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To: Sam Taylor

From: Dragan Curcija

Re: Role and importance of fenestration computer modeling tools in the future DOE efforts

Date: October 30, 2001

Cc:

Computer tools are used for both product design and product rating. In the next 10 years we need to move to windows with U-factors in the range of 0.1 to 0.2 (e.g, R5-R10), and solar control windows, which will provide high solar gains in northern climates and low solar gains in southern climates, while preserving the most fundamental purpose of windows, to provide good view and daylight for lighting load reduction. To design and rate such very high performance products, it is necessary to have accurate tools. Testing is expensive and inconsistent, and the fenestration industry is asking that testing be reduced to a bare minimum. Instead of massive commercial scale testing efforts, it is more desirable to have a few very high quality research – class testing laboratories, which will be used to validate new generation of computer tools.

Current modeling tools (i.e., W5, T5, O5) are the first generation of user-friendly tools that can be successfully used by industry. In addition to user-friendliness, they incorporate some of the advanced algorithms, developed under the sponsorship of DOE in the last decade. These algorithms, such as advanced radiation modeling, convection modeling in glazing cavities, sophisticated error estimation, calculation of solar optical properties of complex products, etc. are used today to rate and design products and produce new indices that could not be tackled just a few years ago (i.e., projecting products, commercial building window products, selected shading devices, condensation resistance, etc.)

Over the next few years, tools need to be updated in the next several versions in several areas:

- Extend applicability to emerging technologies and all major product areas;
- Improve accuracy for not only NFRC minimum standards, but for more robust design capability;
- Add capabilities to model other performance indicators important to the marketplace;
- Extend programs capabilities to enable integration with future energy simulation programs needed for whole building optimization.

Industry is too fragmented and focused on short term profit margins, proprietary rights and patents, to be able to come together and develop such tools without government support. This was evident before and remains true today. It will be a big mistake to think that market forces will resolve this in the next period.

Extend applicability to emerging technologies and all major product areas so that the range of products that is currently not possible to simulate (i.e., Condensation resistance of sloped and wide cavity products, wider range of shading devices, vacuum glazings, highly projecting products, domed and tubular skylights, commercial skylights, etc.) is reduced or eliminated.

Improve accuracy and consistency of computer models so that high performance products can be modeled within the existing tolerance range. With decreasing testing role, programs need to be made more sophisticated and capable. Historically, we had to be within 10% of the lab test. Now, we use one vs. two tests, which presume more accurate software. Design capability requires increased accuracy. It involves product design and input for building design. It is also important for international harmonization, in that it removes from the discussion areas where compromise is needed. It makes easy the acceptance of such algorithms. Because we are dealing with a range of products, minimum accuracy in some new product areas means that we have higher accuracy for standards products. By adding a higher level of accuracy, the programs become increasingly complex and the task to make this complexity hidden from the user is very challenging. Another benefit of improved software is reducing the cost to become rated. That would expand the number of companies that have NFRC rated products. It would move the industry into the retrofit window area, which tends to be served by medium to small size companies.

This investment in more sophisticated computer tools is cost effective because it saves millions in unnecessary testing and lost productivity. Shah et al. (2001) and Curcija (2000), show how the improved efficiency of fenestration products correlates with the introduction of computer tools and NFRC. The government cannot allow reversing this trend by relying on the market forces alone. We are literally saving hundreds of millions of dollars every year in decreased dependence on foreign fossil fuels, by being able and capable to design and produce better performing fenestration products. This capability has to be preserved and if we want to keep pace with the market and to reduce testing to a minimum, we need to invest more and not less in computer modeling tools.

We are at the point where the increased power of computers starts to bring some real benefits to scientific development, and we should make an effort to avoid most of approximations that we have to use at this time. Our common goal should be to move toward the solution of the given problem by solving the most fundamental form of governing equations, which will give correct results all the time. Right now that is not possible because of number of limitations (e.g., computer power, state-of-the-art in solution methods, etc.), but this should be worked on until we reach that goal. This should be work in progress where we overcome barriers one by one, rather than ceasing development effort because we think that we have achieved satisfactory accuracy. If we stop now, and just go into maintenance mode, in several years, we will again reach crisis, where number of products don't validate and it is not possible to use tools to rate and design new products, because the correlations and assumptions that were good now, are not going to be good in the future. At that point we are already behind, and it is much harder to get to speed again.

