

# White Paper

What is Wrong With My Windows  
Identifying Problems in Stained Glass Windows



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& ASSOCIATES

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## EXECUTIVE SUMMARY

The American Industrial Revolution, beginning in the late 18<sup>th</sup> century, yielded a level of prosperity for the American entrepreneurs that rivaled the riches of European royalty. By the mid to late 19<sup>th</sup> century, the nouveau-riche railroad barons, industrialists and prosperous merchants were spending millions of dollars building sumptuous mansions, classical public buildings and monumental Churches. To further embellish these buildings, over one-hundred thousand beautiful windows were produced, many of them of very high quality.

Stained glass is a building material that many stewards of buildings are unfamiliar with. Glass is magical, it is precious and it can be a daunting task for building owners to determine if their stained glass is in good condition. The matrix that holds the individual pieces of glass can be made from a variety of materials, but lead is the most common. There are leaded windows that are 400 years old and still in good condition and there are leaded windows that are 50 years old and in very poor condition; age alone is not the determinant factor. Owners can often be convinced to pay for repairs that are unnecessary. How do building stewards determine if a window is in bad shape? If there are problems, how serious are they? Does the level of deterioration warrant removal of the window, or can the problems be addressed in situ? How can an Owner or Project Manager navigate the proper course of conservation when the waters are muddied with myriad opinions of what is wrong and what is the proper solution? If conservation funds are limited, what is the best way to spend the money available?

Our great American stained glass heritage is at risk of being damaged or lost. This may be the result of the typical forces of deterioration or inadvertent damage by well meaning but misinformed craftsmen. Magnificent jewels of light, line and color could be rendered into lumps of putty, lead dust, and glass shards. This white paper will explore the questions posed above, and offer information to assist decision makers to understand the problems with their windows and the appropriate conservation solutions. These are complex issues. This white paper is intended to provide basic information; not specifications for an actual project. Additional sources for information will also be provided herein.



## THE PROBLEM

Due to a combination of factors, such as: the inherent limitations of the materials used, the damaging effects of sun and weather, and the well-intentioned but often ill-informed actions of owners and craftsmen, thousands of windows are imperiled and at risk of being permanently lost or damaged. Horror stories abound: In New York City, the screws that attached the frame of a ventilator from a clerestory window to the masonry surround had rusted away to nothing. The ventilator, with its stained glass panel intact, fell 50 feet crashing onto the stone floor of the sanctuary and nearly struck the Sexton of the Church.

In every community, scores of windows can be seen that have deflected from the original design plane, bowing and bending to the point where they look more like free-form sculptures than windows. As the deflection worsens, glass breaks and falls out from the retaining lead matrix. A Church in Connecticut housed a beautiful Tiffany figure window in need of repair. The condition of the window was serious enough to warrant removal to a proper studio for conservation. The Church was convinced by a studio that the window could be restored without removal to the studio, thereby appearing to save the Church money. The workers proceeded to smear the windows with silicone, in an attempt to glue a support bar to the lead comes and to cover cracks in the glass. Original broken Tiffany glass was discarded and replaced by poorly matched modern glass. Broken solder joints were also "glued" together with silicone. The Church lost hard to acquire funds and the window was permanently damaged.

## HOW DID THE PROBLEM DEVELOP?

The conditions that have placed thousands of art glass windows at serious risk of permanent damage or loss are physical, professional and institutional.

**PHYSICAL Discounting** modern windows made in the last 60 years, the majority of the stained glass windows that still exist in this country were fabricated here or imported from Europe during the period from 1830 to 1925. Many of these windows are failing as their individual elements age (particularly the lead came and support systems). Factors particular to American windows accelerate the normal aging cycle.

**Design Architectural trends and the emerging opalescent stained glass era gave way to ever-larger stained glass panels with little or no intrusion of T-bars and other supporting armatures. Individual panel sizes were two to four times larger than medieval panels. Plating (the multiple layering of glass) in opalescent windows increased the windows' weight and overtaxed the frames and support systems.**

**Supporting Matrix** The advancements in metallurgy during the early part of the 19<sup>th</sup> century produced pure lead comes. While these were considered progressive, they were actually much weaker than earlier lead came alloys that contained small amounts of copper, tin, antimony, silver and other impurities. Copper adds resistance to fatigue damage through the formation of homogeneous crystal size as lead moves from the molten to solid state. Tin and antimony add to the tensile



strength thereby resisting creep (plastic deformation) and deflection of the panels. Tin also adds resistance to corrosion. During the manufacture of modern restoration grade leads, these trace elements are added back to the mix, resulting in an alloy that is more resistant to creep, deflection, fatigue damage and corrosion.

