Appendix F

Interior Light Level Measurements

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F.1 Introduction

The use of windows with lower visible transmittance (VT)[1] glazing has the capability of reducing unwanted solar infiltration that is associated with added interior heat and glare. As a general rule, the better the window is as an insulator, the lower the VT. However, the lower VT glazing will also reduce the availability of sunlight that may be used for interior tasks such as reading. A potential concern is that a lower VT glazing may increase electric lighting use to compensate for lost daylighting. Also, a lower VT may give the appearance to the naked eye of a 'darker' view outside compared to a glazing with a higher VT. The darker view may also be of concern to a homeowner.

For these reasons, an experiment was conducted to measure the VT of the Lab Homes in identical selected locations in the homes. Measurements were taken at the Lab Homes with the windows shown in Table F.1.

Table F.1. VT Specifications of the Windows Lab Home A and Lab Home B

Window Type	National Fenestration Rating Council VT Rating	Lab Home A (Baseline)	Lab Home B (Experimental)
Vinyl Double-Pane Low-E (Kinro)	0.59	X	X
Vinyl Triple-Pane Low-E (Jeld-Wen)	0.36		X
Aluminum Double-Pane Clear	0.71	X	

F.2 VT Measurement Evaluation Options

To realistically qualify and quantify a representative loss of daylighting, and therefore electric lighting use to compensate, would require a year-long study to capture the variability of all the involved factors including:

- sun angle (varies throughout the year)
- cloud cover (varies over seasons, days, and hours)
- interior space use by occupants (a typical pattern would need to be determined)

Sensitivity of occupants to light levels (the human eye is quite adaptable) and thus a typical threshold when electrical lighting was manually operated would need to be established. However, given that the Lab Homes are not occupied and there were insufficient time and resources to undertake such a study, this approach was considered too involved to address the issue at hand.

[1] The visible transmittance (VT) is an optical property that indicates the amount of visible light transmitted. The National Fenestration Rating Council (www.nfrc.org) VT rating is a whole window rating and includes the impact of the frame, which does not transmit any visible light. While VT theoretically varies between 0 and 1, most values among double- and triple-pane glazing windows are between 0.30 and 0.70. The higher the VT, the more light is transmitted. A high VT is desirable to maximize daylight.

Another option would be extensive modeling of the lighting conditions in the homes covering changing conditions over a year. From this modeling, representative light levels at specific locations verified with spot measurements could be developed. Again, given insufficient time and resources, this level of effort was not considered appropriate for the issue.

A third more reasonable level of effort option involves a simple comparison of glazing transmittance characteristics as they relate to possible "reading" conditions in representative spaces in the homes. This would involve a few sets of representative measurements aimed at understanding the magnitude of the effect on "reading" capability with the three window types. While this approach would not capture all conditions for a complete calendar year, it may be sufficient to allay any major concerns about VT and/or help identify and needed further analysis.

F.3 Measurement Method

A representative set of tests were carried out in the two homes using a calibrated Konica Minolta T-10 illuminance meter with detachable head and cable (see below) to capture basic characteristics of lighting with the factory and two retrofit window products in the homes.

Figure F.1. Konica Minolta T-10 Illuminance Meter

For each window condition, the measurements were taken in Lab Home A and Lab Home B on a single day within a ½ hour time period in order to take measurements during nearly identical weather conditions (daylight/sky conditions).

Measurements were first taken in both homes with the identical factory-installed vinyl-fame double-pane low-e windows in each home. Measurements were then taken after the homes were retrofitted: Lab Home A with aluminum-frame double-pane clear windows and Lab Home B with vinyl-frame triple-pane

low-e windows. For all measurements, there were no screens on the exterior of the windows and no window coverings.

The measurements taken are as follows:

- location: one bedroom each on the north and south sides of each home. These are considered the most likely to have lowest light levels (one window only).
- illuminance measurements #1: 3 feet and 6 feet from the center of the window on floor surface in each bedroom
- illuminance measurements #2: at a representative location near the window surface just inside and just outside each window to capture relative solar transmittance of the glazing product.

Figure F.2 shows the measurement layout for the illuminance measurements at the floor level and Figure F.3 shows the measurements being taken. Figure F.4 shows the interior vertical measurement taken at a representative location near the window surface and the vertical transmittance measurement taken inside. Figure F.5 shows the vertical transmittance measurement taken outside. See Attachment 1 for the measurement procedure for test method details.

