Rating[1] the Energy Performance of Fenestration Systems in Commercial Buildings

John W. Lewis, Jr., National Fenestration Rating Council

ABSTRACT

The National Fenestration Rating Council has developed a new, improved method for developing commercial fenestration energy ratings called the *Component Modeling Approach Program (CMA).* This new program enables users to assemble a 'virtual' commercial fenestration product by combining glazing, frame, and spacer using the CMA software tool ("CMAST"). CMAST enables quick calculation of the U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT) for the developed product. This information can be used for commercial product bidding efforts, quickly changed during the design process, and final confirmation of product performance as required by energy codes, including ASHRAE 90.1[2], California's Title 24, and the International Code Council's (ICC) International Energy Conservation Code® (IECC).

CMA simplifies the rating process by taking the computer-simulated frame conductivity and establishing a best and worst case scenario for the potential glazing and IG spacer under consideration. By establishing the performance boundaries for that framing system and utilizing the appropriate algorithms, product performance calculations with various glazing systems can be quickly performed. For each individual product, total fenestration product U-factors, SHGCs, and VTs is reported for the specified configuration at the NFRC standardized model size.

The potential for the CMA Program to facilitate transformation to higher-performing commercial fenestration is tremendous. The current penetration of low-e glass in the commercial building market in 2003 was estimated at only 30% or about half the residential low-e fenestration market penetration (Benney). This demonstrates a tremendous potential for improving the energy efficiency of fenestration systems in nonresidential or commercial buildings.

The Need for Fenestration Energy-Related Performance Ratings

Since the late 1950s, energy consumption in the United States has outpaced domestic supply, and the difference has been made up by importing fossil fuels (EIA, 2008). In fact, the general trend is increasing to the extent that in 2008, net imported energy accounted for 26% of total consumption (EIA, 2008). This increasing reliance on imported sources of energy and the associated risks have pushed 'energy independence' to the forefront to the extent that it heavily influences both foreign and domestic policy.

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[1] For the purposes of this paper, "rating" is defined as an energy-related performance metric related to a fenestration system or component, and taken by itself, does not provide an indication of the system or component performance vis-à-vis the achievable performance range. "Energy-efficient," "high performance," "poor performance" and similar assessments are determined by other authorities and are beyond the scope of this paper.

[2] American Society of Heating, Refrigerating and Air-Conditioning Engineers' ANSI/ASHRAE 90.1 *Energy Standard for Buildings Except Low-Rise Residential Buildings*

In response to continued and growing dependence on foreign sources of energy, the United States Department of Energy (DOE) has established the goal for commercial buildings to be constructed in such a manner as to be viable 'net-zero energy buildings' by the year 2025 (DOE, 2010).

The impact of attaining energy savings in the commercial building stock is significant. The energy consumed in commercial buildings represents 19% of total consumption in all sectors—commercial, industrial, transportation and residential (EIA, 2008).

The Role of Fenestration in Commercial Construction

Of the consumption within commercial buildings, many of the end uses of energy are linked closely with or influenced by fenestration—windows, doors, and skylights.

For example, space heating loads can be lowered through the use of high efficiency fenestration that reduces heat loss as measured by U-factor. Space heating reductions can also be realized by capturing solar gain, as measured by SHGC.

The loads attributable to lighting can be reduced by providing sources of natural daylight through fenestration systems. The VT is one of the metrics used to rate such performance.

Air conditioning loads can be managed by reducing solar gain through fenestration (i.e., lowering the SHGC), and further reduced by supplanting heat-producing lighting arrays with natural light as measured by VT.

The energy used to provide ventilation in commercial construction is also significant, and fenestration plays a role here with its ability to provide a source of natural ventilation.

Obviously, the intelligent integration of energy-efficient fenestration systems into the building envelope has the potential to dramatically reduce energy demand in commercial buildings and thereby reduce the load on the energy supply infrastructure.

To be able to develop optimal fenestration systems that are considered an integral part of the energy-efficient building envelope, a reliable set of performance metrics or "ratings" are required. When rating the energy performance characteristics of fenestration, the most significant of these are those previously listed: U-factor, SHGC and VT. The fenestration ratings are not independent of each other, and the design professional must consider the performance of the fenestration system as a whole. For example, changing the glazing component can dramatically impact all three of these metrics.

The increasingly more stringent requirements for lower U-factor ratings can be achieved by both lowering frame conductivity and through the use of low-emissivity (low-e) coatings on glazing. But the selection of the glazing system also determines the system SHGC and VT; today's spectrally selective low-e coatings also afford varying degrees of SHGC reduction. Now the design professional has the ability to tailor the fenestration systems' ability to accept, reject or regulate solar gain as required for buildings in the various climate zones across the United States.

Accurately determining and reporting fenestration and fenestration attachment energy-related performance ratings are functions performed by the NFRC, and with the advent of the new CMA Program, these ratings are considerably easier to determine than was the case with the previous rating system.

The Evolution from 'Reporting' to 'Predicting'

As the simulation and analysis tools used to perform building energy calculations become more sophisticated and robust, there has been a natural progression from reliance on physical testing to determine fenestration energy performance towards the adoption of computer simulation and modeling.