**Glass and Paint** Certain experimental glasses that were developed by American glassmakers with more art than science, are chemically unstable. Exposure to changes in temperature and humidity can result in the breakdown of the covalent chemical bonds that hold the molecules of glass together, resulting in the total failure of the affected glass. Improper firing, chemical incompatibility of the paint and the substrate glass, and certain fluxes that were used to lower the fusing temperature of the paint, can lead to deterioration and loss of the applied vitreous paint that were commonly used on stained glass windows from this period.

**Exterior Glazing** In the 1960s, fueled by fears of damage from protesting political factions and the higher cost of heating oil, many Churches and institutions began to install “protective glazing” on the exterior of their stained glass windows. Much of this glazing was comprised of polycarbonate plastic held in aluminum frames, or attached directly to the frames that supported the stained glass windows. This material was sold as a panacea for stained glass. Many stewards of the windows were sold on the idea that they did not have to restore their windows if they were covered with polycarbonate. While polycarbonate will protect windows from impact damage, the windows continue to deteriorate as a result of the expansion/contraction cycle, fatigue of the lead comes and corrosion of the lead. Ironically, if polycarbonate is installed improperly (ninety percent of the installations are incorrect), the rate of deterioration of the stained glass is increased, due to the increased temperature range and higher levels of humidity that the window components are subject to.

**PROFESSIONAL** To date, the traditional stained glass studios in the United States have not pooled their resources. They have thought it wiser to protect restoration techniques as if they were family recipes and to teach employees only specialized steps in the window-making process. This isolationist approach to business stagnates the industry and serves no constructive purpose. Research and development occupy a very low priority with studio owners and limited funds are available for government-sponsored programs. All too often, methods and materials are used to restore windows simply because “we have done it that way for years” with little understanding of what long term effect the procedure or material may have on the window under restoration. Few standards exist to guide restoration or to ensure competence among craftsmen. The deficiency of these standards and the complete absence of a national standard of competence for craftsmen often results in restoration plans that are the product of ill-informed opinions or expedience rather than expertise and experience.

Apprenticeship programs are few and far between. Very few craftsmen can afford to enter a traditional apprenticeship program, which can mean years of work at low wages. To survive, the studio must get a high level of production from anyone being paid the full journeyman’s rate. The lack of accredited alternative education drives many craftsmen to open studios and accept work that they may not be qualified to perform.



**INSTITUTIONAL** The stewards of our great stained glass windows are often the vestries or board members of Churches or Synagogues. Many of them may have a basic understanding of the masonry, wood and roof components of their buildings but to most, stained glass is a mystical and lost art. The stewards are committed to caring for their buildings and very well-intentioned. However, financial pressure and/or the opinions of the congregation acting on these groups can sometimes make cheap, short-term solutions to window problems very attractive. Board members often do not understand the cost-effectiveness of expert, long-term restoration procedures. Unfortunately, unscrupulous members of the profession can sometimes leave the client with false expectations of how effective the less expensive proposed restoration plan will be in order to close a sale.

There are limited funds available to operate Churches, Synagogues and other related institutions. Unfortunately, institutions are often forced to take money earmarked for building maintenance and use it for more pressing needs. As the elements of the building are neglected, the rate at which they deteriorate usually accelerates. This can result in a very serious problem developing from what might have been a less-expensive and more straightforward maintenance issue.

## WHAT IS WRONG WITH MY WINDOWS?

The relative strength and condition of a stained glass window is determined by the condition of different elements or systems that interrelate to form the whole window. These systems are: the glass-retaining matrix, the glass, the weatherproofing (often referred to as *cement*), the support system and the method of installation. The breakdown of one or more of these systems tends to hasten the breakdown of the remaining systems and thereby, may ultimately result in the complete failure of the window. Unfortunately for the untrained eye, the failure of a stained glass window occurs over time; stained glass windows can look beautiful and be the picture of good health until the moment glass starts to fall out onto the sidewalk. It is not unlike the long distance runner suffering a massive heart attack one hundred yards from the finish line. It is important to understand what can go wrong, how to look beyond the surface beauty and be able to see the early signs of failure.

