spacer System Effective Conductivity vs. IG Placement Residential Frame

5. Conclusions and Recommendations

This study examined 74 different spacer systems and found that the range in the spacer system effective conductivity ran from 0.15 to 7.6 W/mK. When total product U-factor was plotted against spacer system effective conductivity it was determined that effective conductivities greater than 2.0 W/mK did not increase the total product U-factor.

Aluminum and galvanized-steel spacer system design variation resulted in large variation in spacer system effective conductivity, but did not impact the total product thermal performance as their effective conductivity was at or above 2.0 W/mK. Aluminum and galvanized-steel spacer system designs could be grouped to simplify the number of spacer system to be evaluated. Design variations in stainless steel and non-metal spacer systems did impact the total product thermal performance as their effective conductivities were below 2.0 W/mK. The thermal performance of the total fenestration product changed significantly as the spacer system effective conductivity changed and will need to be addressed in any spacer system calculation tool.

The choice of sealant material and overall spacer system height affects the spacer system effective conductivity for spacer systems with an effective conductivity below 2.0 W/mK and will impact the total product thermal performance and will have to be addressed in any spacer system calculation tool.

The thickness of the primary sealant had a large impact on metal spacer system effective conductivities and a smaller impact on non-metal spacer systems, but will have to be accurately modeled in a spacer calculation tool to properly calculate the spacer system effective conductivity.

The spacer wall thickness for aluminum and galvanized-steel spacer systems did not impact the overall product thermal performance and can be included in the grouping of aluminum and galvanized-steel spacers. The wall thickness of stainless-steel spacer systems did impact the thermal performance of the total fenestration product and will need to be accurately modeled in a spacer calculation tool to account for the spacer system heat flow.

The placement of the IG unit in the fenestration product frame did not impact the thermal performance of the total product. The results indicate that if the spacer depth were standardized a ½” below the frame sightline the total product thermal performance would not be significantly impacted.

Appendix A

Total Product U-factor and Spacer System Effective Conductivity Graphs

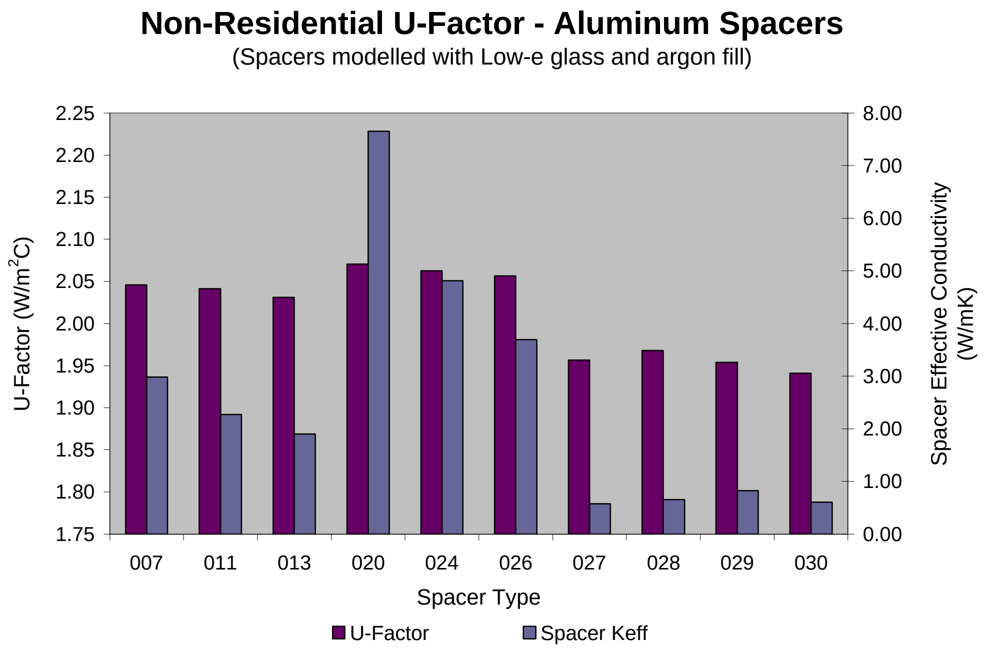


Figure A1 – Total Product U-factor and Spacer System Effective Conductivity Spacer 007 - 030

