Chunk from FAISS:Optics, Window, and THERM software. Optics is used to manage the glazing and glazing system databases common to all three programs. THERM is used to model frame elements, and Window is used to create glazing systems and combine frame elements into NFRC standard products for system certification and product comparison between competing manufacturers. 14.1. ‘Glass Performance’ Terminology We have already touched on a few of the common measures of thermal performance uring our discussion of substrates and coatings. It is, however, best to begin our discussion of thermal analysis with a review of its terminology. A curtain wall professional will soon find themselves bombarded by questions from clients and consultants regarding U-values, Solar Heat Gain Coefficients, and Relative Heat Gain. The terms are commonly used in the industry and even more commonly misused. A U-Value (U) is a measure of thermal transmittance for a material or construct which is calculated or measured by applying standardized boundary conditions. Do not confuse a U-Value with the thermal transmittance of the same material or construct. Thermal transmittance is a value measured or calculated based on the boundary conditions that exist at the time of the measurement. A U-Value is useful for comparing similar products; a thermal transmittance value will tell you how much energy you’re losing at some instant in time. The method for determining fenestration product U-Value is delineated in NFRC 100. A solar heat gain coefficient (SHGC) is similar to a U-Value in that it is based on a standardized set of boundary conditions. It too is useful for comparing like products. In this case the value represents a ratio of incident solar radiation to that which manifests itself as heat on the interior side of the specimen tested. The method for determining fenestration product SHGC can be found in NFRC 200. A SHGC is to relative heat gain (RHG), as a U-value is to thermal transmittance. The RHG is the actual measurement of heat gained on the ‘cold’ side of a construct resulting from the application of radiant energy to the hot side. Visible Transmittance (VT) is a measure of how much visible light enters a space through fenestration as a ratio of the total amount of incident solar radiation in the visible spectrum on the unit. Think of VT as a measure of how ‘transparent’ a particular glazing system is. VT is calculated using

Chunk from FAISS:[10] is ASTM C1036, which addresses standard specifications for flat glass. Reference [8] on the other hand, is ISO/FDIS 15099, a very important standard for the BP. It addresses detailed calculation methods for determining the thermal performance of windows, doors, and shading devices. If one combines the calculation methodology in NFRC 200 with the calculation method described in Section 4.2 of ISO/FDIS 15099, you get Equation 14-8 below. 14-8 where: SHGCg: glazing solar heat gain coefficient (dimensionless) SHGCo: spandrel solar heat gain coefficient (dimensionless) SHGCT: product solar heat gain coefficient (dimensionless) Ag: projected area of glazing (ft2) Ao: projected area of frame element (ft2) Apf: total product area (ft2) NFRC 200 indicates that for the purpose of total product calculation; edge values are to be treated to the same SHGC values as the center-of-glazing SHGC; so, they are conspicuous by their absence from Equation 14-9. Unit visible transmittance, by comparison, is easy to calculate. Since only transparent elements transmit visible light, one needs but to area-weight the visible transmittance (τv) of the glazing to determine the unit VT. 14-9 where: VT: frame visible transmittance (dimensionless) Apf: total product area (ft2) τf: glazing transmittance (dimensionless) Ag: area of glazing (ft2) Lately, on the East coast, it seems like consultants and architects are more interested in area-weighting the various components of curtain wall units, as opposed to area-weighting the units as a whole. This is due to the fact that they enter components into their whole building energy analysis software rather than units. For example; their software may differentiate fixed glazing, horizontal spandrel, vents, and vertical opaque or ‘spandrel’ as separate inputs when, in fact, all of these components are incorporated into a single curtain wall unit (Figure 176). The alternating yellow and blue boxes on Figure 176 show how the area of a curtain wall unit has been divided by component in response to a request by an architect. In order to provide the design team with a meaningful input; the elements present in each one of these components must be area-weighted as

