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ENERGY & ENVIRONMENT DIVISION

Technology Reviews: Glazing Systems

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E.S. Lee, and S. Selkowitz

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TECHNOLOGY REVIEWS : GLAZING SYSTEMS

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Executive Summary

We present a representative review of existing, emerging, and future technology options in each of five hardware and systems areas in envelope and lighting technologies: lighting systems, glazing systems, shading systems, daylighting optical systems, and dynamic curtain wall systems. The term *technology* is used here to describe any design choice for energy efficiency, ranging from individual components to more complex systems to general design strategies.

The purpose of this task is to characterize the state of the art in envelope and lighting technologies in order to identify those with promise for advanced integrated systems, with an emphasis on California commercial buildings. For each technology category, the following activities have been attempted to the extent possible:

- Identify key performance characteristics and criteria for each technology.
- Determine the performance range of available technologies.
- Identify the most promising technologies and promising trends in technology advances.
- Examine market forces and market trends.
- Develop a continuously growing in-house database to be used throughout the project.

A variety of information sources have been used in these technology characterizations, including miscellaneous periodicals, manufacturer catalogs and cut sheets, other research documents, and data from previous computer simulations. We include these different sources in order to best show the type and variety of data available, however publication here does not imply our guarantee of these data. Within each category, several broad classes are identified, and within each class we examine the generic individual technologies that fall into that class. Each technology section has the following format:

I. TITLE PAGE & CONTENTS

II. SUMMARIES

- Summary descriptions for each technology.
- Summary table(s) showing comparative performance characteristics or other comparative information.
- Brief discussion/summary of the most promising technologies and trends in this category. Emphasis is on electricity peak reduction and on potential for integration with other systems or technologies.
- List of product brand names for each sub-category.

III. DATA ENTRY FOR EACH TECHNOLOGY

Each sample technology is characterized through one or more of the following. Sections may deviate as required:

- Description
- Sources
- Status of availability
- Pros and con
- Energy performance
- Comfort performance
- Impact on building design
- Cost, per unit basis
- Life cycle cost economics
- Market share, expected trends
- Case study installations

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TECHNOLOGY REVIEW: GLAZING SYSTEMS

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GLAZING SYSTEMS: SUMMARIES

OVERVIEW

Glazing is a primary factor in the radiative, convective and conductive heat transfer through the building envelope and can be used to control or limit each of these energy flows. It is also the primary component in fenestration systems affecting the admission of natural light into buildings and thus critically affects the potential of energy savings through daylighting. Glazing is perhaps the building material with the broadest range of impact; its selection will affect all of the issues below.

Glazing impacts:

Operating costs:	• Energy use. • Peak electrical demand.
Developer concerns:	• First costs for HVAC and lighting. • Floor space required for HVAC.
Market value:	• Occupant comfort. • Facade appearance. • Window area. • View.

Existing and emerging glazings, and the development of future glazings, currently fall into three performance goal categories for improved energy efficiency.

Glazing performance goals:

- Reduce solar gain in cooling conditions.
- Reduce heat loss in heating conditions.
- Increase and or redirect visible transmission in daylighting conditions.

To meet these design strategies, research and development in glazings has branched into three areas of performance control. New glazing developments generally address one or two of these.

Glazing control strategies:

- Spectral control
- Intensity control
- Directional control

Heat loss is not a major issue in most California climates, so the focus of this review is towards daylighting and control of solar heat gain.The high energy intensity of direct solar radiation makes it by far the most significant external source of cooling loads. Direct solar radiation contributes to cooling loads in transmission through fenestration and, at a lower rate, in absorption by the building envelope to be re-radiated to the interior. Most strategies are thus directed towards preventing primarily the transmission of direct solar radiation through building fenestration and secondarily its absorption by the building envelope. However, daylight admission through fenestration can contribute towards the required levels of interior illumination, allowing reduction of electric lighting energy. In addition, daylight offers an overall better efficacy, i.e., lumens/watt, than electric lighting and can reduce cooling load if used correctly. Energy savings may then be realized from reduction of both lighting and cooling requirements.

Glazing technologies to reduce cooling loads are directed towards decreasing primarily solar transmittance through the glazing and secondarily solar absorptance by the glazing. Generally, these strategies do so at the cost of visible transmittance. However, since transmission of the visible part of the solar spectrum may be desirable for daylight utilization (as well as for view, facade appearance, etc), the latest glazing technologies are directed towards materials which are selectively transmissive and reflective. Solar radiation at sea level is approximately half visible light and half heat, with a small percentage in the ultraviolet range (fig.1). New glazing technologies are being tuned to respond differently to various wavelengths within the solar and blackbody spectra (fig.2).

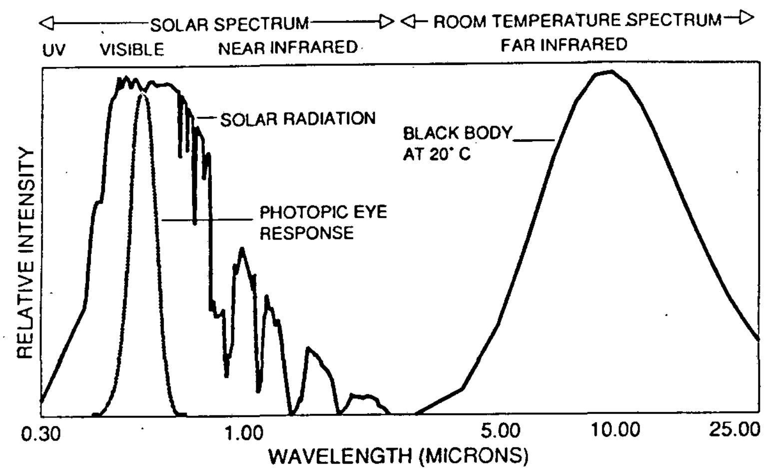

Figure 1: Typical intensity per wavelength of solar radiation at sea level, with normalized spectral distribution of radiation from a room temperature emitter and relative spectral sensitivity of human photopic visual response. Horizontal scale is logarithmic.

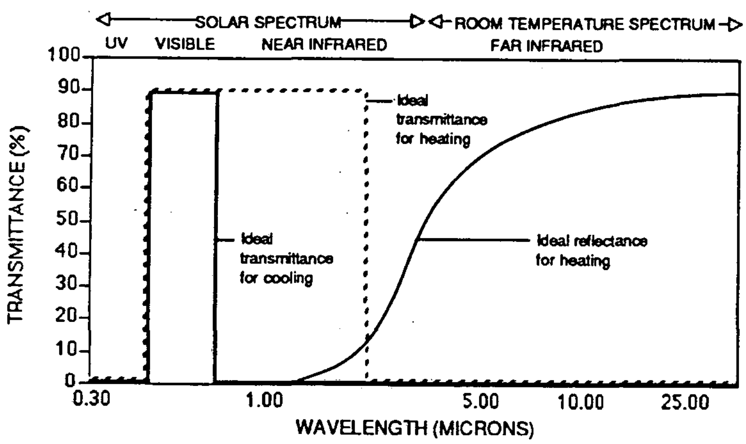

Figure 2: Ideal (theoretical) spectral response of glazings depending on dominant thermal requirements of the building, for glazings with static properties. Dynamic glazings vary these properties for the particular conditions at any given time to balance the lighting and cooling requirements.

Selective transmission means theoretically up to half of the solar energy striking the glazing can be rejected, with minimal loss of light. An index of spectral selectivity has been defined as *luminous efficacy* (K_e), which is the ratio of visible transmission to shading coefficient (Arasteh 1986). Manufacturers have begun to use this metric in their product literature, with terms like "coolness index" or "light coolness." Clear glass is almost evenly transmissive through the solar spectrum and thus has a K_e of 1.0. The effect of many tints and coatings is to lower shading coefficient more through visible transmission reduction than infrared, resulting in a K_e between 1.0 and 0.5. Low-emissivity coatings and some tints have the opposite spectral response, for a K_e between 1.0 and 1.5. In general, for a given shading coefficient and assuming the use of daylighting controls, the higher the K_e the better. There is a physical limit to K_e before degradation of color neutrality, in the range of 2.0 (fig.3).

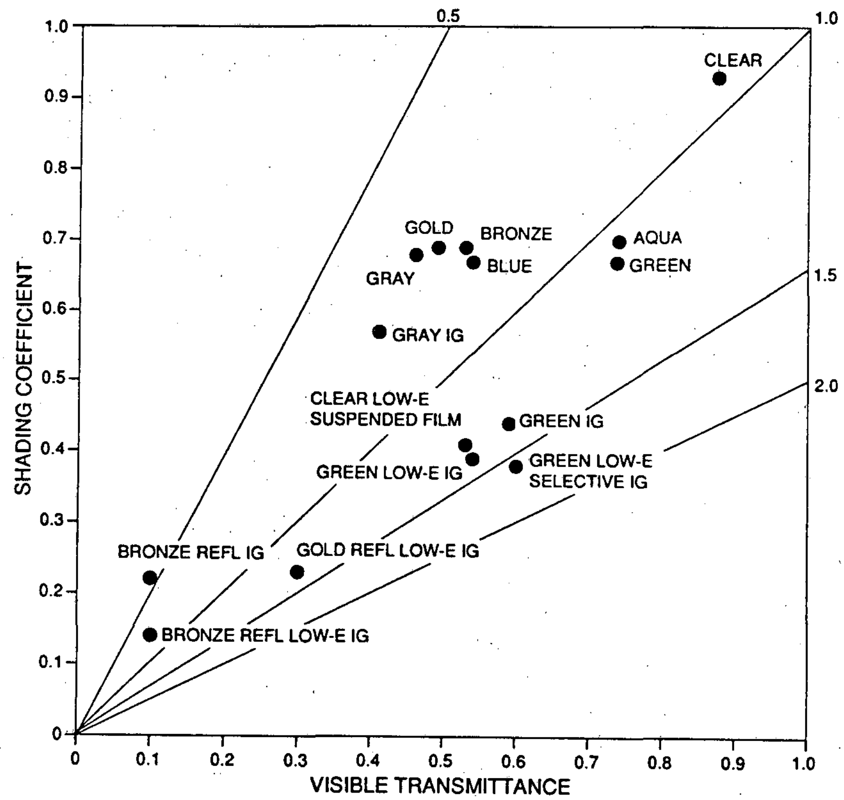

Figure 3: Luminous efficacy of some sample glazings. Diagonal lines indicate Ke constants.

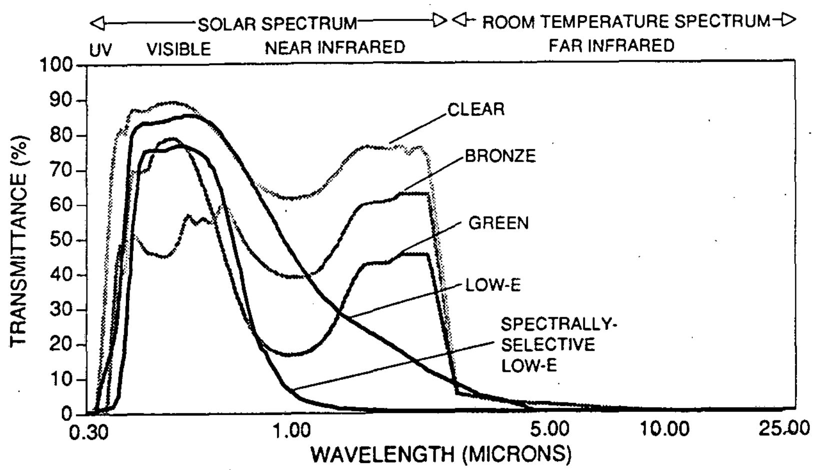

Figure 4: Spectral transmittances of glazing materials. Green and blue tints tend to be naturally selective in favor of daylight, while bronze and gray tints are the opposite. Low-E coatings, while originally developed to increase reflectivity in the far infrared (spectral reflectivities are not shown here), are also naturally selective for daylight. Low-E coatings are now being tuned to further reduce transmission of solar heat.

The architectural impact of spectral selectivity is found in greater design freedom of fenestration apertures and a greater range of glazing options for less trade-off penalties between design criteria. For example, in a given building design, the selection of a highly selective glass (i.e., maximum ratio of visible transmittance to shading coefficient) over a traditional product yields the following possibilities:

- A clearer view without affecting cooling load.
- Larger window area without affecting cooling load.
- Lower cooling load without affecting view clarity or window area.
- Potential of installing daylight controls.
- Improved daylighting savings.

Such glazing systems, accomplished through finely tuned tints or through modified versions of low-e coatings, have already penetrated the building industry and are expected to substantially replace conventional glazing in time. In the case of low-e coatings, an industrial advantage contributing to quick market penetration is that the same basic technology can be used for both heating and cooling applications by slightly tuning spectral response of the coating and also by changing the position of the coating in the window assembly. In heating applications, spectral properties of the coating are designed to admit solar heat and reflect interior heat, and the coated surface is closer to the room side of the window assembly. In cooling applications, the coating is tuned to reject solar heat and is applied closer to the exterior side of the assembly (fig.4).

The latest research in glazing technologies is directed towards glazing systems of controllable variable solar-optical properties, which can be adjusted according to variations in outdoor and indoor conditions. Because both desired indoor environment and the outdoor solar and temperature conditions can vary over a wide range and within short periods of time, optimal energy and comfort performance indicates glazing properties be dynamic. Research and development in "switchable" (chromogenic) glazing technology is promising, however is is expected that such technologies will not be commercially available until 1995 or later.

With conventional glazings, the focus remains on either solar control or insulation. Current practice with respect to solar control includes three general classes of glazing : clear, tinted/heat absorbing and reflective. Clear glass can also be combined with solar control films to offer similar performance to tinted and reflective glazings.

Other efforts in glazing technologies address conductive and convective heat loss. Single pane windows in inexpensive highly conducting frames are the most prevalent in California commercial buildings, almost always for cost reasons. In buildings with extremely high internal loads, it is advocated by some designers that such systems aid the annual cooling energy by allowing internal heat an easy route of escape. For improved insulation or comfort attributes, current practice includes double or triple glazed (rare in commercial buildings) systems, where the air spaces between layers function as insulating barriers. Highly transparent low-emissivity coatings originally developed for cold climate applications have some value in commercial buildings in any climate to reduce perimeter losses and improve comfort. Leading edge technologies utilize special gas fills with better insulating properties than air. Moreover, gas fills improve the performance of low-emissivity coatings (which reduce radiative heat transfer) by reducing conductive and convective heat transfer. These coating and gas fill combinations are becoming more widely commercially available but are greatly underutilized in commercial buildings. Combinations of multi-layer glazing systems with gas fills and low-emissivity coatings represent opportunities for "super windows," which have the visible transmittance of clear glass and the insulating properties of exterior walls. A significant additional benefit of highly insulating glass is the elimination of perimeter heating. Prototype units have been tested in demonstration buildings and several manufacturers are now offering commercial products.

As glazing technology advances, the choice of glazing perhaps will no longer be an independent decision that forces other design decisions (HVAC most notably) around it. Glazing decisions may soon evolve through an iterative process concurrent with HVAC, lighting, and other design decisions to find the best combination of all building elements. In general, the following categorizes possible glazing options by performance strategy:

1. To reduce cooling load, improve cooling comfort, reduce peak electric demand:
   - Active modulation of transmittance (chromogenic materials).
   - Passive rejection of solar radiation (tints; films; spectrally and/or directionally selective materials).

2. To increase daylight:
   - Spatial and spectral control (spectrally and/or directionally selective materials).
   - Glare control (chromogenic materials).
   - Daylight intensity control (chromogenic materials).
   - Light collection and distribution (optical systems: concentrators and guides).

3. To reduce heat loss:
   - Inhibit conducted, convected and radiated heat flow (low-e coatings, gas fills, evacuated spaces, transparent insulation materials).

CAPSULE SUMMARIES

1. TINTS

1.1. STANDARD TINTS

Tinted glass utilizes absorbing materials dispersed throughout the glass itself, to lower the shading coefficient of clear glass. These materials absorb in all wavelengths of the solar spectrum, however tinted glazing is often called "heat absorbing" because that is the characteristic most responsible for its energy performance characteristics. Tints also give color to a glass, which is the dominant characteristic examined for architectural selection. Heat absorbing glass is classified by color and is most widely available in grey, bronze, gold, blue and green. Other varieties are also available, and for all categories there exists a wide range of shading coefficient and visible transmittance properties. Tinted glass can also be combined with coatings, typically reflective or low-e, for an even greater range of available properties. The total absorptance is a function of the absorbing material and the thickness of the glass, with thicker glass providing greater absorption and less transmission. Grey glass will transmit approximately equal amounts of visible light and infrared solar radiation. Bronze glass, because it uses different absorbing materials, generally transmits more infrared solar radiation than visible light. Blue and green glass act in the opposite way, with much higher light transmittance than infrared solar transmittance. All of these glazings are commonly used, although often not effectively for performance optimization.

