THE FRAMEPLUS™ ONLINE MODEL FOR SIMULATING AND SPECIFYING THE THERMAL PERFORMANCE OF FENESTRATION SYSTEMS

Stephen L. Kemp, P.Eng., M.A.Sc., Stephen Carpenter, P.Eng., M.A.Sc.
Enermodal Engineering Limited
Kitchener, Ontario
skemp@enermodal.com, scarpenter@enermodal.com

ABSTRACT

FRAMEPlus™ online is a simplified, web based, calculation tool that can accurately determine the thermal performance of fenestration products. Currently, computer software, such as FRAMEPlus™, is being successfully used to rate the energy performance of windows. Window simulation labs, building researchers and window manufacturers are the primary users of this software. The building design community of architects, HVAC engineers and builders has not used this tool because it is too complex and time consuming. FRAMEPlus™ Online uses a database of calculated FRAMEPlus™ results for typical fenestration framing constructions and an independent centre-of-glass calculation. The results for centre-of-glass, edge of glass and frame are then area weighted to calculate the thermal performance of the window. FRAMEPlus™ Online provides an easy to use interface for commonly used commercial fenestration options and also has a capability to produce a specification report. This easy to use tool allows users to quickly evaluate the effect of specification options on the thermal performance of fenestration systems.

INTRODUCTION

In 1995 Natural Resources Canada commissioned the development of a software tool to assess the energy performance of fenestration products, it was dubbed FRAMEPlus™. This software combined the functionality of the previously independent software applications, FRAME and VISION. FRAME performed two-dimensional heat transfer analysis on window framing systems while VISION calculated the centre of glass thermal and optical properties of the insulated glazing unit (IGU). FRAMEPlus™ has been a success in rating window performance for both the Canadian Standards Association (CSA) and the National Fenestration Council (NFRC).

Its users include windows designers, window raters and R&D professionals. However, it does require a high degree of skill to use successfully, as well as detailed drawings of the window product to be modelled. Do to these shortcomings FRAMEPlus™ has not been widely adopted by professionals responsible for specifying fenestration products such as architects. Since these are the users with the greatest influence in specifying energy efficient windows for building projects, it was decided that a simpler, easier to use version of FRAMEPlus™ would increase the awareness of those window features which would increase the energy efficiency of the Canadian building stock.

FRAMEPLUS™ ONLINE CALCULATION METHODOLOGY

The original FRAMEPlus™ combines two calculation methodologies to model the thermal and optical performance of fenestration products. The frame and edge of glass calculation is performed using a two dimensional analysis, while the centre of glass calculation utilizes a one-dimensional thermal and optical calculation. The user enters detailed dimensional and material information for both the framing system and the insulating glazing unit. FRAMEPlus™ then calculates the thermal performance for each frame segment (head, sill and sides) as well as the centre of glass. The results are then area weighted to calculate the overall U-value, SHGC and other properties of the fenestration system. A modifier is calculated and applied to the entire fenestration system accounting for self-viewing radiation heat transfer in the window cavity.

When setting out to create FRAMEPlus™ Online, the goal was to eliminate the time-consuming user task of defining the exact dimensional and material characteristic of the window framing system. It was decided that the user would choose between four basic window types (fixed, casement/awning, curtain wall, spandrel panel) and then choose a basic framing material (see Table 1). This simplifies the data entry requirements demanded from the user, while still covering the major factors affecting the thermal conductivity of the framing system. In addition the user is asked to describe the IGU system in some detail, including number of panes, type of glass (including thickness, tint, coatings etc.)

and the edge spacer material. The user's choices would select a specific framing system from a database of generic frames that is then coupled to a custom glazing system of their own design.

These simplifications allow the model to avoid having to perform the time consuming two-dimensional calculation for the framing system. Instead the database of generic framing systems also contain pre-calculated results for frame and edge-of-glass. The centre of glass calculation, which can be performed nearly instantaneously, is dynamically calculated based on the user inputs. The boundary conditions used by the model correspond to the latest iteration of the CSA rating standard, circa 2003.

CENTRE-OF-GLASS CALCULATION

The centre-of-glass model has been ported from the original model and compiled into a COM+ binary file that allows it to be called in a client-server relationship by any COM+ compliant application. The model has two components, a one-dimensional heat transfer calculation, and an optical properties calculation. Both equations are solved simultaneously to determine the heat flux between each node in the system (see Figure 1). Solar energy absorbed in each glazing node is treated as a heat source at that node.