These computer simulation tools, such as Lawrence Berkeley National Laboratory's *WINDOW* and *THERM* and NFRC's CMAST, when coupled with improved test methods, offer the designer the opportunity to move past reliance on a reported set of energy characteristics for a discrete product to accurately predicting these same values via computer simulation. CMAST further simplifies the simulation process by allowing simulation and rating of components to be done 'in advance', and then these approved components are placed into an online library for use by various stakeholders. When the designer selects a set of components (framing system, glazing system, insulating glass edge seal assembly), the performance characteristics can be quickly calculated with CMAST.

Benefits of a Fenestration Energy-Related Performance Rating Program

NFRC recognized early on the need for a commercial program to parallel its highly successful and widely adopted residential energy rating for windows, doors and skylights. The NFRC "Site-Built" program was developed in response to the demand for a comprehensive energy performance rating program addressing commercial fenestration.

As an independent, non-profit organization, the NFRC has provided fair, accurate, and uniform rating and labeling systems for fenestration for two decades. Many in the design and construction industry, as well as consumers, know of NFRC's energy performance labels on residential windows. NFRC's third-party residential program is well recognized, well regarded, and user-friendly. The Site-Built program was an outgrowth of the residential program, and was designed to provide a similar program for the commercial sector.

Both programs generate U-factor, SHGC, and VT values in accordance with NFRC 100—*Procedure for Determining Fenestration Product U-Factors* and NFRC 200—*Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence*.

Credible ratings are necessary for effective code compliance, and fenestration energy performance ratings developed in accordance with NFRC 100 and NFRC 200 are required by ASHRAE 90.1, IRC, IBC, IECC, California's Title 24 energy code, and the U.S. *ENERGY STAR®* program, among others. For the ratings to be credible, they must be developed in the context of a third-party certification program such as NFRC provides.

Critical to the success of utility 'above-code' incentive programs is the ability to show that design performance closely matches actual performance. NFRC's fenestration ratings make attaining that goal a more realistic endeavor.

Evolution of the NFRC Commercial Program

Origins—the Site-Built Program

The Site-Built program (SBP) was developed by NFRC and launched in 1997. As an outgrowth of the residential program, the SBP followed many of the procedures used in that program. Instead of a 4" x 4" temporary label, the SBP required a Label Certificate for each fenestration type required on the project. Computer simulations and corresponding validation (physical) testing were performed as with the residential program.

The SBP used the tools available at the time (WINDOW and THERM) to meet the needs of the commercial sector. However, the SBP was not embraced as was the residential program. Unlike typical residential window products that can be mass produced to identical specifications, commercial fenestration systems use a variety of components to meet different performance characteristics demanded from project to project. The SBP required simulation of each unique fenestration framing/glazing system as well as validation testing of this system. The design-simulate-validation test process could take months to complete; for some projects with multiple fenestration types, this timeframe was often not sufficient to meet the needs of the construction schedule.

Furthermore, the SBP did not provide real-time, widely available access to product performance and certification information, and the program offered limited ability to be used as a research tool for generating performance values able to be used in whole-building energy analysis. For example, if a design professional was interested in evaluating the performance of an existing curtainwall system with the latest insulating glass unit system with a just-released low-emissivity coating, coupled with inert gas filling and a low-conductance spacer edge seal assembly, she would contact the curtainwall manufacturer (who owns the THERM simulation files of the framing system) and request that a simulation be run on the existing framing system, but with the new glazing system. With limited resources, many manufacturers would be unable to meet a significant volume of such requests, limiting the effectiveness of the SBP for research and development efforts.

The NFRC Component Modeling Approach Program H2

To address the shortcomings of the SBP, NFRC initiated the development of the next generation of the commercial rating and certification program in 1992. This new program eventually became known as the Component Modeling Approach (CMA) Product Certification Program.

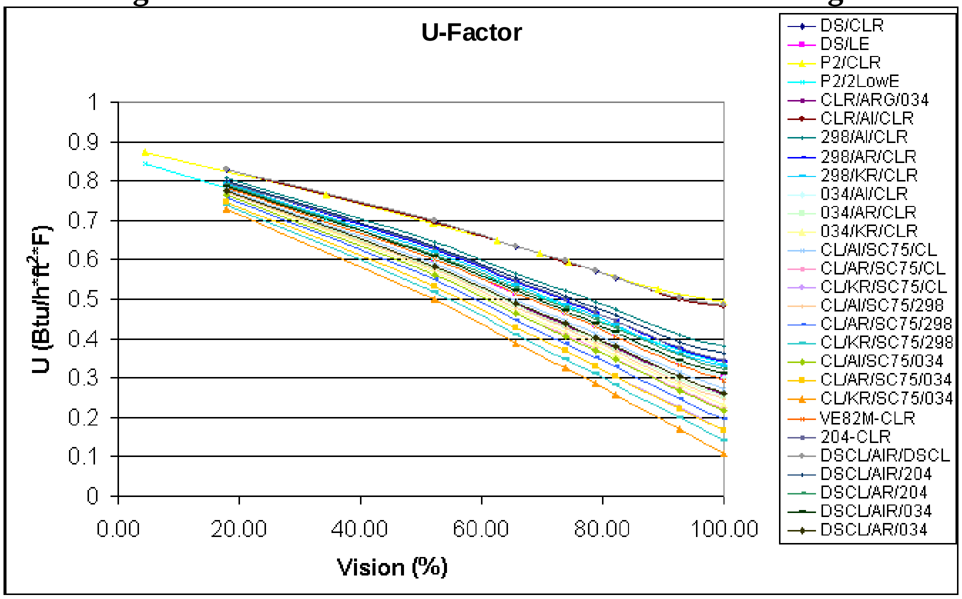
Vision of the new program. The CMA program was envisioned to streamline the process of obtaining a label certificate—the certified document used to prove not only compliance with energy codes, but compliance with the requirements of above-code programs.

