C E E R E

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Report:

Investigation of the Effects of Glass Thickness and Spacer Configuration on Thermal Performance of Windows

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March 11, 2005

EXECUTIVE SUMMARY

New NFRC non-residential technical procedure utilizes Component Modeling Approach, or CMA (Curcija 2003), which incorporates interpolation routines for spacers and glazing system options. During the August, 2004 non-residential task group meeting in Silver Spring, MD, several unresolved technical issues were identified. Most of the issues were related to the glass thickness, glazing bite and spacer position within the IGU. This study was carried out to determine the level of these effects and possible solution for implementation in CMA..

Approved NFRC simulation tools, WINDOW 5.2 and THERM 5.2, were used to carry this study. Four typical window types were analyzed, coupled with the range of spacer assemblies and glazing options. These window options were analyzed for a range of glazing bites, glass thicknesses and spacer heights in order to determine the effect on overall window heat transfer.

The conclusion from this study is that glazing bite, glass thickness and spacer position have very small effect on the overall window heat transfer. However small these effects have clear trend and in most cases this trend is nearly linear, so simple correlations could be developed to account for them.

INTRODUCTION

New NFRC non-residential technical procedure utilizes Component Modeling Approach, or CMA (Curcija 2003), which incorporates interpolation routines for spacers and glazing system options. During the August, 2004 non-residential task group meeting in Silver Spring, MD, several unresolved technical issues were identified. The following is the list of outstanding technical issues as identified by the task group:

1. How do we develop a correlation between standard glazing bite and changes in bite design-we don't expect variation to be more than 1/8th "+/-.
2. Develop correlation for std. ht. spacers vs. custom ht. spacers.
3. Keep CRF values/procedures in mind when considering the technical issues/procedures.
4. Establish frame grouping rules (both interior, exterior & profiles/depths)
5. For certification purposes how are we going to handle size issues (i.e. NFRC size vs. Project size?)
6. How do we handle effect of glass thickness (i.e. Lami) & glass conductivity?

Excluding issues that are less technical and more certification, like frame grouping and size and also not addressing CR issue which is non-mandatory index, most of the issues were related to the glass thickness, glazing bite and spacer position within the IGU. This study was carried out to determine the level of these effects for various glazing and spacer options, including different position of spacer within IGU.

This study has not identified any new algorithms based on its findings but rather presents all the facts and discusses their level. Further work can address possible algorithmic solutions if there is consensus among participants that these effects should be included.

WINDOW 5.2 and THERM 5.2, approved NFRC simulation tools, were used in this study. The study cover the entire range of window frames, glazing and spacer options, which allows for full conclusions to be drawn and algorithms developed.

MODELING DETAILS

Window Types:

Four different window types were investigated:

1) Thermally-broken Aluminum Fixed Window (2001 NFRC Testing Round Robin - TRR01)
2) Aluminum Horizontal Slider Window (1999 and 2000 NFRC Testing Round Robin - TRR99)
3) PVC Casement Window
4) Wood Fixed Window (THERM sample window)

Appendix A contains model drawings for each of the windows.

Glazing bite:

Glazing bite was investigated in increments of 2.5 mm, from -10 mm up to +10 mm, where 0 distance is defined as flush mounted spacer (i.e., top of spacer assembly flush with the sightline).

Spacer Conductivities:

Several different spacer conductivities were investigated, in order to simulate range of expected spacer configurations. Because the component modeling approach utilizes solid spacer block with the equivalent effective conductivity, k_{eff}, same approach was utilized here. The real spacer was replaced by a solid rectangular block and its k_{eff} was calculated using the following procedure:

Overall U factor of individual spacer assembly was calculated using THERM. Using the electrical analogy of series of resistance, the reciprocal value of U-factor, thermal resistance or R_{tot} was used to calculate effective conductivity of the spacer assembly.

$$R_{tot} = \frac{1}{h_o} + \frac{L}{k_{eff}} + \frac{1}{h_i} \qquad (1)$$

Where L is the length of the spacer, hi and ho are inside and outside heat transfer coefficients respectively and R_{tot} (=1/U) is overall resistance.

From equation (1):

$$\frac{L}{k_{eff}} = R_{tot} - \frac{1}{h_o} - \frac{1}{h_i} \qquad (2)$$

or

$$k_{eff} = \frac{L}{R_{Tot} - \frac{1}{h_o} - \frac{1}{h_i}} \quad (3)$$

In order to verify that the effective conductivity of spacer assembly gives equivalent results (i.e., heat transfer performance) to the real spacer assembly, the two U-factors were compared. Table 1 shows performance calculated with actual spacer assembly and with spacer block having k_{eff}.. The agreement between the two results is excellent.

In addition to the effective conductivities calculated from the actual spacers in those windows, several generic values were also considered, in order to provide range of performances for comparison. The following effective conductivities were used in this study:

k_{eff} = 0.05 Btu/h-ft-F,

k_{eff} = 0.10 Btu/h-ft-F,

k_{eff} = 0.20 Btu/h-ft-F,

k_{eff} = 0.50 Btu/h-ft-F,

k_{eff} = 1.00 Btu/h-ft-F,

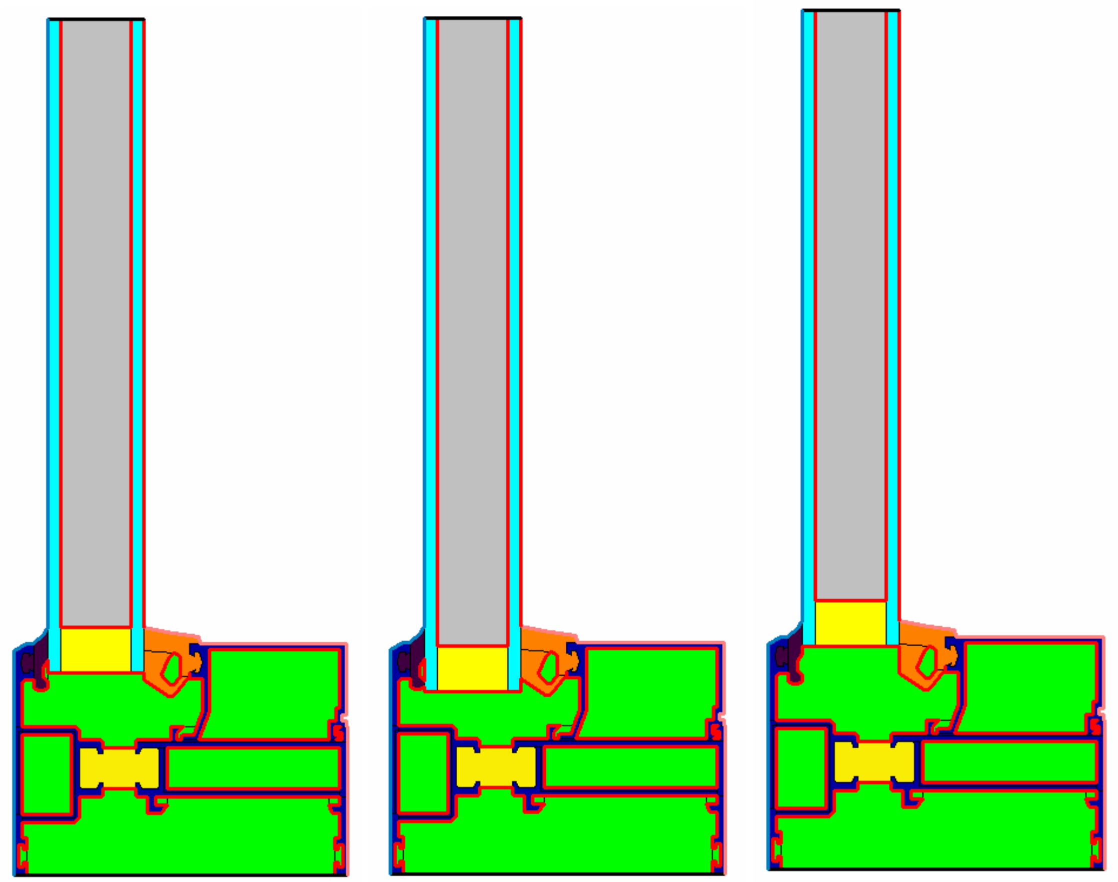
k_{eff} = 2.00 Btu/h-ft-F,

Table 1. Comparison of U-factors with Actual Spacers and k_{eff} Spacer Blocks

	TB-Al Fixed	Al slider	PVC Casement	Wood Fixed
U-factor (actual spacer)	0.586	0.505	0.313	0.475
U-factor (keff)	0.585	0.506	0.312	0.469
Keff (Btu/(hr-ft-F))	0.644	0.589	0.196	0.673
Ucog (Btu/(hr-ft^2-F)				
Initial glazing bite (mm)	-5.337	-2.04	-4.28	0

INVESTIGATION OF THE EFFECT OF GLAZING BITE

Glazing bite usually refers to the recess of spacer into the sash or frame. In this work, several different glazing bites were considered. Flush configuration (i.e., when top surface of the spacer is in the same plane as indoor sightline) was considered as 0 bite, while further recess into the frame was labeled as negative bite and the other way around was labeled positive bite. Figure A shows example of flush, recessed spacer and exposed spacer for one of analyzed windows.



(a) (b) (c)

Figure A. (a) Flush Mounted Spacer; (b) -5 mm Glazing Bite; and (c) +5 mm Glazing Bite

Range of glazing bites from -10 mm to +10 mm, or less as limited by the specific frame configuration were investigated for the three different glazing systems and the range of spacer effective conductivities, as indicated above. For some of the windows, it was not possible to achieve full -10 to +10 mm range, because of the limitations of the particular frame design (i.e., not enough room for glazing to be further inserted, etc.).

The results have been summarized in a series of graphs in Figures 1 to 13.

Figures 1 to 4 show change in U-Factor of each of the typical windows with respect to the glazing bite and effective spacer. The glazing systems in these figures were the original product glazing. Figures 5 to 13 show performance of each of those windows, coupled with three generic glazing systems, so that effects of different glazing performance can be investigated. The generic glazing systems investigated were: Double clear air, Double low-e HC Argon, and

Double low-e SC Krypton. Distance, indicated on the x axis of the figures 1-13 indicates glazing bite in mm, where 0 denotes upper surface of a spacer flush with the sight line.