Chunk from FAISS:the surface resistances and nodal temperatures as the software accounts for heat flow through the FE mesh as a function of the physical properties of the material and temperature differences between nodes. Subsequent iterations continue to refine the direction and magnitude of heat transfer as a function of the node temperatures. An error checking routine results in mesh refinement in areas where the geometry of the mesh causes problems with convergence. The ‘refinement’ continues until the iterations result in convergence within specified parameters. 14.3. Area-weighting U-value and Solar Heat Gain The Building Physicist creates thermal models of all the elements comprising the most typical unit once it has been identified. NFRC standard boundary conditions are first applied to each frame element in simulation. This process yields a U-value for each frame element and for the glazing edges associated with them. To calculate the overall U-value for the unit, the Building Physicist must area-weight all its element values. I probably mentioned area-weighting somewhere else in this text without actually defining what it was. Frankly, there are as many different ways to area-weight the performance of a curtain wall unit as there are architects and consultants to request performance data. The NFRC is more specific than either of these groups and the analyst must area-weight his product according to NFRC standards before he can expect the organization to rate his product. As shown in Figure 175, the NFRC has its own scheme for area weighting fenestration. The method used by NHF is based on the NFRC’s scheme but has been slightly modified for module performance analysis based on the realities of the configuration of unitized curtain wall. Sometimes modification is necessary for complex modules, but the basic ‘NHF scheme’ is shown in Figure 176 which follows. Intentionally Blank Figure 175. NFRC Area-weighting Scheme (NFRC 100) Intentionally Blank Figure 176. ‘Feature Weighting’ NHF Scheme for a Curtain Wall Unit You can area-weight the performance of anything that has more than one element. It is done by breaking an assembly into its elements by area, applying an appropriate weighting factor to each element, adding up the area-weighted elements, and then dividing by the total area of the assembly. Where determining overall curtain wall unit heat flow is concerned; the weighting factor is the element U-factor determined by THERM simulation. Figure 175 is taken from NFRC 100, but the area-weighting scheme depicted applies to the determination of a

Chunk from FAISS:unpleasant; particularly when they are not applied symmetrically. Since the interior surface of the façade is usually a different temperature than the free air temperature of the enclosed space; there is almost always buoyant airflow next to the inside of the curtain wall. The body in a draft will sense a temperature drop of about 1°F for every 0.45 mph increase in air flow. A draft of less than 0.45 mph will not be perceived unless it is significantly colder than the interior free air temperature. This kind of draft is the result of the façade not being airtight during winter months. Radiant heat exchange between a human and its environment is a function of the view factors you learned about in Section 5.5.3. This means that the amount of radiant heat exchanged between enclosed space and occupant is a function of where the occupant is within the space. ASHRAE 55 calls view factors, ‘angle factors’. To calculate Mean Radiant Temperature, you must define the enclosure surface temperatures, and the surface temperatures of significant sources of heat within the enclosure. Once these temperatures have been determined, MRT can be determined using Equation 7-2 and Figure 100. Figure 100. Angle Factors (ASHRAE 55) (7-2) where: Tr̄: mean radiant temperature (°R) Tn: surface ‘n’ temperature (°R) Fp-n: angle factor, occupant to surface ‘n’ The Radiative Film Coefficient for exposed human skin is 0.828 Btu/(h∙ft2∙°F). Both film coefficients, Tr̄, and the free air temperatures are needed to determine the operative temperature (Equation 6-2). Once you’ve determined operative temperature and interior temperature you can go to the ASHRAE 55 Comfort Chart (Figure 101), to see if your occupant falls within the comfort region for the conditions you expect in the enclosure. The ‘1.0 Clo’ zone is for winter conditions and the ‘0.5 Clo’ zone is for summertime conditions. Figure 101. Comfort Chart (ASHRAE 55) 8. Façade Testing Believe it or not; there is often a disconnect between how we in the curtain wall business say a unit is going to perform and how it actually performs in the field. Sometimes the disconnect is related to how the unit is fabricated or

