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Again, thank you for the opportunity to comment on the draft fenestration criteria for nonresidential and highrise residential buildings. This is a follow-up to my previous comments submitted July 5, and testimony provided at the October 13 workshop.

As we continue our dialogue, it is useful to remind ourselves that we do agree on many items in the proposed update. However, while there have been some changes in the latest proposal, I still have real concerns about how the daylighting is being addressed, and whether we are going to achieve the claimed energy savings in real life.

I strongly support daylighting, and remain concerned that the proposal makes a serious mistake by focusing on an oversimplified minimum VT requirement. Daylighting and VT are not synonymous. Daylighting is inherently complex, and the designer must look at a number of factors including the building and room geometry, function of the space, window location and properties, shading and glare control, lighting fixture location and control, etc. VT is only one small aspect of daylighting, and without considering other factors, is simply the wrong metric. *Daylighting is about the right amount of light, not the highest amount of light.*

If absolutely forced to simplify, I would say there are three important factors common to good daylighting design, in order of importance:

1. Lighting controls
2. Good distribution of glazing – both laterally and vertically – to spread the light.
3. Appropriate window properties *for that specific application*

The green codes (IgCC, ASHRAE 189.1) address all these aspects. The same is true for the Title 24 toplighting requirements. I applaud your work there, and the proposed update is also very strong on lighting controls. However, the fenestration proposal then misses the mark by focusing on VT alone while ignoring glazing distribution in different building types and doing nothing to encourage good daylight zones and spread of light. This is a major flaw.

The CASE report is based on a single prototype building with equally distributed glazing. The analysis then erroneously assumes that the energy savings from this ideal situation can be extrapolated to all future buildings in California – highrise offices, schools, banks, hotels, restaurants, strip malls, warehouses, etc. But unless all these buildings are equally ideal, **the energy savings are being grossly exaggerated and will not be realized.** This is a very important point as the "very large" energy savings has repeatedly been cited as the basis to support the new minimum VT requirement, as well as a "significant loss" if the VT requirement is not included.