1.2. SPECTRALLY SELECTIVE TINTS

The natural selectivity for visible light of the blue and green family of tints has been exploited and extended in some new products. These are currently available but are still too new on the market for widespread application. Spectrally selective tints, used on their own in single or multipane assemblies, are limited in efficacy improvement potential and may not move much beyond the current K_e maximum of 1.18 for commercial single pane tinted products. Further daylight selectivity can be achieved through the addition of low-e coatings, which are usually used in insulating glass units (although pyrolytic low-e coatings may be applied to monolithic glazing). The application of conventional reflective coatings to tinted glazings generally reduces K_e.

2. COATINGS

2.1. LOW-EMISSIVITY COATINGS

Low-emissivity coatings, often referred to as "low-e," consist of very thin, transparent layers of metals and oxides deposited on glass or plastic. These coatings work by reducing the ability of the material to transfer heat through radiation. The material works much like the inside of a thermos bottle to reflect long-wave infrared back to its source. These coatings were originally designed to improve insulation performance in cold climates, by maximizing solar transmittance and longwave reflectance. Uncoated glass is highly absorptive in the far infrared, and it re-radiates absorbed heat both indoors and out; low-e coatings transform absorption into reflection, thus reducing overall heat transfer (fig. 5). Short wave solar heat is admitted into the space while long wave heat re-radiated from warm indoor surfaces is not allowed to escape back outside. These coatings are functional in warm climates as well, where longwave radiation from warm surfaces outside is not admitted through the glass. There are two major general types of low-e coatings. Pyrolytic coatings are a single layer of doped metallic oxides that are normally applied to glass as part of the float production process. Sputtered coatings are applied after glass production in a vacuum chamber and are built in multi-layer stacks, where the metallic heat-reflecting layer is sandwiched between two anti-reflective dielectric coatings to maintain light transparency. The original low-e coatings permitted transmission of the full solar spectrum, which remains the case for solar heating applications. For cooling applications, see the next section. Low-e coatings can be combined with tints, other coatings, and gas fills.

Low-e coatings first became available in 1981 and have steadily increased in market share ever since. As of 1991, they have captured over 30% of the residential market and a smaller but growing share of commercial windows as well. Low-e has experienced one of the most rapid industrial acceptances for a new building technology.

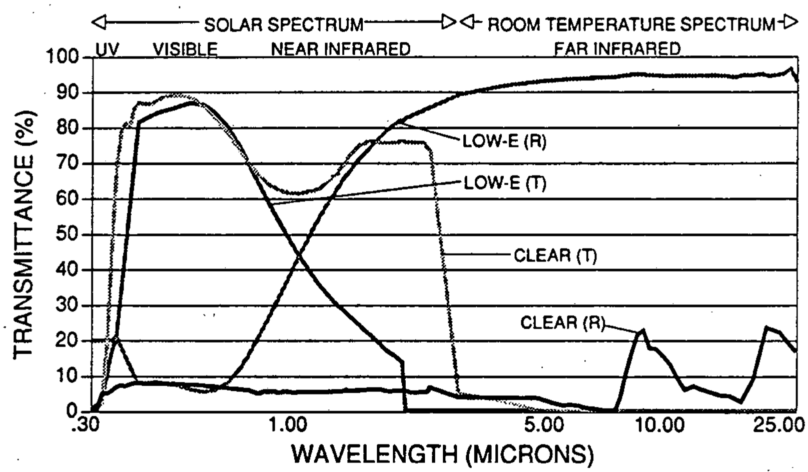

Figure 5: Transmittance and reflectance of uncoated glass and glass with a low-emissivity coating.

2.2. SPECTRALLY-SELECTIVE LOW-EMISSIVITY COATINGS

Since the original low-e coatings were highly transmissive to solar radiation, they were not as suitable for warmer climates or for most commercial buildings. However, since transmission of the visible part of the solar spectrum may be desirable for daylight utilization, the latest glazing technologies are directed towards selectively transmitting visible light and reflecting solar infrared. Such leading edge glazing systems, which started as modified versions of low-emissivity glazings, now include coatings on both clear and tinted glass for even better performance. The units can also include reflective coatings and gas fills. Several glazings that have significantly higher daylight transmittance than overall solar transmittance are now commercially available. The most daylight-selective product available today in a low-e IGU has a K_e of 1.58. Such products have begun to penetrate the building industry at a slow rate, because most designers are still unaware of their existence and because the cost of these units is higher than standard practice glazing. In general, selective coatings are more desirable than nonselective coatings, for most commercial buildings in virtually all California climates. Once fully developed, these coatings will offer designers a full range of aesthetic options with solar gain reductions of 30% to 50%.

2.3. REFLECTIVE COATINGS

Reflective glazings utilize a surface coating that may be deposited any number of ways to reflect and absorb incident energy. Reflective coatings are standard practice, and they can be deposited on either clear glass or tinted substrates. The properties are highly dependent on the materials used for the coatings and the process by which they are deposited. These in turn vary widely depending on whether the coating must survive in an exposed environment or whether it will be protected in the air space of a double glazed unit. The higher performance coatings generally are metallic films and require some protection within a sealed glass unit. Reflective coatings are generally poor in daylight selectivity (K_e = .5).

3. FILMS

3.1. SOLAR CONTROL RETROFIT FILMS

The shading coefficient of an existing glazing can be increased by gluing solar control film to it, for example to convert clear glass to tinted or reflective glass. Tinted and/or aluminized polyester solar control films for retrofit were first introduced in the early 1960s. Various metals can be used to control color or reduce shininess. Newer coatings have improved in spectral selectivity, and films are also available with low-e coatings. See the Shading Systems Technology Review for further information.

4. PLASTICS

4.1. PLASTIC GLAZINGS

Plastic glazings were originally developed as safety glazings, for the greater strength and impact resistance of plastics over glass. Plastics are now widely used for other advantages beyond these, including sound abatement, thermal insulation and ease of manipulation into curves and shapes. Many of the coatings and additives used with glass for increased performance or for coloring can also be applied to plastics. However, because plastic glazings are less rigid and less dimensionally stable than glass, it is currently not possible to apply low-e films to them. The plastics industry is examining market demand and feasibility of this, and may eventually develop low-e plastics (Olson 1991). Plastic glazing is available in either acrylic or polycarbonate sheet. Extruded, multichamber plastic panels are also available, when added strength is desired and a clear view is not important.

5. FILLS

5.1. GAS-FILLED WINDOWS

The insulating value of double and triple glazed systems is attributed to the air trapped between glass layers. To further increase the insulating properties of such systems, air is replaced by low-conductance gases. Argon is the gas most commonly used, and the more expensive krypton and sulfur hexafluoride are used as well. Gas-filled units have to be hermetically sealed and able to contain the injected gas over long periods of time. Widely used in Europe, these products are still leading edge in the U.S.. Gas fills provide the greatest benefit when used in conjunction with low-emissivity coatings.

5.2. EVACUATED WINDOWS

The "fill" strategy with the lowest conductance would be the use of a hard vacuum between low-e coatings. However, the long-term integrity of seals and the structural stability of the unit (keeping it from collapsing due to pressure differences) has proven difficult to master in a cost-effective manner. Research is continuing in this area.

5.3. TRANSPARENT INSULATION MATERIALS (TIM)

TIM permits opaque, insulated facade elements to admit light and/or solar heat without sacrificing thermal properties of the envelope. Transparent insulation can be used to significantly inhibit heat loss across transparent/translucent building openings, or it can be used in combination with a darkened, heat-absorbing surface to turn the fenestration system into a passive solar heater. Two main types of TIM exist.

Aeogel is a type of TIM that has been known for more than 50 years. Aerogel is a microporous silica matrix that traps air in tiny holes. It is transparent because the holes are smaller in diameter than visible light wavelengths, although there is some haze due to scattering. Research for window applications has been underway since the late 1950s. Currently two kinds of prototype are available: 1) highly transparent "tiles" usually 2 cm thick and currently prototyped in dimensions up to 60 x 60 cm^2; 2). granules of varying diameter (1-10 mm), for a cheaper product but with strong light scattering. Both would typically be used as fill in a double-pane glazing assembly. Both systems can be improved with a soft vacuum (.1 atmosphere) or special gas fills. Current research attention on aerogel is directed towards appliance insulation (e.g. refrigerators). This is a technology-push development for architectural applications.

Honeycomb or capillary structure transparent materials are another form of this technology. Some European prototype fenestration units using these materials have been designed to act as passive heating devices. These units absorb solar radiation and re-radiate it indoors, so that the inner wall surface acts like a large low-temperature wall heater.

6. DIRECTIONALLY SELECTIVE MATERIALS

Directionally selective materials reject or redirect incident solar radiation as a function of the geometric relationship between the radiation and the material. To enhance daylight use, they may redirect the incoming sunlight to spread it more usefully within the space. If the angle-dependent transmissivity of such glazings could be fine-tuned for each building application and orientation, useful solar control could be achieved. The transmittance properties could theoretically respond as a function of solar incidence angle. For example, a window coating might be tuned to reflect all energy striking the surface above some critical angle of incidence. It may be possible to produce such effects with oriented coatings, holographic films or through materials embedded within the glazing substrates. These function much like refractive optical systems (e.g. linear Fresnel prisms) normally seen at a much larger scale. There is potentially an opportunity to combine angle-selective technologies with chromogenic materials for further control of the system. Current technologies in this category include Glass Block (typically used for aesthetic reasons and not a promising technology for fine control); Silk-screened glazings; Prismatic Devices; Enclosed Louvers within the window assembly; Holographic Films; and Imbedded Structures within the glass substrates. Some of these are discussed further below.

6.1. PRISMATIC DEVICES

Prismatic glazing systems use the principles of light refraction through dielectric materials to redirect light. Incoming light can be redirected toward more useful destinations, for example onto the ceiling instead of into an occupant's eyes. See Daylighting Optical Systems section for further information.

6.2. HOLOGRAPHIC MATERIALS

Glazing materials which utilize holographic optics might contribute to substantially increased daylight levels up to 40 feet or more in from the window wall than with traditional fenestration systems. Holographic devices use diffractive structures to control light transmission and outgoing direction. To date, the holographic daylighting devices developed as laboratory prototypes consist of photopolymers or embossed films applied to glass. Incoming light is redirected as a function of angle of incidence and wavelength of the incoming light.

Current development strategy is to fabricate large polyester sheets, containing an embossed diffractive structure, that can be attached to the upper portion of any visibly transparent aperture facing orientations that range from southeast to southwest (northern hemisphere). Direct sunlight falling on the device will be diffracted towards the ceiling deep into the room, which will reflect glare free, diffuse light onto the work surfaces. Undesirable direct sunlight is thus not admitted into the space, being transformed instead into useful diffuse light. Current prototypes are partially transparent, which allows vision through them although working therefore with less than perfect efficiency. The view through is darkened somewhat but remains undistorted. At this stage in the research and development cycle, there is a great deal of uncertainty in performance, technical details, and practicality of architectural applications.

7. SWITCHABLE OPTICAL MATERIALS

There is a tremendous variability in the environmental forces confronting a building exterior and in the occupant needs inside. In addition, these wide-ranging variations can occur rapidly and unexpectedly. Slower, seasonal variations are only slightly more predictable. Exterior variables include temperature, solar position, and available daylight. Interior variables include task requirements, thermal comfort, glare control, and desire for privacy or view. The range of values each variable can take, and the infinite combinations between the variables, indicates that dynamic control of one or more glazing properties is required for optimum performance of the fenestration system. One approach is to use a device from the vast array of window accessories currently available, such as adjustable venetian blinds. However, analysis shows superior performance is possible if control of fenestration performance attributes is intrinsic to the glazing material itself (fig.6).

Switchable, or chromogenic, materials have optical properties that can be passively or actively altered. The application of these materials in architectural glass can allow dynamic regulation of radiant energy transfer through the fenestration, such that comfortable lighting and temperature are maintained in response to changing indoor and outdoor conditions and, ideally, while minimizing energy use. Major applications for chromogenic glazing include the control of glare, privacy, interior fading, daylight, and solar heat gain. Energy implications include reduced energy use and reduced peak demand. HVAC equipment can also be downsized due to reduced thermal loads. Shading devices can possibly be eliminated.

Much of the fundamental physics and technical details of chromogenic materials are not yet well understood. Among the major concerns are stability with respect to UV and temperature stresses.

There are currently four major known types of chromogenic materials under consideration for use in architectural applications: Photochromics, Thermochromics, Electrochromics, and Liquid Crystals. All four have been known, in general principle, for many years. The concept of applying them in buildings has gained momentum over the past decade.

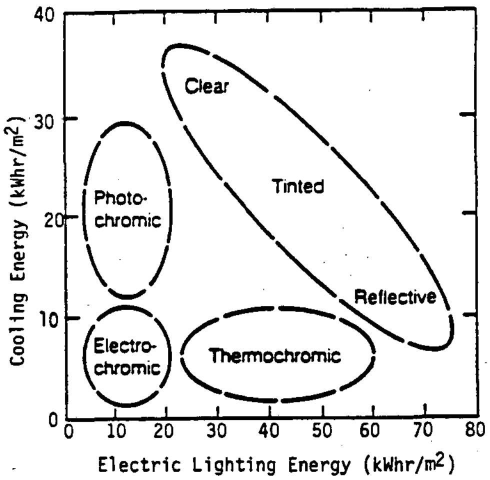

Figure 6: Schematic representation of projected cooling energy and electric lighting requirements for a typical building under cooling conditions and assuming the use of electric lighting reduction when daylight is available. Relative requirements for cooling and lighting are shown for three types of conventional glazings and for three types of chromogenic glazings. Specific energy requirements depend on glazing properties, building type and location, window orientation and other design or occupant details (Selkowitz and Lampert 1989).

7.1. PHOTOCHROMIC COATINGS

Photochromic materials change their optical properties as a function of light intensity. They are widely used in sunglasses. The spectral and intensity dependent optical responses and temperature dependent effects have been investigated. Since the switching phenomenon depends primarily on light intensity, such a device would behave in the same way in the summer as in winter when the intensities are equal. This lack of seasonal selectivity would not be an issue for glare control (the requirements for which remain the same year round), however it is highly desirable for solar control. Thus the primary benefit of photochromic coatings would be to improve visual comfort.

7.2. THERMOCHROMIC MATERIALS

Thermochromic materials change their optical properties as a function of their temperature. Liquid crystal temperature indicators are common examples of materials whose optical properties change when heated. Basic research is in progress to better understand switching mechanisms and then create doped materials that will switch within the thermal range of interest for aperture applications. Research is directed towards liquid and gel based materials and thin-film solid state devices. Gel based coatings are developed the furthest. One manufacturer expects to have a product available in 1992. These typically switch from transparent when cool to a white, reflective/diffusing state when heated. While probably inappropriate for most primary-view glazing, such materials could be useful for roof apertures and possibly in some curtain wall systems. However, the long-term durability of such materials is uncertain. The addition of light absorbing dyes can make the material respond to solar gain as well as air temperature, but it would still lack the ability to be actively controlled by occupants.

15. ELECTROCHROMIC MATERIALS

Electrochromic materials are multilayer films whose optical properties can be controlled using an applied voltage. In principle, these have the greatest versatility since their transmittance can be controlled at any instant based not only on outside temperature and sunlight conditions, but also on interior thermal and visual requirements. However, these materials tend to be multi-layer systems that are potentially more complex and difficult to fabricate, and more expensive than simple, single layer photochromic or thermochromic systems. In addition they must be linked electronically to sensors or building automation systems, which is both a difficulty and their major advantage. Electrochromic materials are well known in the display industry and have been investigated extensively for applications such as flat display panels and digital watch displays. Durable, long-life window coatings have yet to be demonstrated at laboratory scale; scaling up to architectural sizes will take additional time. However, the ability to control the transmittance of such materials for privacy, visual comfort, thermal comfort, peak load management, and other building functions suggests that they will play a critical role in future high performance commercial building envelopes. Both field testing of lab prototypes and computer simulation indicate very large energy savings potential with electrochromics. This highly promising technology is not expected to reach commercialization for several years.

16. LIQUID CRYSTAL MATERIALS

Like electrochromics, liquid crystal systems also change properties upon electric field changes. Liquid crystal molecules are typically suspended between two transparent electrodes. Molecules normally are randomly distributed, thus scattering and absorbing light that enters. When the device is electrically charged the molecules neatly align, allowing light to pass through unobstructed. The device is thus clear in the "on" state and cloudy when "off." There is currently one liquid crystal product commercially available, and its primary use if for privacy control. Because the device does not alter in shading coefficient, its potential for energy savings are limited. A further disadvantage is that a continuous voltage application is required to maintain the clear state. Another type of liquid crystal technology known as "liquid suspension" is a cross between the currently available product and true electrochromics. Still in research and development, this prototype can dim through a range of tints and maintain transparency (like electrochromics), but requires a continuous voltage to maintain its clear state (like the current liquid crystal product).