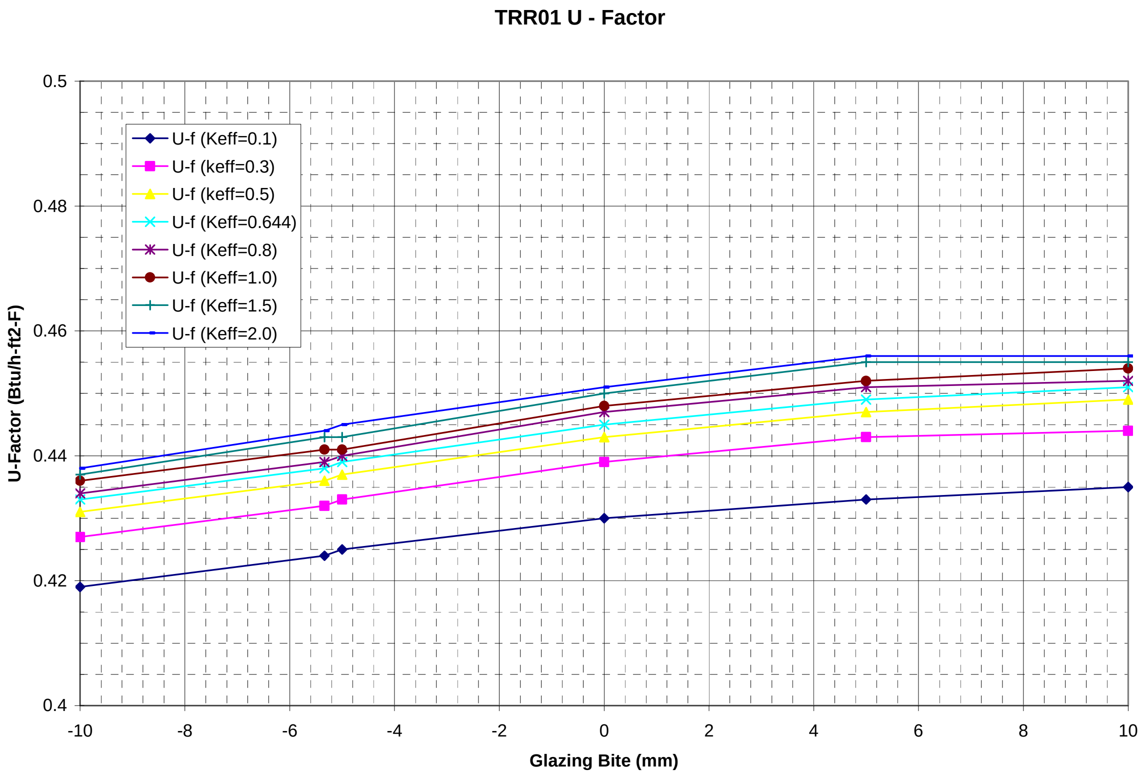


Figure 1: Thermally broken Aluminum, Fixed Window –TRR01

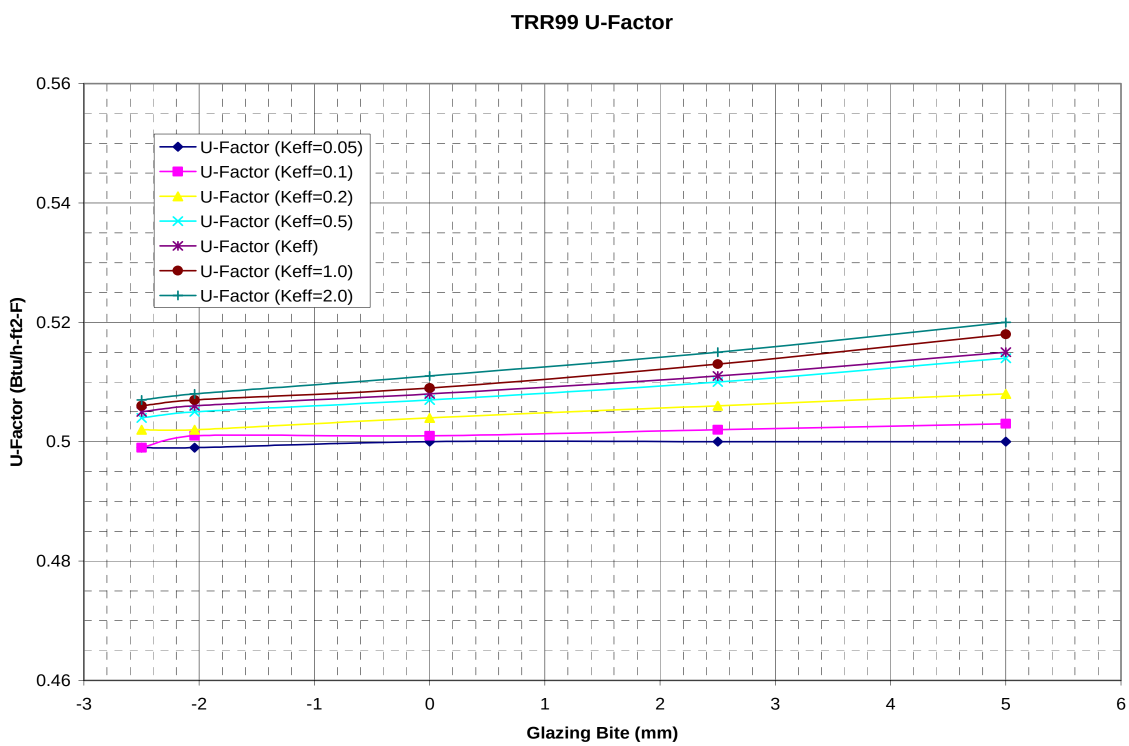


Figure 2: Aluminum Horizontal Slider Window –TRR99

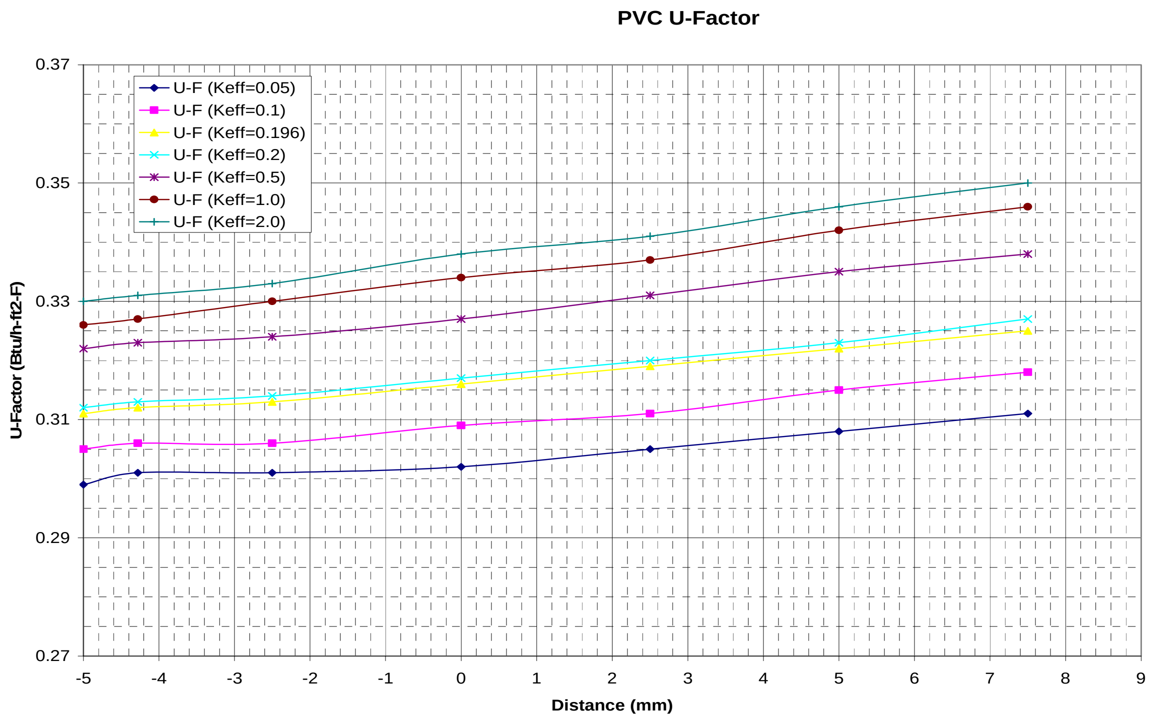


Figure 3: PVC Casement Window

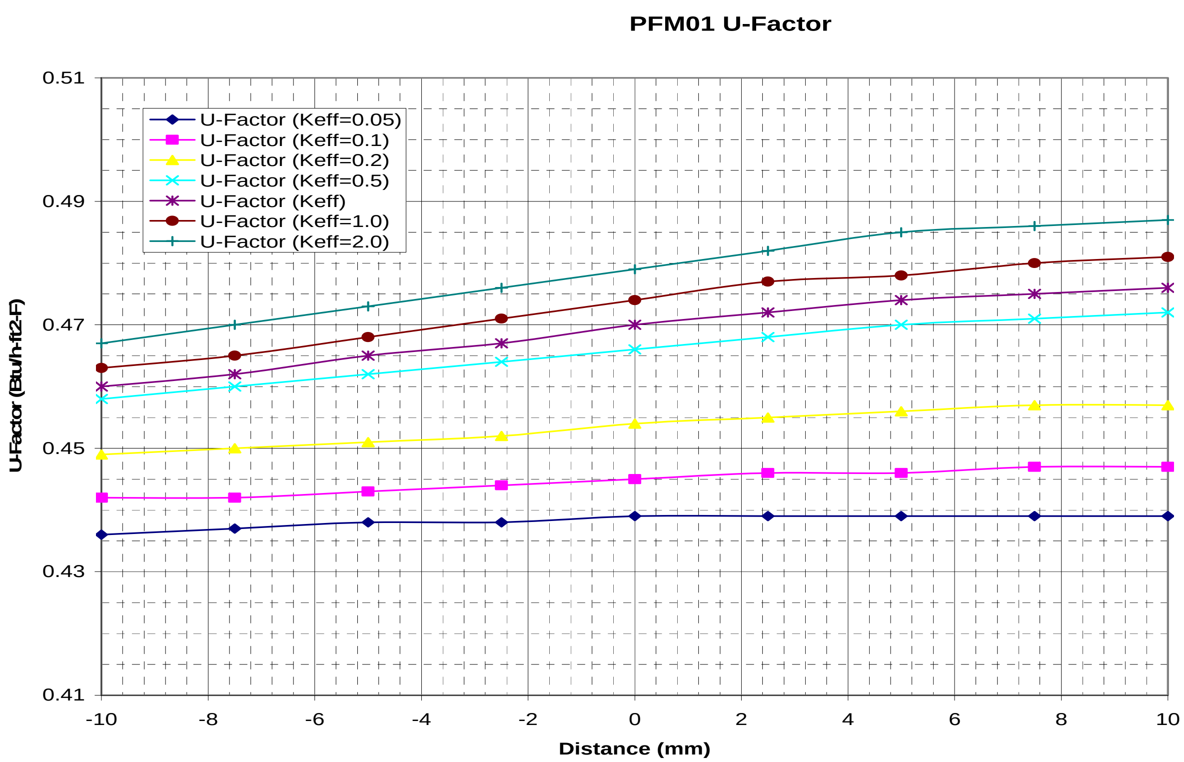


Figure 4: Wood Fixed Window

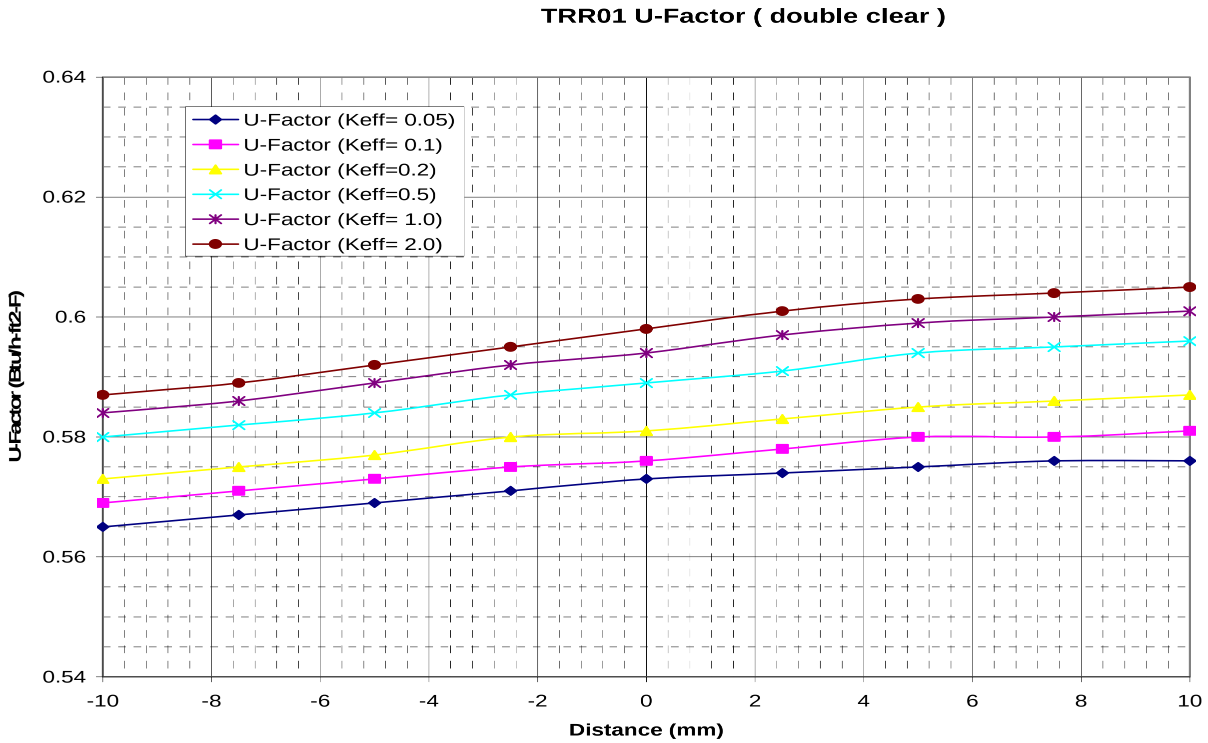


Figure 5: Glazing bite effects on U-factors for Double, Clear Glazing

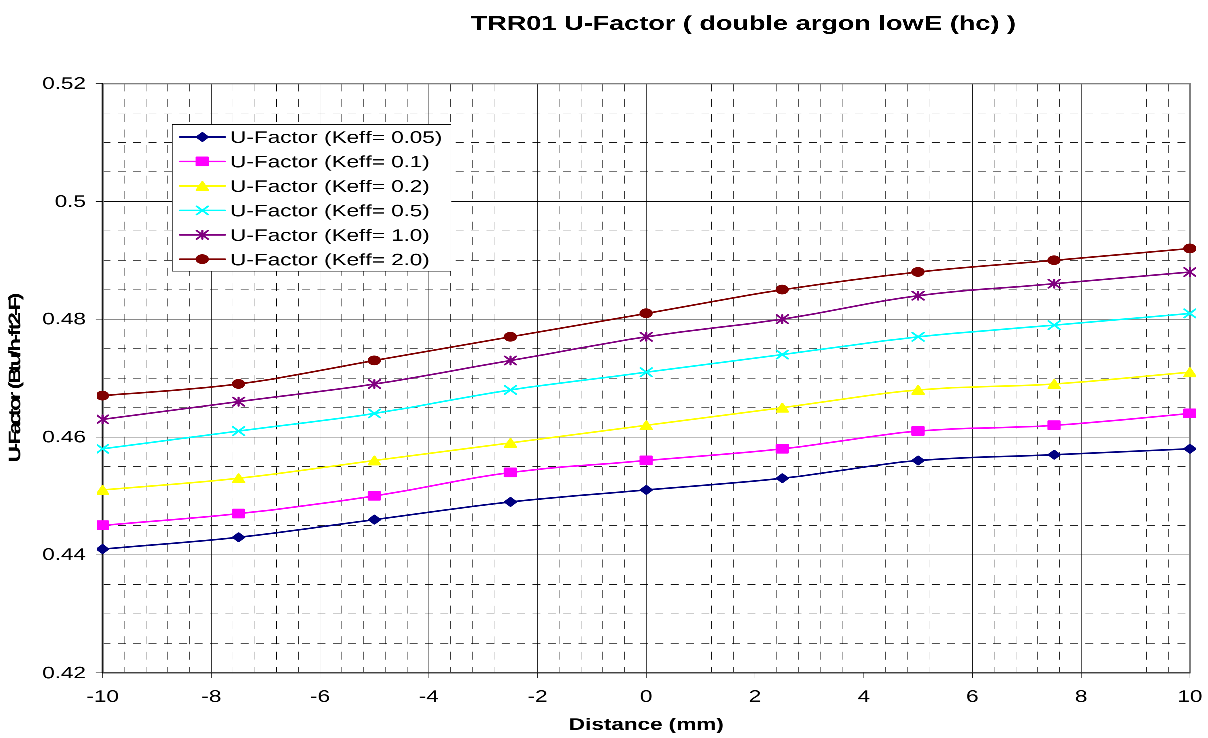


Figure 6: Glazing bite effects on U-factors for Double, Low-e (hc), Argon Filled Glazing

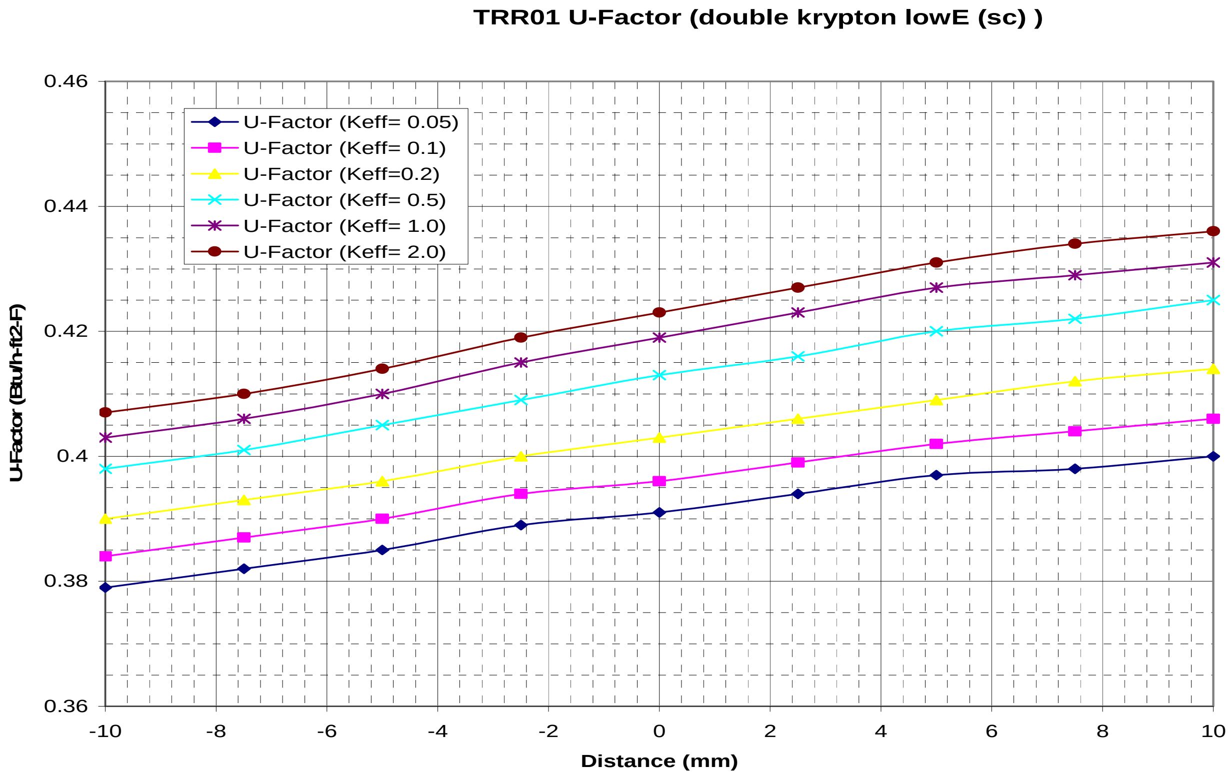


Figure 7: Glazing bite effects on U-factors for Double, Low-e (sc), Krypton Filled Glazing