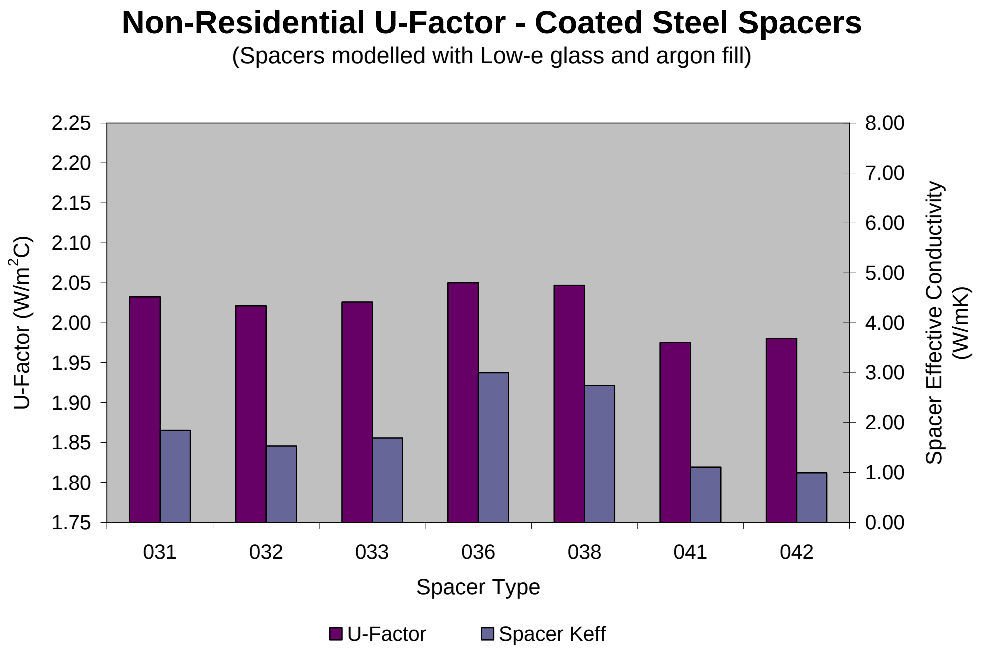


Figure A2 – Total Product U-factor and Spacer System Effective Conductivity Spacer 031 - 042

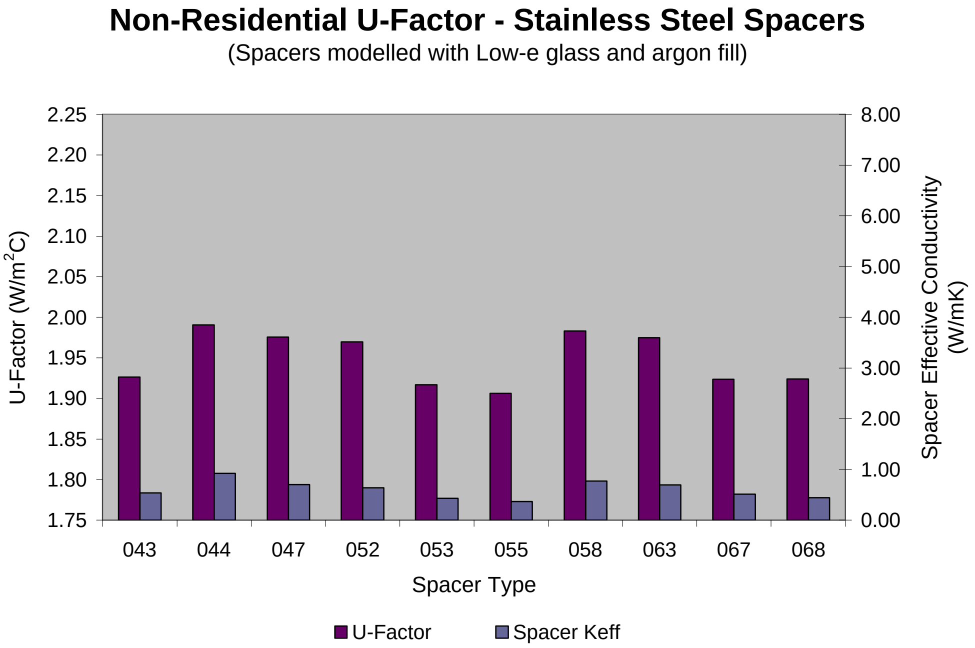


Figure A3 – Total Product U-factor and Spacer System Effective Conductivity Spacer 043 – 068