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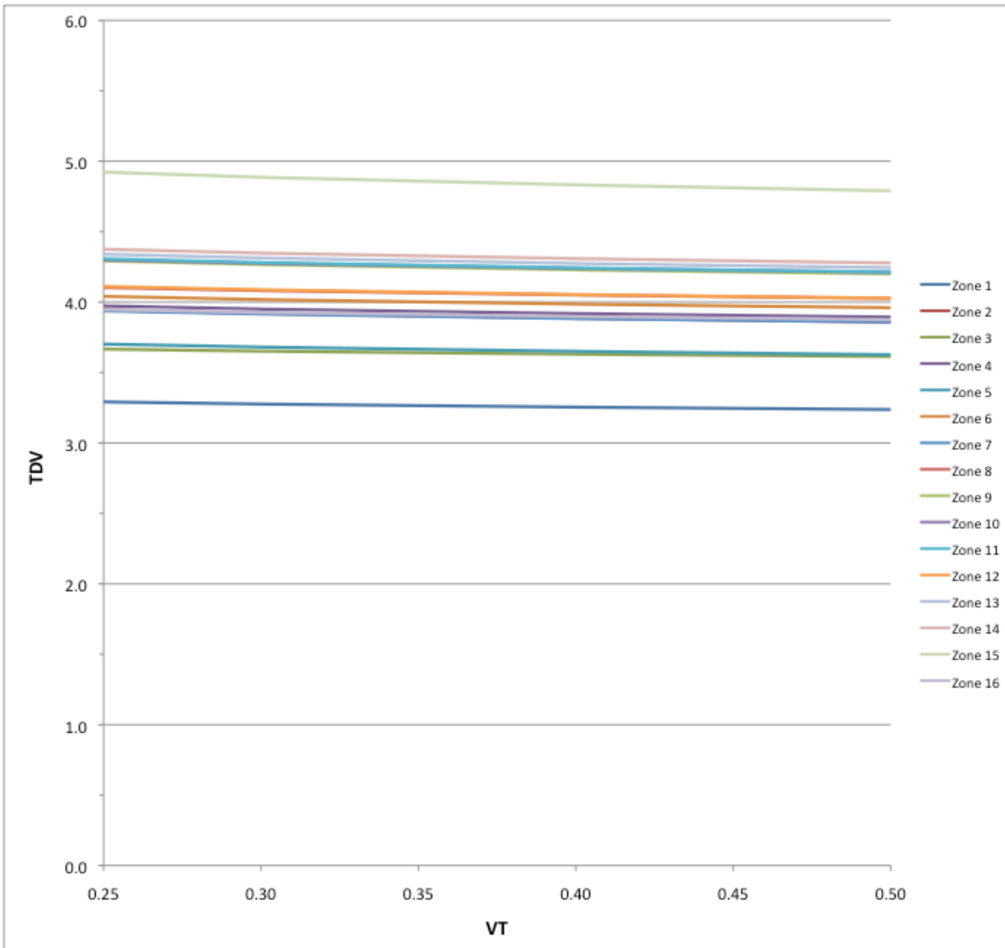
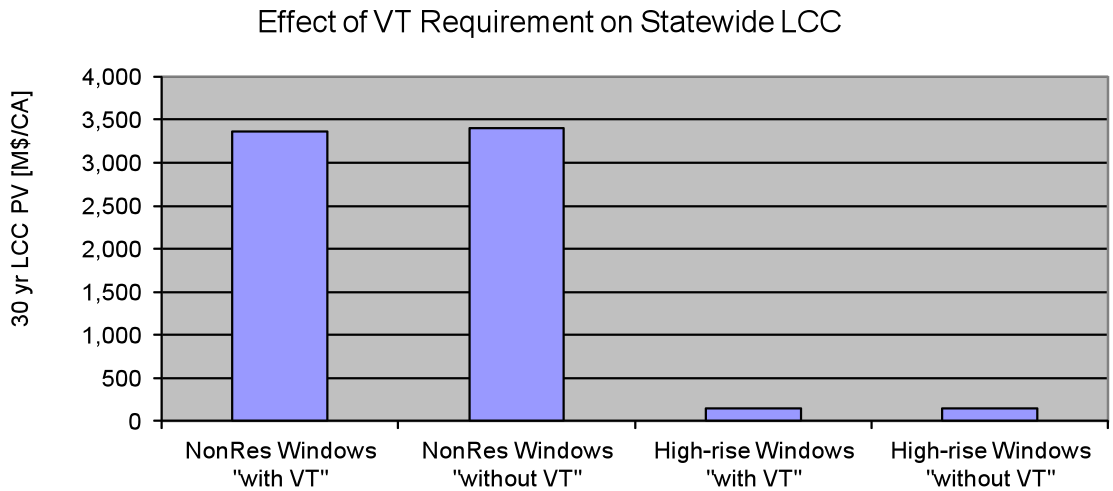
My comments will address two aspects where the energy savings are being exaggerated – within the building prototype model, and then the extrapolated state energy savings. At the end, I will also provide a recommended solution to more appropriately account for daylighting.

But first, it is useful to put the energy savings at stake into perspective. The CASE report assigns extreme significance to VT, but in fact, zooms in on very small changes in energy savings. Below is a plot of the TDV energy cost versus VT for the prototype office building using the correlation developed in the CASE study, but plotted to show the total value without zooming in:



It is apparent that the relationship between TDV energy cost and VT is actually rather flat, and the savings are quite small when put in context. Please don't misunderstand – *daylighting* energy savings can be significant, but daylighting is a lot more than just VT. Certainly, such a small change in energy savings over this large VT range does not justify picking one value or another as a new requirement, let alone eliminating 95% of the products shown in Figure 7-10 of the report.

Going further, the CASE report claims "significant life cycle savings loss" if a VT requirement is not included, showing a huge 20-40% loss in energy savings in Figure 7-18. However, when the actual results from the work files are plotted, the real "loss" is miniscule, as shown below. The actual percentage is between 0.5-0.9%, and for reasons outlined below, even these numbers are exaggerated.



Now that the potential energy savings have been put in proper context, I believe even these numbers are erroneously high because of two problems in the analysis – one in the way the building prototype was modeled, and one in the way the extrapolated state energy savings were calculated.

<u>1. Errors within the building model which lead to exaggerated savings</u>

First, the prototype building model assumes the interior blinds are being operated in a nearly ideal manner. The analysis uses the "OnIfHighGlare" model within EnergyPlus, which assumes that building occupants only lower the blinds when a specified glare index threshold is exceeded, and then reopens the blinds once the condition has passed.