8. ASSEMBLIES

8.1. SINGLE PANE WINDOWS

Single pane window assemblies dominate the California commercial market. Low-e coatings can improve insulating value of single-pane glazing, although low-e single glazing is rare and can lead to condensation problems. Improvements in framing technology can also benefit these assemblies. Single pane windows are best improved through solar control treatment, with tints and coatings. Spectrally selective tints and coatings can significantly improve the solar control and daylighting potential of single pane assemblies.

8.2. MULTIPANE WINDOWS

Multipane windows offer the most potential for both insulation improvement and improved solar control with maximum spectral selectivity. Building codes are beginning to require more double glazing for commercial buildings in California. There is some concern that double glazing may lead to increased annual cooling energy in some California climates. This has not been rigorously substantiated, nor have the life cycle cost impacts been studied for these circumstances.

8.3. LAMINATED WINDOWS

Laminated glass, sometimes called "safety glass," can be used in any glazing application where impact resistance is required. It is most commonly used, for code requirements, in sloped or overhead applications and in storefronts and other public entrances. Laminated glass is made by sandwiching a plastic interlayer between panes of glass and bonding the unit together under heat and pressure. When the glass is broken, fragments adhere to the plastic instead of falling.

Recently, one manufacturer has added a spectrally-selective low-e coating to the interlayer. This type of low-e application differs from the more typical IGU because there is no air space facing the coating and thus no reduction in long-wave heat loss through the unit due to radiative transfer between the panes. However, the spectral selectivity of the low-e coating is maintained. The coating has been tuned to reject short-wave infrared while admitting daylight and blocking almost all UV. This is therefore a low-e application strictly for solar control and not for insulation benefits.

8.4. "SUPERWINDOWS"

Superwindows result from combining technologies for solar control and convective/conductive heat loss. The original intent has been the development of highly insulating glass for residential applications in cold climates. In addition to energy savings, these units also provide a great improvement in thermal comfort by reducing radiative heat loss to a cold glass surface. The potential for these windows in commercial buildings lies in the issue of thermal comfort. Standard practice glazings in a cold climate can create discomfort for occupants near the glass through radiative heat loss to the cold surface and through downdrafts. Perimeter heating systems are typically installed in commercial buildings to combat these sources of discomfort by heating up the glass surface. Superwindows eliminate this discomfort problem and thus result in the elimination of perimeter heating systems, saving both energy and building space. Multiple layers of clear, tinted, or reflective glazings with multiple low-emissivity coatings and gas fills promise overall energy performance better that the best insulating walls. Current technology includes a triple-layer system with two low-emissivity coatings and krypton or krypton-argon gas fills. These assemblies presents opportunities for up to R-10 insulating value at the center of the glass (R4-R8 overall for a commercial-sized window), with high visible transmittance for daylight utilization and provision of view. These products are commercially available although still in very limited use. Among needed improvements are better frames and edges, although this is not as significant a problem for commercial applications.

Spectrally-Selective Tints

DESCRIPTION

Tint is achieved in glazing by adding materials to the glass itself. The tinting materials increase absorptance of solar radiation and may change the color appearance of the glass. Different color tints affect the glazing spectral transmissivity differently. **Blue, green** and **aqua** are naturally selective for the visible wavelengths. Spectrally selective tints are those which have been further tuned to absorb solar infrared radiation while maintaining visible transmittance.

PERFORMANCE CRITERIA

Luminous Efficacy: The ratio of visible transmittance to shading coefficient, given as a unitless constant K_e ($K_e = T_{vis} + SC$). This is a measure of the "coolness" of the light delivered through the glazing. A glazing with $K_e > 1.0$ is considered to be selective for visible light.

SOURCES AND STATUS OF AVAILABILITY

All manufacturers produce a tint in the blue-green family. Improved blue and green tints are available from PPG and LOF. These are are relatively new on the market and are thus still somewhat unknown among designers. It is expected that other colors will be available eventually.

PROS AND CONS

Spectrally-selective tints, used alone in single-pane units, are a significant improvement over conventional tinted and reflective single-pane windows, which are the prevalent window choice for California commercial buildings. Used alone, they will not provide a shading coefficient much lower than around .5, however a low-e coating can be added or the tint can be used in a multi-pane unit.

ENERGY PERFORMANCE

These tints significantly improve solar control and daylighting efficacy. The impact of this on energy savings depends on the design trade-offs. If a designer chooses to trade glazing efficacy for a larger area of glass, then cooling load is unaffected. If the trade-off is for a lower shading coefficient, then cooling load is reduced. If daylighting controls are installed, then lighting savings will be realized.

COMFORT PERFORMANCE

Will improve thermal comfort due to reduced solar infrared transmission. High visible transmittance may require additional light control to reduce glare. On the other hand, improved view clarity may improve occupant satisfaction.

IMPACT ON BUILDING DESIGN

Allows greater design freedom in the trade-offs between window size, view clarity, shading coefficient, daylighting potential, and cooling load. Allows more flexibility in meeting Title-24 daylighting options.

COST AND LIFE CYCLE ECONOMICS

These tints currently increase first cost by approximately 25% over standard tints, but that may change as market share grows. Payback on this added cost depends on the particular application. Several utilities offer a rebate for this technology, which typically offsets the added first cost. The market value of larger windows, clearer views, and daylighting may be significant, although difficult to assess.

MARKET SHARE, EXPECTED TRENDS

The LOF and PPG products are apparently selling well, perhaps due to fairly aggressive marketing. As other colors become available and as designers become educated about the benefits of these tints, it is reasonable to expect a very large share of the tinted glazing market will belong to spectrally selective tints.

Low-Emissivity Coatings

DESCRIPTION

An ultra-thin, transparent, long wave infrared-reflecting coating is achieved with a metal layer sandwiched between optical anti-reflective coatings. The metal layer is the heat reflector and the two anti-reflective coatings maintain transparency. *Pyrolytic* (sometimes called "soft") coatings are applied on-line while the glass is still hot in the float line. *Sputtered* ("hard") coats are applied off-line, on cool glass in a vacuum chamber. In general, sputtered coatings are better performers.

SOURCES AND STATUS OF AVAILABILITY

Low-emissivity coatings are a leading edge technology. They are available and market share continues to grow rapidly, however this is a relatively new and expensive technology. It may become standard practice in the residential market in the near future but will likely remain leading edge in commercial buildings for some time.

PROS

Exceptional energy and comfort performance in 2-pane IGUs, equivalent to traditional 3-pane units. Because commercial buildings almost never use 3-pane glazing, the advantage of replacing the cost, thickness and weight of 3-panes is realized more in the residential market. Low-emissivity windows offer substantial heating savings, cooling savings, and improved comfort due to the reduction of radiant heat transfer from people to window glass. High degree of inherent and beneficial spectral selectivity in infrared, ultraviolet and visible wavelengths, which can be tuned or adjusted as necessary.

CONS

Work best in IGUs, which are not standard practice for California commercial buildings. Higher cost over traditional windows may not pay back in energy savings alone. It is not clear whether cooling-dominated buildings appreciate energy savings due to increased insulation value.

ENERGY PERFORMANCE

Most clear seen in heating savings, and probably in most cooling applications as well. The inherent spectral selectivity may also lead to better use of daylighting strategies and hence will yield lighting savings as well.

COMFORT PERFORMANCE

Excellent improvement for comfort, since there is a significant reduction in the radiant heat transfer between the window pane and a person sitting near it. For this reason alone, cooling-dominated buildings that do not find an energy advantage in increased insulation may still benefit from low-e windows.

IMPACT ON BUILDING DESIGN

Allows greater freedom in fenestration design. In particular, may allow greater glazing area without an energy penalty. May allow reduction of perimeter heating equipment.

COST AND LIFE CYCLE ECONOMICS

The increased cost of these units will pay back in colder climates, however the life cycle economics for milder California climates is not clear.

MARKET SHARE, EXPECTED TRENDS

Have captured over 30% of the residential market and a growing portion of the commercial market. Both segments continue to grow. Low-emissivity glazing is expected to dominate the residential market within a few years. It is difficult to estimate the ultimate penetration in commercial market.

Holographics

DESCRIPTION

Holographic devices use diffractive structures to control light transmission. Incoming light is redirected as a function of angle of incidence and wavelength of the incoming light. There are two processes for creating holographic devices to date: 1) photopolymer process (thick film); 2) embossing process (thin film relief). The holographic films can be assembled either in series or in parallel.

Current development uses large polyester sheets, containing an embossed diffractive structure, that can be attached to the upper portion of any visibly transparent aperture facing orientations that range from southeast to southwest (northern hemisphere). Direct sunlight falling on the device will be diffracted towards the ceiling deep into the room, which will reflect glare-free, diffuse light onto the work surfaces. Undesirable direct sunlight is thus not admitted into the space, being transformed instead into useful diffuse light. Current prototypes are partially transparent, which allows vision through them although working therefore with less than perfect efficiency. The view through is darkened somewhat but remains undistorted.

PERFORMANCE CRITERIA

Angular control:	The device should be able to redirect incoming light as desired.
Spectral control:	The device should be able to remix light for neutral color.
Efficiency:	The device should be able to adequately use much of the incoming light, over a wide range of incidence angles.

SOURCES AND STATUS OF AVAILABILITY

At this stage in the research and development cycle, there is a great deal of uncertainty in performance, technical details, and practicality of architectural applications. At the present time, holographic applications for windows remain highly speculative and very experimental. Current technical development has progressed from theoretical design to only fabrication of laboratory prototypes. The largest prototype to date with appropriate optical properties is 2" in diameter. Research and development is attempting to scale up, however this has not yet been successfully achieved will maintaining optimum properties. A California firm leads holographic window research in the US.

PROS

Might contribute to substantially increased daylight levels up to 40 feet or more in from the window wall than with traditional fenestration systems. May substantially reduce contrast glare in spaces with apertures on only one wall. Use of a film means less compromise on building appearance and other design issues (compared to an external, protruding device like a light shelf). If successfully developed, is expected to outperform all other optical systems. May effectively "track" the sun without a heliostat, if a device is perfected for all appropriate incoming angles. Potential for lighting savings and associated cooling savings from daylighting.

CONS

There are a tremendous number of technical difficulties to be resolved before architectural suitability is clear. Current prototypes produce severe chromatic dispersion (light is spread into rainbows), and this has not yet been solved without substantially degrading efficiency. It is difficult to spread outgoing light evenly, especially at oblique angles of incidence. It is difficult to date to create high efficiency devices at low cost. Other uninvestigated potential trouble spots include optical performance stability, structurally stability, overall durability, and installation requirements.

ENERGY PERFORMANCE

There is not yet adequate data to evaluate energy potential for holographics. Lab measurements and theoretical calculations show promise, but it is not yet possible to make a positive determination of practical value or even to perform a proper energy analysis.

COMFORT PERFORMANCE

Good potential for glare control, by spreading the brightness of the window wall around the room.

Photochromics

DESCRIPTION

Photochromic glazing, based on the incorporation of metal halides, changes optical properties when exposed to light and reverts to its original state in the dark. For a window application, this would mean the glass lowers its transmissivity (by increasing absorptivity) as outdoor light levels increase. Photochromism has been studied since the late 1800s. Photochromic glass is widely used in sunglasses, however is has only recently been considered for building applications and is still very much experimental. Current lab prototypes are not in window application sizes, and it has not yet proven economical to manufacture photochromic glass in large areas.

SOURCES AND STATUS OF AVAILABILITY

Currently no known commercial product is available for building windows. It has been reported that a recent product for car sunroofs is available in Europe. There is still a great deal of research and development work to be done in this field prior to commercialization of photochromic windows. Manufacturing of photochromic glass in the float process has not yet been achieved, and it is uncertain whether or not this will ever be possible.

PROS

Photochromic glazing could be effective for lighting requirement reduction and for glare control. It may replace traditional window treatments for glare control such as shades and blinds.

CONS

Single-variable response (a light stimulus, in this case) does not permit the full range of user-initiated dynamic control required for optimum performance. Photochromics may therefore respond inappropriately under certain conditions, for example on cold and sunny days when maximum transparency may be desirable. As with all current electrochromic technologies, the high thermal absorption in the darkened state may cause thermal stress in the unit. Reradiated absorbed energy will also contribute to cooling load. Existing prototypes also absorb more in the visible spectrum than in the infrared.

ENERGY PERFORMANCE

Will reduce required lighting energy but may not help cooling load and could even increase it. Overall energy impact is still uncertain. Photochromics will show more promise if current materials are adjusted for better spectral selectivity and if a low-e coating is applied to the inward-facings side to restrict reradiated heat flow.

COMFORT PERFORMANCE

Will improve visual comfort through glare control, which is probably its primary overall benefit. Affect on thermal comfort is uncertain.

IMPACT ON BUILDING DESIGN

Would allow more freedom and design optimization for building apertures. May reduce the need for shading devices.

MARKET SHARE, EXPECTED TRENDS

Research and development in photochromics is fairly active, both in glass and in plastics. If cost effective manufacturing problems are resolved, there may develop a specialty market for photochromic glazings. However, success of this technology is largely dependant on whether or not electrochromics are successful. It is not yet clear that photochromic flat architectural glass can ever be produced at competitive costs, especially if electrochromics come to market at lower costs and with greater controllability. It will be several years before viability of this technology is proven, and additional time beyond that would be required for commercialization.

Thermochromics

DESCRIPTION

Thermochromic materials change their optical properties when heated and revert when cooled to the starting temperature. Thermochromic windows change from clear to opaque when a critical temperature is reached. Current prototypes absorb and/or diffuse solar energy, but are not heat reflective. Thermochromism has been studied since the late 1800s in general principle. There are two promising types for windows (thermochromic materials that function within comfort zone temperatures):

1. Vanadium oxides, which were first discovered in 1959.
2. "Cloud Gel," a polymer-water solution sandwiched between layers of plastic film.

SOURCES AND STATUS OF AVAILABILITY

There are currently no known commercial products available, although at least one has come to market in the last few years but apparently has disappeared. Suntek's "Cloud Gel" is currently the only prototype product expected to reach the market by 1992.

PROS

Significant reductions in air conditioning loads and electricity peak demand are expected with thermochromics. Thermochromics may not provide any lighting savings. They will be more promising if spectral selectivity is developed, which Suntek claims to have achieved in "Cloud Gel." Thermochromics may permit elimination of traditional solar control devices, such as glazing tints, films and shading devices.

CONS

These materials do not remain transparent to visible light when solar transmission is reduced. Single-variable response (a temperature stimulus, in this case) does not permit the full range of dynamic control required for optimum performance. Thermochromics may therefore respond inappropriately under certain conditions. Current prototypes do not appear to have a life longer than 5 to 10 years, although research continues in this area.

ENERGY PERFORMANCE

The current "Cloud Gel" prototype will transition from 92% solar transmission to around 30% when a 3° temperature change occurs (the setpoint for this can be set between 60 and 140°F). The primary energy savings realized by thermochromic materials will be in air conditioning.

COMFORT PERFORMANCE

Expected to reduce glare and improve thermal comfort.

IMPACT ON BUILDING DESIGN

Would allow more freedom and design optimization for building apertures, especially with skylights. May reduce the need for shading devices.

COST AND LIFE CYCLE ECONOMICS

Suntek expects to sell "Cloud Gel" at costs that are competitive with other building envelope components. With the potential HVAC savings associated with thermochromics, this would indicate a highly attractive economic scenario.

MARKET SHARE, EXPECTED TRENDS

Would be appropriate for both new and retrofit construction, and may be particularly well-suited for skylights. The "Cloud Gel" plastic film may be taped onto existing windows and thus may see good market penetration for retrofits. However, there is still a significant amount of work ahead in the field of thermochromics. Success of thermochromic glazings may depend on whether or not electrochromics are successful, since electrochromics are the better switchable technology. However, cost differences between the two may maintain a market for thermochromics, since they will probably be less expensive.

Electrochromics

DESCRIPTION

Electrochromic materials change their optical properties due to the action of an electric field and change back upon field reversal. This works through insertion and removal of ions in the electrochromic layer. Electrochromic windows transition from transparent to fully darkened heat-absorbing and can be maintained at any grade of tint in between. The phenomenon was first reported in 1951, but the potential was apparently not appreciated until about 1969. To date, electrochromic devices include an ion-containing material in proximity with the electrochromic layer, plus transparent layers for establishing a distributed electric field.