Chunk from FAISS:0.1 psf. Not a great structural load, but the gas tight seal from mullion to interior partition and from smoke seal to smoke seal is a particular concern when smoking rooms incorporated in the project design. - EQ-C2: Indoor Environmental Quality, Increased Ventilation. To earn this credit, the project team must follow the Carbon Trust Good Practice Guide. Increasing natural ventilation typically requires increasing the size of the vents. Size and placement must be coordinated with the curtain wall design team. - EQ-C7.1: Indoor Environmental Quality, thermal Comfort. As you learned in Section 7; the design of the façade has a significant affect on occupant thermal comfort because it has a significant affect on the interior surface temperature of the curtain wall. It is normal for thermal performance to be specified in terms of transmittance and a minimum temperature to avoid risk if condensation. It is rare for a maximum interior temperature to be specified. Standards for thermal comfort are found in ASHRAE 55. To earn points under this credit, the curtain wall design team must be aware of and capable of interpreting this document. EQ-C8.1&8.2: Indoor Environmental Quality, Daylighting & Views. In the LEED Reference Guide for Green Design & Construction, the USGBC defines vision glazing as ‘transparent glazing between 30 and 90” above finished floor. They also indicate that vision glazing is necessary for daylighting and that 75% of a building’s interior spaces must have access to daylight in order to qualify for points toward this credit. The guide also indicates that 90% of regularly occupied interior spaces must have a line of sight view to the outdoor environment in order to earn points toward a credit for ‘views’ through the façade. The curtain wall design plays a significant role in attaining both credits. \*\*\*\*\*\* The curtain wall project manager is not generally a full-time member of the project team; nor will he interact directly with the Green Building Council. He should expect to be called on periodically to provide façade performance data and information regarding the integration of the façade into building systems as part of the rating process. The curtain wall design team will be heavily involved with the project team early on, but this involvement tends to taper off as the design evolves and the project progresses. 10. NFRC Rating Curtain Wall There has been an increasing number of projects tendered by NHF which require NFRC certification of the curtain

Chunk from FAISS:in full sun. This simulation depicts ‘mild’ applied boundary conditions; the interior and exterior temperature difference being just 20°F and the radiation indicative of New York City in the winter. As you can see, extreme temperatures exceed the boundary condition free air temperatures by a factor of two. More extreme boundary conditions can result in three digit temperature extremes. Intentionally Blank Figure 203. THERM Model of Head Detailing Shade/Sunlight Transition 14.5. Tilt Effect If you were to design a curtain wall unit such that you could also use it for a skylight, you would find that the thermal performance of the unit changes significantly as you rotate the unit from a vertical orientation toward the horizontal. Unfortunately; the change is for the worse. While those in the curtain wall industry tend to consider the performance effect of the ‘tilt effect’ as being exclusive to skylights; the fact is…it isn’t. In today’s era of increasingly ‘exotic’ building geometry; the tilt effect can be applied to any curtain wall unit which is not installed such that it is vertically oriented (15°of tilt is the magic number). The caveat being; the effect doesn’t apply to the unit…it is the glazing which performs differently as a result of any deviation from vertical installation (Table 23). As you know from our discussion of convection in Section 4.5.2, the shape of a building affects structural loading and thermal performance. However; for the purpose of this discussion, we speak only of the effect of tilt on the thermal performance of the glazing. Table 23. ‘Tilt Effect’ The tilt effect is due to a performance difference between the single convection cell typical of the glazing cavity in vertically oriented integrated glazing units, and a special kind of convection which exists in a horizontal fluid layer which is heated from below. The special convection is called ‘Rayleigh-Bénard Convection’ and it is very likely to occur in a horizontally oriented IGU exposed to a wintertime climate. Figure 204. Rayleigh-Bénard Convection; (L), CFD Model, (R), R-B Cell Forgive me, but I’m going to have to open up a small can of science on you. As you know from our earlier discussions of the nature of convective heating; the difference in density of the hot side fluid, and that adjacent to the cold layer, results in fluid

Chunk from FAISS:if the components stood alone. Further; the area-weighting must be revised every time the curtain wall module size changes, the size of any component in the unit changes, or anytime the arrangement of the features in the unit change relative to adjacent features. An example of four layers (element, unit, elevation, and building) of area-weighting for multiple curtain wall unit typologies is illustrated in Tables 18 and 19 that follow. Table 18. Curtain Wall Unit Element and Unit Area Weighting Table 19. Building Area-weighting The tables above depict spread sheets that does the math of area-weighting for the Building Physicist. The results of the base level of area-weighting; that of area-weighting the element to determine the component and unit level performance, is shown in the table but the calculation fields were omitted from the table due to the redundant detail present. 14.4. Dewpoint Temperature and Condensation Resistance A typical thermal analysis tender or project submittal will, as a minimum, include modeling to predict both U-value and SHGC. The third most common analysis specified is a condensation risk assessment. Project documents will specify an interior free air temperature and relative humidity, and an exterior free air temperature and parallel wind velocity for condensation risk analysis. A condensation risk analysis is performed by modelling the frame elements of a ‘typical’ unit; applying the specified boundary conditions in a two-dimensional finite element software simulation, and then comparing interior surface temperatures from the models with dew point temperature gleaned from the psychrometric chart. The frame section simulations will output thermal transmittance, heat flux density, and…most important for condensation risk analysis…temperature distribution. There is a risk of surface condensation anywhere interior air comes in contact with an area of the interior surface that has a temperature lower than the dew point temperature for the specified interior free air temperature and relative humidity of the air mass. As an example; Figure 177 depicts a THERM two-dimensional finite element analysis model of a vision head transom. The temperature distribution indicated in simulation shows an area at the edge of the sightline where the surface temperature on the glass is less than dew point for the boundary conditions applied to the model (highlighted in yellow). There is a possibility for condensation to form in this area. Intentionally Blank Figure 177. Condensation Risk Analysis Figure 178. THERM Model Showing Dewpoint Isothermal Line Figure 178 above depicts