Figure F.2. Layout of Horizontal Floor-Level Light Level Measurements

Figure F.3. Recording Horizontal Floor-Level Light Level Measurements

Figure F.4. Recording Vertical Light Level Transmittance Measurements Inside

Figure F.5. Recording Vertical Light Level Transmittance Measurements Outside

F.4 Results

Table F.2 summarizes the average values found in footcandles (fc) for the floor measurements at 3 feet and 6 feet from the windows and in percent (%) for the transmittance of the glazing.

Table F.2. Measured Illuminance and Light Transmittance for Lab Home Windows

Lab Home	Window Type	Location	Date/Time	Sky Conditions	3′ From Window (fc)	6′ From Window (fc)	Transmittance Average Both Rooms (%)
A &B	Vinyl Double-Pane Low-E	NE[(a)] Bedroom	Jan. 12, 0930 – 1000	Clear	30	32	66.1
A& B	Vinyl Double-Pane Low-E	SE[(b)] Bedroom	Jan. 12, 0930 – 1000	Clear	175	182	66.1
A	Aluminum Double-Pane Clear	NE Bedroom	Jan. 30, 1330 – 1400	Cloudy	66	47	77.0
A	Aluminum Double-Pane Clear	SE Bedroom	Jan. 30, 1330 – 1400	Cloudy	135	79	77.0
B	Vinyl Triple-Pane Low-E	NE Bedroom	Jan. 30, 1330 – 1400	Cloudy	29	22	37.3
B	Vinyl Triple-Pane Low-E	SE Bedroom	Jan. 30, 1330 – 1400	Cloudy	71	50	37.3

(a) northeast
(b) southeast

Note that for most measurements the light level is at or above 30 fc, which according to the Illuminating Engineering Society 10th edition handbook (2011) is considered an appropriate typical light level for casual reading (for desk area reading the value is 40 fc). Figure F.6 shows the sky conditions for the January 12 measurement and Figure F.7 shows the sky conditions for the January 30 measurements.

In Lab Home B with the vinyl triple-pane low-e windows, at 6 feet away from the window in the NE bedroom with no direct sun, the value drops to 22 fc. However, it is also understood by the lighting industry, that an approximate 15 fc reduction is the threshold where the typical human is able to discern a difference in light levels and therefore it is unlikely that 22 fc would necessitate use of artificial lighting.

It should be noted that the measurements taken after installation of the retrofit of the vinyl double-pane low-e windows in both homes were taken on a day (January 30) in the afternoon under cloudy conditions compared to the measurements prior to retrofit that were taken in on a day (January 12) in the morning with clear sky (sunny) conditions. However, the difference in diffuse daylight availability between the sunny and cloudy conditions (as measured outside the north windows) is less than 10%. Therefore, even under morning cloudy conditions, the interior light availability is not significantly affected.

Figure F.6. Sky Conditions during the January 12, 2012 Light Level Measurements

Figure F.7. Sky Conditions during the January 30, 2012 Light Level Measurements

It is known and shown with these measurements that lower VT glazing will reduce sunlight levels transmitted into a room. However, the direct measurements of interior light levels before and after retrofit of windows (Table F.2) show that for reasonable typical daytime conditions the interior lighting levels in the experimental home are not reduced sufficiently with the installation of the triple-pane low-e windows to cause any significant issues with typical residential reading conditions using natural light.

For short periods of time at early morning or evening times when the sun is just rising or setting, the available light for reading will be reduced with lower VT glazing, but occupant use of lighting at those specific times is not a known quantity and therefore cannot be equated to any measurable change in electric lighting use. These results indicate that the use of lower VT (0.36) glazing should not cause the use of significant additional artificial lighting.

Attachment 1: Measurement Procedure

Measurement Procedure

- Complete the “setup” steps for both homes prior to taking measurements, to reduce time between measurements in Lab Homes A and B.
- Use a calibrated or new instrument – T-10 Minolta illuminance meter with detachable head, cable, and connector.
- Take measurements in Lab Home A (baseline home) and Lab Home B (experimental home) with the factory windows in both homes. Take these sets of measurements as close to the same day and time as possible as described in the rest of this procedure.
- Take measurements with retrofit windows in Lab Home A and Lab Home B. Take these sets of measurements as close to the same day and time as possible as described in the rest of this procedure.