SOURCES AND STATUS OF AVAILABILITY

Electrochromics exist in lab prototypes only. Currently, the largest working prototype developed is approximately 2' x 1', and most samples are only a few inches on a side. One of the first applications has been for automobile rear view mirrors. Architectural applications for electrochromics are not expected to be on the market for several years.

PROS

Multi-variable control enables ideal full-range dynamic control of windows. Electrochromic windows would be connected to the building thermostats, or potentially any other control system. They require voltage only to change their condition, not to maintain any particular state. May be spectrally tuned (for example, to absorb only solar infrared). May replace traditional solar control technologies such as glazing tints, reflective films and shading devices.

CONS

Unknown without further testing. One potential problem is thermal stresses caused by high heat absorption in the darkened states. This may also result in excessive heat radiated by the unit back into a cooled space.

ENERGY PERFORMANCE

Potentially optimal (see fig. 6 on page 11). Will outperform any other building envelope component for both cooling and lighting energy. Excellent potential to minimize peak electrical demand.

COMFORT PERFORMANCE

Potentially optimal for both thermal comfort and glare control.

IMPACT ON BUILDING DESIGN

Would allow more freedom and design optimization for building apertures. May reduce the need for shading devices.

COST AND LIFE CYCLE COST ECONOMICS

Unknown. Products will likely be expensive compared to other components, but developers expect them to eventually become competitive with traditional insulating units, especially if elimination of traditional solar control mechanisms is included in the calculation. Current developer projections estimate an optimistic payback of 5 years.

MARKET SHARE, EXPECTED TRENDS

Currently several car manufacturers continue to study electrochromics for use in car windows and mirrors. Several large architectural glass companies have expressed an interest, most notably in the US, the UK, France and Japan. It is expected that the initial market for electrochromics will be in 1) high visibility/high end projects; 2) utility company demonstrations; and 3) federal agency or regulatory agency demonstrations.

Liquid Crystal Devices

DESCRIPTION

Liquid crystal-based devices , like electrochromics, change optical properties upon electric field changes. Liquid crystal molecules are suspended between two transparent electrodes. There are currently two primary approaches for architectural applications of this technology:

1. Dichroic dye molecules are mixed with the liquid crystals to modulate light absorptance. Sometime known as "liquid suspension" technology, this is a thin layer of needle-shaped polyiodide crystals suspended in a dense fluid between two sheets of glass coated with a transparent conductive material. When charged, the crystals align and allow light to pass through. When the charge is removed, the crystals absorb light and the material appears tinted (unlike #2 below, where the "off" state causes light scattering and thus the material appears opaque). This material can be tinted to any level.
2. Liquid crystal molecules are enclosed in micrometer-sized cavities to modulate light scattering. Molecule alignment is changed to yield a clear or opaque assembly. When the molecules are neatly aligned, visible light can pass through and the material appears almost transparent. When the molecules are randomly displaced, light passing through is absorbed or scattered, which makes the material translucent or opaque. This material has only two states, clear and opaque.

SOURCES AND STATUS OF AVAILABILITY

Currently the only commercially available product is of the liquid crystal type (clear/opaque) from the Taliq Corporation. At least one other of this type is currently ind development. Research Frontiers has a window-sized prototype of the "liquid suspension" technology and hope to have a product available in the next year.

PROS

The clear/opaque type has privacy control as its only clear advantage, although there is the potential for cooling load savings. Liquid suspension systems that can be tinted at any level offer more potential for both comfort and energy savings.

CONS

Unlike electrochromics, this technology requires a continuous voltage application to maintain the clear state. Products currently available are very expensive, although Research Frontiers expects to offer competitive pricing. The Taliq product is opaque when "darkened." Its transparent state is still slightly hazy, especially from certain angles. Its ultraviolet stability is poor, although this is possibly improvable. Performance in high temperatures is uncertain, and, like other switchables, the high absorptivity of liquid crystal devices may cause internal thermal stresses and an increased cooling load due to reradiated heat.

ENERGY PERFORMANCE

For the clear/opaque type, energy benefits are uncertain and probably are quite limited, as the device changes absorptivity only in the visible spectrum with relatively little effect on solar heat gain. Dimming types hold more potential for cooling savings and glare control.

COMFORT PERFORMANCE

Uncertain, although glare control may be a benefit.

COST AND LIFE CYCLE COST ECONOMICS

The current product available from Taliq is expensive and will not pay back with energy savings.

MARKET SHARE, EXPECTED TRENDS

The Taliq product is used solely for privacy control and will likely remain in that specialty market. Dimming products, if they are successfully commercialized, will be used for energy efficiency as well. Success of liquid suspension glazings may depend on whether or not electrochromics are successful, since electrochromics are the better switchable technology and do not require continuous voltage to maintain a clear state.

PARTIAL LIST OF MANUFACTURERS/VENDORS/R&D FIRMS BY PRODUCT TYPE

Commercial Products only/ Primarily North America

Availability Key: No Symbol = commonly available
· = specialty item
• = R & D only

SPECTRALLY-SELECTIVE TINTED GLASS

LOF Co., Toledo, OH. (*EverGreen*™)
PPG Industries, Pittsburgh, PA (*Azurlite*™)

LOW-EMISSIVITY COATED GLASS

All major manufacturers.

SPECTRALLY-SELECTIVE LAMINATED GLASS

Monsanto (*Solarflex*® interlayer)

LOW-EMISSIVITY COATING ON SUSPENDED FILM

Southwall Technologies, Palo Alto, CA. (*Heat Mirror* ®)

GAS-FILLED UNITS

All major manufacturers.

SUPERWINDOWS

· Southwall Technologies, Palo Alto, CA. (*Superglass* ®)
· A.B.P. Products, Inc., Montreal, Quebec (*Superglass* ® in aluminum and vinyl frames)
· Hurd Millwork Company, Medford, WI (*Superglass* ® in wood frames)

ELECTROCHROMIC GLAZING

• SAGE Corporation, Valley Cottage, NY
• Asahi Glass Co., Tokyo, Japan
• Central Glass Co., Tokyo, Japan
• PPG Industries, Pittsburgh, PA
• Research Frontiers, Woodbury, NY (liquid suspension)

THERMOCHROMIC GLAZING

• Suntek, Inc., Albuquerque, NM (*Cloud Gel*)

LIQUID CRYSTAL GLAZING

- Taliq Corporation, Sunnyvale, CA (*Varilite*™)

HOLOGRAPHIC GLAZINGS (LABORATORY PROTOTYPES ONLY)

- Advanced Environmental Research Group

PARTIAL DIRECTORY OF GLAZING PRODUCT MANUFACTURERS, SUPPLIERS, COATERS, AND R & D FIRMS

Commercial Products only/ Primarily North America

AFG Glass Inc.
75 Doney Crescent
Concord, Ontario L4K 1P6
Canada
Phone: (416) 669-1930
Fax: (416) 669-9493

Alpen
5400 Spine Road
Boulder, CO 80301
USA
Phone: (303) 530-1150

Cardinal IG
12301 Whitewater Drive
Minnetonka, MN 55343
USA
Phone: (612) 935-1722

Flachglas AG
Auf der Reihe 2
P.O. Box 100851
4650 Gelsenkirchen
Germany
Phone: (02 09) 1681

Ford Glass
4 Parklane Blvd, Suite 464
Dearborn, MI 48126
USA
Phone: (313) 390-4343

Guardian Industries
14600 Romine Road
Carleton, MI 48117
USA
Phone: (800) 521-9040

Interpane Coatings, Inc.
Deerfield, MI 49238
USA

LOF Co.
811 Madison Avenue
Toledo, OH 43695
USA
Phone: (419) 247-4892

Monsanto Company
800 N. Lindbergh Blvd.
St. Louis, MO 63167
USA
Phone: (800) 248-6844

Nippon Sheet Glass
8, 4-chome, Dosho-machi
Higashi-ku, Osaka
Japan
Phone: 06-202-1161

Pilkington Glass, Ltd.
Alexandra Works St. Helens WA10 3TT
England
Phone: (0744) 69 2998

PPG Industries, Inc.
One PPG Place
Pittsburgh, PA 15272
USA
Phone: (412) 434-2858

Saint-Gobain
Exprover S.A.
Avenue de Tervuren, Bte 4
B-1150 Brussels
Belgium
Phone: (32) 2 762 8242

Southwall Technologies
1029 Corporation Way
Palo Alto, CA 94303
USA
Phone: (415) 962-9111
Fax: (415) 967-0182

Spectrum Glass Products, Inc.
P.O.Box 408
520 E. Railroad Street
Clinton, NC 28328
USA
Phone: (800) 334-1797

Taliq Corporation
1277 Reamwood Avenue
Sunnyvale, CA 94089-2234
Phone: (800) 626-1334
Fax: (408) 745-1456

Viracon, Inc.
800 Park Drive
Owatonna, MN 55060
USA
Phone: (800) 533-2080
Fax: (507) 451-4871

RESEARCH AND DEVELOPMENT FIRMS

Advanced Environmental Research Group
Route 2, Box 2948
Davis, CA 95616
(916) 757-2567

SAGE Corporation (Sun Active Glass Electrochromics)
704 Executive Blvd.
Valley Cottage, NY 10989
Phone: (914) 268-7502
Fax: (914) 268-0220

Suntek, Inc.
6817A Academy Parkway East
Albuquerque, NM 87109

Research Frontiers, Inc.
Woodbury, NY

Inclusion in these lists does not imply applicability or endorsement. Additional companies may also manufacture these products.

TABLE 1:DATA FOR EXISTING PRODUCTS (PARTIAL)

The following sheets are from a large database of glazing product characteristics, which is being compiled from manufacturer literature. Most glazing manufacturers use the LBL program *Window 3.0* to calculate performance characteristics, therefore these data are considered to be generally accurate and comparable. This table is not yet complete and will be periodically updated over the course of the project.

Format of the table:

- Each row of data applies to a specific existing product.
- The table is broken into three major categories, indicated in the first column:
  - *Uncoated 1-pane* is monolithic units of uncoated glazing.
  - *Durable 1-pane* is coated monolithic units.
  - *2-pane* is insulating units, both coated and uncoated.
  - *Heatmirror* is low-emissivity insulating units where the low-e coating is on a plastic film suspended in the air space between two panes of glazing.
  - *Laminates* are two panes of glazing with a low-e coating on the laminated plastic interlayer.
- *Name* is an abbreviated product name.
- *Index* is an internal reference to source of data for that product.
- *Tv* is the visible transmittance.
- *Ts* is the solar transmittance.
- *Uw(air)* is the winter U-value for monolithic units and for air-filled insulating units.
- *SC* is the shading coefficient.
- *Uw(arg)* is the winter U-value for argon-filled insulating units.
- *Ke* is the luminous efficacy, calculated as visible transmittance divided by shading coefficient.
- *Apparant color* is the appearance of the glazing when viewed from outside, as described by the manufacturer.
- *Manufacturer* is the glazing supplier. Note that glazing manufacturers often distribute products both directly to the retail market and to other glazing distributers, thus a product listed in this table may be available under several different product names.
- *Product name* is this manufacturer's name for the product.

Inclusion in these lists does not imply applicability or endorsement. Additional companies may also manufacture these products.

	NAME	INDEX	Tv	Ts	Uw(Air)	SC	Uw(Arg)	Ke	Apparent color	Manufacturer	Product name
uncoated	CLEAR	1.4	0.8	0.61	0.48	0.82		0.98			
1-pane	GREEN	1.405	0.68	0.36	0.48	0.55		1.24			
	GRAY	1.41	0.37	0.36	0.48	0.55		0.67			
	BRONZE	1.415	0.47	0.36	0.48	0.55		0.85			
	BLUE	1.42	0.51	0.38	0.48	0.57		0.89			
	CLEAR	1.5	0.8	0.61	0.48	0.82		0.98			
	GREEN	1.501	0.68	0.36	0.48	0.55		1.24			
	GRAY	1.502	0.37	0.36	0.48	0.55		0.67			
	GRAY14	1.503	0.13	0.32	0.48	0.51		0.25			
	BRONZE	1.504	0.47	0.36	0.48	0.55		0.85			
	BLUE	1.505	0.51	0.38	0.48	0.57		0.89			
	PPG-BRZ	1.506	0.2	0.24	0.48	0.38		0.53			
	PPG-GRY	1.507	0.16	0.18	0.48	0.37		0.43			
	FORD-BRZ	1.508	0.19	0.2	0.48	0.37		0.51			
	FORD-GRY	1.509	0.16	0.19	0.48	0.36		0.44			
	FORD-BLU	1.51	0.17	0.15	0.48	0.32		0.53			
	CLEAR	2.4	0.89	0.78	1.13	0.95		0.94	Clear	PPG	
	SOLEX	2.401	0.75	0.46	1.13	0.69		1.09	Medium Green	PPG	
	SOLBRZ	2.402	0.52	0.46	1.13	0.71		0.73	Light Bronze	PPG	
	SOLGY	2.403	0.42	0.4	1.13	0.64		0.66	Medium Gray	PPG	
	GRYL	2.404	0.14	0.26	1.13	0.53		0.26	Black	PPG	
	AZUR1/4	2.5	0.72	0.37	1.1	0.62		1.16	Aqua	PPG	
	CLR3/32	2.501	0.9	0.87	1.13	1.01		0.89	Clear	PPG	
uncoated	CLR1/8	2.502	0.9	0.85	1.12	1		0.90	Clear	PPG	
1-pane	CLR5/32	2.503	0.9	0.84	1.11	0.99		0.91	Clear	PPG	
	CLR3/16	2.504	0.89	0.81	1.11	0.97		0.92	Clear	PPG	
	CLR1/4	2.505	0.88	0.79	1.1	0.96		0.92	Clear	PPG	
	CLR5/16	2.506	0.88	0.75	1.09	0.94		0.94	Clear	PPG	
	CLR3/8	2.507	0.88	0.72	1.08	0.91		0.97	Clear	PPG	
	CLR1/2	2.508	0.86	0.67	1.06	0.87		0.99	Clear	PPG	
	SLX3/32	2.509	0.85	0.67	1.13	0.86		0.99		PPG	
	SLX1/8	2.51	0.83	0.62	1.12	0.8		1.04		PPG	
	SLX5/32	2.511	0.81	0.58	1.12	0.79		1.03		PPG	
	SLX3/16	2.512	0.78	0.53	1.11	0.74		1.05		PPG	
	SLX1/4	2.513	0.77	0.49	1.1	0.69		1.12		PPG	
	SLBZ3/32	2.514	0.72	0.71	1.13	0.85		0.85		PPG	
	SLBZ1/8	2.515	0.66	0.64	1.12	0.85		0.78		PPG	
	SLBZ5/32	2.516	0.63	0.59	1.11	0.81		0.78		PPG	
	SLBZ3/16	2.517	0.59	0.55	1.1	0.78		0.76		PPG	
	SLBZ1/4	2.518	0.52	0.49	1.1	0.7		0.74		PPG	
	SLBZ3/8	2.519	0.37	0.33	1.08	0.6		0.62		PPG	
	SLBZ1/2	2.52	0.28	0.24	1.07	0.5		0.56		PPG	
	SLGY1/8	2.521	0.6	0.59	1.13	0.79		0.76		PPG	
	SLGY9/64	2.522	0.6	0.59	1.13	0.79		0.76		PPG	
	SLGY3/16	2.523	0.5	0.48	1.11	0.71		0.70		PPG	
	SLGY1/4	2.524	0.44	0.42	1.1	0.64		0.69		PPG	
	SLGY3/8	2.525	0.33	0.3	1.08	0.56		0.59		PPG	
	SLGY1/2	2.526	0.26	0.24	1.06	0.5		0.52		PPG	
	GRYLT1/8	2.527	0.31	0.43	1.13	0.66		0.47		PPG	
	GRYLT1/4	2.528	0.14	0.25	1.1	0.5		0.28		PPG	
	CLR3/32	3.1	0.91	0.87	1.12	1.03		0.88	Clear	LOF	
	CLR1/8	3.101	0.9	0.85	1.11	1		0.90	Clear	LOF	
	CLR5/32	3.102	0.9	0.84	1.1	1		0.90	Clear	LOF	
	CLR3/16	3.103	0.9	0.82	1.1	0.99		0.91	Clear	LOF	
	CLR1/4	3.104	0.89	0.81	1.09	0.98		0.91	Clear	LOF	
	CLR3/8	3.105	0.88	0.74	1.06	0.92		0.96	Clear	LOF	
	CLR1/2	3.106	0.87	0.7	1.04	0.88		0.99	Clear	LOF	
	CLR5/8	3.107	0.85	0.65	1.01	0.84		1.01	Clear	LOF	
	CLR3/4	3.108	0.84	0.61	1	0.81		1.04	Clear	LOF	
	CLR1	3.109	0.82	0.55	0.95	0.75		1.09	Clear	LOF	
	BLGN1/4	3.11	0.76	0.51	1.09	0.73		1.04	Blue Green	LOF	