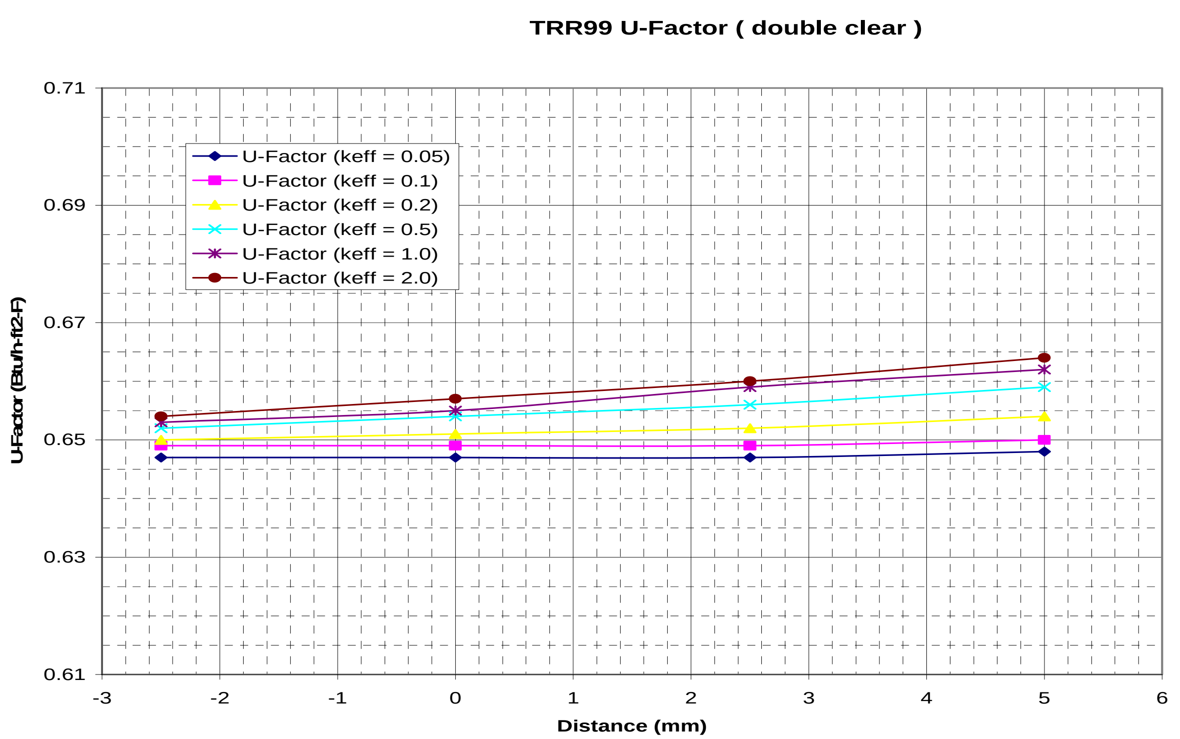


Figure 8: Glazing bite effects on U-factors for Double, Clear Glazing

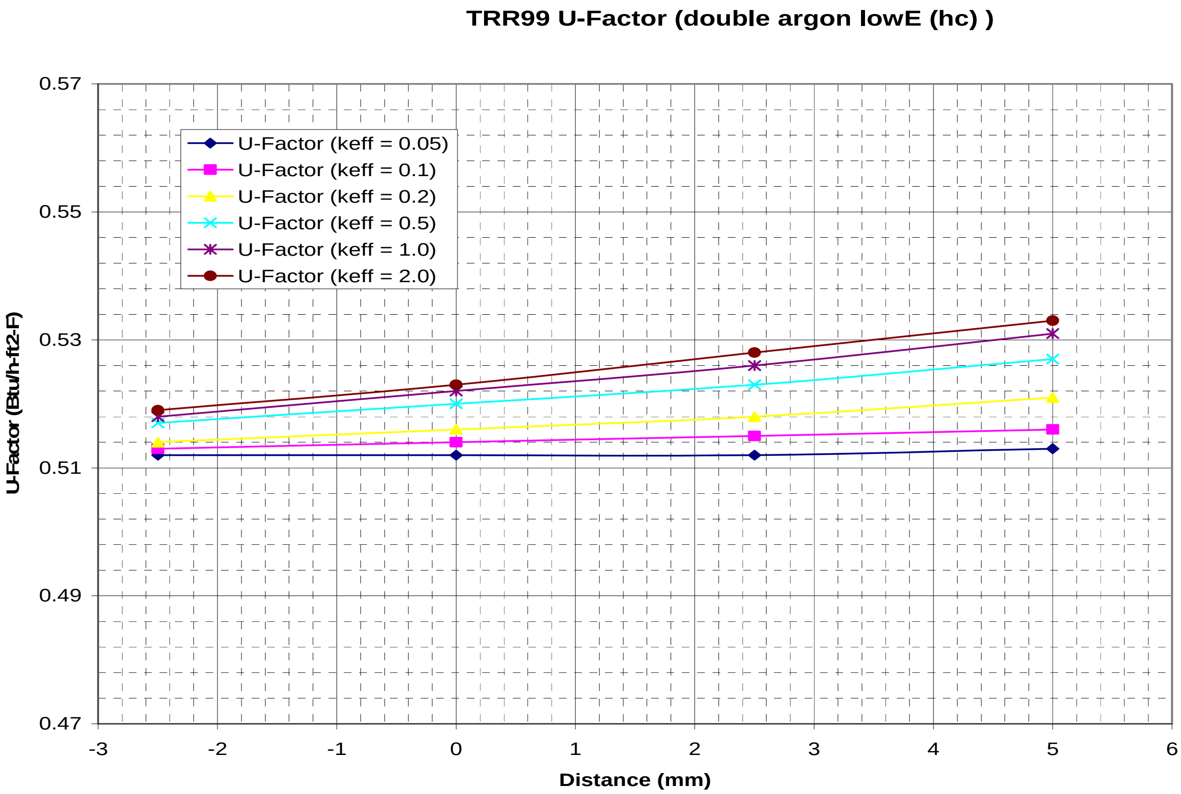


Figure 9: Glazing bite effects on U-factors for Double, Low-e (hc), Argon Filled

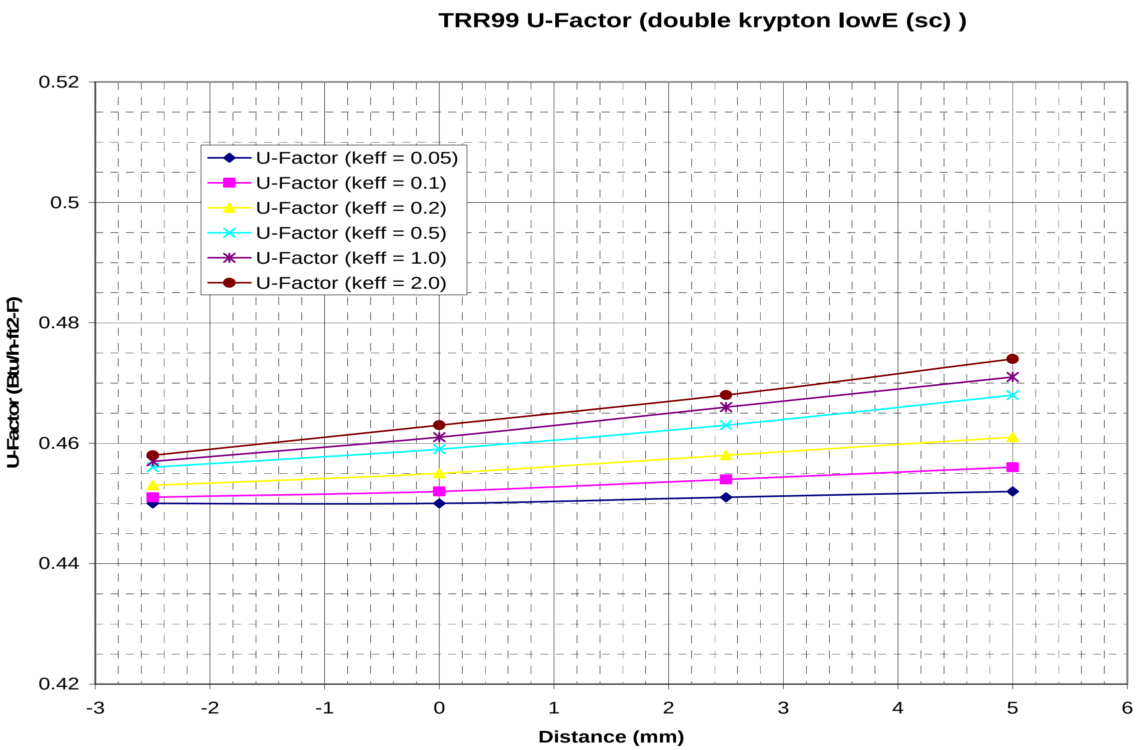


Figure 10: Glazing bite effects on U-factors for Double, Low-e (sc), Krypton Filled Glazing

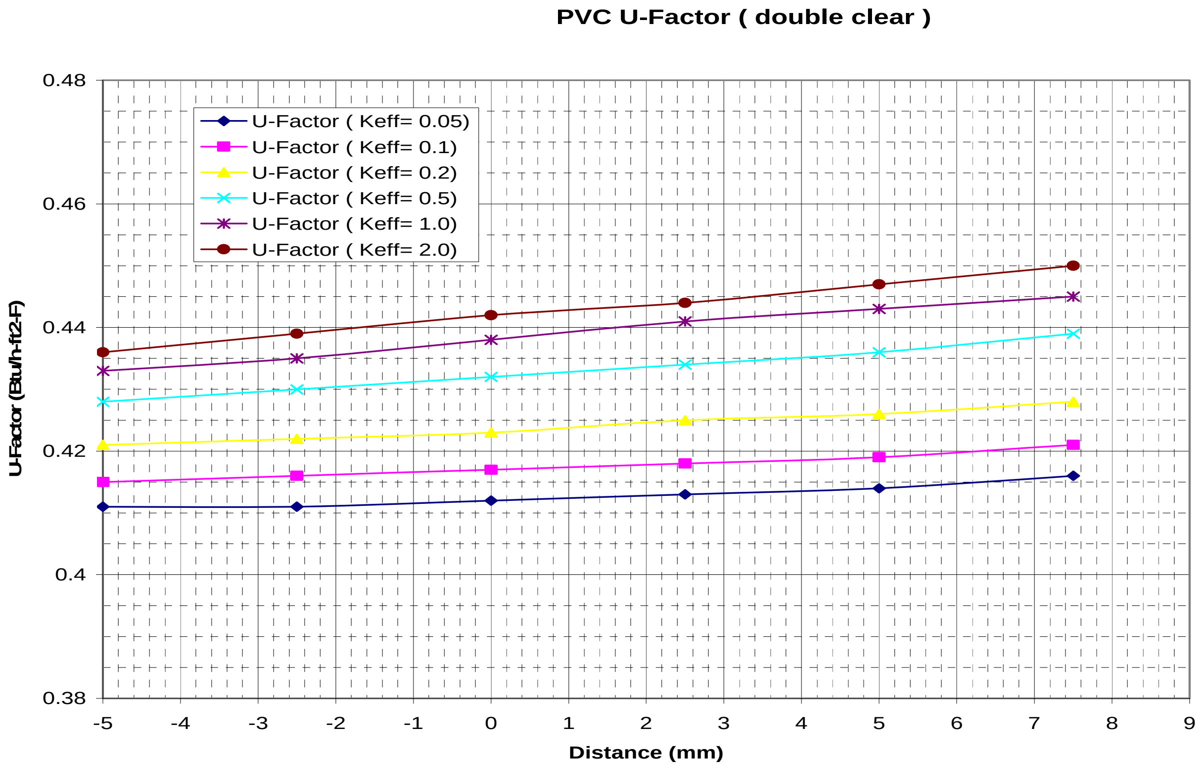


Figure 11: Glazing bite effects on U-factors for Double, Clear Glazing

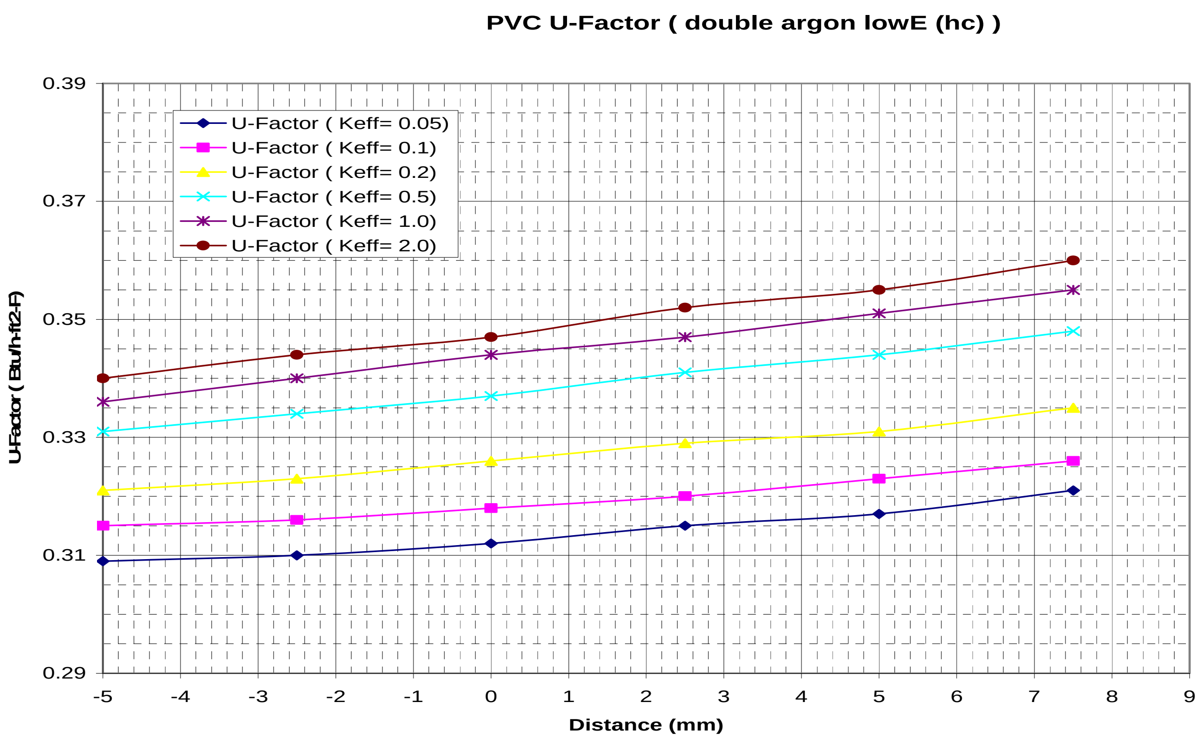


Figure 12: Glazing bite effects on U-factors for Double, Low-e (hc), Argon Filled Glazing

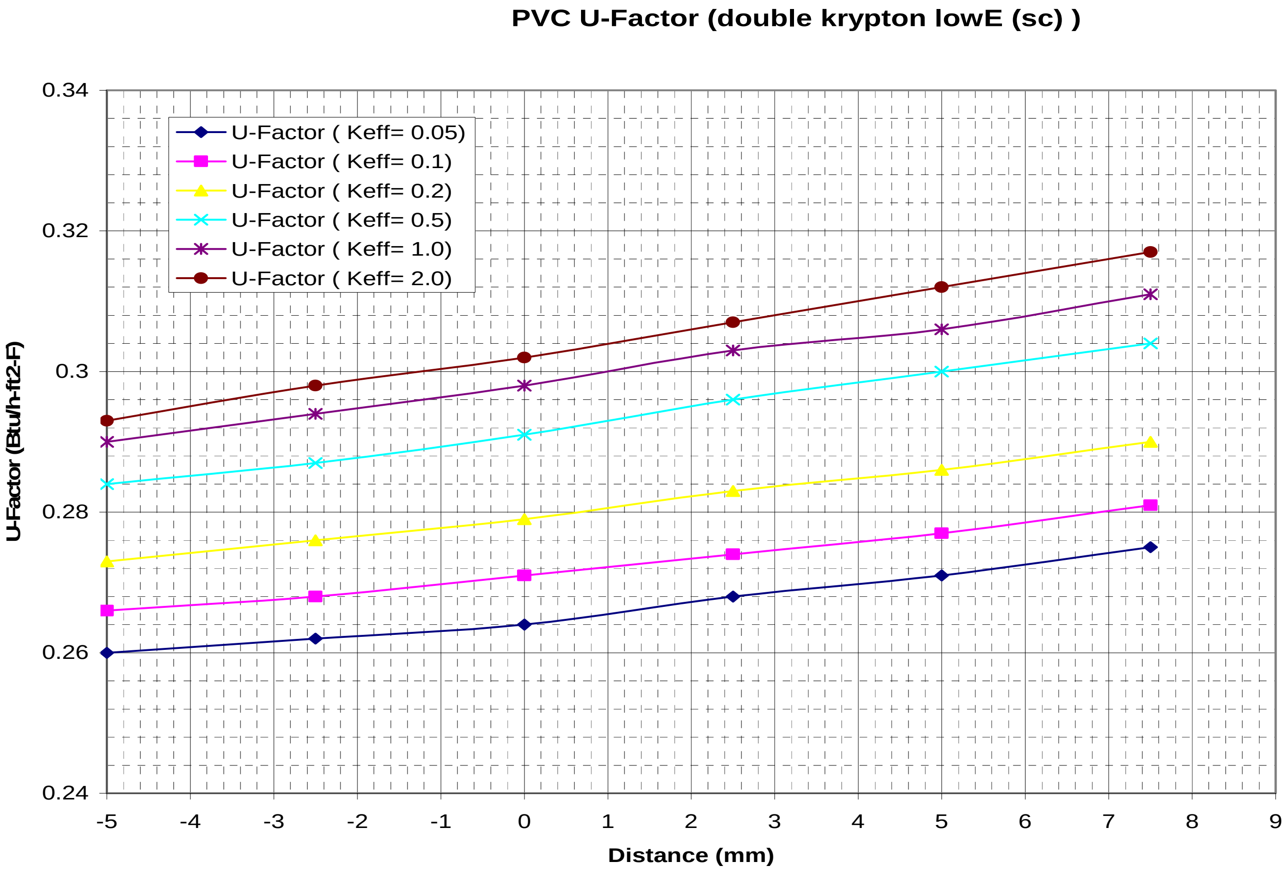
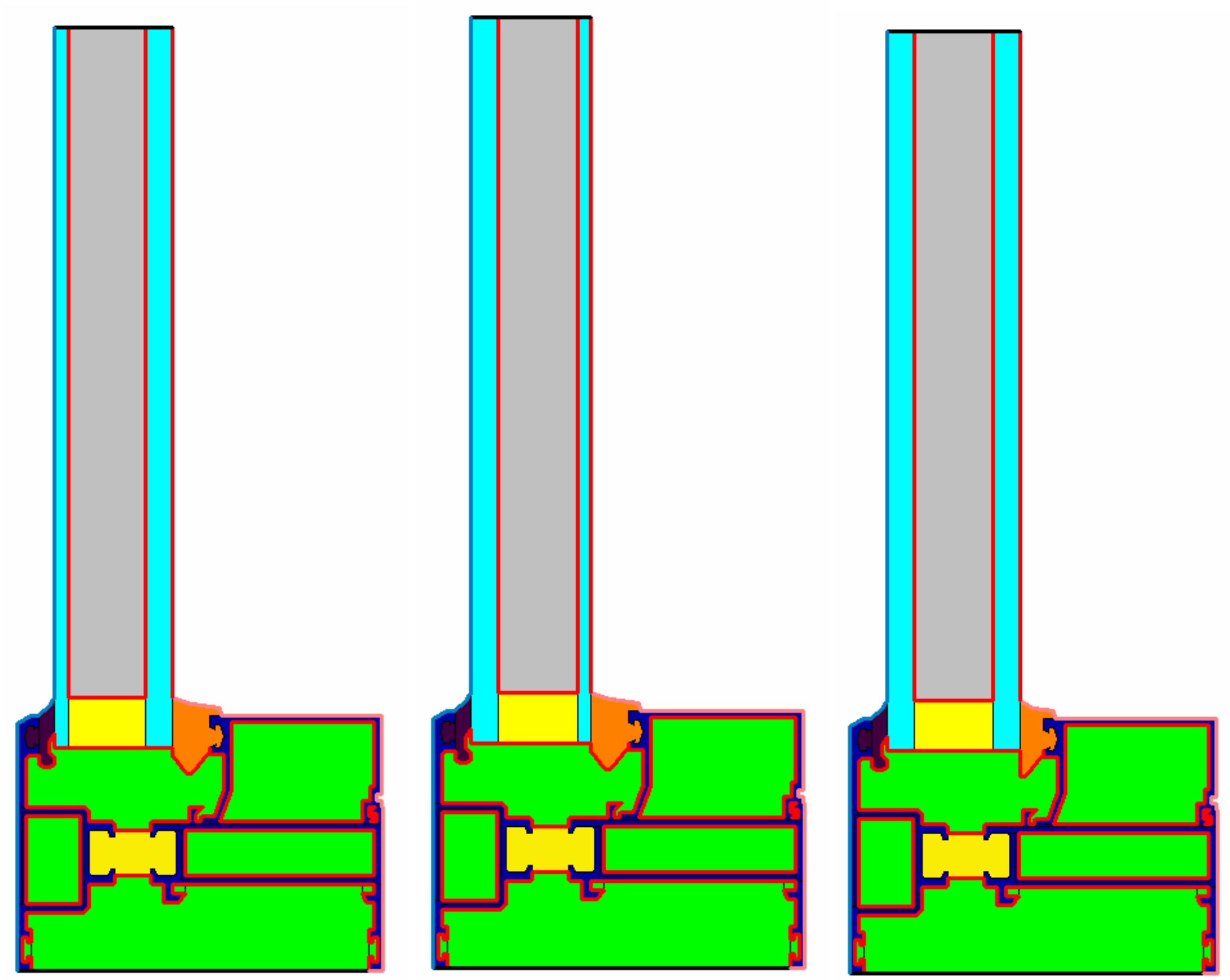