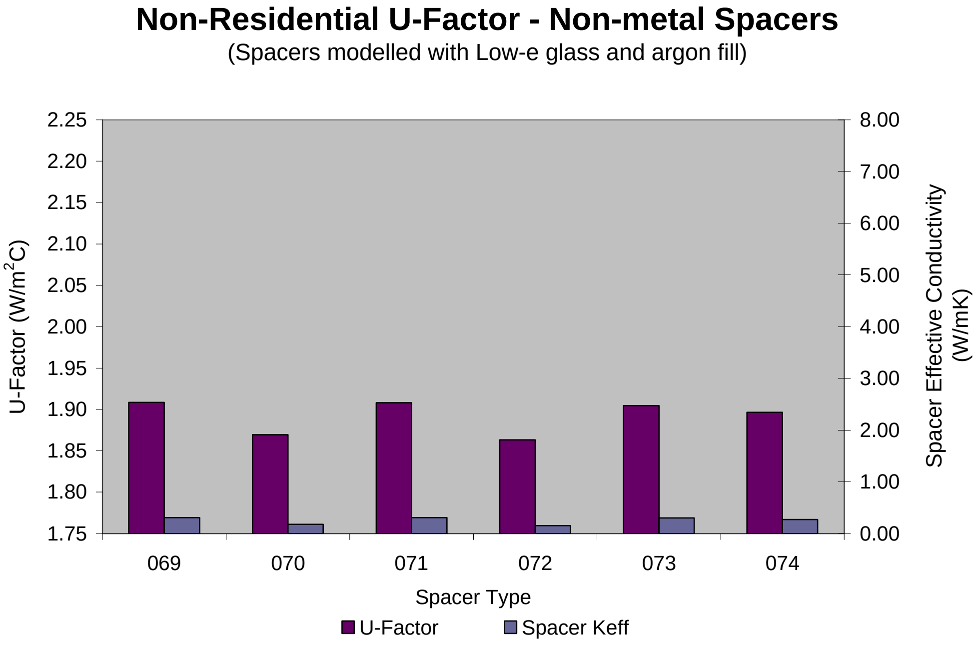


Figure A4 – Total Product U-factor and Spacer System Effective Conductivity Spacer 069 – 074

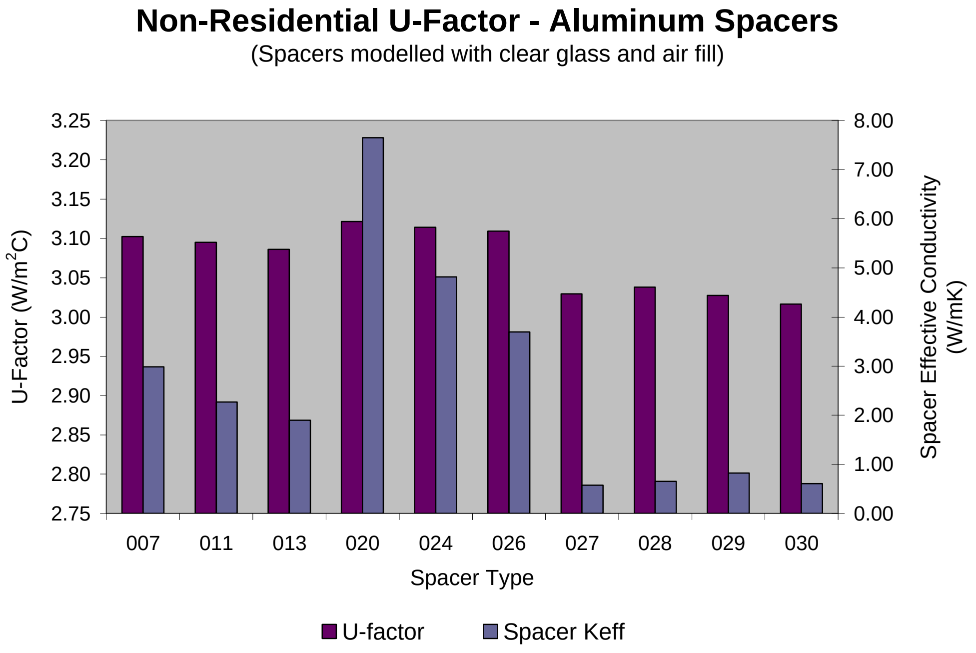


Figure A5 – Total Product U-factor and Spacer System Effective Conductivity Spacer 007 – 030