	NAME	INDEX	Tv	Ts	Uw(Air)	SC	Uw(Arg)	Ke	Apparent color	Manufacturer	Product name
	BLGN3/8	3.111	0.67	0.38	1.06	0.62		1.08	Blue Green	LOF	
	EVGN3/16	3.112	0.7	0.38	1.1	0.63		1.11	Green	LOF	
uncoated	EVGN1/4	3.113	0.66	0.32	1.09	0.58		1.14	Green	LOF	
1-pane	GRY1/8	3.114	0.62	0.63	1.11	0.83		0.75	Gray	LOF	
	GRY3/16	3.115	0.5	0.53	1.1	0.75		0.67	Gray	LOF	
	GRY1/4	3.116	0.45	0.48	1.09	0.71		0.63	Gray	LOF	
	GRY3/8	3.117	0.28	0.31	1.06	0.56		0.50	Gray	LOF	
	GRY1/2	3.118	0.19	0.22	1.04	0.48		0.40	Gray	LOF	
	BRZ1/8	3.119	0.68	0.65	1.11	0.85		0.80	Bronze	LOF	
	BRZ3/16	3.12	0.58	0.55	1.1	0.76		0.76	Bronze	LOF	
	BRZ1/4	3.121	0.54	0.5	1.09	0.73		0.74	Bronze	LOF	
uncoated	BRZ3/8	3.122	0.38	0.34	1.06	0.59		0.64	Bronze	LOF	
1-pane	BRZ1/2	3.123	0.28	0.24	1.04	0.51		0.55	Bronze	LOF	
durable	SS-108	1.1	0.08	0.06	0.87	0.22		0.36	Silver	Cardinal	
1-pane	SS-114	1.101	0.14	0.1	0.9	0.28		0.50	Silver	Cardinal	
	SS-120	1.102	0.2	0.16	0.93	0.36		0.56	Silver	Cardinal	
	SS-208	1.103	0.06	0.04	0.87	0.25		0.24	Silver Green	Cardinal	
	SS-214	1.104	0.12	0.06	0.9	0.28		0.43	Silver Green	Cardinal	
	SS-220	1.105	0.17	0.09	0.93	0.33		0.52	Silver Green	Cardinal	
	SS-308	1.106	0.04	0.04	0.87	0.26		0.15	Silver Gray	Cardinal	
	SS-314	1.107	0.07	0.06	0.9	0.3		0.23	Silver Gray	Cardinal	
	SS-320	1.108	0.09	0.09	0.93	0.33		0.27	Silver Gray	Cardinal	
	SS-408	1.109	0.05	0.04	0.87	0.26		0.19	Silver Bronze	Cardinal	
	SS-414	1.11	0.09	0.06	0.9	0.29		0.31	Silver Bronze	Cardinal	
	SS-420	1.111	0.1	0.1	0.93	0.34		0.29	Silver Bronze	Cardinal	
	SS-508	1.112	0.05	0.04	0.87	0.26		0.19	Royal Blue	Cardinal	
	SS-514	1.113	0.09	0.07	0.9	0.3		0.30	Royal Blue	Cardinal	
	SS-520	1.114	0.13	0.1	0.93	0.34		0.38	Royal Blue	Cardinal	
	TI-120	1.115	0.2	0.13	0.89	0.33		0.61	Silver Blue	Cardinal	
	TI-130	1.116	0.3	0.22	0.97	0.43		0.70	Silver Blue	Cardinal	
	TI-220	1.117	0.17	0.08	0.89	0.3		0.57	Blue Green	Cardinal	
	TI-230	1.118	0.25	0.13	0.97	0.36		0.69	Blue Green	Cardinal	
	TI-320	1.119	0.1	0.09	0.89	0.32		0.31	Blue Gray	Cardinal	
durable	TI-330	1.12	0.15	0.14	0.97	0.39		0.38	Blue Gray	Cardinal	
1-pane	TI-410	1.121	0.05	0.04	0.87	0.26		0.19	Copper Bronze	Cardinal	
	TI-420	1.122	0.13	0.1	0.89	0.33		0.39	Blue Bronze	Cardinal	
	TI-430	1.123	0.18	0.15	0.97	0.4		0.45	Blue Bronze	Cardinal	
	TI-520	1.124	0.13	0.1	0.89	0.33		0.39	Deep Blue	Cardinal	
	TI-530	1.125	0.19	0.15	0.97	0.4		0.48	Deep Blue	Cardinal	
	SC1-BRZ	2.405	0.21	0.25	1.13	0.45		0.47		PPG	
	SC1-GY	2.406	0.17	0.22	1.13	0.41		0.41		PPG	
	SC1-GYL	2.407	0.05	0.14	1.13	0.35		0.14		PPG	
	SC2-BRZ	2.408	0.21	0.26	1.13	0.52		0.40		PPG	
	SC2-GY	2.409	0.17	0.22	1.13	0.49		0.35		PPG	
	550132GY	2.41	0.07	0.08	0.97	0.32		0.22		PPG	
	550132CL	2.411	0.14	0.13	0.97	0.32		0.44		PPG	
	550132BZ	2.412	0.08	0.08	0.97	0.32		0.25		PPG	
	550132GN	2.413	0.12	0.08	0.97	0.31		0.39		PPG	
	550182GY	2.414	0.1	0.1	0.99	0.36		0.28		PPG	
	550182CL	2.415	0.19	0.17	0.98	0.37		0.51		PPG	
	550182BZ	2.416	0.11	0.11	0.98	0.35		0.31		PPG	
	550182GN	2.417	0.16	0.11	0.98	0.36		0.44		PPG	
	550222GY	2.418	0.12	0.13	1.03	0.39		0.31		PPG	
	550222CL	2.419	0.25	0.22	1.01	0.44		0.57		PPG	
	550222BZ	2.42	0.15	0.13	1	0.39		0.38		PPG	
	550222GN	2.421	0.21	0.13	1.02	0.39		0.54		PPG	
	56080GY	2.422	0.04	0.04	0.89	0.27		0.15		PPG	
	56082CL	2.423	0.08	0.08	0.91	0.25		0.32		PPG	
	56082BZ	2.424	0.05	0.05	0.88	0.27		0.19		PPG	
	56082GN	2.425	0.07	0.04	0.89	0.26		0.27		PPG	

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	NAME	INDEX	Tv	Ts	Uw(Air)	SC	Uw(Arg)	Ke	Apparent color	Manufacturer	Product name
	560142GY	2.426	0.07	0.07	0.94	0.31		0.23		PPG	
	560142CL	2.427	0.14	0.12	0.94	0.3		0.47		PPG	
durable	560142BZ	2.428	0.08	0.07	0.94	0.31		0.26		PPG	
1-pane	560142GN	2.429	0.11	0.07	0.94	0.3		0.37		PPG	
	560202GY	2.43	0.1	0.1	0.97	0.35		0.29		PPG	
	560202CL	2.431	0.19	0.16	0.97	0.37		0.51		PPG	
	560202BZ	2.432	0.12	0.1	0.98	0.35		0.34		PPG	
	560202GN	2.433	0.16	0.1	0.97	0.35		0.46		PPG	
	565202GY	2.434	0.11	0.12	1.02	0.39		0.28		PPG	
	565202CL	2.435	0.22	0.2	1.01	0.43		0.51		PPG	
	565202BZ	2.436	0.14	0.13	1.02	0.4		0.35		PPG	
	565202GN	2.437	0.2	0.13	1.02	0.4		0.50		PPG	
	570202GY	2.438	0.11	0.1	0.98	0.36		0.31		PPG	
	570202CL	2.439	0.21	0.15	0.98	0.36		0.58		PPG	
	570202BZ	2.44	0.13	0.1	0.99	0.35		0.37		PPG	
	570202GN	2.441	0.18	0.1	0.98	0.35		0.51		PPG	
	570302GY	2.442	0.17	0.14	1.01	0.41		0.41		PPG	
	570302CL	2.443	0.31	0.24	1.02	0.46		0.67		PPG	
	570302BZ	2.444	0.18	0.15	0.99	0.41		0.44		PPG	
	570302GN	2.445	0.27	0.16	1.01	0.42		0.64		PPG	
	ECLCLR1	3.124	0.33	0.43	1.09	0.56		0.59		LOF	
	ECLCLR2	3.125	0.33	0.43	1.08	0.58		0.57		LOF	
	ECLBGR1	3.126	0.33	0.28	1.09	0.44		0.75		LOF	
	ECLBGR2	3.127	0.33	0.28	1.08	0.5		0.66		LOF	
	ECLGRY1	3.128	0.2	0.29	1.09	0.45		0.44		LOF	
	ECLGRY2	3.129	0.2	0.29	1.08	0.53		0.38		LOF	
	ECLBRZ1	3.13	0.25	0.3	1.09	0.46		0.54		LOF	
durable	ECLBRZ2	3.131	0.25	0.3	1.08	0.53		0.47		LOF	
1-pane	LOFEE	3.22	0.82	0.74	4.34	0.893		0.92		LOF	
	SS8	4.501	0.08	0.07	0.9	0.23		0.35		Guardian	
	SS14	4.502	0.14	0.11	0.94	0.3		0.47		Guardian	
	SS20	4.503	0.2	0.16	0.99	0.37		0.54		Guardian	
	CS14	4.504	0.14	0.12	0.92	0.3		0.47		Guardian	
	CS20	4.505	0.2	0.17	0.95	0.37		0.54		Guardian	
	TS20	4.506	0.2	0.14	0.95	0.35		0.57		Guardian	
	TS30	4.507	0.3	0.24	1	0.46		0.65		Guardian	
	SS8	4.508	0.06	0.04	0.9	0.25		0.24		Guardian	
	SS14	4.509	0.11	0.06	0.94	0.29		0.38		Guardian	
	SS20	4.51	0.16	0.09	0.99	0.34		0.47		Guardian	
	TS20	4.511	0.17	0.09	0.95	0.34		0.50		Guardian	
	TS30	4.512	0.26	0.15	1	0.4		0.65		Guardian	
	SS8	4.513	0.05	0.04	0.9	0.26		0.19		Guardian	
	SS14	4.514	0.08	0.06	0.94	0.3		0.27		Guardian	
	SS20	4.515	0.12	0.1	0.99	0.35		0.34		Guardian	
	SS8	4.516	0.04	0.04	0.9	0.26		0.15		Guardian	
	SS14	4.517	0.07	0.06	0.94	0.31		0.23		Guardian	
	SS20	4.518	0.1	0.09	0.99	0.35		0.29		Guardian	
	TS20	4.519	0.1	0.08	0.95	0.33		0.30		Guardian	
	TS30	4.52	0.15	0.14	1	0.4		0.38		Guardian	
	CB8	4.521	0.08	0.07	0.9	0.26		0.31		Guardian	
	CB14	4.522	0.14	0.13	0.96	0.34		0.41		Guardian	
	CB20	4.523	0.2	0.19	1.02	0.42		0.48		Guardian	
	CP8	4.524	0.08	0.07	0.91	0.26		0.31		Guardian	
	CP14	4.525	0.14	0.14	0.99	0.35		0.40		Guardian	
	CP20	4.526	0.2	0.19	1.02	0.42		0.48		Guardian	
	CR8	4.527	0.08	0.07	0.89	0.27		0.30		Guardian	
	CR14	4.528	0.14	0.13	0.95	0.35		0.40		Guardian	
	CR20	4.529	0.2	0.19	1.01	0.43		0.47		Guardian	
	CB8	4.53	0.07	0.04	0.9	0.27		0.26		Guardian	
	CB14	4.531	0.12	0.08	0.96	0.33		0.36		Guardian	
	CB20	4.532	0.17	0.11	1.02	0.38		0.45		Guardian	

	NAME	INDEX	Tv	Ts	Uw(Air)	SC	Uw(Arg)	Ke	Apparent color	Manufacturer	Product name
	CP8	4.533	0.07	0.04	0.91	0.27		0.26		Guardian	
	CP14	4.534	0.12	0.08	0.99	0.33		0.36		Guardian	
	CP20	4.535	0.17	0.11	1.02	0.37		0.46		Guardian	
	CR8	4.536	0.07	0.04	0.89	0.27		0.26		Guardian	
	CR14	4.537	0.12	0.08	0.95	0.33		0.36		Guardian	
	CR20	4.538	0.17	0.11	1.01	0.37		0.46		Guardian	
	CB8	4.539	0.05	0.04	0.9	0.27		0.19		Guardian	
	CB14	4.54	0.08	0.08	0.96	0.33		0.24		Guardian	
	CB20	4.541	0.12	0.11	1.02	0.38		0.32		Guardian	
	CP8	4.542	0.05	0.04	0.91	0.27		0.19		Guardian	
	CP14	4.543	0.08	0.08	0.99	0.34		0.24		Guardian	
	CP20	4.544	0.12	0.12	1.02	0.38		0.32		Guardian	
	CB8	4.545	0.04	0.04	0.9	0.27		0.15		Guardian	
	CB14	4.546	0.07	0.08	0.96	0.33		0.21		Guardian	
	CB20	4.547	0.1	0.11	1.02	0.38		0.26		Guardian	
	CP8	4.548	0.04	0.04	0.91	0.28		0.14		Guardian	
	CP14	4.549	0.07	0.08	0.99	0.34		0.21		Guardian	
	CP20	4.55	0.1	0.12	1.02	0.38		0.26		Guardian	
	CR8	4.551	0.04	0.05	0.89	0.28		0.14		Guardian	
durable	CR14	4.552	0.07	0.08	0.95	0.33		0.21		Guardian	
1-pane	CR20	4.553	0.1	0.11	1.01	0.38		0.26		Guardian	

	NAME	INDEX	Tv	Ts	Uw(Air)	SC	Uw(Arg)	Ke	Apparent color	Manufacturer	Product name
non-dur	LOE-178	6	0.86	0.65	0.68	0.787		1.09			
1-pane	LOE-178	7	0.86	0.65	1.06	0.803		1.07			
	LOE-278	8	0.75	0.42	0.68	0.582		1.29			
	LOE-378	9	0.43	0.38	0.68	0.54		0.80			
	LOE-478	10	0.52	0.4	0.63	0.559		0.93			
	LOE-578	11	0.55	0.37	0.68	0.535		1.03			
	SUN-162	13	0.63	0.44	0.67	0.554		1.14			
	SUN-262	14	0.54	0.29	0.67	0.438		1.23			
	SUN-362	15	0.32	0.24	0.67	0.394		0.81			
	LP-113	42	0.13	0.11	0.88	0.294		0.44			
	LP-118	43	0.19	0.17	0.92	0.37		0.51			
	LP-122	44	0.22	0.2	0.94	0.413		0.53			
	LP-213	45	0.12	0.07	0.88	0.291		0.41			
	LP-218	46	0.17	0.1	0.92	0.337		0.50			
	LP-222	47	0.19	0.12	0.94	0.362		0.52			
	LP-313	48	0.07	0.06	0.88	0.291		0.24			
	LP-318	49	0.1	0.09	0.92	0.334		0.30			
	LP-322	50	0.11	0.11	0.94	0.36		0.31			
	LP-413	51	0.08	0.07	0.88	0.294		0.27			
	LP-418	52	0.11	0.1	0.92	0.34		0.32			
	LP-422	53	0.13	0.12	0.94	0.366		0.36			
	LP-113	54	0.09	0.07	0.88	0.294		0.31			
	LP-518	55	0.13	0.09	0.92	0.328		0.40			
	LOE -170	56	0.77	0.43	0.65	0.543		1.42			
	LOE -270	57	0.67	0.31	0.65	0.466		1.44			
	LOE -370	58	0.39	0.24	0.65	0.389		1.00			
	LOE -470	59	0.46	0.26	0.65	0.408		1.13			
	LOE -570	60	0.5	0.28	0.65	0.43		1.16			
	SUN-145	61	0.48	0.33	0.7	0.474		1.01			
	SUN-245	62	0.41	0.22	0.7	0.391		1.05			
	SUN-345	63	0.24	0.18	0.7	0.353		0.68			
	SUN-445	64	0.29	0.2	0.7	0.367		0.79			
	SUN-545	65	0.32	0.21	0.7	0.379		0.84			
	AFG LOE	66	0.72	0.41	0.65	0.516		1.40			
	LOE-178	10	0.87	0.68	1.09	0.827		1.05			
	LOE-178	11	0.87	0.68	1.09	0.827		1.05			
	LOE-178	12	0.87	0.68	1.08	0.827		1.05			
	LOE-178	13	0.87	0.67	1.08	0.819		1.06			
non-dur	LOE-178	14	0.87	0.67	1.08	0.819		1.06			
1-pane	LOE-178	15	0	0	0	0					
	LOE-178	16	0	0	0	0					
	LOE-178	17	0.86	0.64	1.07	0.795		1.08			
	LOE-178	18	0.86	0.65	1.06	0.803		1.07			
	LOES-462	19	0.49	0.37	0.67	0.501		0.98			
	LOES-462	20	0.45	0.34	0.67	0.477		0.94			
	LOES-462	21	0.39	0.29	0.66	0.437		0.89			
	LOES-140	22	0.42	0.31	0.71	0.441		0.95			
	LOES-140	23	0.42	0.29	0.71	0.426		0.99			
	LOES-140	24	0.42	0.29	0.7	0.428		0.98			
	LOES-140	25	0.42	0.29	0.7	0.429		0.98			
	LOF LOWE	29	0.83	0.75	1.09	0.926		0.90			
	LOF LOWE	30	0.82	0.74	1.09	0.918		0.89			
	LOF LOWE	31	0.82	0.72	1.08	0.902		0.91			
	LOF LOWE	32	0.81	0.7	1.07	0.886		0.91			
	LOF LOWE	33	0.81	0.68	1.07	0.87		0.93			
	LOE2-170	34	0.78	0.45	0.67	0.557		1.40			
	LOE2-170	35	0	0							
	LOE2-170	36	0	0							
	LOE2-170	37	0	0							
	LOES-145	38	0	0							
	LOES-145	39	0.49	0.35	0.483	0.483		1.01			