To meet the needs of the commercial fenestration industry, a new approach—component modeling—was proposed. Unlike the SBP, the CMA program would center on "assembling" virtual products using pre-defined and pre-certified fenestration components to generate energy ratings. It was proposed to maintain the performance data in online libraries of approved fenestration components (glazing, frame, and spacer). Together, the component data would be used to generate certified whole-product performance ratings for U-factor, SHGC, and VT in accordance with the requirements of NFRC 100 and NFRC 200.

Development of the new program. The CMA process uses a procedure wherein a linear correlation for center of glazing performance versus overall product performance is calculated.

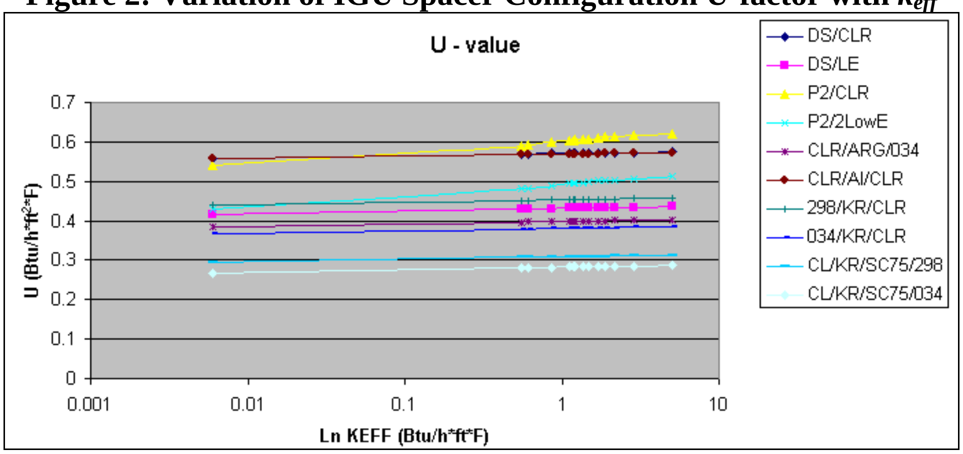
During the research phase of the CMA project, it was concluded that assuming a linear relationship between center of glazing performance and overall product performance was reasonable. Figure 1 shows the relationship between center of glazing U-factor and percent vision area for a wide variety of fenestration systems.

Figure 1: Variation of U-factor with Vision Percentage



Source: Curcija et al., 4

Figure 2: Variation of IGU Spacer Configuration U-factor with k_{eff}

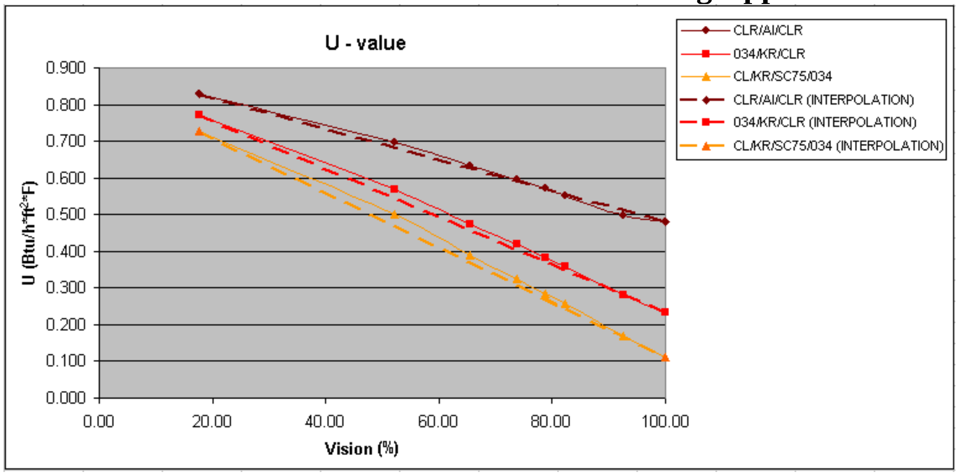


Source: Curcija et al., 7

In addition, it was determined that insulating glass edge seal and spacer performance (K_{eff}) could be calculated using logarithmic correlation as shown in Figure 2.