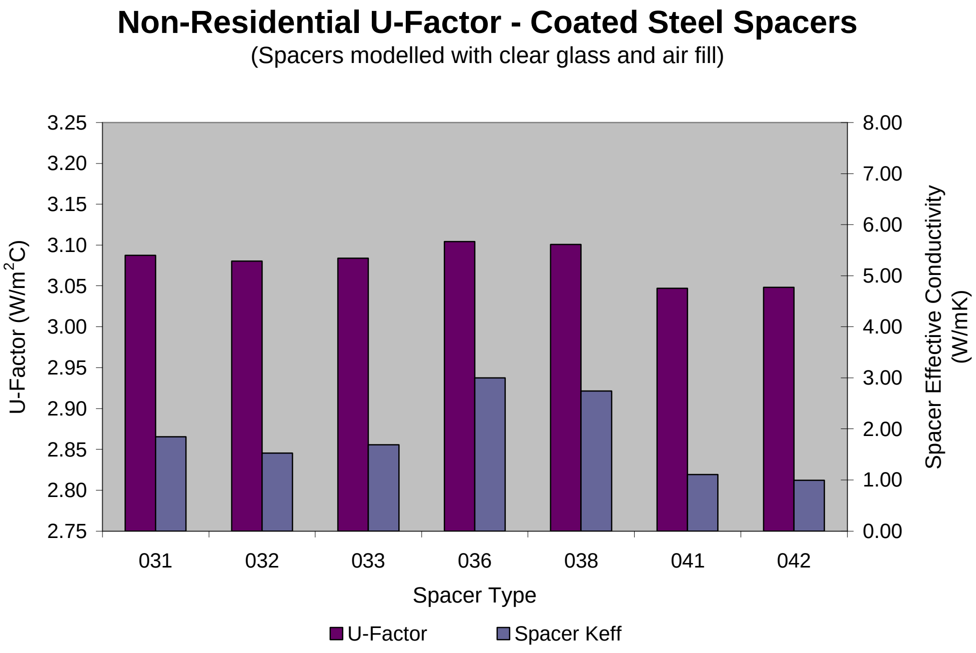


Figure A6 – Total Product U-factor and Spacer System Effective Conductivity Spacer 031 - 042

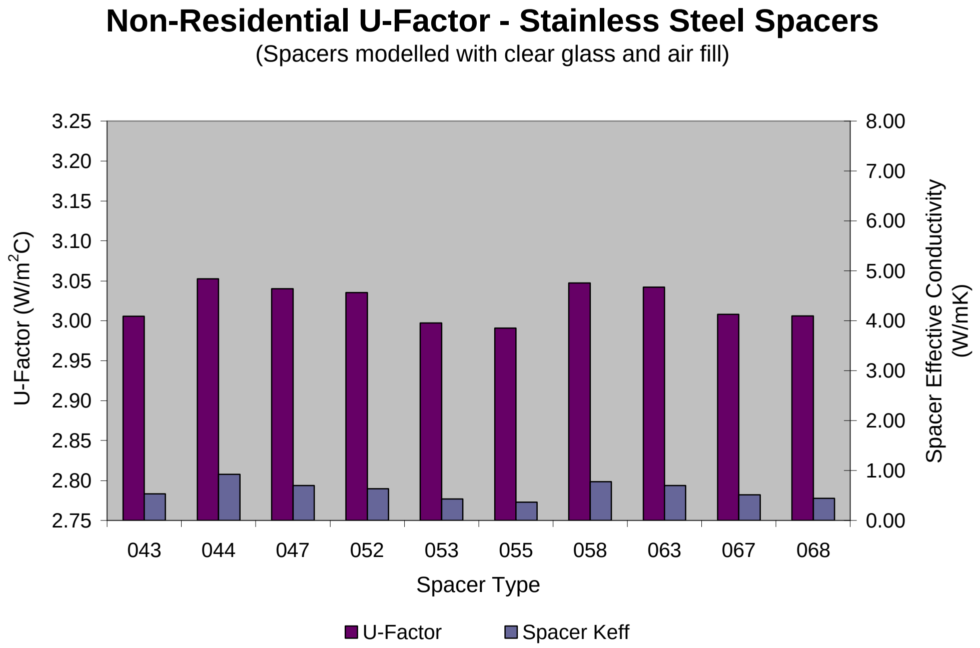


Figure A7 – Total Product U-factor and Spacer System Effective Conductivity Spacer 043 – 068