Figure 13: Glazing bite effects on U-factors for Double, Low-e (sc), Krypton Filled Glazing

INVESTIGATION OF THE EFFECT OF GLAZING THICKNESS

The Component Modeling Procedure (CMP) recommends use of generic glazing thickness for its B/W options. In order to investigate effects of glazing thicknesses that are different than generic ones, three different thicknesses were considered for each one and also both glazing. Figure B shows example of single thickness, double thickness and triple thickness for one of the analyzed windows.



(a) (b) (c)

Figure B. (a) Indoor Glass Variation; (b) Outdoor Glass Variation; (c) Both Glass Variations

Figures 14 to 22 show effects of glazing thickness on U-factor of TRR01 window for the three glass type variations shown in Figure B.

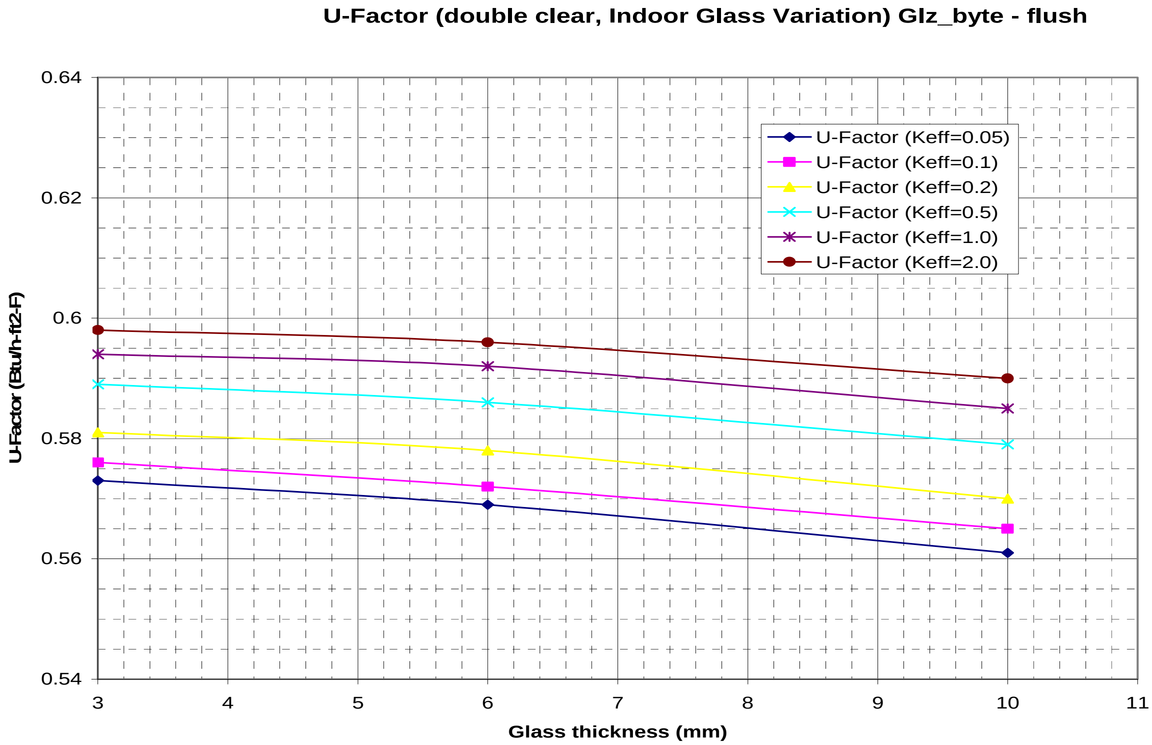


Figure 14. Effect of Glass Thickness on Overall U-Factor for TRR01, Indoor Glass Variation, Double-Clear glass, and Flush Glazing Bite

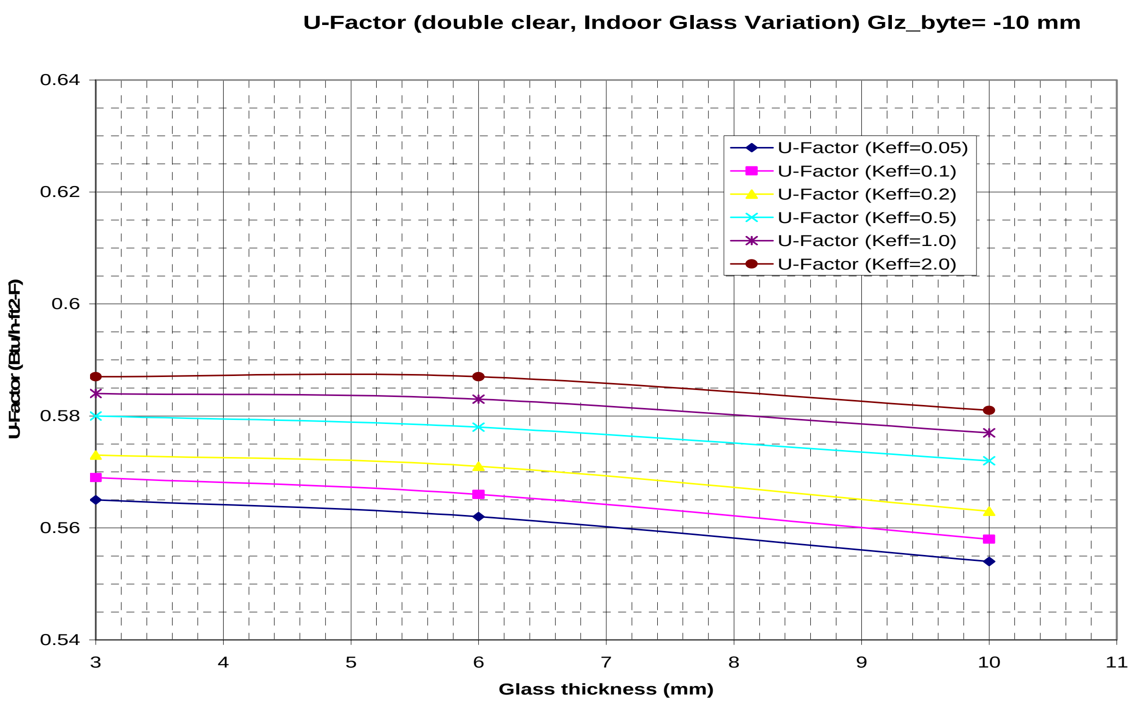


Figure 15. Effect of Glass Thickness on Overall U-Factor for TRR01, Indoor Glass Variation, Double-Clear glass, and -10 mm Glazing Bite

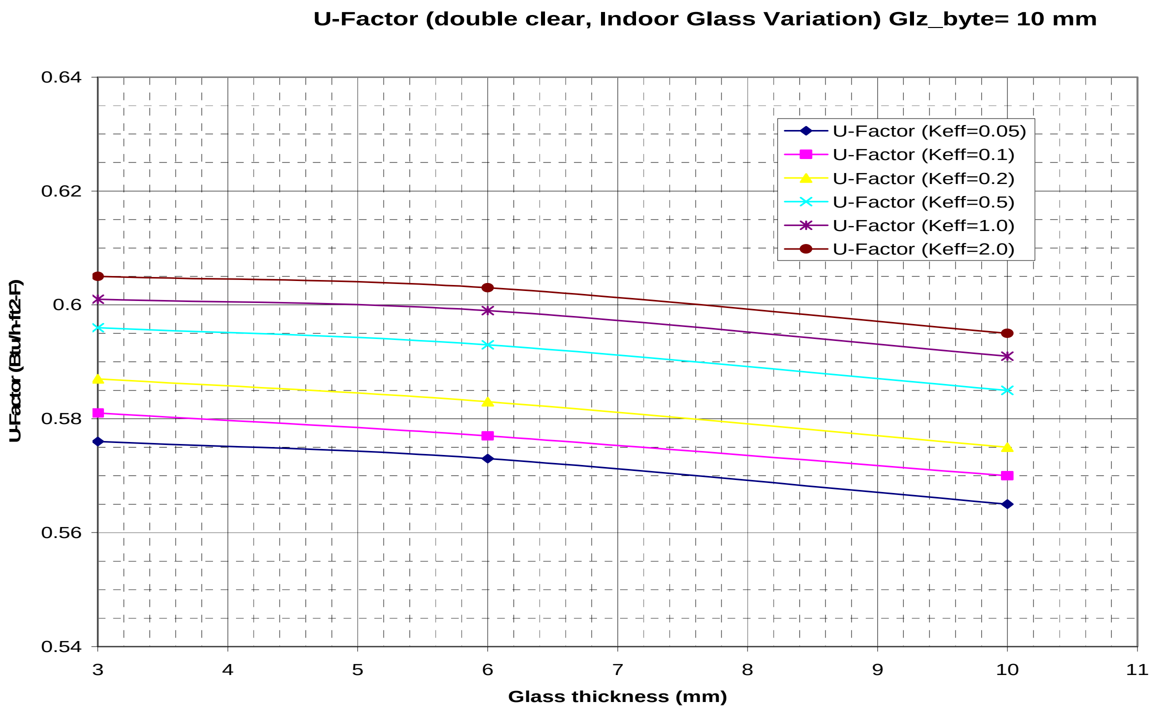


Figure 16. Effect of Glass Thickness on Overall U-Factor for TRR01, Indoor Glass Variation, Double-Clear glass, and +10 mm Glazing Bite

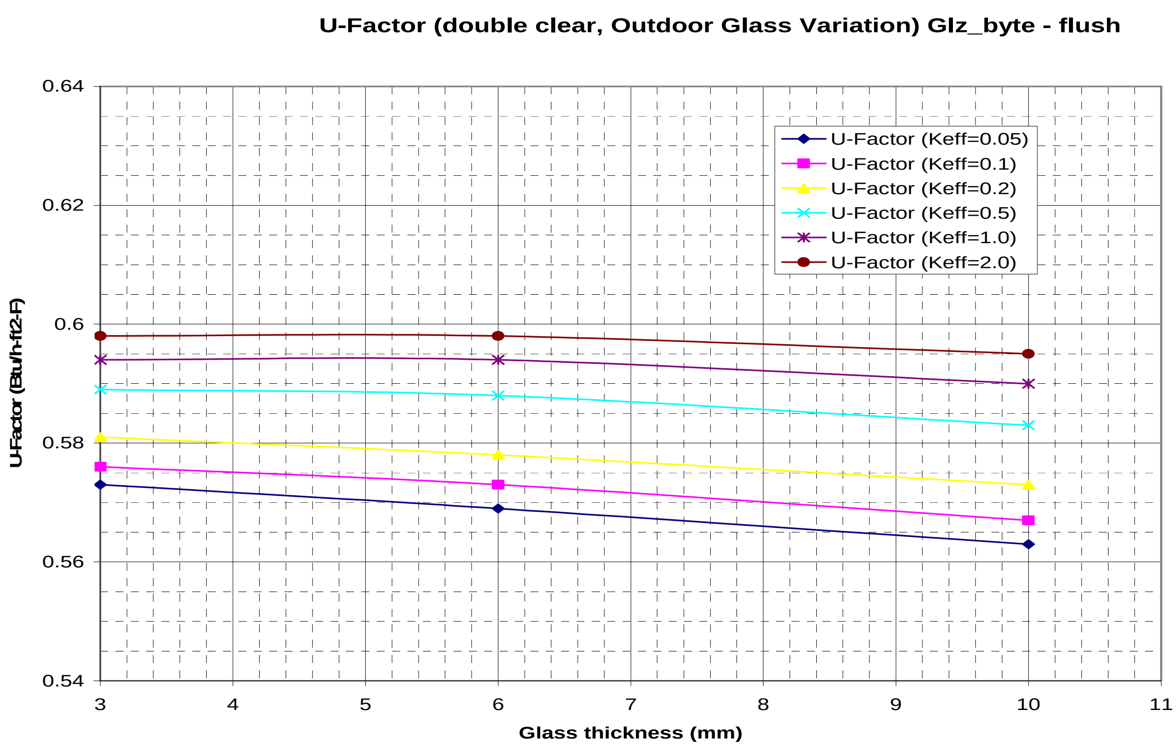


Figure 17. Effect of Glass Thickness on Overall U-Factor for TRR01, Outdoor Glass Variation, Double-Clear glass, and Flush Glazing Bite

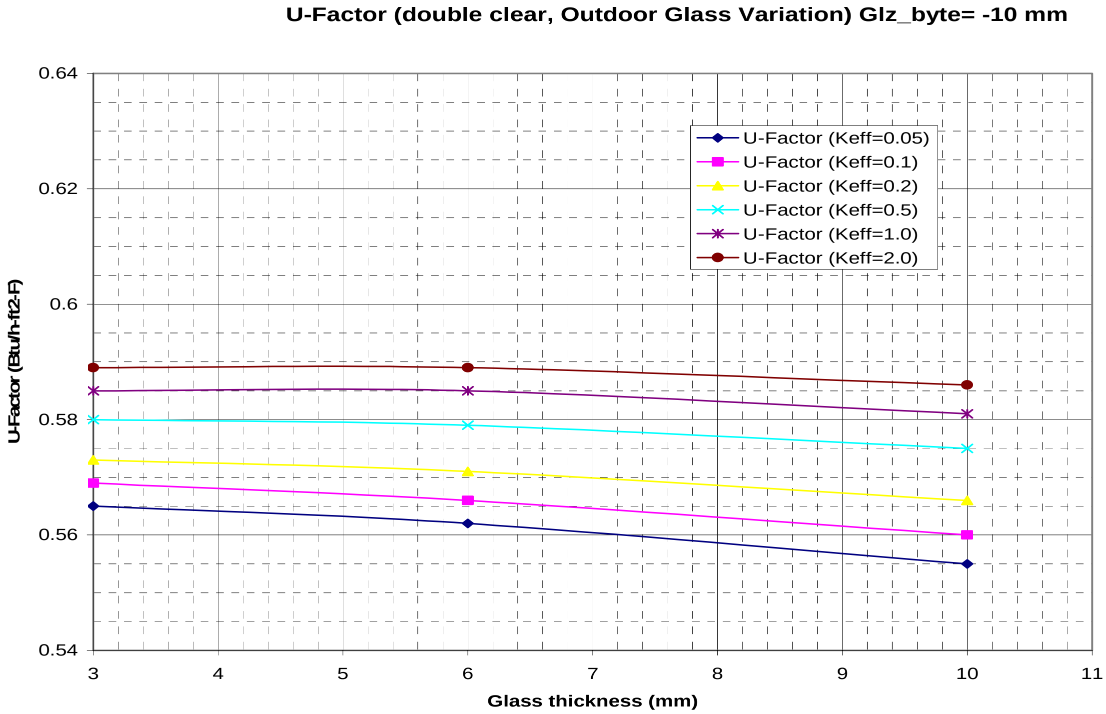


Figure 18. Effect of Glass Thickness on Overall U-Factor for TRR01, Outdoor Glass Variation, Double-Clear glass, and -10 mm Glazing Bite