This simplified approach incorporates the combination of the two correlations to calculate whole-product energy performance ratings. For three representative glazing options, the U-factor, SHGC, and VT ratings derived from the simplified CMA calculation method were compared to U-factor, SHGC, and VT ratings calculated via the traditional, detailed modeling approach using THERM and WINDOW[3]. These ratings were plotted as a function of vision percentage; the results for U-factor are shown in Figure 3.

Figure 3: Variation of U-factor vs. Vision Percentage as Determined via the CMA Method and Traditional Detailed Modeling Approach Method



Source: Curcija et al., 15

It is evident from examination of the data that the results obtained from the CMA interpolation technique compare very well with those obtained from detailed modeling[4].

The CMA process supersedes the requirement to model every glazing and spacer option in THERM and WINDOW to determine a rating by the modeling of frames with a generic glazing and spacer to calculate a whole-product performance rating.

An additional benefit of this component modeling, area-weighing method was the ability to generate performance values for not just the NFRC standard product sizes (used for product comparison and code compliance purposes), but at any product size. This ability affords design professionals, energy consultants, building scientists and other stakeholders interested in performance of actual sized products access to a much more useful and powerful data set.

Given that the CMA method was proven to generate virtually the same performance ratings as the traditional THERM detailed calculation method, NFRC approved this simplified component modeling approach, and the development of the software tool by Carli, Inc. began in 2007. After a comprehensive development, evaluation and pilot program, the CMA Program was launched on January 01, 2010.

[3] The generation of fenestration energy-related performance values using WINDOW and THERM has been proven countless times to closely predict the actual product performance as measured during laboratory 'guarded hot box tests' of fenestration units.

[4] A similar analysis of solar heat gain coefficient and visible transmittance was conducted and the results showed excellent agreement between the values calculated with the CMA method and the traditional WINDOW-THERM detailed calculation method; these graphically-displayed results are available for review within the paper published by Curcija et al.

The CMA Program in 2010

At its core, the CMA Program utilizes CMAST to generate energy-related fenestration ratings, but the Program is more than just the ability to generate ratings; it is a 3rd-party fenestration and fenestration attachments energy performance rating certification program.

Overview of the Program

Figure 4 provides an overview of the key elements of the CMA program.[5] At the top component level, glazing components (i.e., glazing layers from the LBNL IGDB, applied films), frame components (i.e. sills, jambs, mullions, heads, etc.) and spacer components all go through a simulation and approval process, initiated by the component manufacturer and overseen by a 3rd party inspection agency to then be uploaded into the online CMA component database. Framing components still go through the validation test process, and "grouping rules" established by NFRC allow similar shapes to be considered a single product line, and therefore able to be validated with a single physical test conducted in accordance with NFRC 102—*Procedure for Measuring the Steady-State Thermal Transmittance of Fenestration Systems*.

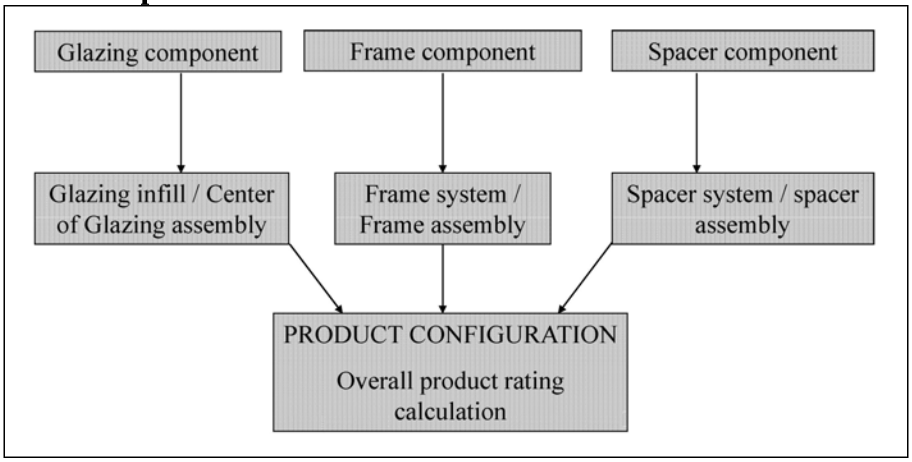
The approved components are then available online to any user of the CMA software tool. Various stakeholders who have purchased CMAST can then assemble 'virtual' products by selecting the glazing system, the framing system, and the spacer IGU edge seal system that meets the project specifications or analysis requirements. Furthermore, the products can be grouped into 'projects' that correspond to the fenestration schedule for a selected commercial building under consideration.

The availability of CMAST to the greater commercial construction and design industry is a significant change from prior practice. Under the SBP, only accredited simulation laboratories (ASLs) or individuals trained in the use of WINDOW and THERM were capable of performing the simulations necessary to generate whole-unit fenestration performance values. With CMAST, the necessary simulation work is still done by ASLs, but these components are then available for 'assembly' by any user trained in the use of CMAST.

Figure 5 provides an overview of the entire CMA process from the beginning through to the generation of the CMA Label Certificate. The process should not be thought of as strictly linear, as various users can be performing different operations simultaneously. The process works as described above, but this Figure also points out the use of CMAST to generate 'pre-bid certificates' or 'bid reports' (similar to Label Certificates, but generated by any user, and not subjected to 3rd party review—therefore not certified) for use in determining compliance with code and project requirements.

