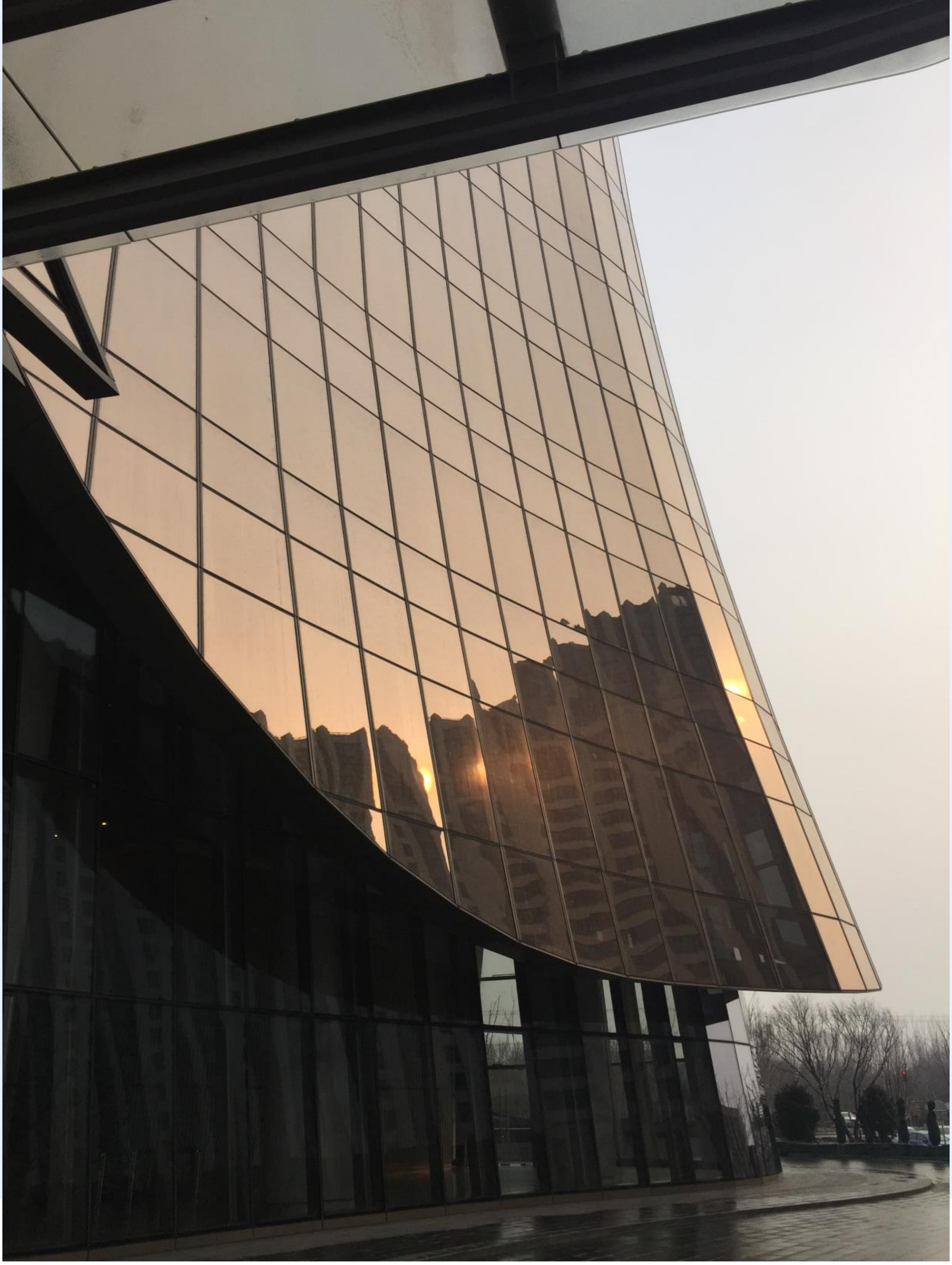

Reflected Heat – The Physics, Design Considerations & Responses

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While low-E glazing has been a revolution in terms of the energy efficiency and aesthetics of building façades, Senior Building Physics + Sustainability Engineer Lawrence Le and Building Physics + Sustainability Alexander Flatley consider the Physics, Design Considerations & Responses to potential reflected heat.