While this is better than assuming no blinds at all, this glare control model overestimates the energy savings associated with VT. Staff from Lawrence Berkeley National Laboratory have commented that the glare control strategy in EnergyPlus is empirically unrealistic, and "assumes perfect control of the shades, e.g., they are lowered and raised by very devoted occupants whenever the appropriate criteria are met."[1]

Second, it is unrealistic to assume the blinds are immediately opened again once the glare condition has changed. Previous studies show that a significant portion of users set their blinds for glare protection and then rarely readjust them.[2,3] This is borne out by simple observations of buildings around Sacramento. A quantitative analysis of the photos on the following pages demonstrate that of the blinds that were shut when there was direct sun on the façade, **over 95% remained shut** well after the sun and glare condition had moved on.

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[1] D.B. Belzer, "An Exploratory Energy Analysis of Electrochromic Windows in Small and Medium Office Buildings – Simulated Results Using EnergyPlus", Pacific Northwest National Laboratory, PNNL-19637, August 2010.

[2] D Bourgeois, C Reinhart, I Macdonald, "Adding advanced behavior models in whole building energy simulation: A study on the total energy impact of manual and automated lighting control", Energy and Buildings vol 38, #7, July 2006

[3] C.F. Reinhart, "Lightswitch 2002: a model for manual control of electric lighting and blinds", Solar Energy 77(1) 2004, 15-28.

9th & L St, Sacramento CA, southwest façade, 45-50% WWR

Oct 13, 2011   2:40 pm

Oct 13, 2011   6:52 pm

204 windows visible
(142 on the SSW,
62 on WNW
not including the
central section)

54% have blinds
closed at least
halfway.

Only 3 shades were
reopened after the
sun was gone.
> 97% remained shut.

(6 others were lowered
between the two photos,
but not reopened.)

Red = shades opened
Blue = shades lowered

9th & J St, Sacramento CA, ESE facade, ~ 38% WWR

Oct 12, 2011 1:19 pm

Oct 12, 2011 4:03 pm

228 visible windows

64% have blinds closed at least halfway.

Only 8 shades were reopened once the sun moved off the façade. 95% remained shut.

Red = shades opened
Blue = shades lowered

Other buildings showing majority of blinds are not reopened once the direct sun has past.
Photos taken in early evening, after sunset, to ensure they had adequate time to reopen the blinds.


12th & L St.   SSW and WNW, ~ 20% WWR   Oct 13, 2011   both at 6:45 pm


14th & L St, SW and WNW
~ 33% and 62% WWR
Oct 13, 2011
both at 6:41 pm

By ignoring this fact, the model is overestimating the energy savings associated with VT. **In fact, the variation in energy consumption from different shading strategies can be larger than the claimed energy savings from the VT requirement.**[4] This raises a serious question about the validity of drawing any conclusions about VT from the study.

The CASE report also claims that blinds do not necessarily affect lighting levels even when closed. While this may be partially true for white louvered blinds with the louvers set in an optimal manner, simply looking at manufacturer product literature verifies that different blinds and shades can cut out anywhere from 5 – 95% of the light.

Finally, the argument was put forward that glare is a moot point, because no glazing can mitigate glare from direct sun. The analogy provided was that even sunglasses do not sufficiently help with glare when looking at the direct orb of the sun. But using that analogy, those sunglasses certainly help with glare when reading your book by the pool — i.e. the effect of glazing on glare on the work plane. Also, glare is more than just from direct sun, and contrast glare due to the light/dark differences between the glazing and wall must also be considered. Glare and shading must be considered and accounted for in a realistic manner; by not doing so, the energy savings associated with the VT requirement are being exaggerated, leading to inaccurate conclusions.

2. Errors in extrapolation of state energy savings

Second, the errors in the building model were further compounded when the savings from the prototype simulations were aggregated into a statewide energy savings. The analysis did try to account for construction share over the next 10 years by climate zone, building type, and window-to-wall ratio.

However, the analysis made one very serious error by falsely assuming that *all* buildings constructed in California over the next 10 years would have the same energy savings per square foot as the prototype building. In essence, it assumed that *all* buildings would have the:

- same energy use per ft2 despite building type (large offices, small offices, hospitals, schools, colleges, banks, restaurants, hotels, big box retail, strip malls, warehouses, ...)
- same ratio of window area to floor area, or perimeter to core
- same ideal, equal distribution of glazing
- same proportion of energy end uses
- same use of lighting controls in every perimeter room, in both the primary and secondary daylight zones.