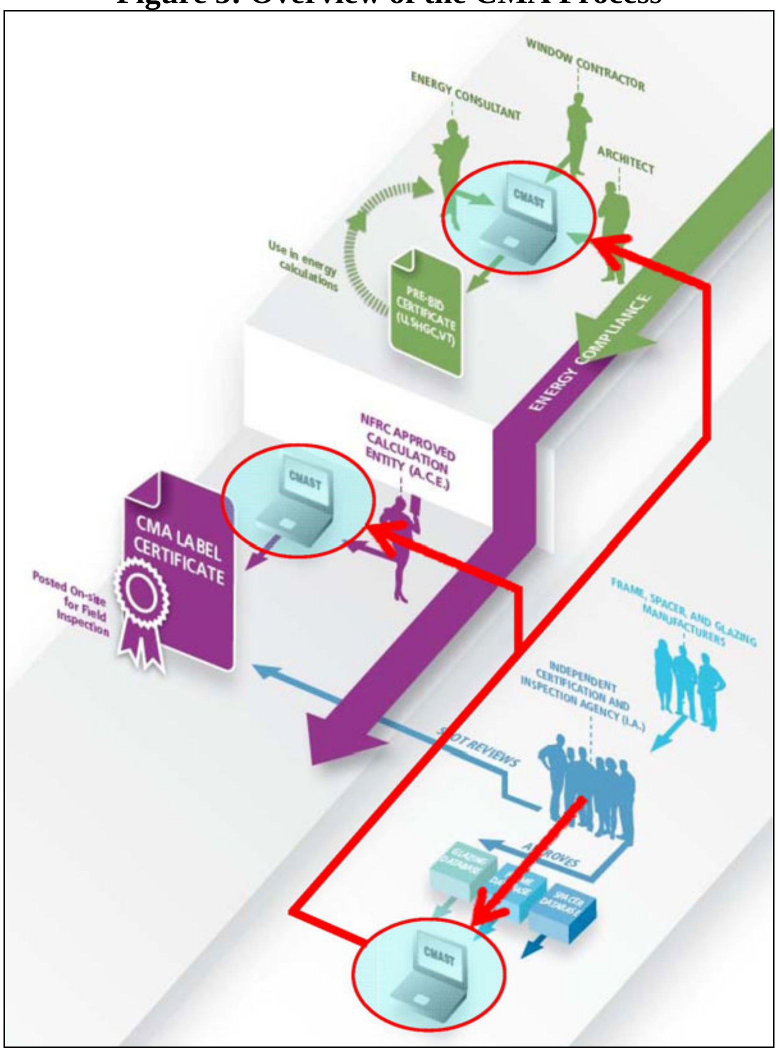
[5] A 4th component is the fill gas used within the IGU assembly; various gases are provided within CMAST; as their properties are defined and constant, these gases do not require submittal by a manufacturer, and as such, are not part of the approval process required of the other 3 components.

Figure 4: Simplified Representation of the CMA Method of Assembling Components into Assemblies and Fenestration Products



Source: National Fenestration Rating Council (2009)

Figure 5: Overview of the CMA Process



Source: National Fenestration Rating Council (2009)

The determination of the final fenestration system is usually an iterative process, and CMAST lends itself well to such an approach. At this initial stage of the design-build process, and during the value engineering or revision process, the design professional can easily change any of the components and determine if the resulting fenestration assembly is in fact equivalent as far as energy performance considerations.

Once the specifications for the fenestration system have been finalized, the party responsible for ensuring the manufactured and installed fenestration matches the specified system[6] contracts with a firm referred to as an Approved Calculation Entity (ACE) Organization as shown in Figure 5. Only the ACE Organization is authorized to generate a CMA Label Certificate, which is subject to 3rd-party oversight and verification.

After the ACE Organization has assembled the virtual fenestration system and generated the Label Certificate, the Specifying Authority is notified it is available online, where a secure .pdf certificate is available for download and printing. The Certificate is available to anyone for viewing by accessing the online CMA database; if printed by anyone other than the Specifying Authority, a watermark is applied to the Certificate indicating it is not to be used for certification purposes.

Overview of the Software Tool

At this writing, the current version of CMAST is V1.1.11; the tool is updated on an ongoing basis to address 'bugs' and make minor improvements to functionality. CMAST is both a 'client' and a 'server' application; Figure 6 depicts the CMAST client home screen. The 3 'buckets'[7] have been circled in red. The blue oval indicates the three "Assemblies" buttons (glazing infill assemblies, frame assemblies, and spacer edge seal assemblies), and the green oval indicates the three buttons used to select completed products and projects. The tabular information relates to 'recent projects' that have been downloaded from the CMAST server.