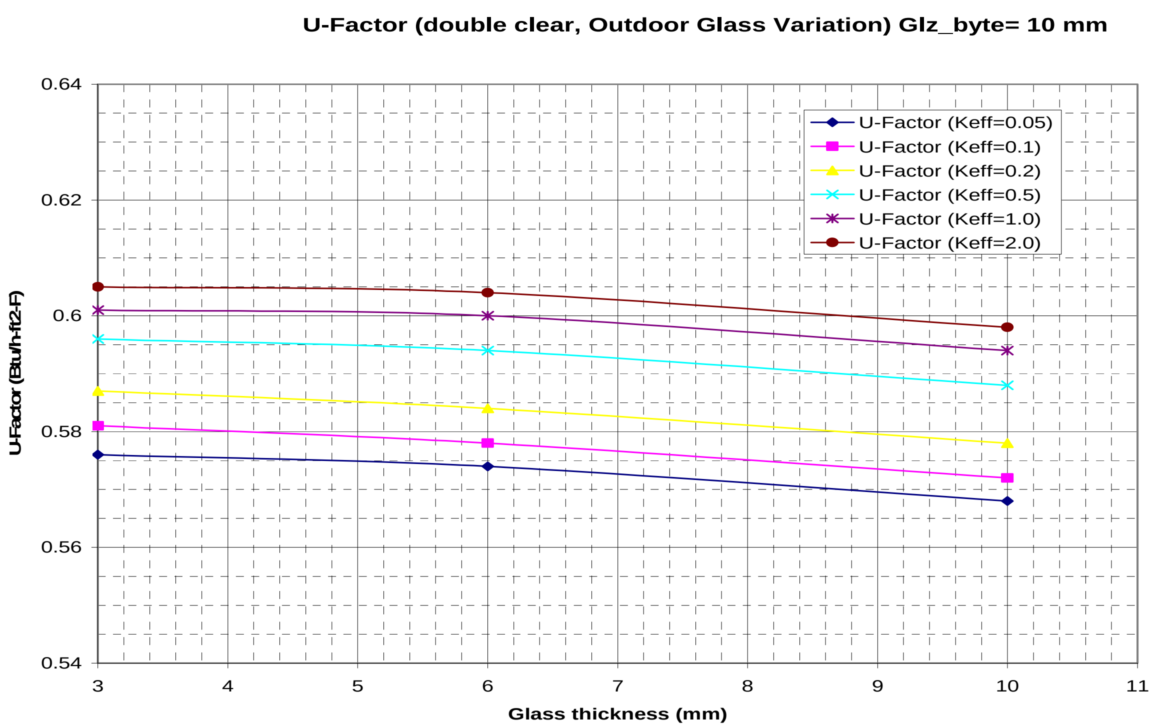


Figure 19. Effect of Glass Thickness on Overall U-Factor for TRR01, Outdoor Glass Variation, Double-Clear glass, and +10 mm Glazing Bite

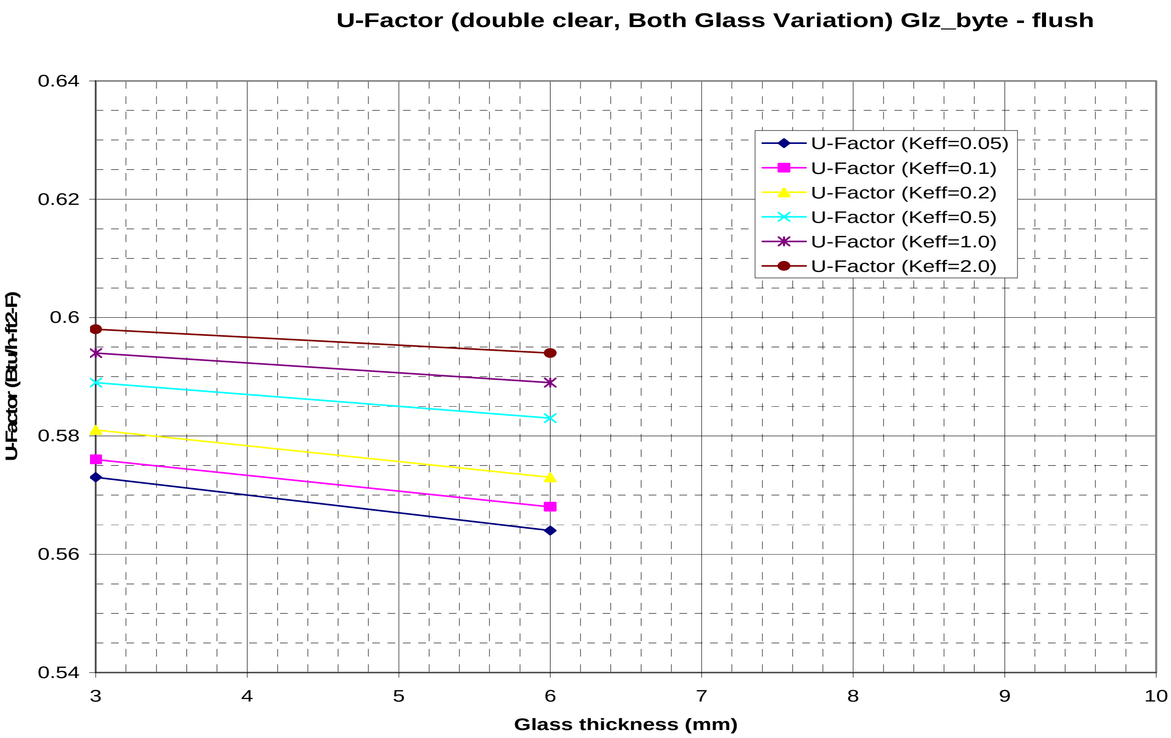


Figure 20. Effect of Glass Thickness on Overall U-Factor for TRR01, Both Glass Variation, Double-Clear glass, and Flush Glazing Bite

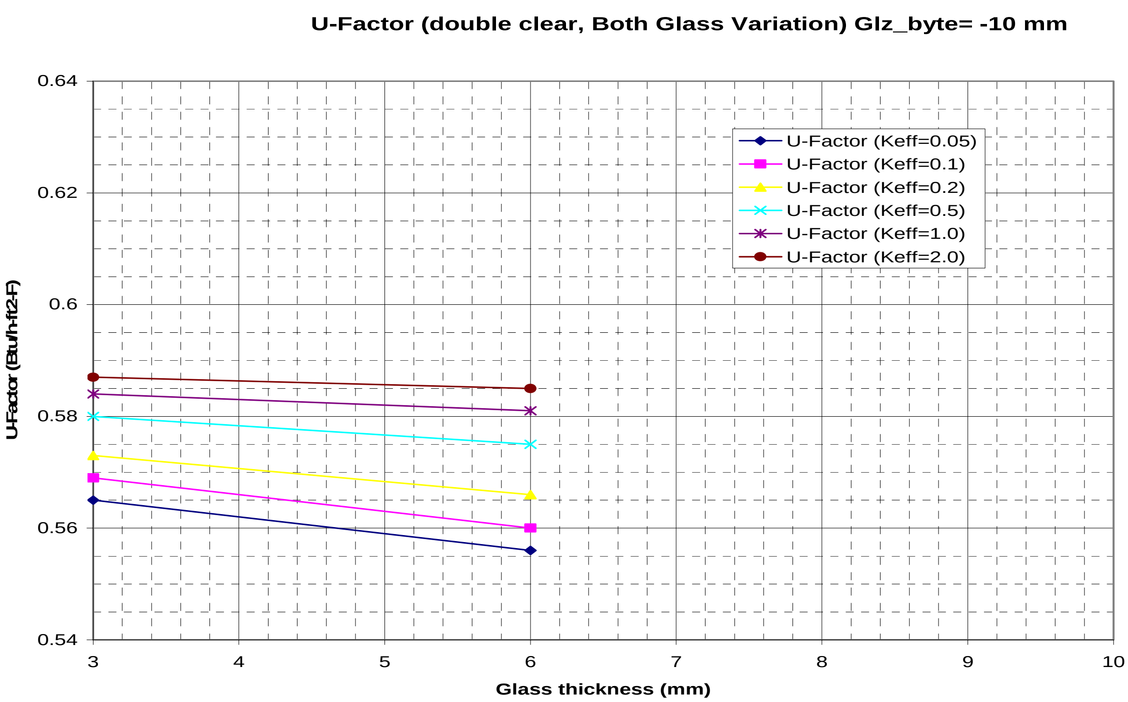


Figure 21. Effect of Glass Thickness on Overall U-Factor for TRR01, Both Glass Variation, Double-Clear glass, and -10 mm Glazing Bite

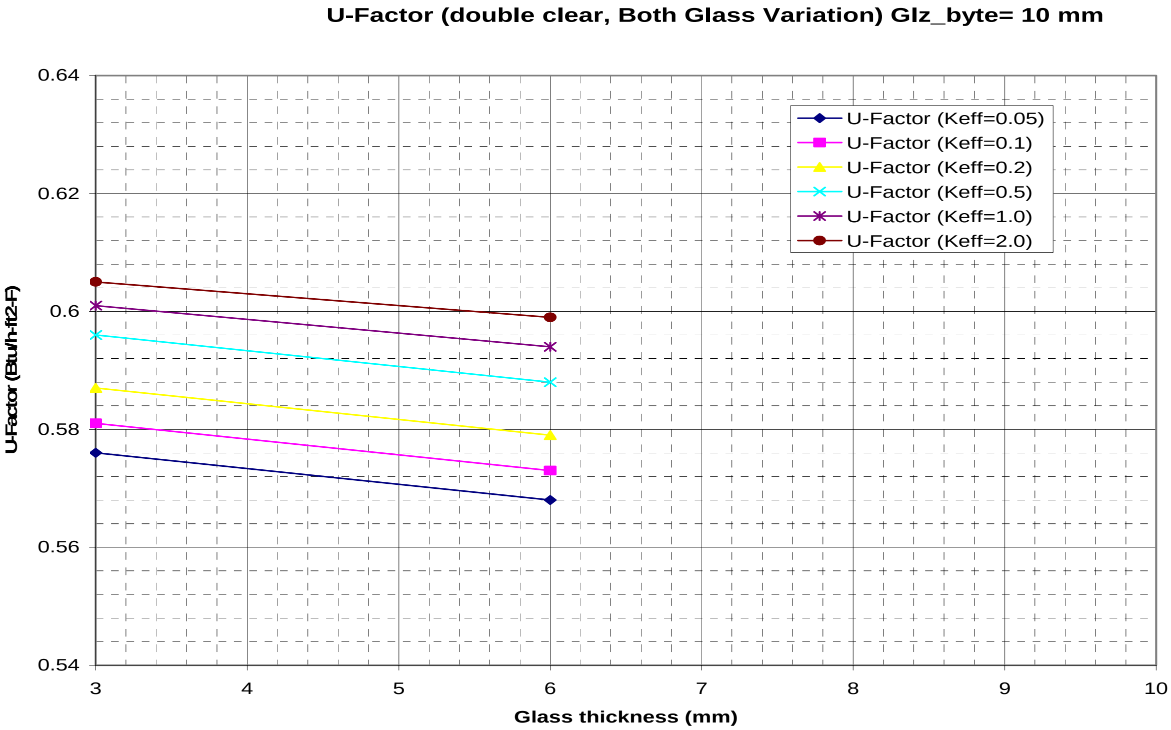


Figure 22. Effect of Glass Thickness on Overall U-Factor for TRR01, Both Glass Variation, Double-Clear glass, and +10 mm Glazing Bite

Figure 23. Effect of Glass Thickness on Overall U-Factor for TRR99, Outdoor Glass Variation, Double-Clear glass, and flush Glazing Bite

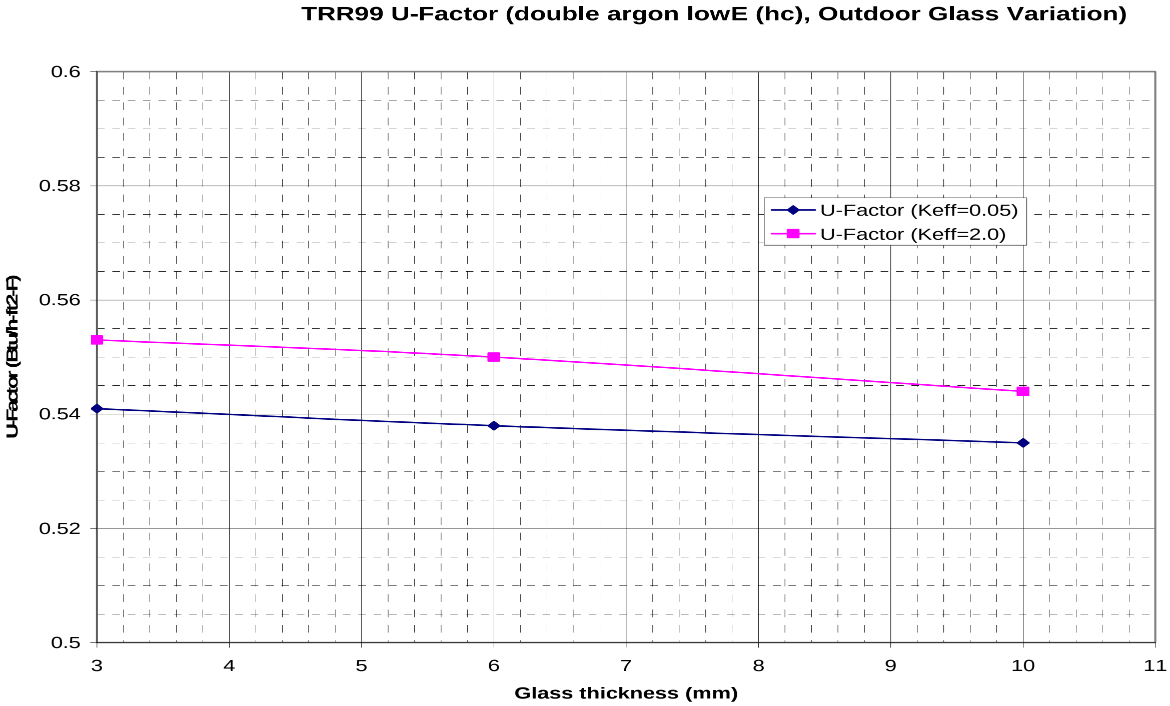


Figure 24. Effect of Glass Thickness on Overall U-Factor for TRR99, Outdoor Glass Variation, Double, Low-E (hc), Argon Filled Glazing and Flush Glazing Bite

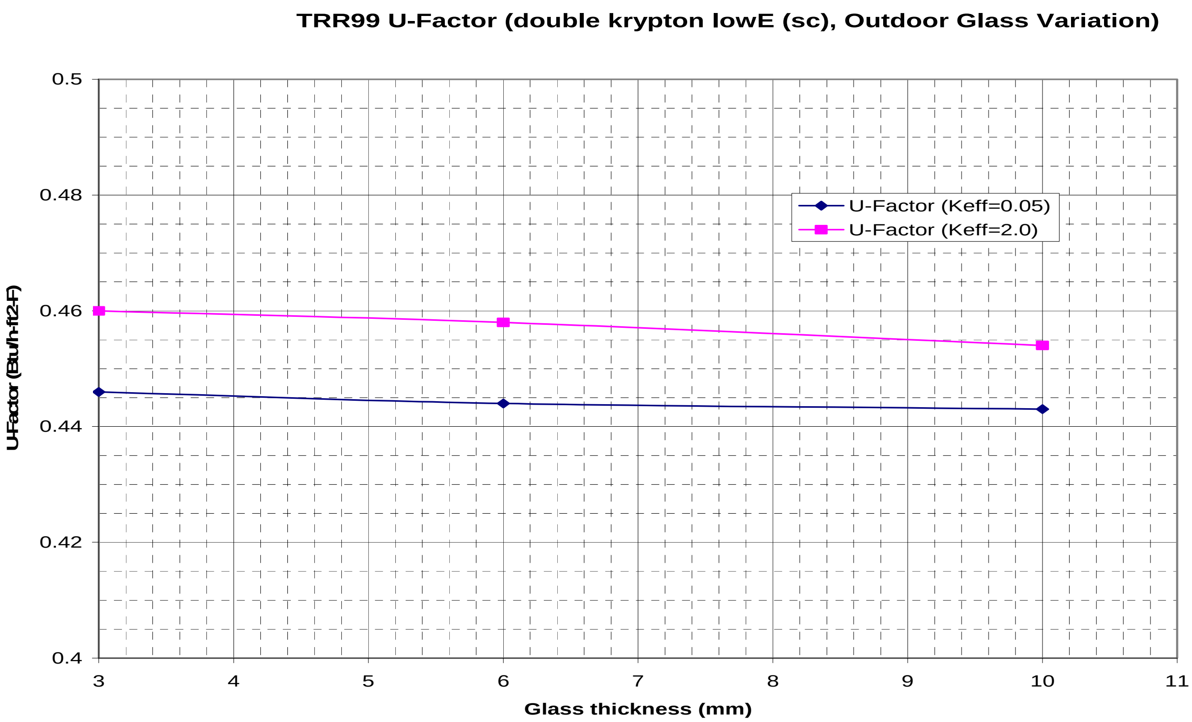


Figure 25. Effect of Glass Thickness on Overall U-Factor for TRR99, Outdoor Glass Variation, Double, Low-E (sc), Krypton Filled Glazing and Flush Glazing Bite