- Measurements with the existing windows need to take place before January 23 as these windows will be retrofitted the week of January 23.
- Measurements of the retrofitted windows should take place before January 30 as the homes will be 'sealed' the week of January 30 for the start of the first experiment.

Setup

1. For each set of measurements, choose measurement day and time at which there is minimal:
    a. low-angle sun (avoid late afternoons or early mornings)
    b. cloud cover
    c. fog
    d. blowing dust, leaves, etc.
    e. frost on ground
2. Ensure there is no blockage at any windows (i.e. vehicles, equipment, persons, foliage) or objects that are nearby that could reflect sunlight into windows.
3. Clean inside and outside of all windows in the room where measurements will be taken within a few days prior to the measurements.
4. Open all blinds (if existing) on all windows in the room.
5. Turn off all electric lights in the room.
6. The room should be free of obstructions (furniture, etc.).
7. Have ready a large stiff flat panel to use as a floor platform for horizontal measurements. The panel should be:
    a. at least 1 foot square
    b. neutral to dark flat color; can be black but should not be white or very shiny
    c. any material but must be reasonably stiff
    d. placed centered over each measurement point with measurement point indicated on the platform
8. Identify a spot on the window that will be consistently lighted by the sun during the entire set of measurements with either full unshaded sun or fully shaded sun (i.e. from roof overhang) and is not obstructed by any objects.
    a. Draw an approximate 6 inch circle on this window spot (inside) with a thin marker that can be cleaned off later.
    b. Record the location of the center of this circle:
        i. Identify window.
        ii. Record dimensions of center of circle from identifiable edges (i.e., X inches from bottom, Y inches from left side – measured on the inside).
    c. Have ready a small shim block (approximately 2" by 2") that is 3/8 inch thick (to offset the meter sensor when taking vertical measurements – needed for the T-10 meter and probably others)

9. Take photographs of each test setup and room configuration.

Horizontal Measurements

1. Start with Lab Home A (baseline home—south home).
2. Ensure all setup steps are completed.
3. Shut all doors to room.
4. Place light meter measurement head flat on the platform centered over the measurement point. Make sure it lies flat with no tilt. Use double-sided tape if it will not stay flat.
5. Move out of the way of the sensor head so that you are:
    a. not in the way of any sunlight
    b. not in a position where any significant sunlight can reflect off of you and onto the sensor.
6. Record:
    a. date
    b. time
    c. location
    d. lux
    e. exterior and interior room conditions if other than described in this procedure
    f. window type
    g. meter model and serial numbers.
7. Complete the same measurement in two rooms on opposite sides of the lab home (see measurement location list).
8. Move directly to Lab Home B (experimental home-north home) and repeat and record the same measurements.
9. Move back to Lab Home A and repeat and record the same measurements for reference purposes. (Note: this provides the data to determine whether sun movement changes have affected the initial Lab Home A readings).

Vertical Measurements

1. Start with Lab Home A or B (If two measurement teams/persons and two similar meters are available, the horizontal and vertical measurements can be taken simultaneously but this is not required).
2. Ensure all setup steps are completed.
3. Using the meter with the head in detached and connected configuration, tape the 2” by 2” shim onto the face of the connector adapter (just below the sensor). This is critical to keep the white sensor dome from contacting the window glass.
4. From the inside, place the light meter measurement head (with shim) flat against the window within the marked circle (ensure no tilt) with the white sensor dome facing outside.

5. Record:
    a. date
    b. time
    c. location (location of circle should have been measured and recorded at setup)
    d. lux
    e. meter model and serial numbers.
6. On the outside of the same window, place the light meter measurement head flat against the window within the marked circle (ensure no tilt) with the white sensor dome again facing outside. Ensure that you and other objects are against the wall and out of the path of any sunlight.
7. Move directly to the second lab home and repeat and record the same measurements
8. Move back to the initial lab home and repeat and record the same measurements for reference purposes. (Note: this provides the data to determine whether sun movement changes have affected the initial home A or B readings).

Measurement Location List: Same for each lab home

Horizontal on floor using platform panel:

1. Master bedroom (SE corner)
    a. 3 feet back from window directly on centerline of window (suggest measuring from east wall to center of window as the other measurement)
    b. 6 feet back from window directly on centerline of window
2. Bedroom #2 (farthest east bedroom on north side)
    a. 3 feet back from window directly on centerline of window
    b. 6 feet back from window directly on centerline of window

Vertical:

- Within 6” circle on window in each room as described in procedure