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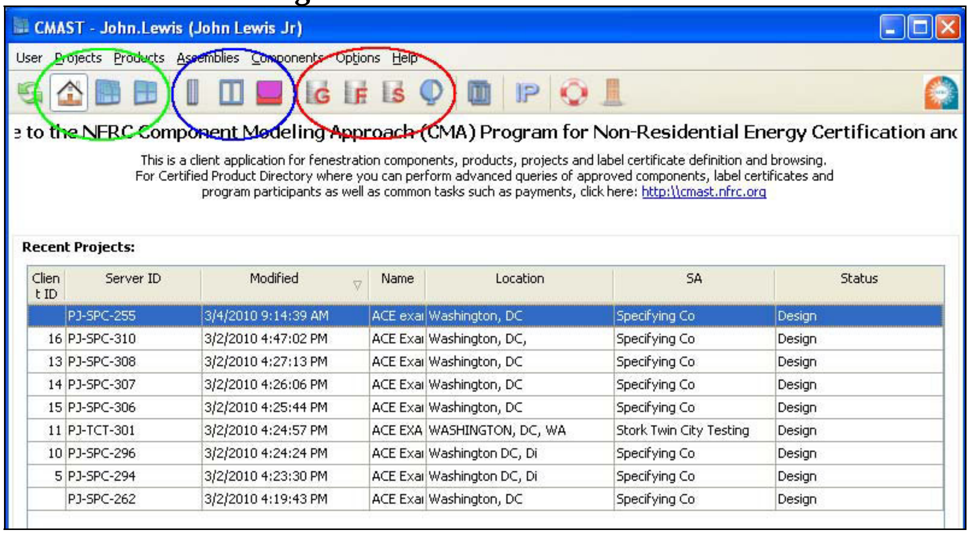
[6] In CMA parlance, this individual or firm is referred to as the 'Specifying Authority', and has similar responsibilities as did the 'Responsible Party' introduced with the SBP. The Specifying Authority can be the architect, the glazing subcontractor, the fenestration system supplier, or other party. The Specifying Authority 'owns' the label certificate.

[7] In reality, 4 'buckets' (data libraries) exist: 1. Frame components; 2. Glazing components; 3. Spacer Components, and; 4. Fill Gases. See footnote 2 regarding the 'fill gas' bucket depicted by the balloon.

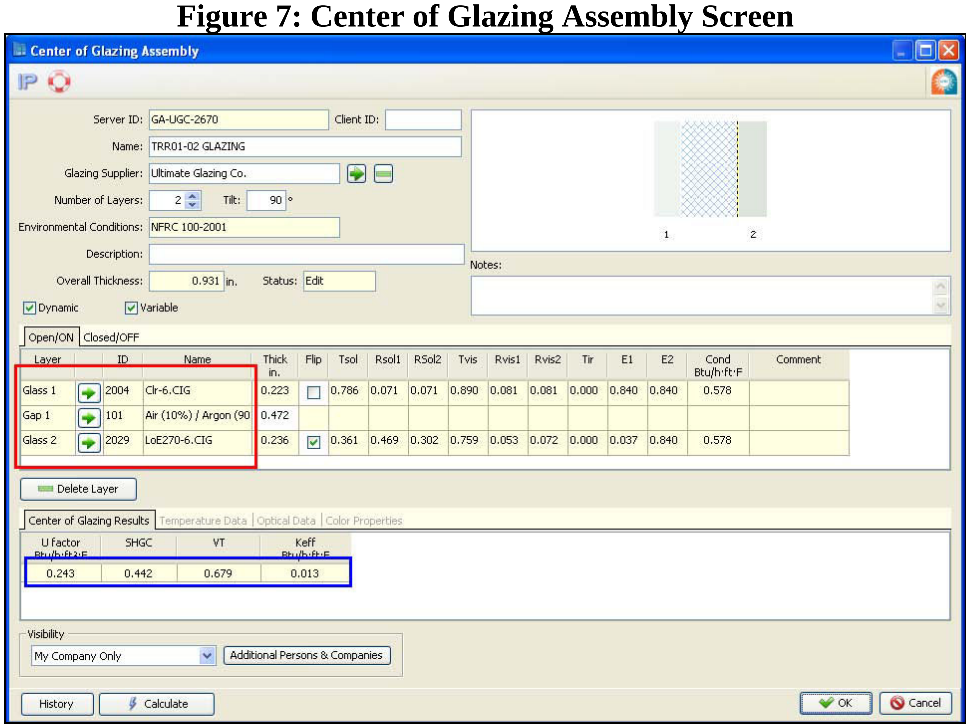
Figure 6: CMAST Home Screen



Source: National Fenestration Rating Council (2010)

Figure 7 depicts the "Center of Glazing Assembly" screen; the glazing layers and fill gas have been indicated with the red rectangle; the center of glazing results have been indicated with the blue rectangle. On this screen, CMAST users can easily change glazing options and fill gasses and quickly determine the impact on the whole-unit performance values, which are displayed on the Product screen discussed below.