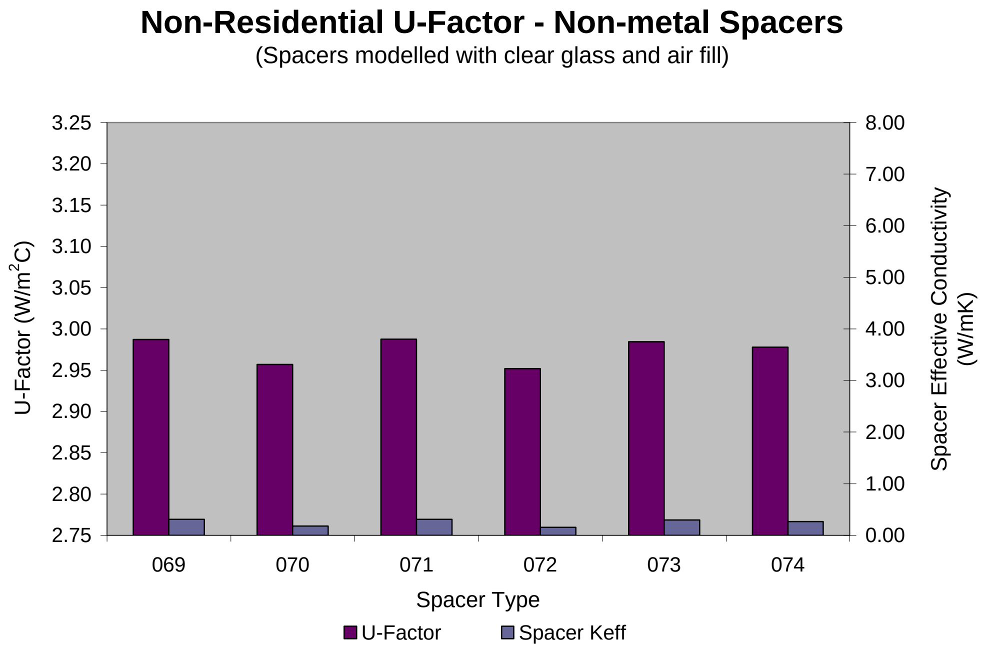


Figure A8 – Total Product U-factor and Spacer System Effective Conductivity Spacer 069 – 074

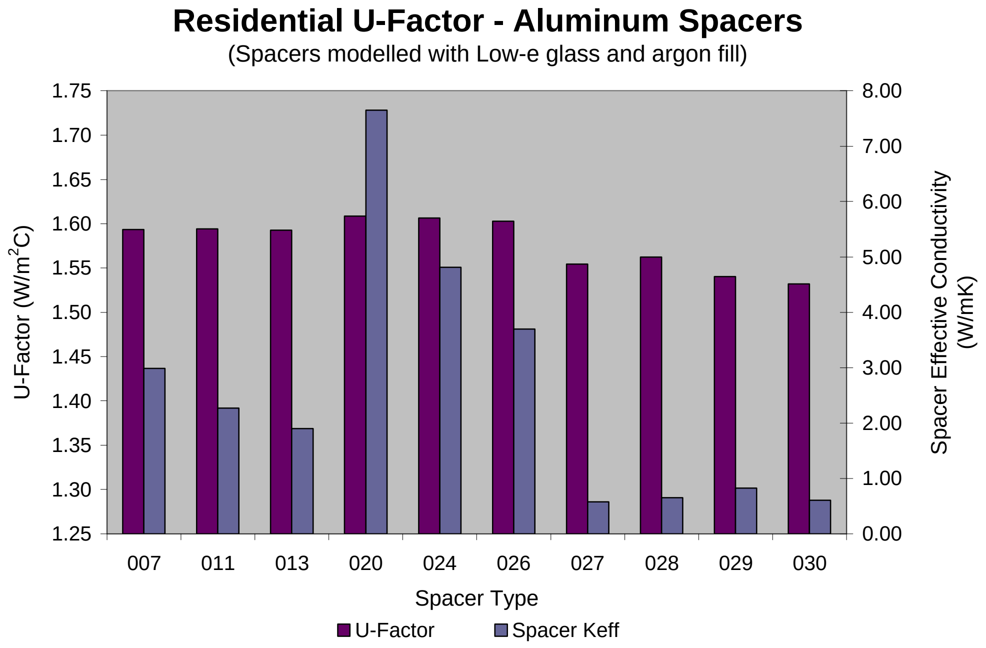


Figure A9 – Total Product U-factor and Spacer System Effective Conductivity Spacer 007 – 030

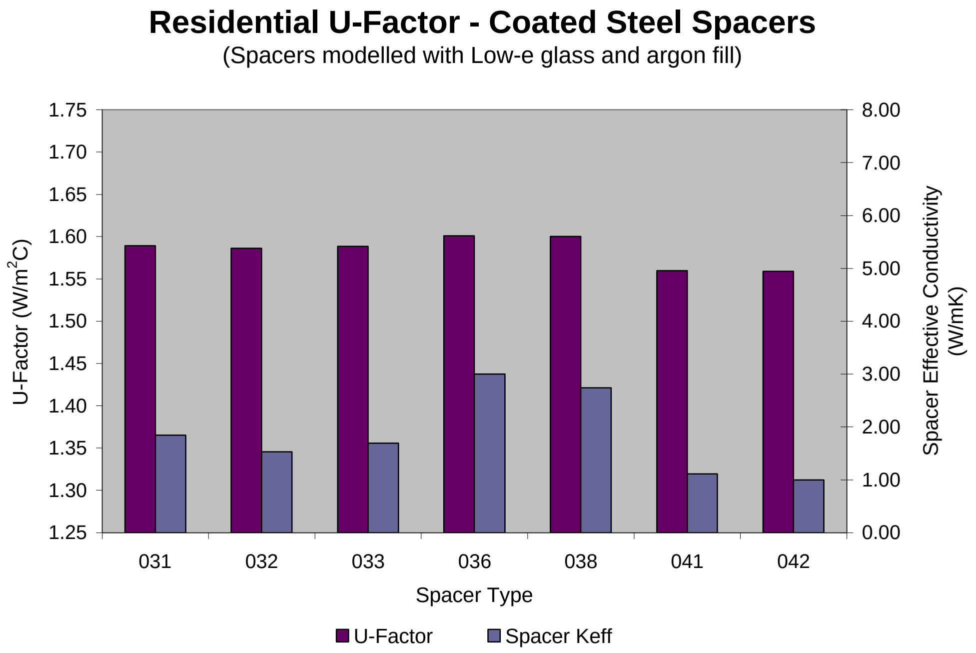


Figure A10 – Total Product U-factor and Spacer System Effective Conductivity Spacer 031 - 042