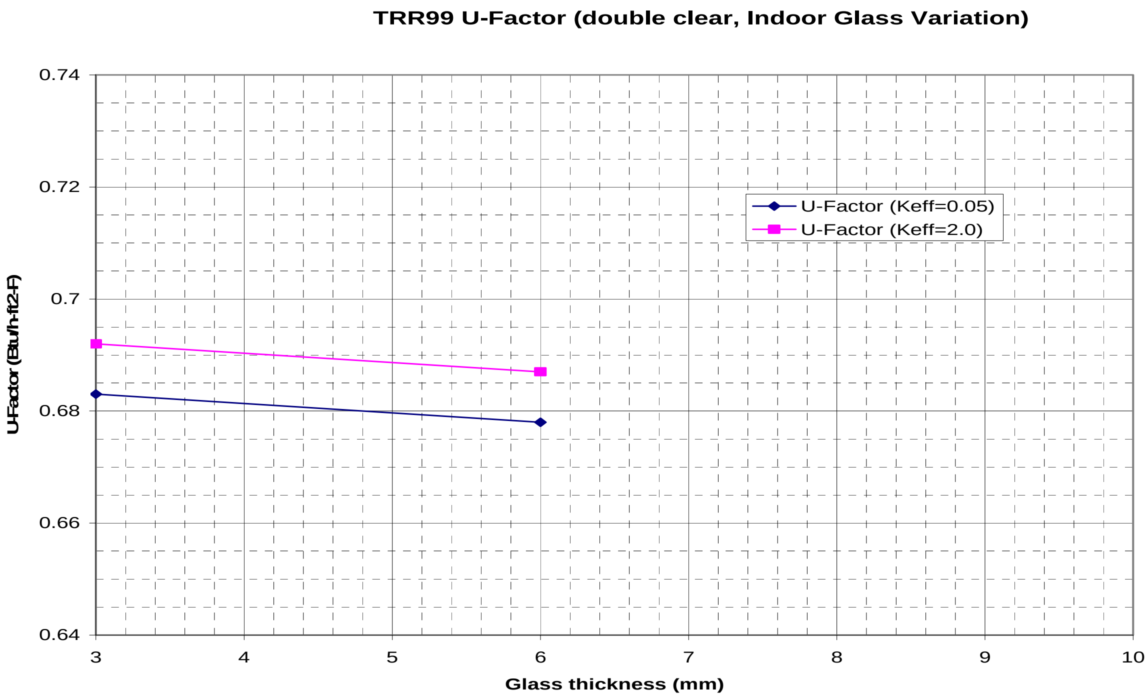


Figure 26. Effect of Glass Thickness on Overall U-Factor for TRR99, Indoor Glass Variation, Double-Clear glass, and Flush Glazing Bite

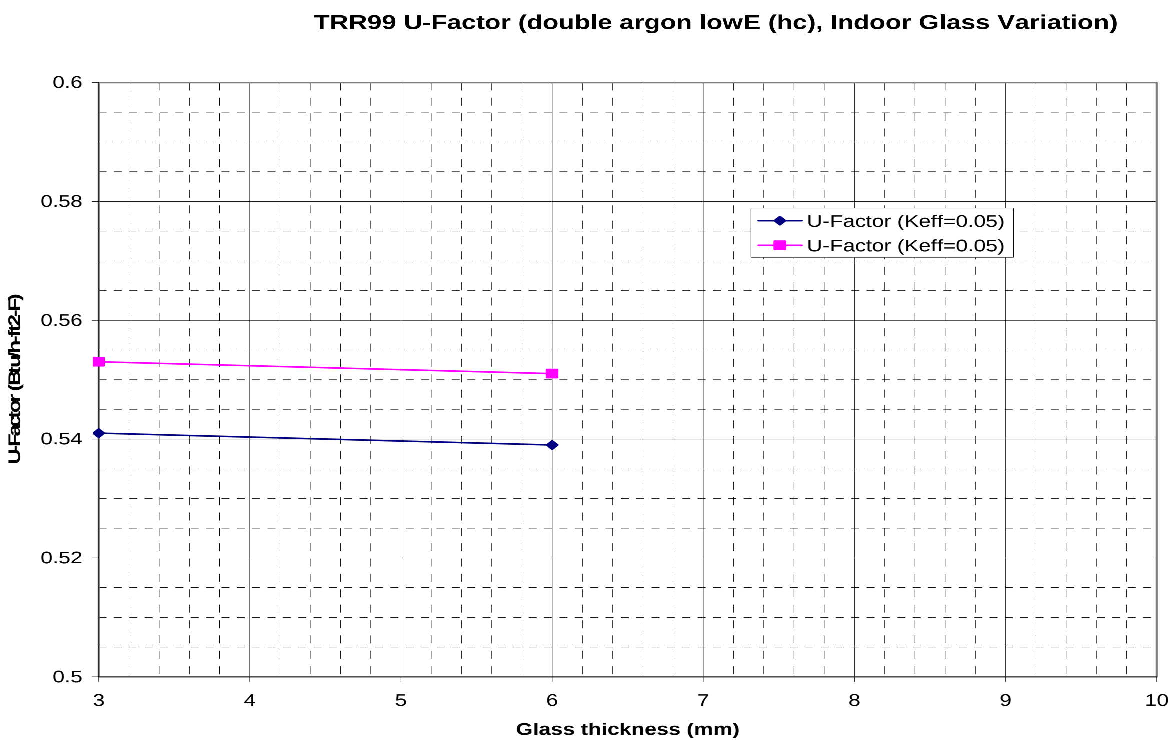


Figure 27. Effect of Glass Thickness on Overall U-Factor for TRR99, Indoor Glass Variation, Double, Low-E (hc), Argon Filled Glazing and Flush Glazing Bite

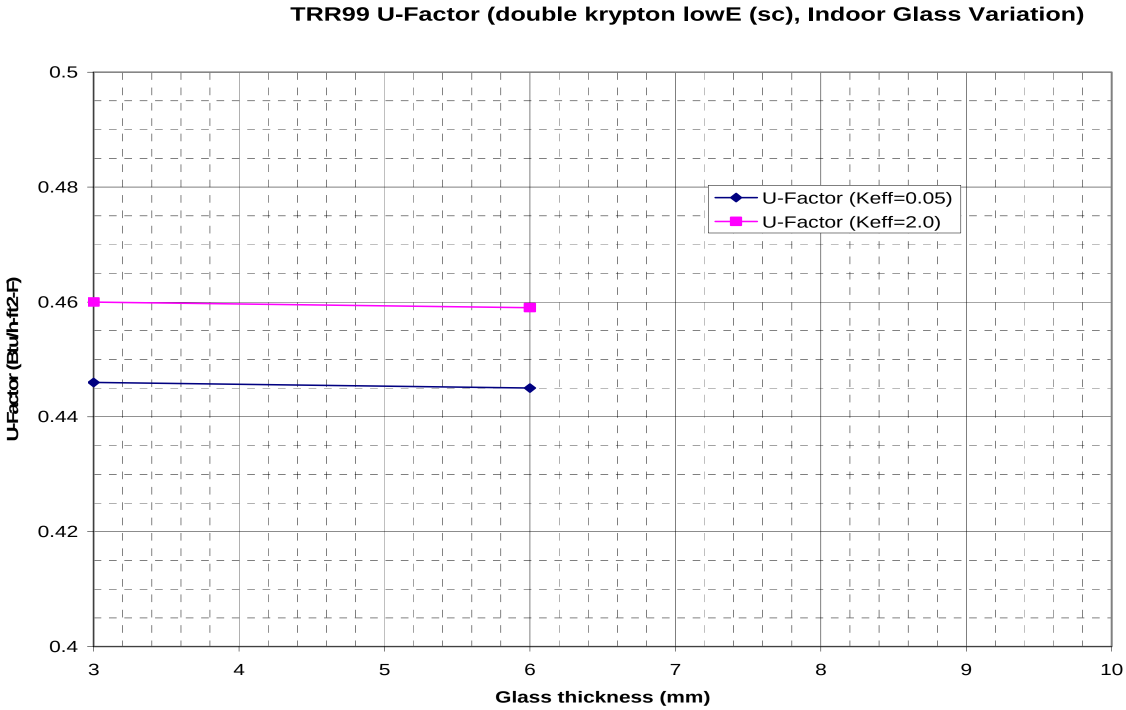


Figure 28. Effect of Glass Thickness on Overall U-Factor for TRR99, Indoor Glass Variation, Double, Low-E (sc), Krypton Filled Glazing and Flush Glazing Bite

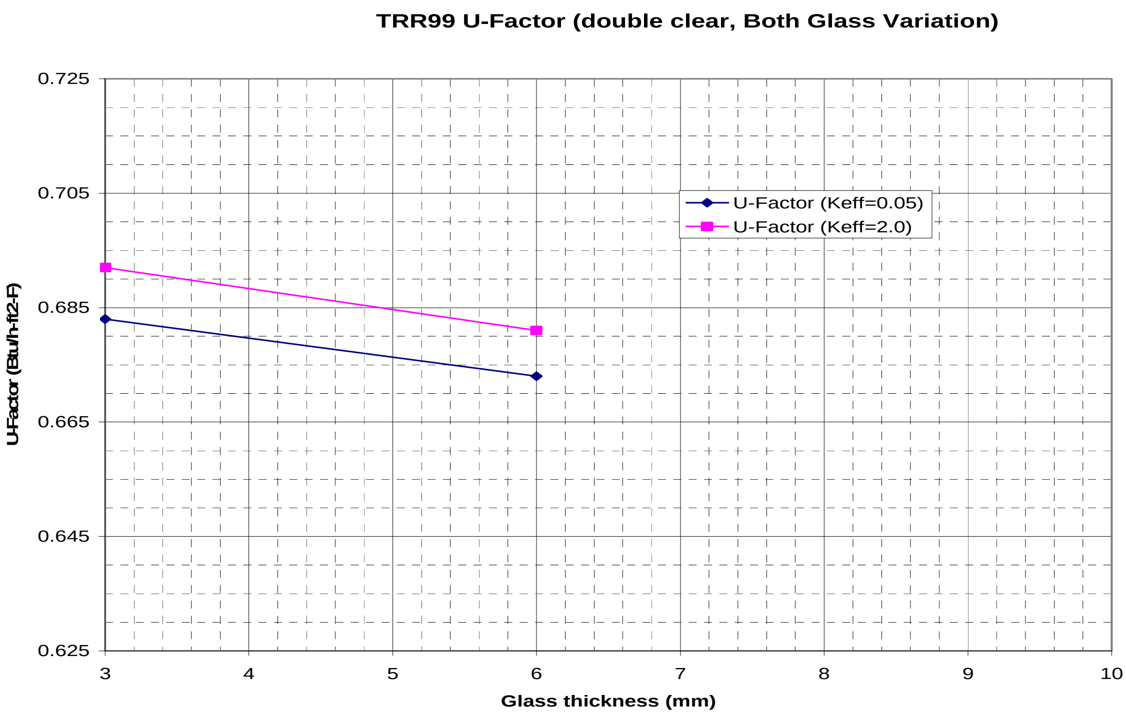


Figure 29. Effect of Glass Thickness on Overall U-Factor for TRR99, Both Glass Variation, Double-Clear glass, and Flush Glazing Bite

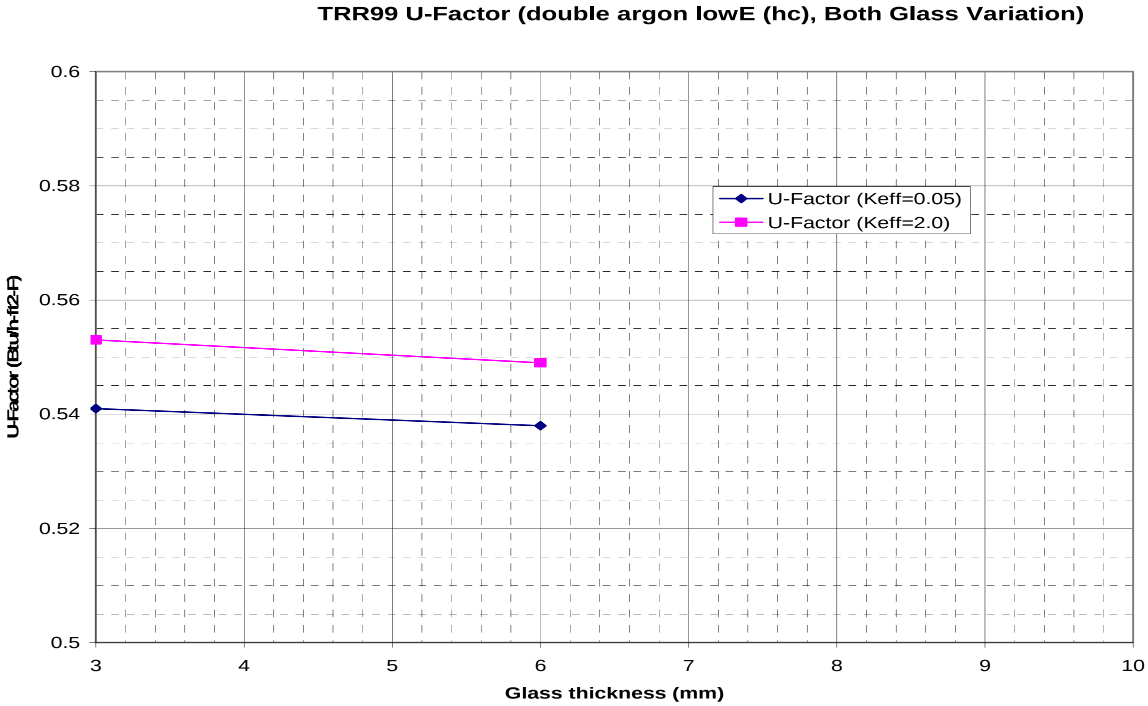


Figure 30. Effect of Glass Thickness on Overall U-Factor for TRR99, Both Glass Variation, Double, Low-E (hc), Argon Filled Glazing and Flush Glazing Bite