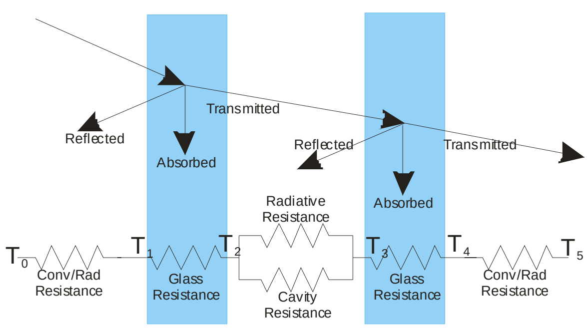

Figure 1 Heat and Solar Radiation Path Modeled in Centre-of-Glass

For each glazing in the database, information concerning conductance, thickness, density and heat capacity is stored. In addition the glazing front side emissivity, back side emissivity and transmittance, for wavelengths between 300nm and 2500nm are also recorded. The optical performance calculation evaluates the emissivity, absorptive and transmittance across the solar spectrum accounting for the effects of adjacent glazings absorbing, transmitting and reflecting solar radiation; as well as transmitting its own long wave radiation. Simultaneously the conductance of heat energy through the glazing and the gas cavity is calculated. The solution to the system of equations is then simultaneously solved. This method complies with ISO 15099, which in turn references ISO 9050.

The program includes a database of over 600 glazing products listed by manufacturer and product name. Therefore the user has access to a complete library of glazing products to compare the performance of different manufacturer's products. As the list of glass products is quite extensive, it can be filtered according to the following parameters:

- Thickness
- Low-e coatings
- Tint

Cavity size is determined by subtracting the thickness of each glazing system from a user entered value for overall IGU thickness, then dividing the result by N-1 where N is the number of glass layers. Thus the model assumes that the cavity thickness is the same for each cavity in the glazing system. A choice of two gas fills is presented to the user, air or argon. In the model choosing argon results in a conservative assumption of an 80% argon, 20% air mixture to be modeled.

In addition to SHGC and U-value, the visible transmittance, UV transmittance and reflected CIE (Commision Internationale de L'Eclairage) L*a*b* values are also calculated. The calculation is similar to the SHGC calculation, differing in the interval of wavelengths evaluated. The CIE L*a*b* values describe the colour and intensity of the light reflected off the exterior of the glazing unit. For the reflected colour calculation a D65 standard illuminant is used in lieu of solar spectral data and the reflected values are weighted by the 1931 CIE tristimulus values for a 3° observer.

FRAME AND EDGE-OF-GLASS CALCULATION

The model does not perform any frame and edge of glass calculations dynamically. Instead a database of generic frames was compiled and evaluated using the desktop version of FRAMEPlus™. The database contains frame and edge U-values for each frame and edge spacer combination. However, for a given frame and spacer type, the frame and edge U-values are a function of the number of glazings, IGU thickness and U-value. Since the user has complete flexibility in defining the IGU properties, a method was needed to minimize the number of entries in the frame database. For each frame/edge spacer combination, two U-values are calculated: one for a standard double glazing and one for a high-performance triple. The frame and edge U-values for a specific product are determined by interpolating between these values for the actual IGU specified. This introduces a potential inaccuracy that is investigated later in this paper.

The database was developed to represent the most common frame types in commercial building construction. The matrix of parameters contained in the database is shown in Table 1.

Table 1 Matrix of Parameters for Frame Types

Parameter	# Options	Options List
Material	3	Fibreglass, alum w 9mm thermal break
Edge Spacer	3	Aluminium, Alum w thermal break, non-conducting spacer
Number of Glazings	2	Standard double or hi-perf triple
Operator Type	3	Fixed, Casement, Curtain wall

The FRAMEPlus™ calculation uses a finite element technique to solve the Newtonian heat transfer equation through the frame and edge of glass. The results are modelled as outlined in ISO 15099. The database also stores the values for the projected and actual surface area of the representative frame chosen. These values are used in the self-viewing radiation heat transfer correction factor calculation.

COMBINING THE RESULTS

After the results of the centre-of-glass calculation are calculated and the framing system is read from the database, the overall U-value, SHGC, Vt, and fading index are calculated using area weighting. The U-value is then modified using a self-viewing correction factor in accordance to the simplified method described in ISO15099 (8.4.2.2).

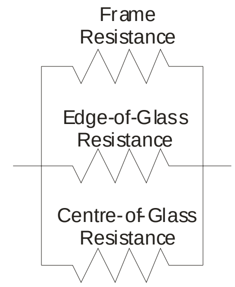

Figure 2 Resistance Network of Window-Frame System. Note that inside and outside film, convective and radiation resistances are included in each component.

