Through the Looking-Glass:

A Report on Efficiency of Window Glass and Coatings

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Introduction

Everyday we use them. Everyday we see them. They are like gateways to the outdoors or signs of protection against nature, but they are not foolproof in the least. We are talking of course of windows, a critical architectural technique to bring the great outdoors inside and put life into otherwise drab dwellings. Since the introduction of windows into architecture, they have been seen as a thing of luxury. This is a legitimate statement because it is simply more difficult to build a stable structure with a large hole in the sidewall. It also makes sense because windows are a major breach in the structure's integrity. Before glass was available on a commercial level, windows were only suitable in areas of mild to warm climate and there their main function was to cool the interior space. Glass is an obvious choice to fill these structural openings, optimal because of its clarity and strength. This glass, however, has several drawbacks in its use. For example, windows, even with glass, are cause for an average of 25% of a house's heat loss during the winter. Since windows have been such a critical component of our homes and businesses for so long, it only seems appropriate for them to be focus of a great deal of our interest. In this paper we intend to pursue the history of glassmaking and focus on a major breakthrough in the protective ability of glass, labeled Low-E coatings (of which more will be shared later). We will discuss the pros and cons of the production processes and the actions being made to make these processes less impacting on nature and we will propose a possible alternative to common glass and discuss its strengths and weaknesses. We hope to illuminate different possibilities for the protection of our interior spaces without sealing them entirely from outdoor conditions.

The impact of the natural world on human beings is something that is undeniably beneficial. For centuries exposure to light and fresh air have been used as remedies to several ailments that have stricken humans. Even today there is a marked increase in productivity in workers when they are exposed to the natural world through either natural light or visual contact[1]. To compound this, many corporations are beginning to see the frugality in natural lighting. If one lets the sun do its job and allows it entrance into the places the people are, then they will not have to use energy to artificially light that space. The implications of this are that industries are using less energy for the running of their buildings, but there is another side to this development.

For millennia windows have been a passive agent in the heating and cooling of interior space, but there is a new passive ability that technology has granted to glass. Insulation. It is now possible to have a glass window with an insulation value similar to that of the surrounding wall and sealed tight enough to not allow noticeable airflow when closed.

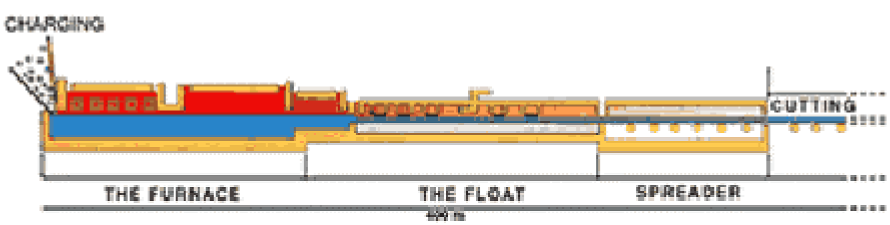
As you can see, there is a great deal riding on the integrity of our windows. Technology has been friendly to the usage of windows, however all sides of the conversation must still be heard to properly discern whether or not these new technologies are truly benefits for the world as a whole or just to specific uses in our private lives. We must consider the overall impact on the earth, what goes into making the materials, applying the materials, what happens after the materials are at the end of their useable life, and what happens to/ what are the leftovers from production. We will

[1] Lockheed Martin showed a 15% increase in productivity after implementing natural lighting into their assembly area and annual energy savings of $500,000.

investigate these things in our paper and we hope to expose the true consequences of this window technology.

The Making of Our Glass: The Float Glass Process

Throughout history the possession of glass was a sign of power and wealth. Glass was a very difficult thing to produce and to possess because of its brittleness and the extreme conditions necessary to form it. Seldom would it be possible to produce glass of the same quality more than once because there was no way to control the conditions with the necessary consistency. All of this changed in 1959 when a Brit by the name of Alaistair Pilkington devises a method of producing glass that not only gave consistency to the process, but uniform products. According to Pilkington's method the materials for the glass, namely silica sand, soda ash (or fly ash), limestone, aluminum, and salt are to be introduced to a furnace heated to 1500 degrees Celsius. Under this intense heat, the ingredients melt together to form one slightly viscous substance. This substance is then