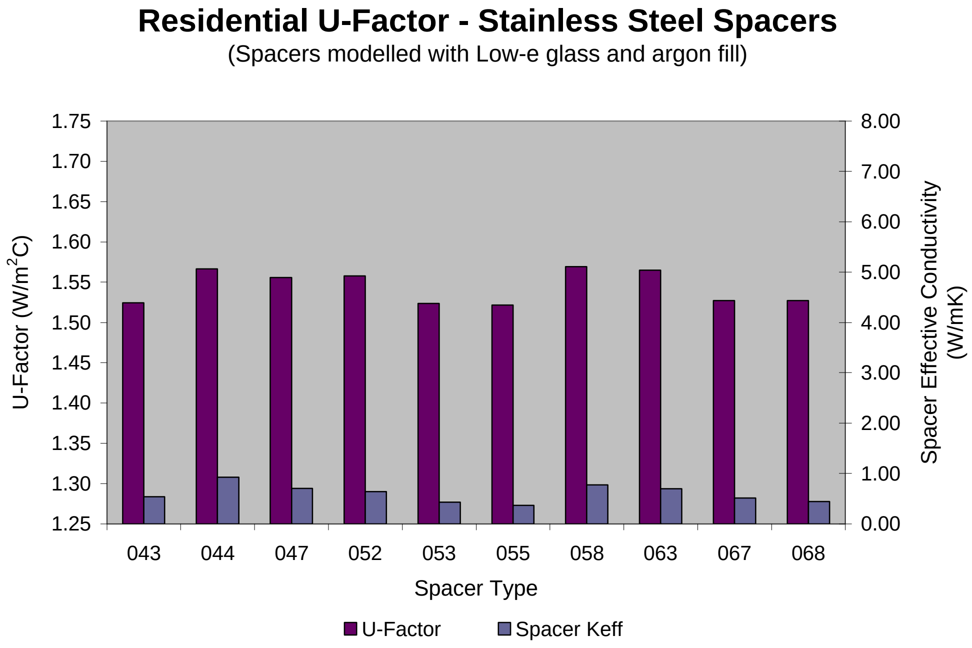


Figure A11 – Total Product U-factor and Spacer System Effective Conductivity Spacer 043 – 068

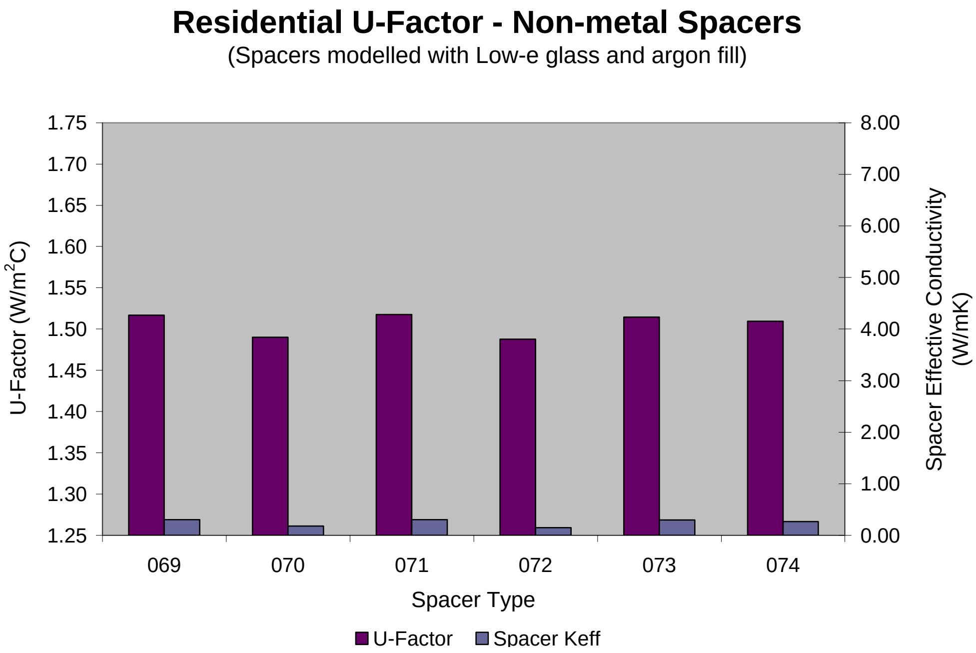


Figure A12 – Total Product U-factor and Spacer System Effective Conductivity Spacer 069 – 074