Figure 7: Center of Glazing Assembly Screen

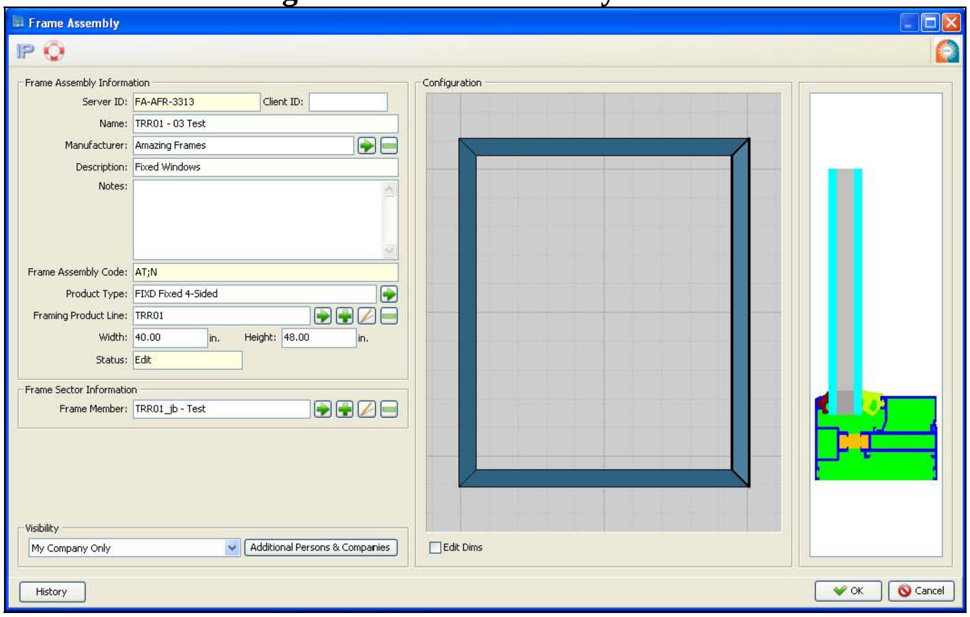


Source: National Fenestration Rating Council (2010)

Figure 8 depicts the "Frame Assembly" screen; note the cross-sectional drawing detail of the right jamb assembly as shown at the right of the elevation drawing of this fixed window. Note the

‘Visibility’ button at the lower left-hand corner of the screen; the user can choose to show the frame cross-sectional to all users, or limit visibility to himself, the company, or a specific user.

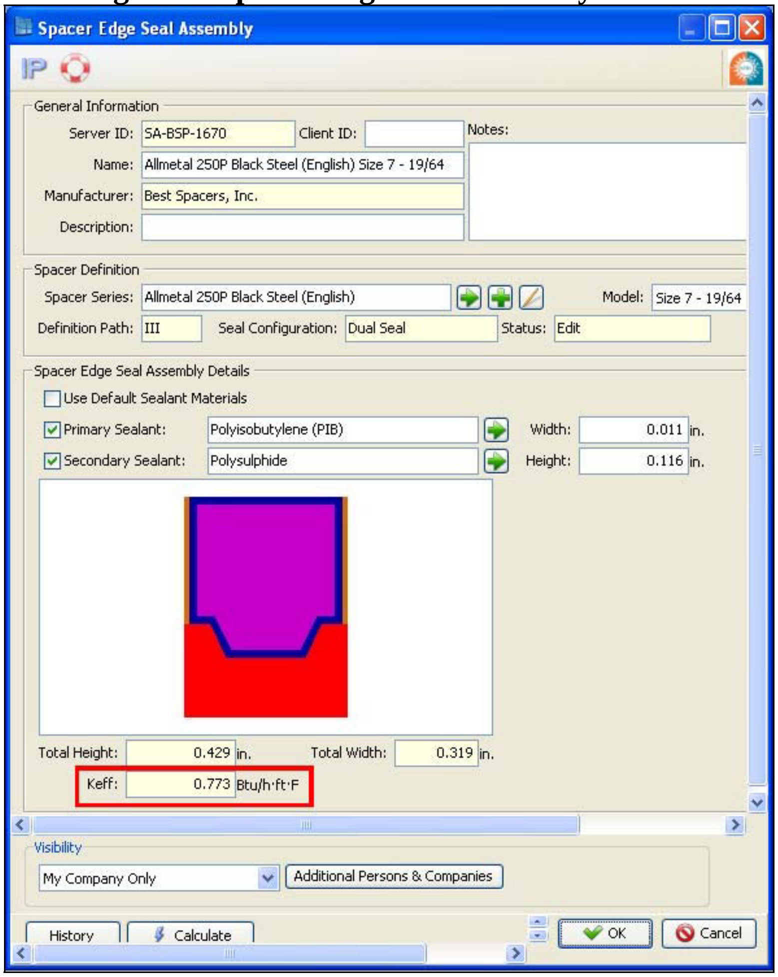
Figure 8: Frame Assembly Screen



Source: National Fenestration Rating Council (2010)

Figure 9 depicts the “Spacer Edge Seal Assembly” screen; note the cross-sectional drawing detail and the K_{eff} value of 0.773 btu/hr/ft/F^{o} for the assembly indicated by the red rectangle.