pushed by the pressure of new ingredients added onto the "float," which is basically a large vat of molten tin. Since the tin is in liquid form as well, and the two materials do not mix, the bottom surface of the glass (in contact with the tin) is perfectly flat, as is the top surface, which was leveled by gravity itself. From here the new sheet of glass is led to the spreader, which cools the glass and makes sure that the thickness of the pane is uniform. After that the glass is ready to be cut and distributed. This process occurs rather quickly by comparison to other "cooked" products, the entire process taking a little over 2 hours. This quick process is in part due to the fact that glass does not crystallize when it cools; it is an amorphous substance, which means simply that it does not have a defined crystalline structure. A side effect of this is the transparency of the material, which makes it so desirable.

This production method, though ingenious and extremely good at utilizing the natural forces present on Earth to do some of its work, is extremely energy intensive. There are currently over 260 float glass plants in the United States alone, running almost constantly to feed our need for glass. This shoots a large amount of carbon dioxide and sulfur dioxide into the air, contributing to decaying air quality across the nation. Maintaining a steady temperature of 1500 degrees is a very difficult thing to do, not to mention protecting workers from that kind of heat and maintaining equipment that must be at that heat for a great deal of time. Another side effect of the float process is a great deal of leftovers from the furnace. As the materials melt together, the heavier substances and the imperfections sink to the bottom of the vat, producing a material called *cullet*. Cullet is very low quality glass scraps that often have a high level of barium or arsenic in them, making them undesirable for commercial use. These pieces have been, in the past, land-filled after their removal from the furnace or neutralized by being encapsulated in concrete; however the Corning Company has recently been researching possible uses for the cullet produced by the ton at float glass plants. They have tested, with positive results, methods of removing the metals and imperfections from the cullet and reusing the silica materials as well as using the grainy leftovers for fill in concrete amongst other applications. Across the European Union there is beginning to be a push to regulate the emissions from glass production plants and control the contaminated industrial water used to cool the machinery throughout the process. These are good steps in the right direction, but until we can find a way to eliminate the impact of such an intensive process, glass making will carry with it a heavy burden.

Compounding the Impact: Hidden Inefficiencies

After the manufacturing process is over one would think that the product would be free of consuming any more energy because it is a passive agent in your home, it is something that will never get plugged in or filled with fuel. But glass is a silent user of energy in the inefficiencies built into the pane. Since glass is a fairly dense material it conducts heat and cold very well, meaning that there is less than you thought between you and the outdoors conditions. Imagine a cold night with an outside temperature of 0 °F and a 15 mph wind. The inside temperature of a single pane window would be approximately 26 °F. This puts increased stress on your home's heating and cooling units, thus costing you a significant amount. Also, regular glass has no protection against the ultra-violet and infrared rays of the sun, rays that can damage the fabrics of your furniture, the colors of your paints, and the skin of your family members. These are the barriers that have kept windows out of many applications. Some manufacturers have tried double-paning their windows, but with moderate success. On the same cold 0 °F night the temperature inside of the double-paned window would only be around 35 °F. During the 1970s, however, there came a significant breakthrough in the insulation and protection of window spaces, and that breakthrough was called Low-E.

Lessening the Impact: Low-Emissive Glass Coatings

The concept behind Low-E coatings is deceptively simple: Put another layer between you and nature. The unique part is that this layer is only a few atoms thick. By taking advantage of unique reflective characteristics of aluminum oxide (Al_2O_3) or alumina we are able to establish a coating that is friendly to direct warming rays (infrared) from the sun, but not from other heated objects that absorb that energy, such as the Earth's surface. Low-E glass reflects this lower form of heat energy. In the summer this helps to keep your house cooler, as the heat from objects outside is kept outside. In the winter, all objects in your home are heated by sunlight or your heating system. As this heat is radiated by the objects towards the windows it is reflected back into your house by the low-E glass. Since the layer is merely a couple of atoms thick on the glass, there is no real visible difference except for a slight tint, but the performance of the window is drastically different. The improvements in performance are compounded by double-paning of this glass and filling the dead air space between the panes with argon gas, a noble gas that is notoriously reluctant to conduct heat. If you remember our previously mentioned 0 °F day, the temperature on the inside of a double-paned Low-E window with argon gas in between would be between 50 and 60 °F. This 25 °F temperature increase shows how significant the impact of putting intelligence into your windows can be. Not only will this technology keep out the cold, but it will also keep the heat that you pump into your home inside of it. Of come concern would be the presence of the argon gas in the windows, which slowly leaks out from in between the panes after a period of time. Argon gas is not flammable and is often used in fire extinguishers because it is an asphyxiant, a gas that can cause an extreme decrease in the concentration of oxygen in an area or in the human body. However, in the levels that it is present in Low-E windows, many people, save those that are very sensitive, would not be affected.