	NAME	INDEX	Tv	Ts	Uw(Air)	SC	Uw(Arg)	Ke	Apparent color	Manufacturer	Product name
	LOES-145	40	0	0							
	LOES-145	41	0	0							
	PPG-SUNC	141	0.82	0.62	0.7	0.761		1.08			
	HM88	401	0.868	0.656	6.17	0.797		1.09			
	HM77	402	0.766	0.504	6.15	0.62		1.24			
	HH66	403	0.658	0.403	6.14	0.499		1.32			
	HM55	404	0.551	0.32	6.14	0.408		1.35			
non-dur	HM44	405	0.439	0.245	6.14	0.333		1.32			
1-pane	HM33	406	0.33	0.178	6.14	0.238		1.39			
2-pane	SS-108	1.2	0.07	0.05	0.4	0.14	0.36	0.50		Cardinal	
	SS-114	1.201	0.13	0.08	0.41	0.19	0.38	0.68		Cardinal	
	SS-120	1.202	0.18	0.13	0.43	0.26	0.39	0.69		Cardinal	
	SS-208	1.203	0.06	0.03	0.4	0.15	0.36	0.40		Cardinal	
	SS-214	1.204	0.11	0.05	0.41	0.17	0.38	0.65		Cardinal	
	SS-220	1.205	0.16	0.07	0.43	0.21	0.39	0.76		Cardinal	
	SS-308	1.206	0.04	0.03	0.4	0.15	0.36	0.27		Cardinal	
	SS-314	1.207	0.06	0.05	0.41	0.18	0.38	0.33		Cardinal	
	SS-320	1.208	0.08	0.07	0.43	0.21	0.39	0.38		Cardinal	
	SS-408	1.209	0.05	0.03	0.4	0.15	0.36	0.33		Cardinal	
	SS-414	1.21	0.08	0.05	0.41	0.18	0.38	0.44		Cardinal	
	SS-420	1.211	0.09	0.08	0.43	0.22	0.39	0.41		Cardinal	
	SS-508	1.212	0.05	0.03	0.4	0.15	0.36	0.33		Cardinal	
	SS-514	1.213	0.08	0.06	0.41	0.19	0.38	0.42		Cardinal	
	SS-520	1.214	0.12	0.08	0.43	0.22	0.39	0.55		Cardinal	
	TI-120	1.215	0.18	0.1	0.41	0.23	0.37	0.78		Cardinal	
	TI-130	1.216	0.27	0.18	0.44	0.32	0.41	0.84		Cardinal	
	TI-220	1.217	0.16	0.06	0.41	0.19	0.37	0.84		Cardinal	
	TI-230	1.218	0.23	0.1	0.44	0.24	0.41	0.96		Cardinal	
	TI-320	1.219	0.09	0.07	0.41	0.19	0.37	0.47		Cardinal	
	TI-330	1.22	0.14	0.11	0.44	0.26	0.41	0.54		Cardinal	
	TI-410	1.221	0.05	0.03	0.4	0.16	0.36	0.31		Cardinal	
	TI-420	1.222	0.12	0.08	0.41	0.22	0.37	0.55		Cardinal	
	TI-430	1.223	0.16	0.12	0.44	0.27	0.41	0.59		Cardinal	
	TI-520	1.224	0.12	0.08	0.41	0.22	0.37	0.55		Cardinal	
	TI-530	1.225	0.17	0.12	0.44	0.27	0.41	0.63		Cardinal	
	LP-113	1.226	0.12	0.09	0.41	0.2	0.37	0.60		Cardinal	
	LP-118	1.227	0.17	0.14	0.42	0.27	0.38	0.63		Cardinal	
	LP-122	1.228	0.2	0.16	0.43	0.3	0.39	0.67		Cardinal	
	LP-213	1.229	0.11	0.06	0.41	0.18	0.37	0.61		Cardinal	
	LP-218	1.23	0.16	0.08	0.42	0.22	0.38	0.73		Cardinal	
	LP-222	1.231	0.17	0.1	0.43	0.24	0.39	0.71		Cardinal	
	LP-313	1.232	0.06	0.03	0.41	0.18	0.37	0.33		Cardinal	
	LP-318	1.233	0.09	0.07	0.42	0.21	0.38	0.43		Cardinal	
	LP-322	1.234	0.1	0.09	0.43	0.24	0.39	0.42		Cardinal	
	LP-413	1.235	0.07	0.06	0.41	0.19	0.37	0.37		Cardinal	
	LP-418	1.236	0.1	0.08	0.42	0.22	0.38	0.45		Cardinal	
2-pane	LP-422	1.237	0.12	0.1	0.43	0.24	0.39	0.50		Cardinal	
	LP-513	1.238	0.08	0.06	0.41	0.19	0.37	0.42		Cardinal	
	LP-518	1.239	0.12	0.07	0.42	0.21	0.38	0.57		Cardinal	
	LP-522	1.24	0.13	0.1	0.43	0.24	0.39	0.54		Cardinal	
	SS-108	1.3	0.07	0.04	0.31	0.11	0.25	0.64		Cardinal	
	SS-114	1.301	0.12	0.07	0.31	0.16	0.25	0.75		Cardinal	
	SS-120	1.302	0.17	0.11	0.31	0.21	0.25	0.81		Cardinal	
	SS-208	1.303	0.05	0.03	0.31	0.11	0.25	0.45		Cardinal	
	SS-214	1.304	0.1	0.04	0.31	0.13	0.25	0.77		Cardinal	
	SS-220	1.305	0.15	0.06	0.31	0.16	0.25	0.94		Cardinal	
	SS-308	1.306	0.04	0.03	0.31	0.12	0.25	0.33		Cardinal	
	SS-314	1.307	0.06	0.04	0.31	0.14	0.25	0.43		Cardinal	
	SS-320	1.308	0.08	0.06	0.31	0.16	0.25	0.50		Cardinal	
	SS-408	1.309	0.04	0.03	0.31	0.12	0.25	0.33		Cardinal	

	NAME	INDEX	Tv	Ts	Uw(Air)	SC	Uw(Arg)	Ke	Apparent color	Manufacturer	Product name
	SS-414	1.31	0.08	0.04	0.31	0.14	0.25	0.57		Cardinal	
	SS-420	1.311	0.09	0.07	0.31	0.17	0.25	0.53		Cardinal	
	SS-508	1.312	0.04	0.03	0.31	0.12	0.25	0.33		Cardinal	
	SS-514	1.313	0.08	0.05	0.31	0.15	0.25	0.53		Cardinal	
	SS-520	1.314	0.11	0.07	0.31	0.17	0.25	0.65		Cardinal	
	TI-120	1.315	0.17	0.09	0.31	0.19	0.25	0.89		Cardinal	
	TI-130	1.316	0.26	0.15	0.31	0.26	0.25	1.00		Cardinal	
	TI-220	1.317	0.15	0.06	0.31	0.15	0.25	1.00		Cardinal	
	TI-230	1.318	0.22	0.09	0.31	0.19	0.25	1.16		Cardinal	
	TI-320	1.319	0.09	0.06	0.31	0.16	0.25	0.56		Cardinal	
	TI-330	1.32	0.13	0.1	0.31	0.21	0.25	0.62		Cardinal	
	TI-410	1.321	0.04	0.03	0.31	0.12	0.25	0.33		Cardinal	
	TI-420	1.322	0.11	0.07	0.31	0.17	0.25	0.65		Cardinal	
	TI-430	1.323	0.16	0.11	0.31	0.21	0.25	0.76		Cardinal	
	TI-520	1.324	0.11	0.07	0.31	0.17	0.25	0.65		Cardinal	
	TI-530	1.325	0.17	0.11	0.31	0.22	0.25	0.77		Cardinal	
	LP-113	1.326	0.12	0.08	0.32	0.12	0.25	1.00		Cardinal	
	LP-118	1.327	0.17	0.12	0.32	0.19	0.25	0.89		Cardinal	
2-pane	LP-122	1.328	0.19	0.14	0.32	0.21	0.25	0.90		Cardinal	
	LP-213	1.329	0.11	0.05	0.32	0.11	0.25	1.00		Cardinal	
	LP-218	1.33	0.15	0.07	0.32	0.14	0.25	1.07		Cardinal	
	LP-222	1.331	0.17	0.09	0.32	0.16	0.25	1.06		Cardinal	
	LP-313	1.332	0.06	0.04	0.32	0.12	0.25	0.50		Cardinal	
	LP-318	1.333	0.09	0.06	0.32	0.14	0.25	0.64		Cardinal	
	LP-322	1.334	0.1	0.08	0.32	0.15	0.25	0.67		Cardinal	
	LP-413	1.335	0.07	0.05	0.32	0.11	0.25	0.64		Cardinal	
	LP-418	1.336	0.1	0.07	0.32	0.14	0.25	0.71		Cardinal	
	LP-422	1.337	0.11	0.09	0.32	0.17	0.25	0.65		Cardinal	
	LP-513	1.338	0.08	0.05	0.32	0.12	0.25	0.67		Cardinal	
	LP-518	1.339	0.11	0.06	0.32	0.15	0.25	0.73		Cardinal	
	LP-522	1.34	0.12	0.09	0.32	0.17	0.25	0.71		Cardinal	
	LE-178#2	1.401	0.77	0.51	0.31	0.71	0.25	1.08		Cardinal	
	LE-178#3	1.402	0.77	0.52	0.31	0.71	0.25	1.08		Cardinal	
	LE2-170	1.403	0.69	0.35	0.29	0.49	0.23	1.41	clear	Cardinal	
	LES-145	1.404	0.43	0.26	0.31	0.4	0.26	1.08	clear	Cardinal	
	LE-278#2	1.406	0.67	0.33	0.31	0.49	0.25	1.37	green	Cardinal	
	LE-278#3	1.407	0.66	0.3	0.31	0.45	0.25	1.47	green	Cardinal	
	LE2-270	1.408	0.6	0.25	0.29	0.38	0.23	1.58	green	Cardinal	
	LES-245	1.409	0.37	0.17	0.31	0.3	0.26	1.23	green	Cardinal	
	LE-378#2	1.411	0.36	0.3	0.31	0.45	0.25	0.80	green	Cardinal	
2-pane	LE-378#3	1.412	0.35	0.3	0.31	0.45	0.25	0.78	green	Cardinal	
	LE2-370	1.413	0.35	0.19	0.29	0.31	0.23	1.13	green	Cardinal	
	LES-345	1.414	0.21	0.14	0.31	0.26	0.26	0.81	green	Cardinal	
	LE-478#2	1.416	0.46	0.32	0.31	0.47	0.25	0.98	bronze	Cardinal	
	LE-478#3	1.417	0.45	0.32	0.31	0.45	0.25	1.00	bronze	Cardinal	
	LE2-470	1.418	0.41	0.21	0.29	0.33	0.23	1.24	bronze	Cardinal	
	LES-445	1.419	0.26	0.16	0.31	0.28	0.26	0.93	bronze	Cardinal	
	LE-578#2	1.421	0.49	0.29	0.31	0.44	0.25	1.11	blue	Cardinal	
	LE-578#3	1.422	0.49	0.32	0.31	0.47	0.25	1.04	blue	Cardinal	
	LE2-570	1.423	0.45	0.22	0.29	0.35	0.23	1.29	blue	Cardinal	
	LES-545	1.424	0.29	0.17	0.31	0.29	0.26	1.00		Cardinal	
	AQUA	2.1	0.64	0.38	0.49	0.47		1.36		PPG	
	SG100	2.101	0.6	0.24	0.31	0.37		1.62		PPG	
	SB550-13	2.102	0.1	0.05	0.42	0.18		0.56		PPG	
	SB550-18	2.103	0.13	0.07	0.44	0.21		0.62		PPG	
	SB550-22	2.104	0.17	0.08	0.45	0.24		0.71		PPG	
	SB560-8	2.105	0.07	0.03	0.4	0.16		0.44		PPG	
	SB560-14	2.106	0.11	0.05	0.42	0.19		0.58		PPG	
	SB560-20	2.107	0.15	0.07	0.43	0.21		0.71		PPG	
	SB565-20	2.108	0.16	0.08	0.45	0.23		0.70		PPG	
	SB570-20	2.109	0.16	0.07	0.43	0.21		0.76		PPG	

	NAME	INDEX	Tv	Ts	Uw(Air)	SC	Uw(Arg)	Ke	Apparent color	Manufacturer	Product name
	SB570-30	2.11	0.24	0.1	0.45	0.26		0.92		PPG	
	SB575-20	2.111	0.18	0.08	0.3	0.17		1.06		PPG	
	SB575-30	2.112	0.25	0.09	0.29	0.23		1.09		PPG	
	SB580-20	2.113	0.16	0.09	0.3	0.18		0.89		PPG	
	SB580-30	2.114	0.26	0.1	0.3	0.26		1.00		PPG	
	SG50CLR	2.115	0.51	0.34	0.31	0.48		1.06		PPG	
	SG50GRN	2.116	0.43	0.21	0.31	0.32		1.34		PPG	
	SG50AZUF	2.117	0.41	0.17	0.31	0.27		1.52		PPG	
	SG50BLU	2.118	0.33	0.29	0.31	0.32		1.03		PPG	
	SG50BRZ	2.119	0.3	0.21	0.31	0.32		0.94		PPG	
	SG50GRY	2.12	0.23	0.21	0.31	0.32		0.72		PPG	
	SG50GRYL	2.121	0.08	0.11	0.31	0.31		0.26		PPG	
	SBSG550	2.122	0.15	0.11	0.31	0.25		0.60		PPG	
	SBSG560	2.123	0.12	0.08	0.31	0.2		0.60		PPG	
	SBSG565	2.124	0.13	0.1	0.31	0.24		0.54		PPG	
	SBSG570	2.125	0.13	0.08	0.31	0.2		0.65		PPG	
	SBSG575	2.126	0.13	0.07	0.29	0.16		0.81		PPG	
	SBSG580	2.127	0.12	0.07	0.29	0.18		0.67		PPG	
	SGG-CLR	2.128	0.3	0.18	0.29	0.23		1.30		PPG	
	SGG-GRN	2.129	0.25	0.11	0.29	0.2		1.25		PPG	
	SGG-AZUF	2.13	0.24	0.08	0.29	0.18		1.33		PPG	
	SGG-BLU	2.131	0.19	0.11	0.29	0.2		0.95		PPG	
	SGG-BRZ	2.132	0.15	0.11	0.29	0.2		0.75		PPG	
	SGG-GRY	2.133	0.16	0.11	0.29	0.2		0.80		PPG	
	SGG-GRYL	2.134	0.05	0.06	0.29	0.19		0.26		PPG	
	CLEAR	2.2	0.8	0.62	0.49	0.82		0.98		PPG	
	SOLEX	2.201	0.68	0.37	0.49	0.55		1.24		PPG	
	SOLBRZ	2.202	0.47	0.38	0.49	0.57		0.82		PPG	
2-pane	SOLGY	2.203	0.38	0.31	0.49	0.5		0.76		PPG	
	GRYL	2.204	0.13	0.2	0.49	0.38		0.34		PPG	
	SC1-BRZ	2.205	0.19	0.21	0.49	0.34		0.56		PPG	
	SC1-GY	2.206	0.16	0.17	0.49	0.3		0.53		PPG	
	SC1-GYL	2.207	0.05	0.11	0.49	0.24		0.21		PPG	
	SC2-BRZ	2.208	0.2	0.21	0.49	0.38		0.53		PPG	
	SC2-GY	2.209	0.16	0.18	0.49	0.34		0.47		PPG	
	SG1002CL	2.21	0.75	0.5	0.31	0.68		1.10		PPG	
	SG1003CL	2.211	0.75	0.5	0.31	0.71		1.06		PPG	
	SG1002GN	2.212	0.63	0.3	0.31	0.44		1.43		PPG	
	SG1002BZ	2.213	0.44	0.3	0.31	0.45		0.98		PPG	
	SG1002GY	2.214	0.35	0.27	0.31	0.41		0.85		PPG	
	SG100GYL	2.215	0.12	0.16	0.31	0.29		0.41		PPG	
	550132GY	2.216	0.07	0.06	0.44	0.2		0.35		PPG	
	550132CL	2.217	0.13	0.11	0.44	0.23		0.57		PPG	
	550132BZ	2.218	0.08	0.06	0.44	0.2		0.40		PPG	
	550132GN	2.219	0.11	0.06	0.42	0.2		0.55		PPG	
	550133GY	2.22	0.06	0.06	0.44	0.31		0.19		PPG	
	550133CL	2.221	0.13	0.11	0.44	0.4		0.33		PPG	
	550133BZ	2.222	0.08	0.07	0.44	0.31		0.26		PPG	
	550133GN	2.223	0.11	0.06	0.44	0.31		0.35		PPG	
	550182GY	2.224	0.1	0.08	0.44	0.23		0.43		PPG	
	550182CL	2.225	0.17	0.14	0.44	0.27		0.63		PPG	
	550182BZ	2.226	0.11	0.09	0.44	0.23		0.48		PPG	
	550182GN	2.227	0.15	0.09	0.44	0.23		0.65		PPG	
	550183GY	2.228	0.08	0.08	0.44	0.33		0.24		PPG	
2-pane	550183CL	2.229	0.18	0.14	0.44	0.45		0.40		PPG	
	550183BZ	2.23	0.1	0.09	0.44	0.34		0.29		PPG	
	550183GN	2.231	0.15	0.08	0.44	0.33		0.45		PPG	
	550222GY	2.232	0.12	0.11	0.46	0.26		0.46		PPG	
	550222CL	2.233	0.23	0.18	0.45	0.33		0.70		PPG	
	550222BZ	2.234	0.14	0.11	0.45	0.26		0.54		PPG	
	550222GN	2.235	0.19	0.11	0.45	0.26		0.73		PPG	