Chunk from FAISS:loading…particularly reactions to wind load. This forces the curtain wall design team to make the curtain wall system more robust. In doing so the reactions at the façade anchor points increase as well, an act which forces those designing the building structure to evaluate and adjust the capacity of their design. Finally, attaching these features to a curtain wall unit almost always results in a thermal bridge which detracts from the overall thermal performance of the system and increases localized condensation risk at the site of attachment. European colleagues of mine call the effect on thermal performance the ‘Cooling Fin Effect’. The presence of fin-like exterior features act much the same as the cooling fins on a stereo amplifier in dissipating heat. In the case of a curtain wall façade in the winter…you don’t want to dissipate heat from interior to the exterior environment. Figure 185. ‘Cooling Fin’ Figure 185 depicts a vertical exterior fin attached to a curtain wall mullion with intermittent aluminum fixing blades. You can clearly see the cooling effect on the mullion pair as a result of the presence of the fixing blade. The NFRC specifies a method for calculating a reduced conductivity for intermittent elements. Using the NFRC’s terminology; the Building Physicist looks at conditions of intermittent attachment as being thermally slotted cross-sections. The method indicated involves weighting the conductivity of the blade in terms of the material it replaces and can be found in Chapter 8 of the NFRC Simulation Manual (Figure 186). It allows the Building Physicist to determine an adjusted U-Value based on the fact that the systems perform better in terms of thermal transmittance in the region without the fixing blades. There is generally more area without the blades than with, but that call must be made by the Structural Engineer. Figure 186. Inputs for Non-Continuous Elements The risk of condensation in the vicinity of the fixing blades presents a much more significant problem to the design team than that of increased thermal transmission. With one exception, Figure 187 depicts the same detail as Figure 185…Figure 187 below models the fixing blade at ‘full conductivity’. Figure 187. Cooling Fin with Blade at Full Conductivity As you can see, the temperature distribution throughout the detail has been affected significantly in an adverse manner. This is indicative of greater condensation risk and typical in designs featuring feature attachments. The differences between these two figures illustrate the obvious problem with analyzing a detail in two dimensions, when its composition varies in

Chunk from FAISS:once the critical value is exceeded the applicable transfer mechanism is convection. (5-6) (5-7) where: θ: angle of tilt of flat plate in degrees (vertical = 90°) g: force of gravity (9.8 m/s2) β: thermal expansion coefficient (3.43x10-3/K for air @ 20°C) ν: kinematic viscosity (15.11x10-6 m2/s for air @ 20°C) Ts: surface temperature (°C) Tfs: free-stream air temperature (°C) x: characteristic length (from sill to head, m) α: thermal diffusivity (1.9x10-5 m2/s for air @ 20°C) This number is particularly important in that it is used to calculate the resistance of the interior surface of a curtain wall unit to heat transfer. The Prandtl number is also very important where curtain wall is concerned; mostly because you need it to calculate the convective heat transfer coefficient for the interior boundary layer. It’s a dimensionless number that can be defined as the ratio of momentum to thermal diffusivity. If you’re like me that definition just makes your head hurt. If it makes it any easier; momentum diffusivity by another name is kinematic viscosity. Kinematic viscosity is the ratio of dynamic viscosity to fluid density and dynamic viscosity is a measure of the fluid’s resistance to internal shear stresses when it flows past a solid. So…kinematic viscosity relates the density of the fluid to the stress induced between the molecules of the fluid at the non-slip condition. Thermal diffusivity tells you how well a fluid conducts heat as a ratio of how well it stores it. It too is a function of the density of the fluid. What this all means is; the Prandtl number is an indicator of what happens to the energy in a fluid when it moves past a solid. If the number is big, then the fluid flows past the solid without converting the kinetic energy inherent in the flow into heat which isn’t conducted away. If the number is small, the forces result in heat which is stored in the fluid; a process which raises its temperature. (5-8) where: ν: kinematic viscosity (1.511x10-5 m2/s for air @ 20°C) α: thermal diffusivity (1.9x10-5 m2/s for air