COMPARISON AGAINST FRAMEPLUS™

The simplified model used will result in some loss in accuracy for the calculated results of window products when compared to the more sophisticated FRAMEplus™ results. In particular the edge of glass effect is not explicitly modeled, while the user can specify nearly any IGU system. The differences are generally small, as is demonstrated in Table 2 where several fenestration systems have been modeled in both applications and the corresponding results for U-value and SHGC are shown.

MODELING SPANDREL PANELS

The web site model includes one option for evaluating fenestration systems that the full version does not, spandrel panels. In a curtain wall system, spandrel panels, unlike vision panels, offer the opportunity to insulate behind the glazing. When modeling a spandrel panel the user can only choose a single glazed system. The user can then specify the amount of insulation inside and behind the spandrel panel as depicted in Figure 3. The resistance network modeled is shown in Figure 4.

Table 2 Comparison of U-value and SHGC results of the detailed and simplified FRAMEPlus™ models

Window			U-Value			Solar Heat Gain Coefficient		
System	Glazing	Spacer	FRAMEplus	Online	% Difference	FRAMEplus	Online	% Difference
Fixed Alumnium 9mm TB	*Double*	*Aluminium*	2.03	2.08	**2.46%**	0.37	0.36	**2.70%**
		Super	1.89	1.95	**3.17%**	0.37	0.36	**2.70%**
	Triple	*Aluminium*	1.46	1.46	**0.00%**	0.24	0.24	**0.00%**
		Super	1.26	1.27	**0.79%**	0.24	0.24	**0.00%**
Fixed Fibreglass	*Double*	*Aluminium*	1.85	1.89	**2.16%**	0.33	0.33	**0.00%**
		Super	1.71	1.74	**1.75%**	0.33	0.33	**0.00%**
	Triple	*Aluminium*	1.53	1.54	**0.65%**	0.22	0.22	**0.00%**
		Super	1.38	1.40	**1.45%**	0.22	0.22	**0.00%**
Casement	*Double*	*Aluminium*	2.97	3.11	**4.71%**	0.29	0.29	**0.00%**
		Super	2.87	2.99	**4.18%**	0.29	0.29	**0.00%**
	Triple	*Aluminium*	2.73	2.73	**0.00%**	0.20	0.20	**0.00%**
		Super	2.64	2.64	**0.00%**	0.20	0.20	**0.00%**
Curtain Wall	*Double*	*Aluminium*	1.73	1.78	**2.89%**	0.39	0.39	**0.00%**
		Super	1.57	1.62	**3.18%**	0.39	0.39	**0.00%**
	Triple	*Aluminium*	1.37	1.37	**0.00%**	0.26	0.26	**0.00%**
		Super	1.20	1.20	**0.00%**	0.26	0.26	**0.00%**

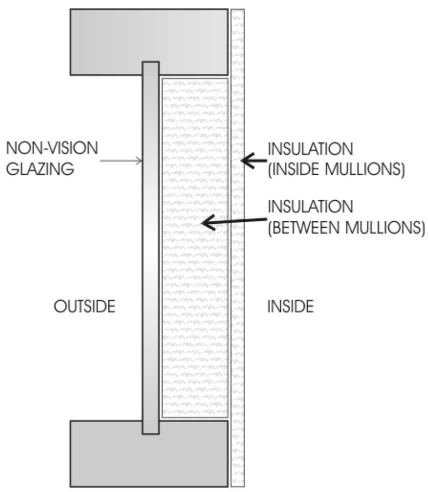

Figure 3 Schematic of Spandrel Panel

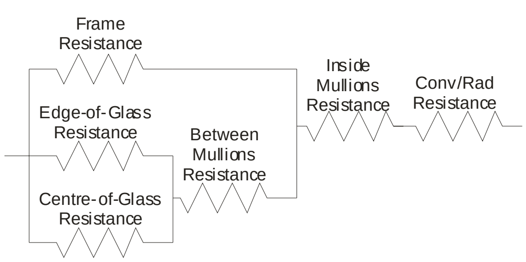

Figure 4 Resistance Network for Spandrel Panel. Note: Outside convective and radiation resistance is included in the frame, edge-of-glass and centre-of-glass values, however inside values have been removed.

CONCLUSIONS

The simplified model used in FRAMEplus™ provides an easy to use method of evaluating windows systems, while also providing reasonable accuracy for the chosen window types it models. It is available on the World Wide Web at http://www.frameplus.net.

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