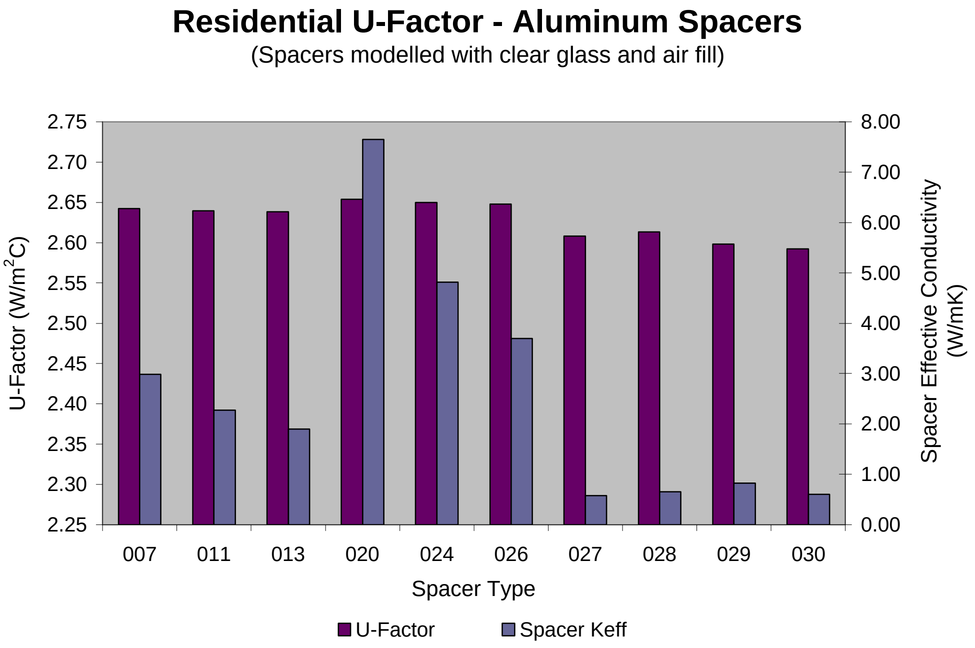


Figure A13 – Total Product U-factor and Spacer System Effective Conductivity Spacer 007 – 030

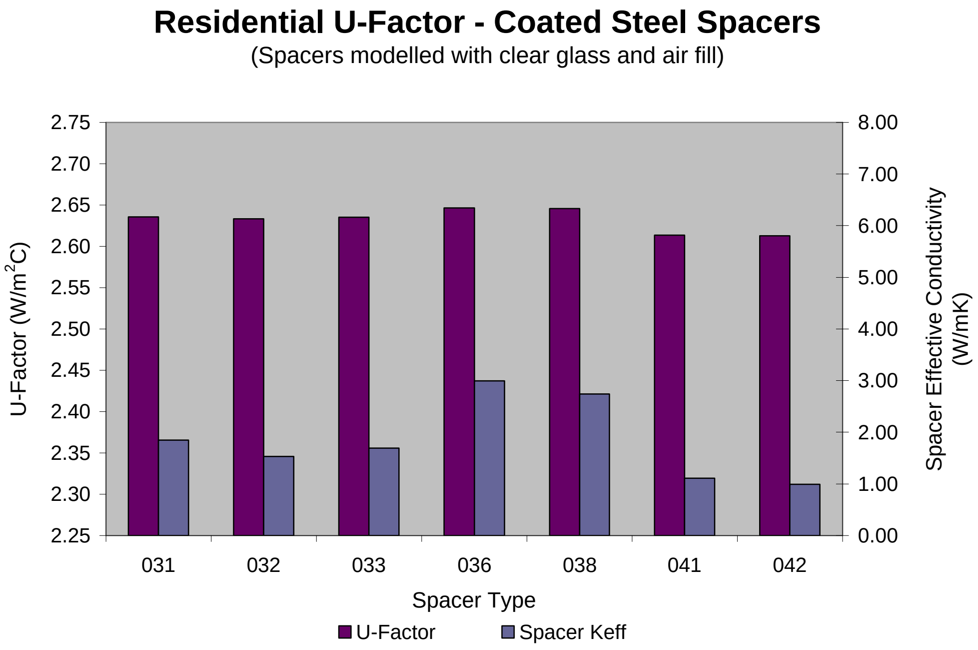


Figure A14 – Total Product U-factor and Spacer System Effective Conductivity Spacer 031 – 042