Chunk from FAISS:SHGC as well. Equation 14-6 which follows serves as the general equation for calculating area-weighted performance in curtain wall. 14-6 where: UT: total product thermal transmittance (Btu/(h∙ft2∙°F)) Apf: total product area (ft2) Uf: frame element U-value (Btu/(h∙ft2∙°F)) Af: area frame element (ft2) Uge: glazing edge U-value (Btu/(h∙ft2∙°F)) Age: area glazing edge (ft2) Uc: center-of-glazing U-value (Btu/(h∙ft2∙°F)) Ac: area of center-of-glazing (ft2) Speaking of SHGC’s…this is as good a place as any to review just how they’re calculated. The methodology is presented in NFRC 200. The method for area-weighting the result of element SHGC’s is very similar to that used for U-values. One important exception is in the calculation of the SHGC for opaque elements of the unit…the frame and opaque infill. 14-7 where: SHGCf: frame solar heat gain coefficient (dimensionless) Apf: total product area (ft2) Uf: frame element U-value (Btu/(h∙ft2∙°F)) Af: projected area of frame element (ft2) As: ‘wetted’ area of the frame element (ft2) hout: exterior convective surface coefficient (assumed to be 5.284 Btu/(h∙ft2∙°F) α: absorptance of frame element (dimensionless…taken to be 0.5 for curtain wall) The second important exception is the fact that NFRC wants the fenestration community to use the software approved in NFRC 102 to calculate the ‘total product’ SHGC; a calculation based on a unit size and configuration only vaguely related to an actual unit. The NFRC’s component modeling approach is described in Section 5.9 of the latest version of NFRC 200. In this section; the analyst is directed to ‘Reference [10]’ for the calculation method for unitized fenestration products. My guess is; they were aiming at Reference [8] and hit Reference [10] by accident. Reference

**Title: The Rise and Evolution of Urban Public Transportation**

Public transportation systems are the veins through which the life of a city flows. From horse-drawn trams to driverless electric trains, the methods through which people commute in urban spaces have evolved dramatically over the centuries. This evolution has not only changed how cities look and operate, but it has also deeply influenced culture, economics, and the very pace of daily life. Understanding the history and current challenges of public transportation helps illuminate its critical role in shaping sustainable, livable urban environments.

The earliest forms of urban transit trace back to the 17th and 18th centuries when carriages were pulled by horses on fixed routes. These early omnibus systems were crude, often uncomfortable, and unaffordable to all but the middle and upper classes. However, they established the foundational idea: that moving people efficiently along shared paths could improve city life.

In the 19th century, technological advances such as steel wheels and rails enabled the introduction of horse-drawn trams. These vehicles were more stable, could carry more passengers, and required less effort from the horses. As cities grew during the Industrial Revolution, these systems became more widespread and more vital. But it was the electrification of streetcars in the late 1800s that marked a transformative leap forward.

Electric streetcars offered faster, cleaner, and more reliable service. They catalyzed the growth of urban suburbs by making it possible to live farther from one's workplace without depending on walking or personal transport. This decentralization of urban populations had long-lasting implications for urban sprawl and land use.

At the same time, underground railways began to appear in large metropolitan areas. London opened the world’s first underground subway system in 1863 with steam-powered trains. By 1890, it had electrified its lines, setting a precedent followed by New York, Paris, and other cities in the early 20th century. Subways were especially important in dense cities where above-ground space was limited and traffic congestion was a growing concern.

As the 20th century progressed, buses became increasingly common. Initially powered by gasoline, and later by diesel and natural gas, buses offered flexibility that fixed-track systems couldn’t. They didn’t require rail infrastructure and could adjust routes quickly based on demand or traffic conditions. However, this flexibility came with downsides — buses contributed to traffic congestion and emitted pollutants, contributing to deteriorating urban air quality.

In many American cities, particularly during the post-WWII era, public transportation suffered a decline. The rise of automobile ownership, spurred by affordable vehicles, expansive highway construction, and suburbanization, led to a decrease in public transit ridership. Investments shifted toward car infrastructure, and many streetcar systems were dismantled. Buses often became the only form of public transit available, and many urban rail systems were left underfunded or neglected.