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	550223GY	2.236	0.11	0.11	0.45	0.36		0.31		PPG	
	550223CL	2.237	0.23	0.18	0.45	0.49		0.47		PPG	
	550223BZ	2.238	0.13	0.11	0.45	0.37		0.35		PPG	
	550223GN	2.239	0.19	0.11	0.45	0.36		0.53		PPG	
	56082GY	2.3	0.04	0.04	0.4	0.16		0.25		PPG	
	56082CL	2.301	0.09	0.07	0.41	0.17		0.53		PPG	
	56082BZ	2.302	0.05	0.05	0.4	0.17		0.29		PPG	
	56082GN	2.303	0.07	0.04	0.4	0.16		0.44		PPG	
	560142GY	2.304	0.07	0.06	0.42	0.2		0.35		PPG	
	560142CL	2.305	0.13	0.1	0.42	0.21		0.62		PPG	
	560142BZ	2.306	0.08	0.06	0.42	0.2		0.40		PPG	
	560142GN	2.307	0.11	0.06	0.42	0.19		0.58		PPG	
	560202GY	2.308	0.1	0.09	0.44	0.23		0.43		PPG	
	560202CL	2.309	0.18	0.13	0.44	0.26		0.69		PPG	
	560202BZ	2.31	0.11	0.09	0.44	0.23		0.48		PPG	
	560202GN	2.311	0.15	0.09	0.43	0.23		0.65		PPG	
	565202GY	2.312	0.11	0.1	0.45	0.26		0.42		PPG	
	565202CL	2.313	0.21	0.17	0.45	0.32		0.66		PPG	
	565202BZ	2.314	0.13	0.11	0.45	0.27		0.48		PPG	
	565202GN	2.315	0.19	0.11	0.45	0.27		0.70		PPG	
	570202GY	2.316	0.11	0.09	0.44	0.23		0.48		PPG	
	570202CL	2.317	0.2	0.13	0.44	0.26		0.77		PPG	
	570202BZ	2.318	0.12	0.08	0.44	0.22		0.55		PPG	
	570202GN	2.319	0.17	0.09	0.44	0.23		0.74		PPG	
	570302GY	2.32	0.16	0.12	0.45	0.27		0.59		PPG	
	570302CL	2.321	0.29	0.2	0.45	0.35		0.83		PPG	
	570302BZ	2.322	0.15	0.13	0.45	0.26		0.58		PPG	
2-pane	570302GN	2.323	0.25	0.13	0.45	0.29		0.86		PPG	
	575202GY	2.324	0.11	0.06	0.3	0.15		0.73		PPG	
	575202CL	2.325	0.2	0.11	0.29	0.18		1.11		PPG	
	575202BZ	2.326	0.13	0.07	0.3	0.16		0.81		PPG	
	575202GN	2.327	0.17	0.07	0.3	0.16		1.06		PPG	
	575303GY	2.328	0.15	0.11	0.29	0.26		0.58		PPG	
	575303CL	2.329	0.32	0.18	0.29	0.36		0.89		PPG	
	575303BZ	2.33	0.19	0.11	0.29	0.26		0.73		PPG	
	575303GN	2.331	0.27	0.11	0.29	0.26		1.04		PPG	
	580202GY	2.332	0.09	0.07	0.3	0.16		0.56		PPG	
	580202CL	2.333	0.18	0.12	0.3	0.2		0.90		PPG	
	580202BZ	2.334	0.11	0.07	0.3	0.17		0.65		PPG	
	580202GN	2.335	0.15	0.08	0.3	0.17		0.88		PPG	
	580303GY	2.336	0.15	0.12	0.3	0.29		0.52		PPG	
	580303CL	2.337	0.33	0.21	0.3	0.41		0.80		PPG	
	580303BZ	2.338	0.19	0.13	0.3	0.3		0.63		PPG	
	580303GN	2.339	0.28	0.12	0.3	0.29		0.97		PPG	
	SBSG550	2.34	0.21	0.15	0.31	0.27		0.78		PPG	
	SBSG560	2.341	0.17	0.11	0.31	0.22		0.77		PPG	
	SBSG565	2.342	0.19	0.14	0.31	0.26		0.73		PPG	
	SBSG570	2.343	0.18	0.11	0.31	0.21		0.86		PPG	
	SBSG575	2.344	0.18	0.1	0.29	0.17		1.06		PPG	
	SBSG580	2.345	0.13	0.1	0.29	0.19		0.68		PPG	
	CLR1/8	3.2	0.82	0.73	0.49	0.91		0.90		LOF	
	CLR3/16	3.201	0.81	0.68	0.49	0.87		0.93		LOF	
	CLR1/4	3.202	0.8	0.65	0.48	0.85		0.94		LOF	
	BLGR1/4	3.203	0.69	0.41	0.48	0.6		1.15		LOF	
	EVGR3/16	3.204	0.63	0.32	0.49	0.49		1.29		LOF	
	EVGR1/4	3.205	0.59	0.26	0.48	0.44		1.34		LOF	
	GRY1/8	3.206	0.56	0.54	0.49	0.72		0.78		LOF	
2-pane	GRY3/16	3.207	0.45	0.43	0.49	0.62		0.73		LOF	
	GRY1/4	3.208	0.41	0.39	0.48	0.57		0.72		LOF	
	BRZ1/8	3.209	0.62	0.56	0.49	0.73		0.85		LOF	
	BRZ3/16	3.21	0.53	0.45	0.49	0.64		0.83		LOF	

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	BRZ1/4	3.211	0.49	0.41	0.48	0.59		0.83		LOF	
	ECLCLR1	3.212	0.31	0.35	0.48	0.48		0.65		LOF	
	ECLCLR2	3.213	0.31	0.35	0.48	0.49		0.63		LOF	
	ECLBGR1	3.214	0.3	0.23	0.48	0.35		0.86		LOF	
	ECLBGR2	3.215	0.3	0.23	0.48	0.38		0.79		LOF	
	ECLGRY1	3.216	0.18	0.24	0.48	0.36		0.50		LOF	
	ECLGRY2	3.217	0.18	0.24	0.48	0.4		0.45		LOF	
	ECLBRZ1	3.218	0.23	0.25	0.48	0.37		0.62		LOF	
	ECLBRZ2	3.219	0.23	0.25	0.48	0.41		0.56		LOF	
	LECLR	3.22	0.73	0.55	0.35	0.81		0.90		LOF	
	LEBLGN	3.221	0.62	0.35	0.35	0.55		1.13		LOF	
	LEEVGR	3.222	0.54	0.22	0.35	0.39		1.38		LOF	
	LEGRY	3.223	0.37	0.33	0.35	0.53		0.70		LOF	
	LEBRZ	3.224	0.44	0.34	0.35	0.55		0.80		LOF	
	LEECLCL1	3.3	0.29	0.3	0.35	0.45		0.64		LOF	
	LEECLCL2	3.301	0.29	0.3	0.35	0.46		0.63		LOF	
	LEECLBG1	3.302	0.28	0.19	0.35	0.32		0.88		LOF	
	LEECLBG2	3.303	0.28	0.2	0.35	0.34		0.82		LOF	
	LEECLGY1	3.304	0.16	0.2	0.35	0.33		0.48		LOF	
	LEECLGY2	3.305	0.17	0.2	0.35	0.36		0.47		LOF	
	LEECLBZ1	3.306	0.21	0.21	0.35	0.34		0.62		LOF	
	LEECLBZ2	3.307	0.21	0.21	0.35	0.37		0.57		LOF	
	SS3/32	3.308	0.76	0.66	0.35	0.82		0.93		LOF	
	DS1/8	3.309	0.75	0.64	0.35	0.81		0.93		LOF	
	5/32	3.31	0.75	0.61	0.35	0.78		0.96		LOF	
	3/16	3.311	0.73	0.58	0.35	0.76		0.96		LOF	
	1/4	3.312	0.73	0.55	0.35	0.74		0.99		LOF	
	SS8	4.101	0.07	0.06	0.4	0.16		0.44		Guardian	
	SS14	4.102	0.13	0.09	0.42	0.21		0.62		Guardian	
	SS20	4.103	0.18	0.13	0.44	0.27		0.67		Guardian	
	CS14	4.104	0.13	0.1	0.41	0.22		0.59		Guardian	
	CS20	4.105	0.18	0.15	0.42	0.28		0.64		Guardian	
	TS20	4.106	0.18	0.12	0.44	0.25		0.72		Guardian	
	TS30	4.107	0.27	0.2	0.45	0.35		0.77		Guardian	
	SS8	4.108	0.05	0.03	0.4	0.15		0.33		Guardian	
	SS14	4.109	0.1	0.05	0.42	0.18		0.56		Guardian	
	SS20	4.11	0.15	0.08	0.44	0.22		0.68		Guardian	
	TS20	4.111	0.16	0.08	0.44	0.23		0.70		Guardian	
	TS30	4.112	0.23	0.13	0.45	0.28		0.82		Guardian	
	SS8	4.113	0.04	0.03	0.4	0.16		0.25		Guardian	
	SS14	4.114	0.07	0.05	0.42	0.19		0.37		Guardian	
	SS20	4.115	0.11	0.08	0.44	0.23		0.48		Guardian	
	SS8	4.116	0.04	0.03	0.4	0.16		0.25		Guardian	
	SS14	4.117	0.06	0.05	0.42	0.19		0.32		Guardian	
	SS20	4.118	0.09	0.08	0.44	0.23		0.39		Guardian	
	TS20	4.119	0.09	0.07	0.44	0.22		0.41		Guardian	
	TS30	4.12	0.13	0.12	0.45	0.28		0.46		Guardian	
	CB8	4.121	0.07	0.06	0.4	0.18		0.39		Guardian	
	CB14	4.122	0.13	0.11	0.43	0.24		0.54		Guardian	
	CB20	4.123	0.18	0.16	0.45	0.31		0.58		Guardian	
	CP8	4.124	0.07	0.06	0.4	0.17		0.41		Guardian	
	CP14	4.125	0.13	0.11	0.44	0.25		0.52		Guardian	
	CP20	4.126	0.18	0.16	0.45	0.31		0.58		Guardian	
	CR8	4.127	0.07	0.06	0.4	0.18		0.39		Guardian	
	CR14	4.128	0.13	0.11	0.42	0.25		0.52		Guardian	
	CR20	4.129	0.18	0.16	0.45	0.31		0.58		Guardian	
	CB8	4.13	0.06	0.04	0.4	0.17		0.35		Guardian	
	CB14	4.131	0.11	0.07	0.43	0.21		0.52		Guardian	
	CB20	4.132	0.16	0.1	0.45	0.25		0.64		Guardian	
	CP8	4.133	0.06	0.04	0.4	0.17		0.35		Guardian	
2-pane	CP14	4.134	0.11	0.07	0.44	0.22		0.50		Guardian	

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	CP20	4.135	0.16	0.1	0.45	0.25		0.64		Guardian	
	CR8	4.136	0.06	0.04	0.4	0.17		0.35		Guardian	
	CR14	4.137	0.11	0.07	0.42	0.21		0.52		Guardian	
	CR20	4.138	0.15	0.09	0.45	0.25		0.60		Guardian	
	CB8	4.139	0.04	0.04	0.4	0.17		0.24		Guardian	
	CB14	4.14	0.08	0.06	0.43	0.21		0.38		Guardian	
	CB20	4.141	0.11	0.1	0.45	0.26		0.42		Guardian	
	CP8	4.142	0.04	0.04	0.4	0.17		0.24		Guardian	
	CP14	4.143	0.08	0.07	0.44	0.22		0.36		Guardian	
	CP20	4.144	0.11	0.1	0.45	0.26		0.42		Guardian	
	CB8	4.145	0.04	0.04	0.4	0.17		0.24		Guardian	
	CB14	4.146	0.06	0.06	0.43	0.21		0.29		Guardian	
	CB20	4.147	0.09	0.09	0.45	0.25		0.36		Guardian	
	CP8	4.148	0.04	0.04	0.4	0.17		0.24		Guardian	
	CP14	4.149	0.06	0.07	0.44	0.22		0.27		Guardian	
	CP20	4.15	0.09	0.1	0.45	0.25		0.36		Guardian	
	CR8	4.151	0.04	0.04	0.4	0.17		0.24		Guardian	
	CR14	4.152	0.06	0.07	0.42	0.22		0.27		Guardian	
	CR20	4.153	0.09	0.09	0.45	0.25		0.36		Guardian	
	SS8	4.201	0.07	0.04	0.31	0.12		0.58		Guardian	
2-pane	SS14	4.202	0.12	0.08	0.31	0.17		0.71		Guardian	
	SS20	4.203	0.17	0.11	0.31	0.22		0.77		Guardian	
	CS14	4.204	0.12	0.08	0.31	0.18		0.67		Guardian	
	CS20	4.205	0.17	0.12	0.31	0.23		0.74		Guardian	
	TS20	4.206	0.17	0.1	0.31	0.21		0.81		Guardian	
	TS30	4.207	0.26	0.16	0.31	0.29		0.90		Guardian	
	SS8	4.208	0.06	0.03	0.31	0.12		0.50		Guardian	
	SS14	4.209	0.1	0.05	0.31	0.15		0.67		Guardian	
	SS20	4.21	0.15	0.07	0.31	0.18		0.83		Guardian	
	TS20	4.211	0.15	0.07	0.31	0.17		0.88		Guardian	
	TS30	4.212	0.22	0.11	0.31	0.23		0.96		Guardian	
	SS8	4.213	0.04	0.03	0.31	0.12		0.33		Guardian	
	SS14	4.214	0.07	0.05	0.31	0.15		0.47		Guardian	
	SS20	4.215	0.1	0.07	0.31	0.18		0.56		Guardian	
	SS8	4.216	0.03	0.02	0.31	0.12		0.25		Guardian	
	SS14	4.217	0.06	0.04	0.31	0.15		0.40		Guardian	
	SS20	4.218	0.08	0.06	0.31	0.17		0.47		Guardian	
	TS20	4.219	0.08	0.06	0.31	0.17		0.47		Guardian	
	TS30	4.22	0.13	0.09	0.31	0.22		0.59		Guardian	
	CB8	4.221	0.07	0.05	0.31	0.14		0.50		Guardian	
	CB14	4.222	0.12	0.089	0.31	0.19		0.63		Guardian	
	CB20	4.223	0.17	0.12	0.31	0.25		0.68		Guardian	
	CP8	4.224	0.07	0.05	0.31	0.14		0.50		Guardian	
	CP14	4.225	0.12	0.09	0.31	0.2		0.60		Guardian	
	CP20	4.226	0.17	0.12	0.31	0.24		0.71		Guardian	
	CR8	4.227	0.07	0.05	0.31	0.15		0.47		Guardian	
	CR14	4.228	0.12	0.09	0.31	0.2		0.60		Guardian	
	CR20	4.229	0.17	0.12	0.31	0.25		0.68		Guardian	
	CB8	4.23	0.06	0.03	0.31	0.13		0.46		Guardian	
	CB14	4.231	0.1	0.06	0.31	0.16		0.63		Guardian	
	CB20	4.232	0.15	0.08	0.31	0.2		0.75		Guardian	
	CP8	4.233	0.06	0.03	0.31	0.13		0.46		Guardian	
	CP14	4.234	0.1	0.06	0.31	0.16		0.63		Guardian	
	CP20	4.235	0.15	0.08	0.31	0.19		0.79		Guardian	
	CR8	4.236	0.06	0.03	0.31	0.13		0.46		Guardian	
	CR14	4.237	0.1	0.06	0.31	0.16		0.63		Guardian	
	CR20	4.238	0.15	0.08	0.31	0.19		0.79		Guardian	
	CB8	4.239	0.04	0.03	0.31	0.13		0.31		Guardian	
	CB14	4.24	0.07	0.05	0.31	0.16		0.44		Guardian	
	CB20	4.241	0.1	0.07	0.31	0.19		0.53		Guardian	
	CP8	4.242	0.04	0.03	0.31	0.13		0.31		Guardian	