These are clearly not true. A large office has a different energy use pattern, different internal loads, different geometry, and different use of glazing than a warehouse or school. A fast food restaurant will not have the same energy savings per square foot as an office. These

[4] Cases 4-6 of reference 1 show a 2-5% variation in source energy use based on shade strategy, compared to the approximate ~ 0.5-1% difference in savings between the “VT” and “No VT” cases in the CASE report.

differences will affect both the energy savings and the aggregated first cost for many building types.

Many rooms in hotels and highrise apartments will fall under the threshold where lighting controls are required: 120 W under the new proposal, or roughly nine 60W-equivalent CFL bulbs. This is likely only in main rooms of larger apartments, and not smaller apartments, bedrooms, bathrooms, or kitchens. This will also be true for many smaller individual offices that will not require lighting controls. As a result, these spaces will not have any energy savings associated with VT, and certainly won't have the same savings per square foot at the prototype.

One of the most significant errors is assuming all buildings will have equal glazing distribution, which is the ideal situation to maximize daylighting energy savings, but does not match reality. According to an analysis of CBECS data by Pacific Northwest National Laboratory, large offices are the *only* case where this is a reasonable assumption, but for all other building types including medium and small offices, there is a significant portion that have unequal glazing distribution.[5]

Table 16. Distribution of Glazing for Post-1980 Buildings

Benchmark Number	Benchmark Building Type	Fraction of Buildings with Equal Glazing Distribution	Fraction of Buildings with Unequal Glazing Distribution	More Equally Dispersed	Less Equally Dispersed
1	Large Office	94%	6%	X	
2	Medium Office	66%	34%	X	
3	Small Office	42%	58%		X
4	Warehouse	66%	34%	X	
5	Stand-alone Retail	19%	81%		X
6	Strip shopping mall	NA	NA		
7	Primary School	60%	40%	X	
8	Secondary School and University	51%	49%		
9	Grocery Store	12%	88%		X
10	Fast Food	42%	58%		X
11	Restaurant	23%	77%		X
12	Hospital	77%	23%	X	
13	Outpatient Health Care	47%	53%		
14	Motel	59%	41%	X	
15	Hotel	65%	35%	X	

The end result is that the energy savings associated with VT in the prototype, already overstated from the incorrect assumptions about blind usage, are grossly exaggerated when extrapolated to state energy savings. This leads to false conclusions about VT, and worse, means that the desired energy savings will never be realized.

[5] D. Winiarski, M. Halverson, W. Jiang, "Analysis of Building Envelope Construction in 2003 CBECS –Post-1980 Buildings", Pacific Northwest National Laboratory, PNNL-SA-55888, March 30, 2007.

Other technical issues

In reviewing the documents, I noted a few other technical issues or questions that should be addressed.

(a) Whatever is decided for nonresidential fenestration also needs to be applied to hotel and highrise residential fenestration. The same general issues exist, and in fact, the potential daylighting savings are even less as noted in the CASE report. It may be simplest to collapse the two tables into one.

(b) Although relatively minor in comparison to the previous issues, I noted a potential discrepancy related to frame-to-glazing ratios. The CASE report mapped the results from fixed 4'x5' windows into other product types, to account for wider structural frames and different frame-to-glazing ratios in different NFRC standard product types. This is good. However, I'm not certain the correct frame ratios were used. Back calculating from the results shown in section 7.10.1, I observe the following:

	Glazing area back-calculated from CASE report VT	My estimate of the glazing ratio using frame width and NFRC standard size
2 ¼" frame, fixed window	85%	84% (good agreement)
3 ¼" frame, fixed window	83%	77%
3 ¼" frame, slider	74%	72% (okay), but 4" frames are common in AW-grade architectural windows. This gives 66%.
4 ½ " frame, casement	62%	53%

If CMAST was used for the mapping, some of this may be due to the exact frame used, but these calculations need to be checked.

(c) On a related note, the proposed equation 140.3-C is used to calculate a whole product VT when a certified rating is not available from NFRC (such as for curved glazing, prismatic films, translucent panels, etc). However, the proposed equation incorrectly uses a glazing ratio only appropriate for casement windows. In the language proposed at the end of this document, I suggest a correction for this equation.