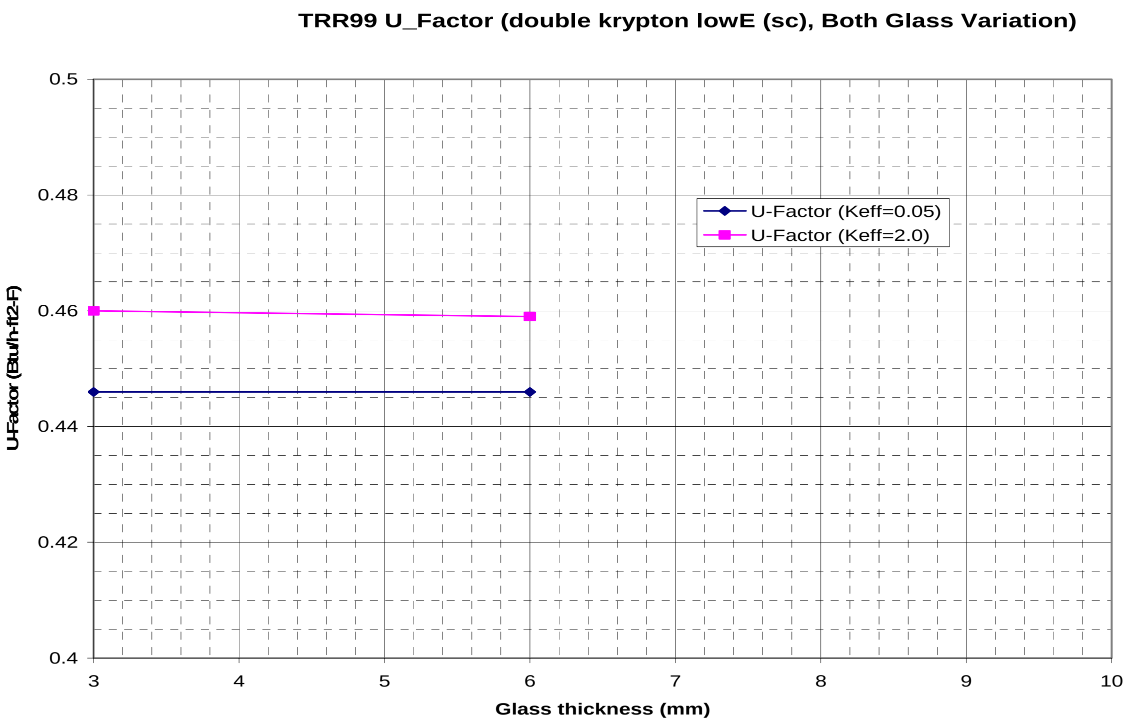
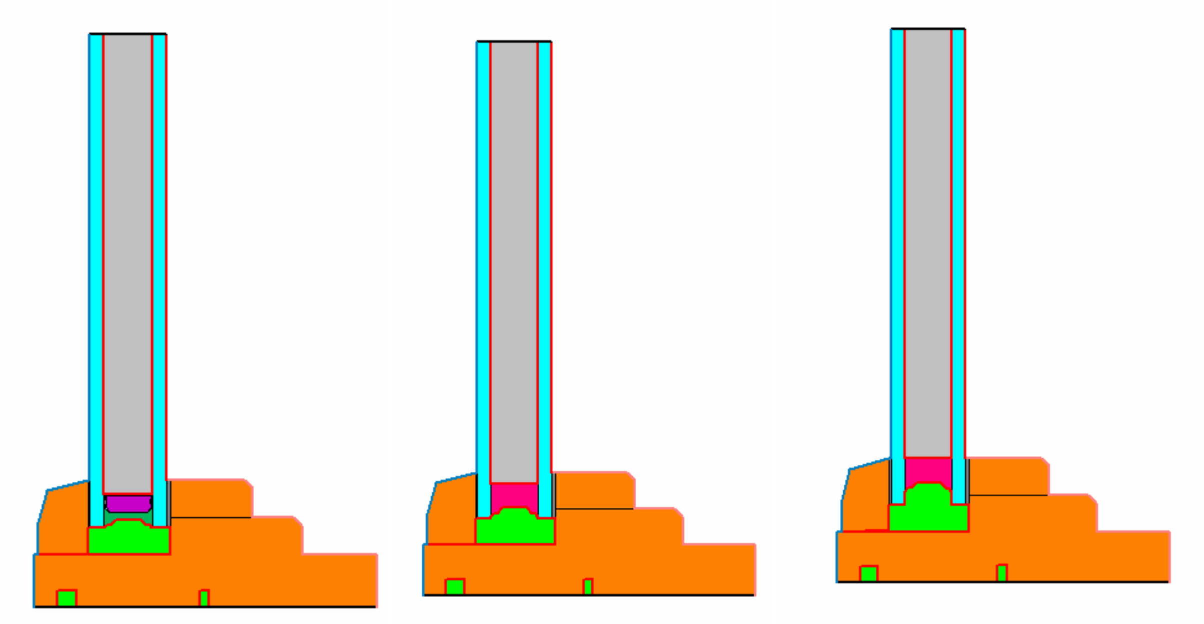


Figure 31. Effect of Glass Thickness on Overall U-Factor for TRR99, Both Glass Variation, Double, Low-E (sc), Krypton Filled Glazing and Flush Glazing Bite

INVESTIGATION OF THE EFFECT OF SPACER POSITION AND HEIGHT

Spacer assemblies are modeled in Component Modeling Approach (CMA) as solid block having effective conductivity from the two extremes of the performance spectrum. These two extremes are labeled “Best” and “Worst” options and they have standard configuration, reflected in their height and position within the glazing system. This part of the study looks at the effect of spacer location within the IGU vs the standard location, where the standard location is defined as bottom surface of spacer assembly flush with the bottom of glazing unit. Figure 32 shows example of spacer location variations.



(a) (b) (c)

Figure 32: Spacer location (a) actual glazing, (b) 1 mm recessed and (c) 5mm recessed

Figures 33 show effects of spacer recess on U-factor of a wood window incorporating Clear-Air-Clear glazing, while Figure 34 show effects of spacer recess on U-factor of a wood window incorporating Clear-Argon-Lowe glazing.

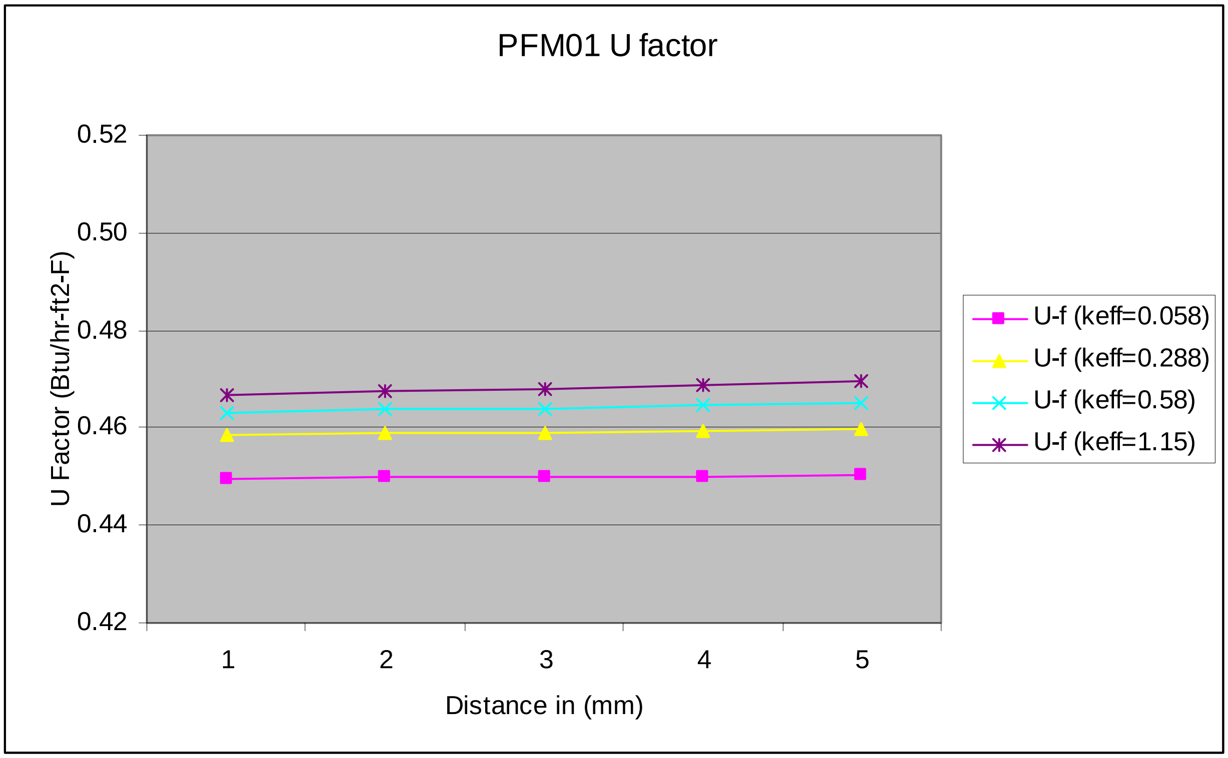


Figure 33. Effect of spacer recess on Overall U-Factor for PFM01 (clear-Air-clear glazing)

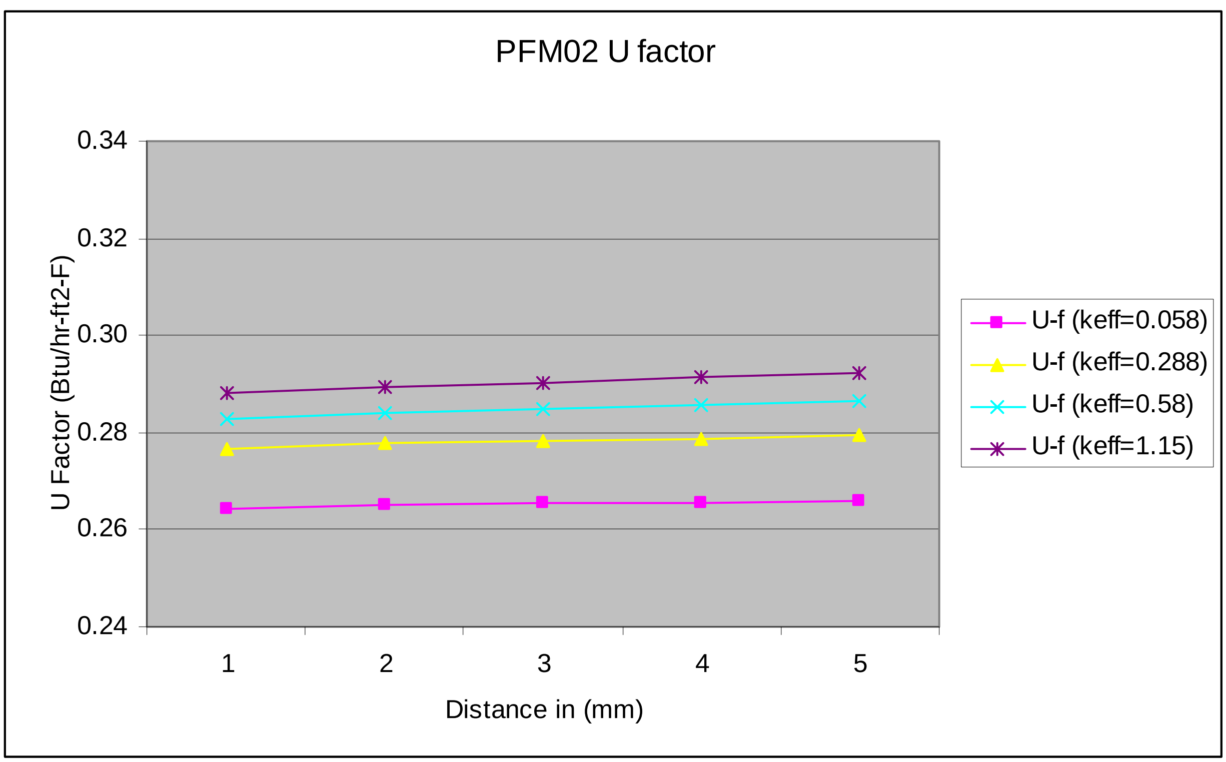


Figure 34. Effect of spacer recess on Overall U-Factor for PFM02 (clear-Argon-Low-e Glazing)

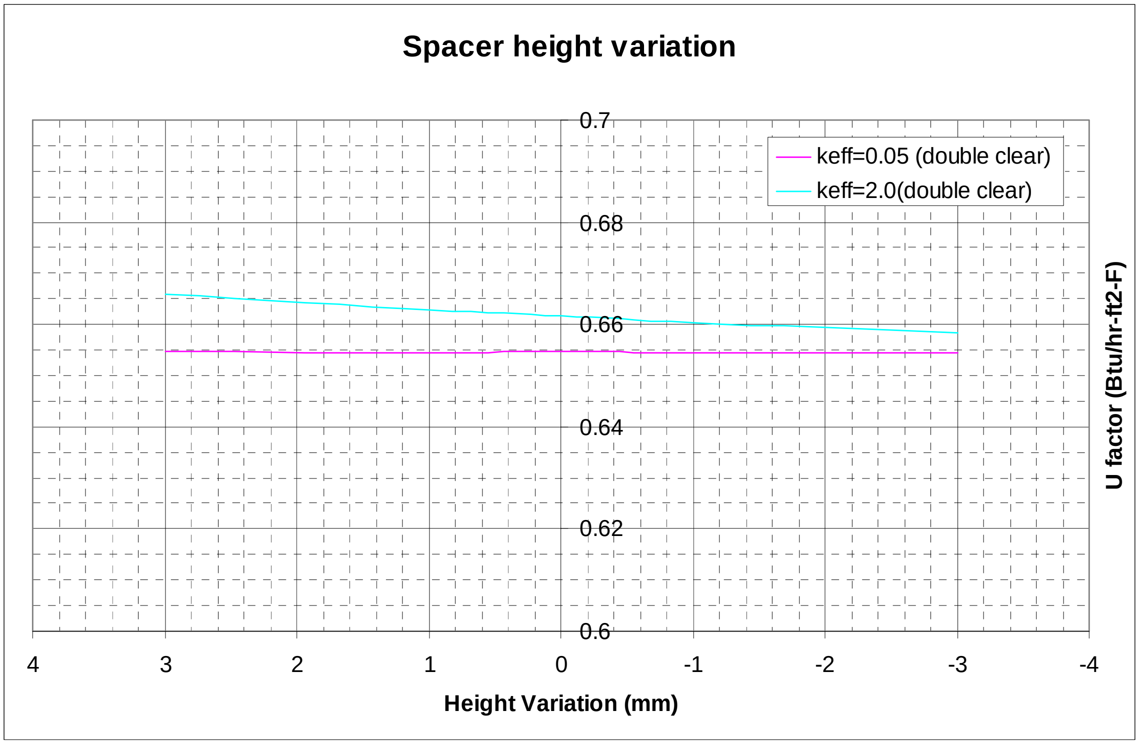


Figure 35. Effect of spacer height variation on Overall U-Factor for TRR99 (clear-Air-clear glazing)

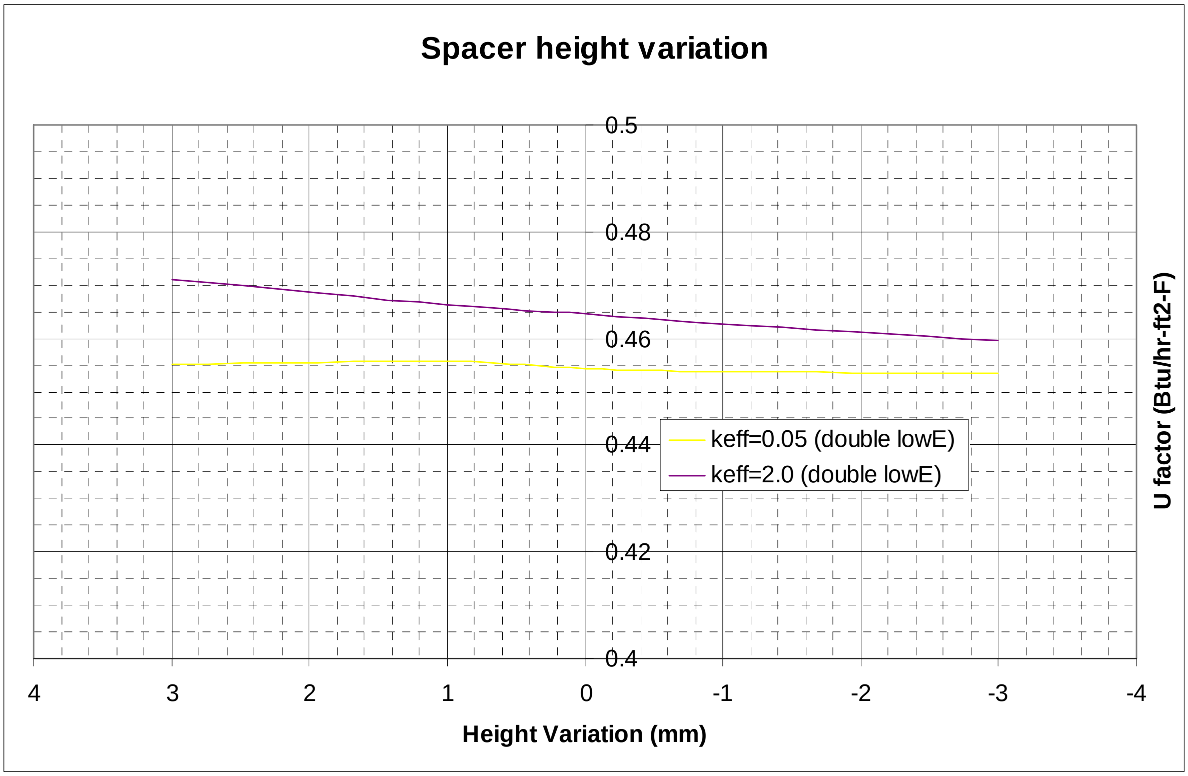


Figure 36. Effect of spacer height variation on Overall U-Factor for TRR99 (clear-Krypton-lowE SC glazing)