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	CP14	4.243	0.07	0.05	0.31	0.16		0.44		Guardian	
	CP20	4.244	0.1	0.07	0.31	0.19		0.53		Guardian	
	CB8	4.245	0.03	0.03	0.31	0.13		0.23		Guardian	
	CB14	4.246	0.06	0.05	0.31	0.16		0.38		Guardian	
	CB20	4.247	0.08	0.07	0.31	0.19		0.42		Guardian	
	CP8	4.248	0.03	0.03	0.31	0.13		0.23		Guardian	
	CP14	4.249	0.06	0.05	0.31	0.16		0.38		Guardian	
	CP20	4.25	0.08	0.07	0.31	0.19		0.42		Guardian	
	CR8	4.251	0.03	0.03	0.31	0.14		0.21		Guardian	
	CR14	4.252	0.06	0.05	0.31	0.16		0.38		Guardian	
	CR20	4.253	0.08	0.07	0.31	0.19		0.42		Guardian	
	SRRP20	4.301	0.17	0.08	0.28	0.15		1.13		Guardian	
	MRRP20	4.302	0.15	0.06	0.28	0.15		1.00		Guardian	
	TRRP20	4.303	0.1	0.05	0.28	0.13		0.77		Guardian	
	CRRP20	4.304	0.08	0.04	0.28	0.13		0.62		Guardian	
	NGCG8	4.305	0.07	0.03	0.29	0.09		0.78		Guardian	
	NGCG14	4.306	0.12	0.06	0.3	0.13		0.92		Guardian	
	CL2NU52	4.307	0.47	0.29	0.3	0.44		1.07		Guardian	
	GN2NU52	4.308	0.4	0.2	0.3	0.33		1.21		Guardian	
	BZ3LE75	4.309	0.28	0.17	0.3	0.31		0.90		Guardian	
	GY3LE75	4.31	0.23	0.16	0.3	0.3		0.77		Guardian	
	CLDBLLE	4.311	0.7	0.43	0.29	0.62		1.13		Guardian	
	GNDBLLE	4.312	0.6	0.3	0.29	0.45		1.33		Guardian	
	BZDBLLE	4.313	0.42	0.26	0.29	0.41		1.02		Guardian	
2-pane	GYDBLLE	4.314	0.35	0.24	0.29	0.4		0.88		Guardian	
	SRRP20	4.401	0.18	0.09	0.29	0.15		1.20		Guardian	
	MRRP20	4.402	0.16	0.06	0.29	0.15		1.07		Guardian	
	TRRP20	4.403	0.11	0.05	0.29	0.14		0.79		Guardian	
	CRRP20	4.404	0.09	0.05	0.29	0.13		0.69		Guardian	
	NGCG8	4.405	0.08	0.04	0.31	0.1		0.80		Guardian	
	NGCG14	4.406	0.13	0.06	0.32	0.13		1.00		Guardian	
	MGCG14	4.407	0.11	0.05	0.32	0.26		0.42		Guardian	
	CBCG14	4.408	0.07	0.04	0.32	0.23		0.30		Guardian	
	DGCG14	4.409	0.06	0.04	0.32	0.22		0.27		Guardian	
	CLNU52	4.41	0.5	0.35	0.32	0.48		1.04		Guardian	
	GNNU52	4.411	0.43	0.23	0.32	0.35		1.23		Guardian	
	BZNU52	4.412	0.3	0.21	0.32	0.34		0.88		Guardian	
	GYNU52	4.413	0.25	0.2	0.32	0.33		0.76		Guardian	
	CL3LE	4.414	0.75	0.5	0.31	0.72		1.04		Guardian	
	GN3LE	4.415	0.64	0.33	0.31	0.5		1.28		Guardian	
	BZ3LE	4.416	0.44	0.3	0.31	0.48		0.92		Guardian	
	GY3LE	4.417	0.36	0.28	0.31	0.46		0.78		Guardian	
	CL2LE	4.418	0.75	0.5	0.31	0.65		1.15		Guardian	
	GN2LE	4.419	0.64	0.33	0.31	0.47		1.36		Guardian	
	BZ2LE	4.42	0.44	0.3	0.31	0.44		1.00		Guardian	
	GY2LE	4.421	0.36	0.28	0.31	0.42		0.86		Guardian	
	CLEARF	4.422	0.8	0.66	0.49	0.84		0.95		Guardian	
	GREEN	4.423	0.68	0.41	0.49	0.58		1.17		Guardian	
	BRONZE	4.424	0.47	0.39	0.49	0.58		0.81		Guardian	
2-pane	GRAY	4.425	0.38	0.38	0.49	0.57		0.67		Guardian	
HeatMirror	HM77CLR		0.61	0.32	0.31	0.49		1.24	Clear	Southwall	HM 77/Clear
	HM66CLR		0.53	0.26	0.31	0.41		1.29	Clear	Southwall	HM 66/Clear
	HM55CLR		0.45	0.21	0.31	0.35		1.29	Clear/Silver	Southwall	HM 55/Clear
	HM44CLR		0.36	0.16	0.31	0.3		1.20	Silver	Southwall	HM 44/Clear
	HM33CLR		0.28	0.12	0.31	0.23		1.22	Silver/Chrome	Southwall	HM 33/Clear
	HM77BRZ		0.35	0.19	0.31	0.34		1.03	Bronze	Southwall	HM 77/Bronze
	HM66BRZ		0.3	0.15	0.31	0.29		1.03	Bronze	Southwall	HM 66/Bronze
	HM55BRZ		0.26	0.12	0.31	0.26		1.00	Bronze	Southwall	HM 55/Bronze
	HM44BRZ		0.21	0.09	0.31	0.23		0.91	Copper Brown	Southwall	HM 44/Bronze
	HM33BRZ		0.16	0.07	0.31	0.18		0.89	Copper Brown	Southwall	HM 33/Bronze

NAME	INDEX	Tv	Ts	Uw(Air)	SC	Uw(Arg)	Ke	Apparent color	Manufacturer	Product name
HM77GRN		0.51	0.24	0.31	0.38		1.34	Green	Southwall	HM 77/Green
HM66GRN		0.45	0.2	0.31	0.33		1.36	Green	Southwall	HM 66/Green
HM55GRN		0.38	0.17	0.31	0.3		1.27	Green	Southwall	HM 55/Green
HM44GRN		0.31	0.13	0.31	0.26		1.19	Blue Green	Southwall	HM 44/Green
HM33GRN		0.24	0.1	0.31	0.21		1.14	Silver Green	Southwall	HM 33/Green
HM77BLU		0.39	0.2	0.31	0.35		1.11	Blue	Southwall	HM 77/Blue
HM66BLU		0.34	0.16	0.31	0.3		1.13	Blue	Southwall	HM 66/Blue
HM55BLU		0.29	0.13	0.31	0.26		1.12	Blue	Southwall	HM 55/Blue
HM44BLU		0.23	0.1	0.31	0.23		1.00	Silver Blue	Southwall	HM 44/Blue
HM33BLU		0.18	0.07	0.31	0.19		0.95	Silver Blue	Southwall	HM 33/Blue
HM77GRY		0.29	0.18	0.31	0.33		0.88	Gray	Southwall	HM 77/Gray
HM66GRY		0.25	0.15	0.31	0.28		0.89	Gray	Southwall	HM 66/Gray
HM55GRY		0.21	0.12	0.31	0.25		0.84	Gray	Southwall	HM 55/Gray
HM44GRY		0.17	0.09	0.31	0.22		0.77	Gray	Southwall	HM 44/Gray
HM33GRY		0.13	0.07	0.31	0.18		0.72	Pewter	Southwall	HM 33/Gray
HM66BLK		0.08	0.1	0.31	0.23		0.35	Black	Southwall	HM66/Graylite
HM44BLK		0.05	0.06	0.31	0.18		0.28	Black	Southwall	HM44/Graylite
HM66ROS		0.42	0.24	0.31	0.39		1.08	Rose	Southwall	HM66/Rosa
HM44ROS		0.29	0.15	0.31	0.29		1.00	Silver Pink	Southwall	HM44/Rosa
HM66AMB		0.3	0.17	0.31	0.31		0.97	Amber	Southwall	HM66/Amber
HeatMirror HM44AMB		0.21	0.1	0.31	0.24		0.88	Yellow Gold	Southwall	HM44/Amber
Laminates		0.74	0.4		0.56		1.32	Clear	Monsanto	Solarflex SF00/74/56
		0.57	0.32		0.5		1.14	Green	Monsanto	Solarflex SF37/57/50
		0.56	0.34		0.51		1.10	Blue	Monsanto	Solarflex SF63/56/51
		0.43	0.24		0.43		1.00	Bronze	Monsanto	Solarflex SF64/43/43
		0.36	0.22		0.41		0.88	Gray	Monsanto	Solarflex SF65/36/41
		0.45	0.29		0.46		0.98	Blue	Monsanto	Solarflex SF75/45/46
		0.64	0.36		0.53		1.21	Blue	Monsanto	Solarflex SF82/64/53
		0.4	0.26		0.45		0.89	Blue	Monsanto	Solarflex SF82/40/45
		0.64	0.35		0.51		1.25	Black	Monsanto	Solarflex SF83/64/51
		0.41	0.23		0.41		1.00	Black	Monsanto	Solarflex SF83/41/41
		0.64	0.36		0.53		1.21	Red	Monsanto	Solarflex SF80/64/53
		0.41	0.28		0.46		0.89	Red	Monsanto	Solarflex SF80/41/46

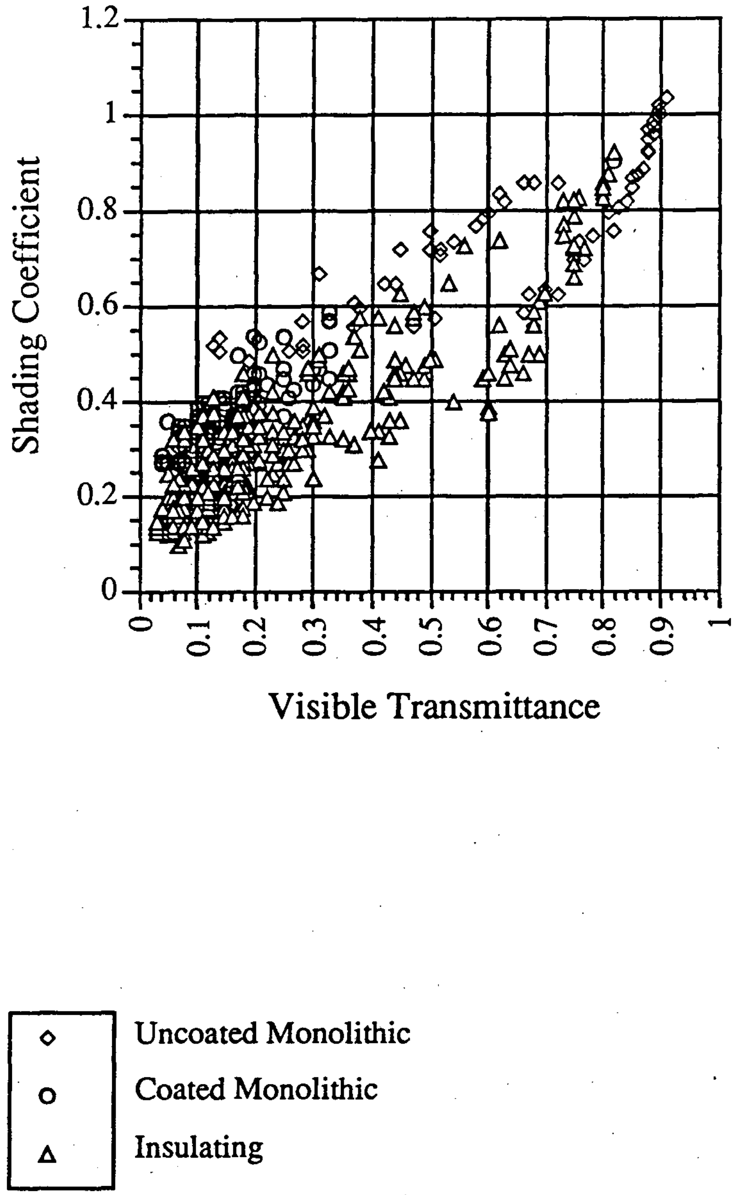

FIGURE 7: VISIBLE TRANSMITTANCE VS. SHADING COEFFICIENT PLOT FOR EXISTING PRODUCTS (PARTIAL)

REFERENCES AND BIBLIOGRAPHY

Arasteh, D., Johnson, R., and Selkowitz, S. "Definition and Use of a Daylight 'Coolness' Index," 1986 International Daylighting Conference Proceedings II, November 1986.

Sweitzer, G., Arasteh, D., and Selkowitz, S. "Effects of Low-Emissivity Glazings on Energy Use Patterns in Nonresidential Daylighted Buildings," December 1986. *ASHRAE Transactions* 93(1):1553-1566 (1987)

Arasteh , D.and Selkowitz, S. "A Superwindow Field Demonstration Program in Northwest Montana," September 1989. *ASHRAE Transactions* 95(1) (1989)

Lampert, Carl and Granqvist, Claes, editors. "Large-Area Chromogenics: Materials and Devices for Transmittance Control," SPIE Institutes for Advanced Optical Technologies, Vol. IS 4, SPIE Optical Engineering Press, Bellingham, WA USA, September 1988.

Johnson, Timothy E. Low-E Glazing Design Guide, Butterworth Architecture, 1991.

Greer, Nora Richter. "Windows Are Far From What They Used To Be," *Architecture* March 1987.

Olson, Christopher. "Plastics cut a glazing edge," Building Design & Construction, August 1991.

AERG FY'91 DOE Funding Proposal.

"Transparent Insulation Technology for Solar Energy Conversion," Fraunhofer-Institut für Solare Energiesysteme, 1991.

ASHRAE Handbook 1981 Fundamentals, Chapter 27 "Fenestration." ASHRAE, Atlanta, GA.

"Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings," Standard 90.1, ASHRAE, Atlanta, GA.

Sweitzer, G., Arasteh, D., and Selkowitz, S. 1987. "Effects of Low-Emissivity Glazings on Energy Use Patterns in Nonresidential Daylighted Buildings," *ASHRAE Transactions* 93(1).

Warner, J., Reilly, M., Arasteh, D. and Selkowitz, S. 1992. "Switchable Glazings: Potential for Peak Demand and Energy Usage Reduction in Commercial Buildings," Windows and Daylighting Group, Lawrence Berkeley Laboratory.

Sullivan, R., Arasteh, D., Sweitzer, G., Johnson, R., and Selkowitz, S. 1987. "The Influence of Glazing Selection on Commercial Building Energy Performance in Hot and Humid Climates," proceedings, ASHRAE Conference on Air Conditioning in Hot Climates, Singapore, September 1987.

Sullivan, R. and Selkowitz, S. 1986. "Residential Heating and Cooling Energy Cost Implications Associated with Window Type," R. Sullivan and S. Selkowitz. *ASHRAE Transactions* 93(1):1525-1539.

Arasteh, D., Connell, D., and Selkowitz, S. 1986. "The Effect of Daylighting Strategies on Building Cooling Loads and Overall Energy Performance," *ASHRAE Transactions* 91(1).

California Energy Commission. 1991. Energy Technology Status Report P500-90-003 (Draft version).

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