Add capabilities to model other performance indicators, not directly related to energy. These additional performance indicators are:

- Durability
- Failure mode analysis
- Acoustical performance
- Structural performance

It is becoming more apparent that durability of fenestration products and premature failures, although not directly related to energy performance, has a potential to reduce, if not completely reverse the benefits of energy efficient products. Homeowners and business owners are interested in saving energy and improving their bottom line, but if these savings come at the expense of reduced lifetime, health problems, decreased comfort and productivity, they may opt not to select energy efficient product. We need tools that can predict durability and failure modes along with thermal performance. If this is done in conjunction with thermal performance calculation, the incremental cost will be marginal and benefits will be huge. This additional capability involves another level of sophistication in computer tools, and will require several versions to become truly useful.

Improved acoustical performance increases occupant comfort and productivity and currently this indicator can be obtained only using expensive testing. This testing is not only expensive to perform, but the manufacturer has to build the prototype unit and send it for testing only to discover that no improvement has resulted from the new design. This process is repeated until desirable performance is met, but it may cost lots of money, and the final performance of the product may not be optimal because of the cost restraints. Existing computer modeling tools can be extended to model acoustical performance and to aid in the development of optimal products.

Structural performance of fenestration products is very important, and industry is just convening to try to address this issue. Structural analysis and modeling can as well be incorporated into the new version of computer tools, and again this analysis can be performed in conjunction with thermal performance modeling, significantly reducing the cost and effort.

It is also beneficial if tools are capable of incorporating embedded energy into the overall calculation. If a manufacturer puts curtain walls in a high rise, for example, and then have to replace significant portion of failed units, not only was money and productivity lost, and bottom line of manufacturer affected, but the energy to produce all these fenestration products is wasted as well.

Extend programs capabilities for future energy simulation programs, so that less human intervention is required in the design process. Current version of THERM program can read CAD file from a window manufacturer and quickly and efficiently prepare model for thermal performance analysis. If this capability was extended to the whole blueprint of the building, the time to prepare energy model of the entire building can be significantly reduced and streamlined. This capability crosses the boundaries of fenestration product application and is a likely scenario how future-modeling tools might evolve. Fenestration program, through its very successful software development effort has the most expertise to tackle this “holy grail”. Benefits of efficient whole building energy modeling are hard to describe in a brief way, but it should be obvious to anyone who ever attempted this task, that benefits are enormous. We should have more and more new buildings fully modeled to optimize them before they are built, so that they become comfortable, healthy, and “energy smart” buildings.

Addendum: Clarifications and Additions to the Explanation of Role and Importance of Fenestration Computer Modeling Tools in the Future DOE Efforts

For the new generation of high performance windows with U-factors in the range of 0.1 to 0.2 (i.e., R5 to R10), current criteria for validation of computer modeling results of 0.04 represents 20-40% of disagreement. These levels are much higher than commonly accepted 10% and should be improved. One of the goals for validation criteria has been to lower current criteria from 10% to more acceptable 5%. Therefore, the future goal for validation criteria should be 5% for all "standard" products and 10% for very high performance products, vs. current 10% and up to 40%.

In order to achieve this improvement, two major areas need to be improved; a) experimental setups and methods, especially research level, and b) computer modeling algorithms and tools.

Research level experimental facilities are very important because they provide controlled environment with no commercial pressure for profitability with experienced and highly qualified personnel. Measurement of U-factors for highly insulating products is a complex task because of relatively small quantities that are being measured. Both basic measurement and standardizing methods need to be improved. The examples of areas that need improvement are: Ability to better control and predict surface heat transfer coefficients, both convective and radiative components; reduction or elimination of extraneous heat losses; improved uniformity in air flow and air temperature inside experimental apparatus; development of novel experimental techniques and apparatuses for tackling areas of greater uncertainty; etc.

Improved computer modeling algorithms and tools should be developed from the existing and ongoing research. For highly insulating products it is more important to be able to accurately predict various thermal effects in fenestration products. For the selected fenestration products for which there are no accepted methods to model their performance (i.e., U-factors for certain class of skylights, like domed, tubular, pyramid, etc.; condensation resistance of all skylights, certain commercial fenestration including all sloped systems, etc.), new methods need to be devised for their modeling and measurements and criteria for validation developed.

For emerging technologies, like vacuum glazing, aerogel glazing, electrochromics glazing, etc. new modeling techniques need to be developed and validated. Also, models should be able to predict performance of new products without the need to specially develop algorithms for every new system. In other words research should anticipate some of further developments in the filed and be "ahead of the game".