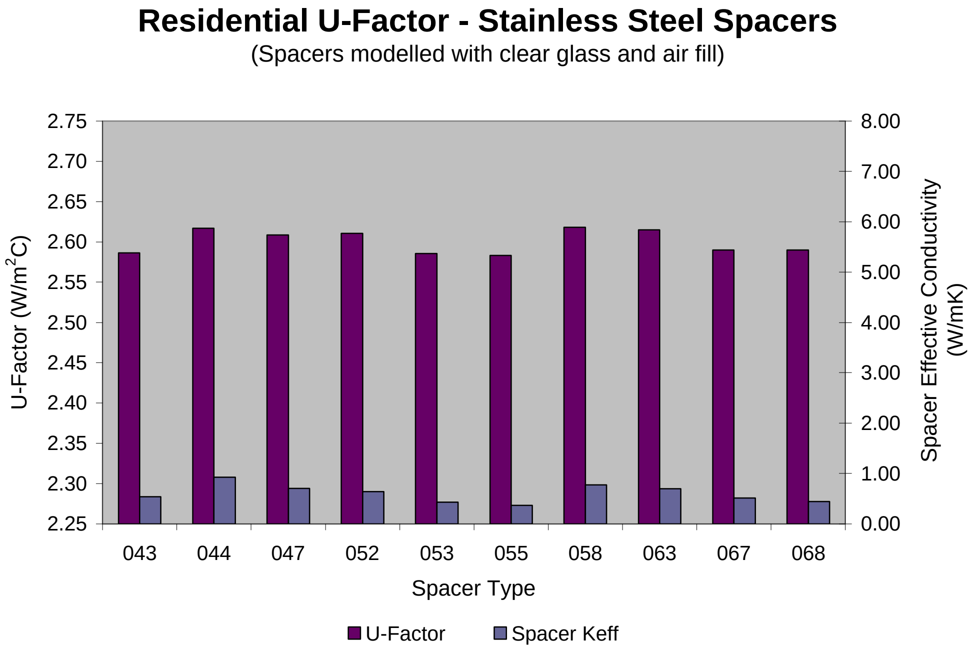


Figure A15 – Total Product U-factor and Spacer System Effective Conductivity Spacer 043 – 068

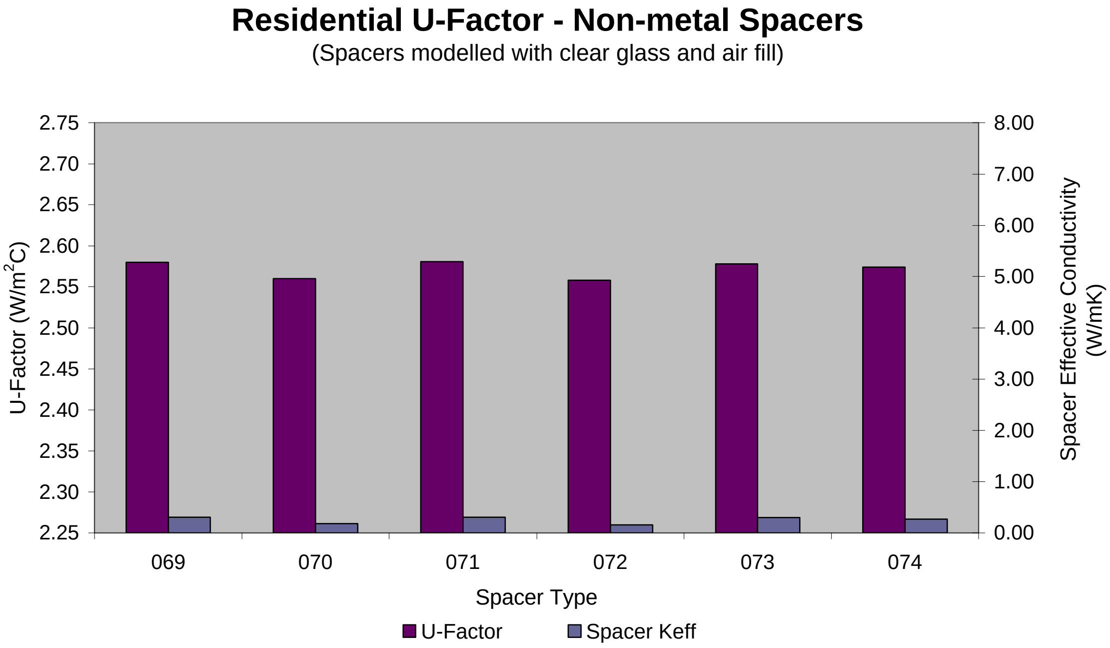


Figure A16 – Total Product U-factor and Spacer System Effective Conductivity Spacer 069 – 074