(d) The language needs to reflect that some spaces may daylit by either sidelighting or toplighting, such as an exception to the sidelighting requirement for spaces in compliance with section 140.3(c).

Proposed Solutions

As previously discussed, VT alone is not a good substitute for daylighting, and the commission needs to look to more appropriate methods to promote daylighting. This is especially true given the new realizations about how the potential energy savings associated with VT have been greatly overstated.

My primary recommendation remains to **drop the minimum VT requirement** (or limit it to where it makes more sense, for glazing located entirely more than 6 ft above the finished floor), and **instead adapt the latest language from the *International Green Construction Code***.
The IgCC language was developed by key daylighting experts from the International Association of Lighting Designers (IALD) in collaboration with the New Buildings Institute (NBI) and the American Institute of Architects (AIA). Alternately, language may be adapted from ASHRAE 189.1.

If it is felt a minimum VT is needed to set a baseline for the performance path, then that can be specified in the performance path like other assumptions, rather than putting an erroneous value in the prescriptive path.

Ultimately, the code needs to **address both distribution of glazing** and **effective aperture**. Without any language to specify good daylight zones, there is no certainty of energy savings being realized. Two options to address glazing distribution are included in the language that follows, based on concepts from the green codes.

Finally, although we disagree about the specification of VT, I think we now agree that a primary sidelit effective aperture of 0.15 is appropriate. The CASE report previously claimed that effective aperture imparts an energy penalty, but as discussed at the workshop, this is not correct. The report author seemed to assume that designers will choose a desired VT number, and then increase glazing area to achieve the required effective aperture. In fact, this is the exact opposite of the design process. Window area and location are chosen first by the architect / designer for the function of the building type and space, and then effective aperture is used to determine what VT is necessary to provide adequate daylight the space.

The author of the CASE report has repeatedly made statements assigning a false motivation that "they want a code which will allow dark glass." This is simply not true, and shows there continues to be a lack of understanding about the fact that there is <u>no</u> single correct VT number that can be applied to every situation. Daylighting design depends on the building geometry, glazing location, function of the space, glare control, etc. Even effective aperture is not perfect, but it does a better job at determining what glazing properties are required to provide adequate daylight. Sometimes the proper choice for VT is high, sometimes it is medium, and sometimes it is low. It is for this reason that the industry offers *all* options, and claiming the industry "wants dark glass" is woefully inaccurate. The industry supports daylighting – after all, you can't have daylighting without glass. What the industry is concerned about is the unjustified restriction of product choice necessary to provide lighting designers and architects a wide design palette to provide the optimal choice for each situation.

The CASE report also implied designers will place glazing on the floor, where it is less useful for daylighting. That may be a valid argument for floor-to-ceiling glass in a tall office building, but that building will be using the performance path. This is the prescriptive path limited to 40% window-to-wall ratio – if the glazing on the floor, it's only going to come up to their chin! Furthermore, the revised proposed language for effective aperture puts in a sill height, below which the glazing does not count towards daylighting.

Based on these points and our earlier discussions, the revised code language would look something like the following:

5. **Windows.** Windows shall:

   A. Have (1) a west-facing area no greater than 40 percent of the gross west-facing exterior wall area, or 6 feet times the west-facing display perimeter, whichever is greater; and (2) a total area no greater than 40 percent of the gross exterior wall area, or 6 feet times the display perimeter, whichever is greater; and

   EXCEPTION to Section 140.3(a)5A: Window area in demising walls is not counted as part of the window area for this requirement.

   B. In buildings with two or fewer stories, not less than 50% of the net floor area shall be located in a Primary Sidelit Daylit Zone or Skylit Daylit Zone. In buildings with three or more stories, not less than 25% of the net floor area shall be located in a Primary Sidelit Daylit Zone or Skylit Daylit Zone.

   EXCEPTION to Section 140.3(a)5B: Enclosed spaces having a designed general lighting system with a lighting power density less than 0.5 watts per square foot, auditoriums, churches, gymnasia, movie theaters, museums, and refrigerated warehouses.

   [This is the option based on the IgCC. This pushes designers to spread out the glazing, as well as push it up high to cover more floor area, but also leaves flexibility. This is the most aggressive for daylighting savings, but admittedly will be a bit challenging on designers, forcing them to find ways to daylight more areas both in the perimeter and core. This is similar to Europe, where you see more "alphabet" buildings with longer aspect ratio and/or central atriums.