Pros and Cons

Many of the technical differences between regular and Low-E glass have already been mentioned, but why should someone invest in one or the other? When Low-E windows debuted in the late 1970s the treatment was rather expensive and could only be applied to windows after production, meaning that the glass itself was not designed to have this layer on it. Some of these layers would rub off or simply wash off over the years, but new technology allows this coating to be bonded with the glass during production or post-production, using more specified techniques to ensure resilience of the coat. Since the early 1980s the price has dropped significantly so that now a Low-E treated window will only cost you $0.11 per square foot of glass. This minor investment pays for itself over and over again through savings in heating and cooling. These windows are not permanent though. The argon gas, as we mentioned earlier, leaks out from in between the panes of glass, causing the need to replace your windows every 20 years or so to maintain the insulating qualities. All of a sudden the cost increases. Also, the application of the alumina to the exterior of the window contaminates the glass, making it more difficult to upcycle to other windows or higher forms of glasswork. Low-E coatings do very little to improve the structural strength of glass as well, so even though you have invested more into your windows, they will break just as easily. This is one of the major drawbacks of glass in general, but a threat that is accepted due to the lack of appropriate alternatives. Perhaps we should look into other possibilities for the panes of our windows!

Coming Change

For millennia glass has been the standard for the sealing of window spaces. It has developed significantly through that time to its present standardized and normalized form. Although these advancements have improved the quality of the glass and its overall performance, little can be done to improve the method by which it is manufactured. This highly energy intensive process has been the mar on the face of glass making since its introduction to the world. Is it possible to produce glass by a different means? Some artists use the power of lightening to provide the impetus for the formation of glass; however, for commercial endeavors this is unrealistic. No one is going to wait for a thunderstorm to put windows in their house. Across Europe new standards are being introduced to help make these huge furnace plants more environmentally friendly, but the nature of the plants themselves is an impact, how can this be remedied?

One answer to this question could be to look elsewhere for your window needs. There are several polymers out there that behave very similarly to glass and even have better insulating and impact resistance characteristics than the industry standard. One of these polymers is called polymethylmethacrylate. This polymer has the desirable characteristic of being scratch resistant and completely transparent. Requiring a great deal less embodied energy to produce, and being completely recyclable into new windows, polymethylmethacrylate is a definite option for anyone who is looking into alternatives to standard glass panes. Because it is an acrylic polymer it is produced from acrylic acid, a known corrosive substance and an unstable one at that, production of windows using polymethylmethacrylate would not be without its critics. If one were thinking, however, of how to make a product’s life go beyond its own useful life, it would appear to us that the best way to do that would not be to add different chemicals and treatments to that product, but to alter the product in a way that would allow it to be reused into its original form. Polymethylmethacrylate has the capacity to do this while treated glass does not.

Although polymethylmethacrylate seems to be a promising horizon in the industry, it is still undesirable to have "plastic" windows in your home. The industry standard is strong as well, and as long as advancements in glass window technology continue to occur, alternatives will not be invested in. With the current push for more environmentally responsible products, however, polymethylmethacrylate and traditional glass will have to duke it out as to which is less damaging to the environment. Both of them have significant benefits to their use, major drawbacks to their production, and limitations to their reuse. Performance for both is comparable, so it may come down to a decision of preference.

Conclusion

The face of industry is changing, that is something that cannot be refuted. People are becoming more environmentally aware and are listening to what environmental scientists are saying about our current situation. We believe that this frontier is going to be one that produces great advancements for the human race, advancements that could solve the now prominent insulation and day lighting problems that plague windows. This is already happening, but the potential for continuing progress is enormous. We are very excited to have had an opportunity to educate ourselves in this way and are looking forward to maintaining a status of involvement in these issues through the years.

Thank you and have a great break!

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