As architecture evolves and becomes increasingly more sophisticated, building façades have become a critical engineering consideration. The proliferation and evolving technology of low-emissivity (or Low-E) glazing has been a revolution in terms of energy efficiency and aesthetic. However, this can make glass more reflective as incoming solar rays interact with it. One of the unintended consequences due to the combination of these two occurrences under certain conditions is the possibility of concentrated solar reflected heat.

Remember the age-old cliché of kids playing around with a magnifying glass under the Sun, burning anything from paper to plants? Ironically, the potential for this phenomenon has been seen in recent years within the building industry, here in Australia but also on high-profile cases in several cities around the world. This can occur due to curved or faceted glass panels forming a concentration of solar energy into a small area or a focal point. A larger concentration of total light being reflected into a smaller area results in a higher intensity of solar concentration. Reflected heat presents another design challenge for design teams on some of the most ambitious projects and require an elevated degree of care in the design process.

Inhabit, a part of Egis Group, provides Building Physics services to guide architects, façade consultants, and building owners in understanding the effects of reflected heat in the built environment. Although uncommon, reflected heat impacts are seldom considered in planning requirements and the consequences of reflected heat are often therefore only realized after construction is completed. As such, there is an increasing need for a better understanding of the impacts that curved façades can have on the nearby environment, as uncontrolled reflections can potentially cause significant property damage or bodily harm.

Understanding heat

To understand reflected heat occurring from façades, we first must understand what heat is. Heat comes in three conventional forms:

- Conduction (through touch and direct physical contact);
- Convection (through heat transfer of fluids due to movement); and
- Radiation (from the Sun, in the form of ultraviolet radiation).

Radiation from our own star is the source of radiative heat. In the context of glazing, a portion of solar radiation is transmitted to the opposite side, a portion of it is absorbed through the glass pane and the remainder is reflected. While glazed façades are subject to solar reflectance, the same is true for polished metal surfaces which have a low surface roughness and reflect light in a specular manner (mirror-type reflections). This differs from diffuse reflections, which occur due to rough surface finishes and are much less perceptible to the human eye.

Reflected Heat

The sun emits electromagnetic radiation over a continuous range of frequencies that can be broadly categorized into ultraviolet, visible, and infrared radiation. While the visible light spectrum contributes to reflected glare, infrared radiation is the key proponent of reflected heat. Irradiance is conventionally used to measure the intensity of reflected heat, with units of Watts per square metre (W/m2). For reference, a typical day in summer with no cloud cover reaches approximately 1000 W/m2 when the sun is directly overhead.

To pursue energy efficiency requirements, modern reflective glazed façades often have high-performance coatings that can reflect sunlight to reduce the transmission of solar gains into the building. The reflected solar radiation can therefore lead to unintended thermal issues to external pedestrians or properties. Curved facades are especially prone to reflected heat impacts, as the curvature can result in the overlapping of reflections at a focal point where the cumulative irradiation is excessively high.

It is crucial how local governments, councils and approval authorities prescribe the issue of reflections occurring from glazed façades for building permits and development applications. The requirements that authorities set in relation to this vary drastically by jurisdiction, with some projects requiring a detailed analysis to show the frequency of occurrence or some not at all.

The criterion for what constitutes an acceptable level of reflected heat is not well defined in many planning requirements, if at all. For example, the Solar Convergence Planning Advice Note published by the City of London (2007) recommends that reflected irradiances above 1000 W/m2 are minimized for areas at street level where pedestrians may be present. Many planning authorities, however, only provide broad wording that seeks to limit adverse reflected heat without specifying a particular methodology or compliance threshold. Instead, expert judgement or advice is typically relied on to ensure that the risks of reflected heat have been mitigated or controlled.