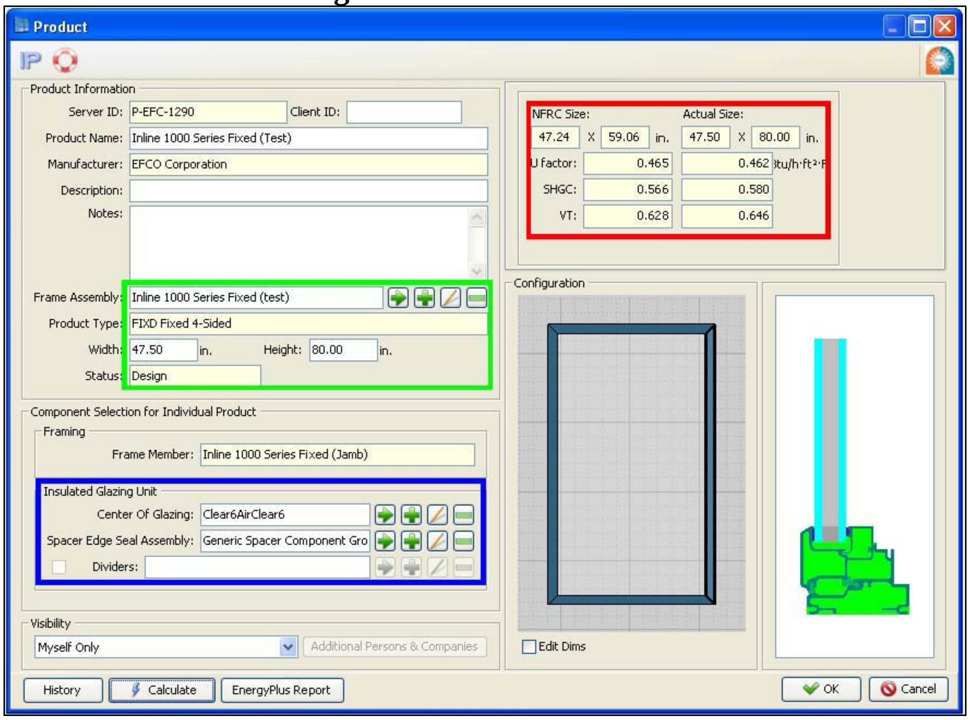
Figure 9: Spacer Edge Seal Assembly Screen



Source: National Fenestration Rating Council (2010)

Figure 10 depicts the "Product" screen; all of the components have been selected and the performance values calculated. This screen looks similar to the Frame Assembly screen, but in that screen, the frame is stand-alone, and contains no glazing or spacer edge seal assembly. Note the cross-sectional drawing detail of the right-hand jamb assembly. Frame information is provided as indicated by the green rectangle. This product is glazed with a clear glass, air filled IG assembly (refer to the blue rectangle), and the energy performance numbers are provided for both the NFRC standard size and the larger 'Actual Size' unit (refer to the red rectangle).

Figure 10: Product Screen



Source: National Fenestration Rating Council (2010)

Addressing Current Needs with the CMA Program

The need for a credible 3rd-party certification program for commercial fenestration has been realized and met by the CMA program. The program addresses the shortcomings of the SBP and adds additional functionality as well.

The latest versions of WINDOW and THERM run in the background of CMAST, and are able to provide solar optical properties that include angular dependencies. CMAST is able to capture this information and export it via an EnergyPlus file, thereby providing a much richer data set than previously available. This additional functionality makes CMAST extremely valuable and useful as part of the process of simulating whole-building energy analysis. DOE-2 output file functionality is slated as one of the first improvements, and should be available later in 2010.

Code compliance and deployment of the CMA program. California is the first state to adopt CMA as a provision within their Title 24 energy code. California's Title 24 provides 3 paths for site-built fenestration to prove compliance, and the NFRC (CMA Program) option affords the most favorable (and accurate) values; when designers are able to use accurate fenestration U-factor information, HVAC systems can be appropriately sized, often resulting in smaller systems.

Other states are following a different approach in adopting the CMA program. While California makes a direct reference to CMA, 38 other states cite ASHRAE 90.1 for their commercial building energy code. ASHRAE 90.1 and the IECC & IBC reference NFRC 100 and 200, and so by default, reference the CMA program.

The CMA Program Moving Forward: Future Enhancements

NFRC is currently working to further enhance the capabilities of the CMA program; inclusion of spandrel systems and complex assemblies are under review.

In addition to the work underway for fenestration assemblies, considerable effort has been expended by NFRC in developing ratings for fenestration attachment products such as roller shades, venetian blinds, solar screens and other shading devices that are coplanar with the fenestration glazing. Once the ratings are developed and approved, the intention is to integrate these attachment products into the CMA Program as well.

The ability to incorporate building information modeling (BIM) functionality, illumination ratings and also provide the basis for sustainability and green indices is under consideration.

Summary and Conclusions

The commercial fenestration market is markedly different from the residential market, and NFRC's commercial rating and certification program has evolved from systems based on residential parameters to the CMA Program. CMA is a new, streamlined rating and certification program that features at its core a full-featured software program referred to as CMAST.

In addition to a web-deployed certification program, the CMA program provides the heretofore underserved commercial fenestration community of users the ability to perform research, iterative design and energy performance modeling on a scale unimagined at the launch of the first commercial fenestration rating program.

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