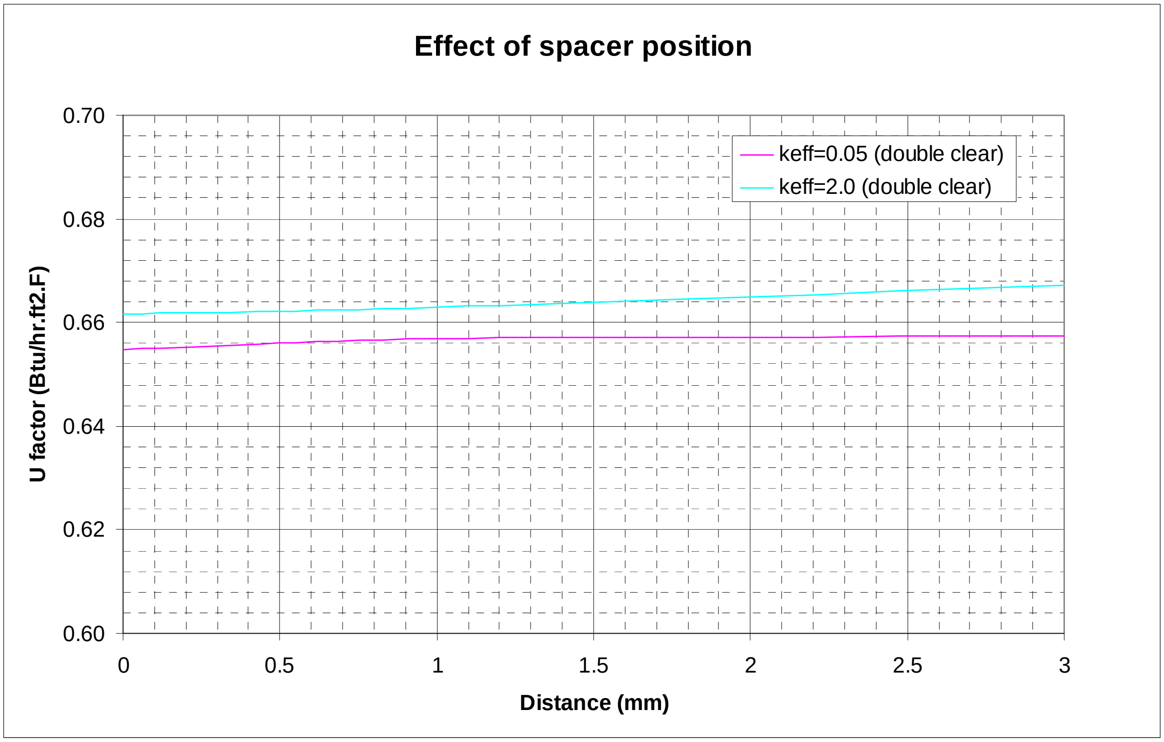


Figure 37. Effect of spacer position on Overall U-Factor for TRR99 (clear-Air-clear glazing)

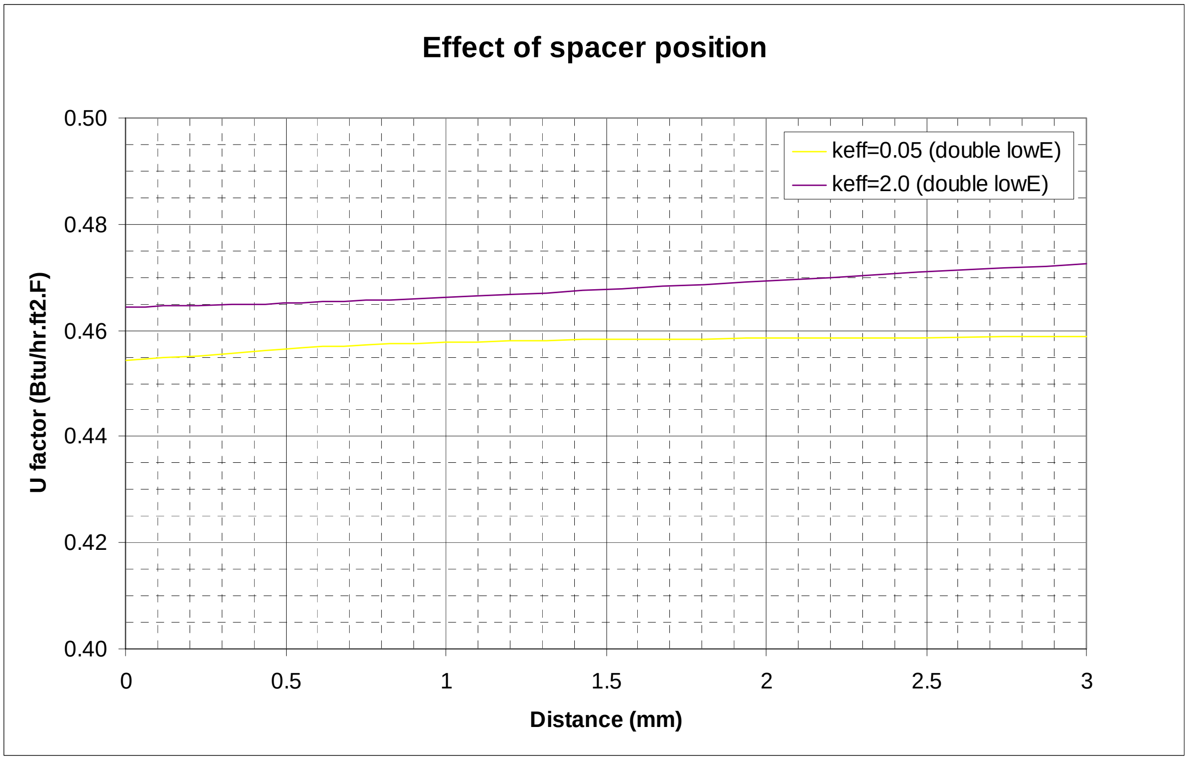


Figure 38. Effect of spacer position on Overall U-Factor for TRR99 (clear-Krypton-lowE SC glazing)

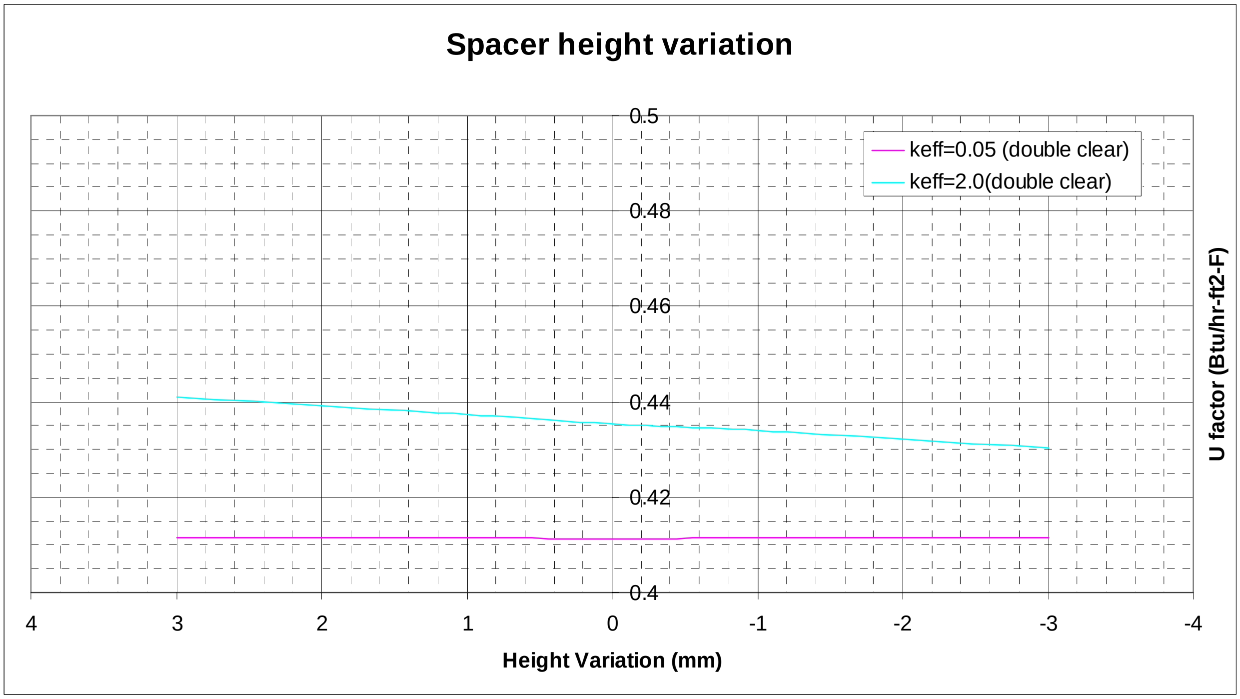


Figure 39. Effect of spacer height variation on Overall U-Factor for PVC window (clear-Air-clear glazing)

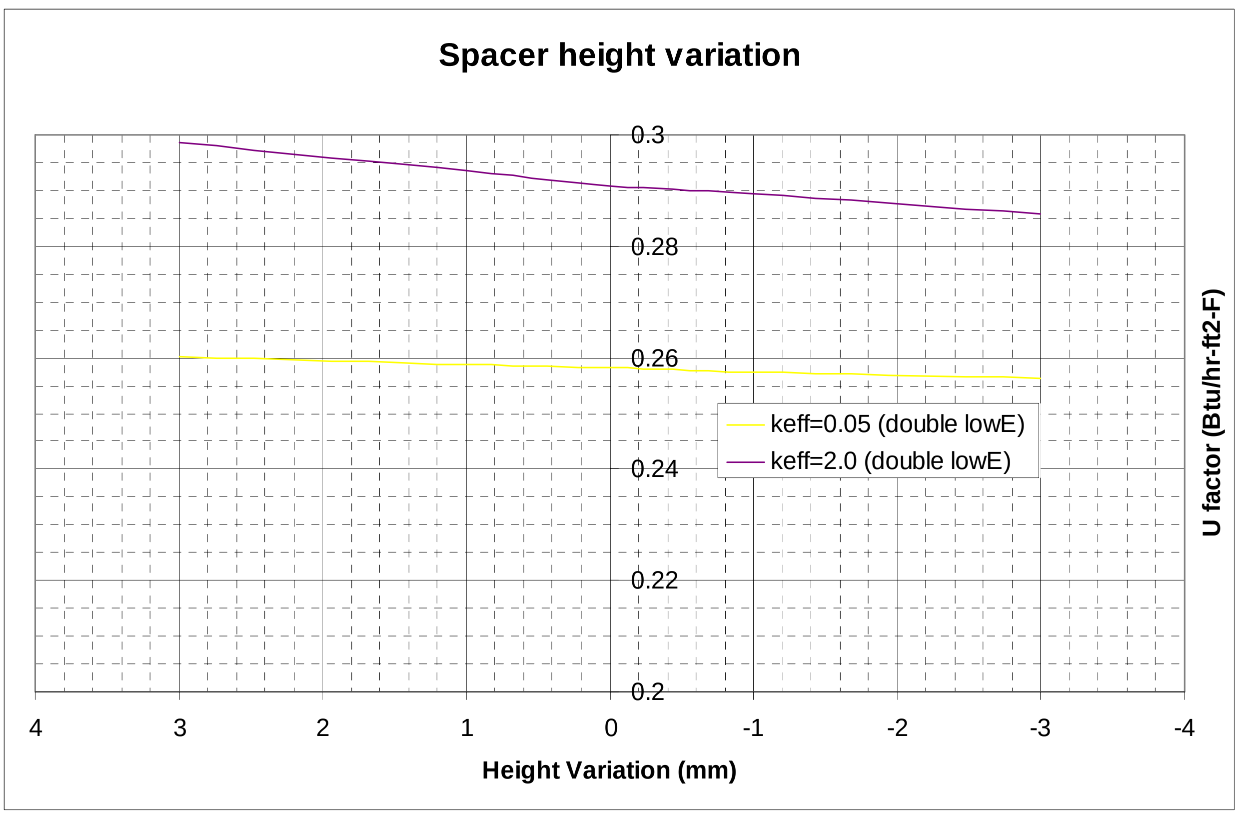


Figure 40. Effect of spacer height variation on Overall U-Factor for PVC window (clear-Krypton-lowE SC glazing)

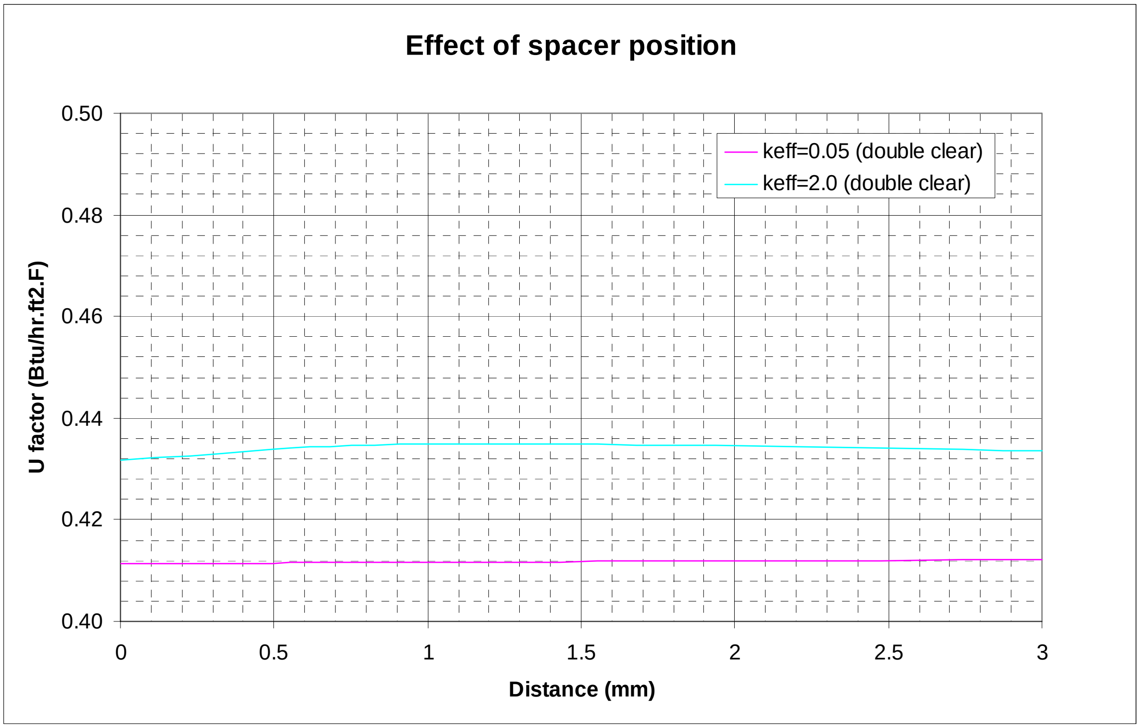


Figure 41. Effect of spacer position on Overall U-Factor for PVC (clear-Air-clear glazing)

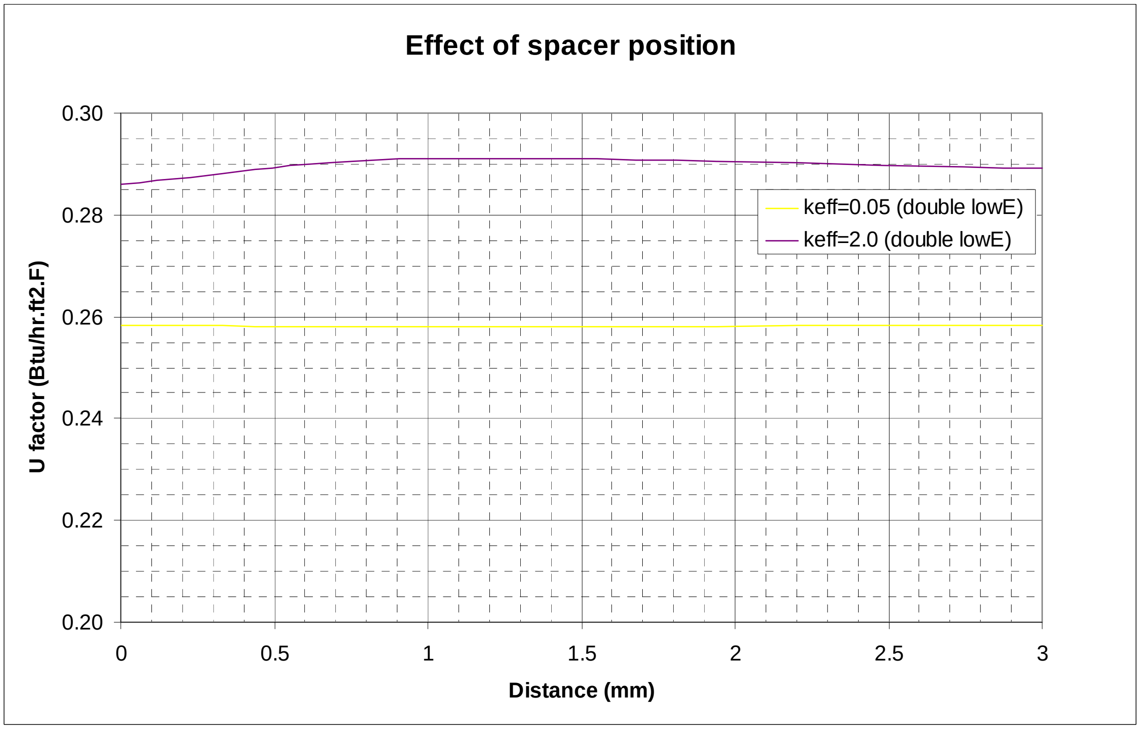


Figure 42. Effect of spacer position on Overall U-Factor for PVC (clear clear-Krpton-lowE SC glazing)