While light fundamentally is a wave and each ray of light can carry varying wavelengths, it is ultraviolet waves (approximately 100-400nm in wavelength), not visible light (400-700nm), that gives light properties of radiative heat. While some states such as Victoria provide guidance in the planning stages around concave façades1 and “discomfort glare”, current prescriptive conditions such as a limitation on reflectiveness of façade materials (typically 15% or 20% specular reflectance) are not conclusive to ensure that the risks can be fully eliminated. The necessity for assessing the possibility of reflected heat typically comes down to a number of factors, including, but not limited to:

- The overall extent of the concavity of the façade;
- The orientation of the concavities of the project;
- The probable locations of where the solar concentration may occur and how people would interact with the space; and
- The probability how a solar concentration would adversely affect the functionality of a space adjacent.

The most beneficial time to assess concentrated reflected heat is in the early stages of the design when the building's vision and architectural massing is still being developed. Inhabit can assist clients with understanding the potential impacts of a curved façade and provide feedback on suitable parameters to control reflected heat concentrations while achieving the design intent.

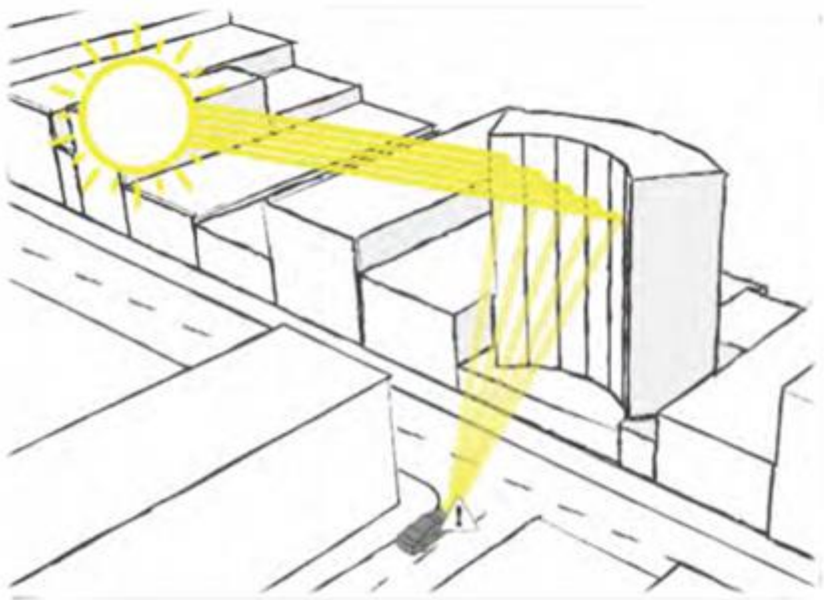

Illustration of incoming solar rays reflecting into a focal point onto an incoming vehicle (Source – PPN96: Glare and reflectivity1).

The other important question is what is a reasonable metric for measuring reflected heat? There is no explicit or widely accepted industry standard for this currently. Physiologically, the human body perceives heat and pain in response to solar radiation. Inhabit's experience with working on projects with reflected heat occurrences is to take into consideration areas that are likely to be trafficked by people or vehicles, or for surrounding buildings and infrastructure. Useful metrics adopted by Inhabit include the following:

800 to 1,200 W/m2 is a typical range of incident solar radiation2. This can vary between climates and seasons.

1,000 W/m2 is considered a threshold of tolerance by a fully clothed person3. This is also the intensity where, within 115 seconds, on onset of pain onto bare skin is expected4.

1,500 W/m2 is considered a threshold of pain on human skin3.

2,500 W/m2 and higher is where pain and skin damage is expected within 30 seconds5.

One example in the world is the infamous 20 Fenchurch Street, located in London, United Kingdom. The reflected heat effect is much more pronounced given the façade is not only concave in plan, but concave in elevation and resembles a glazed curtain wall façade. This led to reported temperatures of up to 91.3 degrees Celsius being reflected from the façade6. It was reported that components of a parked Jaguar vehicle had melted due to the concentrated heat and simulations from Imperial College London showed that peak heat flux have been as high as 3,320 W/m2 within this parking bay7. The project was ultimately remediated by redesigning the façade, which included extensive shading elements needing to be retrofitted and engineered into the design which geometrically prevent solar rays hitting the façade or being reflected to the surroundings. While an extremely costly exercise to retrofit shading previously eliminated from the building design, this was a valuable lesson to the industry of how reflected heat can occur when unmanaged.