   Another option based on ASHRAE 189.1 that is a little less challenging:
   "The combined width of the primary daylit zones shall be at least 75% of the length of the façade wall." *This spreads the windows across the wall, and requires the designer to define the daylit areas and widths, but you don't have to calculate the exact areas (somewhat similar to the simplification being proposed for the lighting controls). The percentage may also be revised downwards to 50-60% if it is felt that 75% is still onerous.]*

   ~~B~~C. Have an Area-Weighted Performance Rating ~~a~~ U-factor no greater than the applicable value in TABLE140.3-A, or TABLE 140.3-B~~, or TABLE 140.3-C~~; and

   ~~C~~D. Have an Area-Weighted Performance Rating relative solar heat gain ~~,~~coefficient, excluding the effects of interior shading, no greater than the applicable value in TABLE140.3-A, or TABLE 140.3-B~~, or TABLE 140.3-C~~. The relative solar heat gain of windows is:

   i. The solar heat gain coefficient of the windows; or

   ii. Relative solar heat gain as calculated by EQUATION 140.3-A, if an overhang extends beyond both sides of the window jamb a distance equal to the overhang projection. For fins, the fin projection is at least equal to the overhang projection, and the fin extends from at least the sill to the head of the window.

   [Note: the original staff language also included "the fin offset is at least equal to the overhang offset". Actually, you don't want to require that, as you will get better shading if the fin is closer to the window edge, not farther.]

   EXCEPTION to Section 140.3(a)5~~C~~D: ~~The applicable "north" value for~~ A relative solar heat gain of ~~in TABLE140.3-A, TABLE 140.3-B, or TABLE 140.3-C or~~ 0.56, whichever is greater, shall be used for windows:

   a. That are in the first story of exterior walls that form a display perimeter; and

   b. For which codes restrict the use of overhangs to shade the windows.

EQUATION 140.3-A RELATIVE SOLAR HEAT GAIN *(unchanged)*

~~D~~E. Have an Area-Weighted Performance Rating VT no less than the applicable value in TABLE 140.3-A or TABLE 140.3-B.

[Note: we continue to disagree on whether to have a VT requirement or not, but the staff language was left above for context.]

EXCEPTION 1 to Section 140.3(a)5E: Enclosed spaces where the Primary Sidelit Effective Aperture is greater than or equal to 0.15.

$$Primary\ Sidelit\ Effective\ Aperture = \frac{\sum Window\ Area \times VT}{Primary\ Sidelit\ Daylight\ Area}$$

Where:

Window Area = rough opening of windows adjacent to the sidelit area that is 24 inches (61 cm) above floor level, ft^2

Window VT = visible light transmittance of window, no units

Primary Sidelit Daylight Area = see Section 131(c)1 daylight area, primary sidelit

EXCEPTION 2 to Section 140.3(a)5E: Enclosed spaces in compliance with section 140.3(c).

~~E~~F. Area-Weighted Performance Ratings shall be calculated according to Equation 140.3-B for TABLE 140.3-A or TABLE 140.3-B; or

~~F~~G. If the Total Visible Transmittance performance value is not available it shall be calculated by using the manufacturers center of glass alone performance value in EQUATION 140.3-C.

EQUATION 140.3-B – AREA WEIGHTED PERFORMANCE RATING CALCULATION *(unchanged)*

EQUATION 140.3-C – VISIBLE TRANSMITTANCE CALCULATION

VTt = GF x VTc

Where:

VTt = Is the VT of the fenestration including glass and frame

GF = fraction of glazing area divided by the total fenestration area including glass and frame

VTc = Is the VT for the center of glass alone.

[The above equation was corrected from the previous staff language, which included a glazing ratio only appropriate for casement windows.

Another option for default VT eqn would list different values for different products:
VTt = 0.53 x VTc for projecting windows
= 0.67 x VTc for sliding windows
= 0.77 x VTc for fixed windows
= 0.88 x VTc for curtain wall / storefront]

Finally, correct Table 140.3-B (Highrise residential, Hotel/Motel) to match Table 140.3-A (Nonresidential). Or as one of the other speakers at the last workshop suggested, just remove the highrise residential table and use the nonres table for both.

Again, thank you for the continued dialogue, and I look forward to working towards a mutual solution.

Best regards,

Thomas D. Culp, Ph.D.