**THE GLASS RETAINING MATRIX** Beyond its decorative nature, the primary purpose of the matrix is to hold the individual pieces of glass together. It is understood that the matrix will ultimately fail and have to be replaced. The preponderance of stained glass windows employ lead comes to form the matrix. To a far lesser degree, copper-foil and zinc or brass comes are used. The lead comes are produced in a myriad of profiles. In cross-section, they resemble an “H” or a “U”. The comes are cut and hand-formed to follow the lines of the design. The glass is inserted into the channel that is formed by the *leaves* (vertical sides of the H) of the came, on either side of the *heart* (horizontal web of the H). The comes are soldered together where they intersect. If the leads are flat, they should be *tucked* meaning the end of one came is inserted into the leaves on the lead it intersects. This results in a sweated joint when soldered. If half round leads are used, they must be cut flush to the intersecting lead. The following are the most common forms of deterioration that may be found when inspecting the matrix.



**Deflection** With the exception of very few installations (i.e., stained glass domes and panels set into curved sash), stained glass windows were always made and installed flat. *Deflection* is the bowing and bending of the individual leaded panels away from their original, flat design plane. Contrary to common belief, gravity and wind-loading play minor roles in the deflection of stained glass windows. The primary cause is the force generated by the expansion/contraction cycle. It is a law of physics that all materials expand or contract as they gain and lose heat. The degree to which any material expands for a given change in temperature (heat gain or loss) is referred to as its *coefficient of expansion*. Lead has a very high coefficient of expansion. This produces powerful stress within the stained glass window. This force is distributed throughout the window as a function of the concentration of lead comes present in an area and the temperature range (degrees of fluctuation from high to low temperature) that the window experiences. If the window is set too tightly in its frame, the window cannot dissipate the stress in a linear (flat) direction. The stress must be dissipated, so the window deflects three-dimensionally, resulting in bends and bulges.

The degree to which any specific part of the window deflects is a function of the strength of the local force exerted, and the ability of that area of the window to resist deflection. The ability of the window to resist deflection is determined by many factors, some of which are:

1. Pattern of the lead lines. Weak patterns are - straight lines that form hinge joints, or multiple thin borders that allow the panel to fold; concentric circles that allow the focus of the circles to telescope in or out; many small pieces of similar shape, this encourages deflection throughout the design.
2. Insufficient or poorly applied support bars.
3. The use of hard-setting sealant compounds at the perimeter of the panel. This inhibits the ability of the panel to expand within a flat plane.
4. The use of lead comes that have flat, thin leaves. These are more subject to bending than half-round profiles.
5. The use of a soft alloy to fabricate the lead comes. These are more subject to bending than alloys containing 1.3 - 1.9 % tin, antimony and copper.

Deflection is often a sign of serious trouble in a window. However, it is the degree to which the window is deflected and when the deflection occurred that are most important. If the deflection is minor (less than 1" over a twelve-inch linear distance) it should be noted, but it is not of great concern. Moderate deflection (1" to 2" over a twelve-inch linear distance) should be monitored carefully, and is of great concern if coupled with other signs of failure in the window. Severe deflection (over 3" over a twelve-inch linear distance) is usually a sign of serious trouble in a stained glass window. When inspecting deflection, it is important to look for broken glass in the same area of the window. If there is impact damage, the deflection may be the result of said damage, and be considered a one-time trauma to the window. If the broken glass appears to be *tension stress* (see broken glass below), the deflection should be considered a failure of the system and the window should be stabilized or conserved as soon as possible. All deflection found during periodic inspections should be noted as to location and severity.



These areas should be closely monitored over time to determine if the forces causing the failure have reached equilibrium, or if they are continuing to deform the window.

**Lead Corrosion** There are two basic types of corrosion generally found on the lead comes of the windows. One is caused by inorganic acids, the other is caused by organic acids. The inorganic corrosion is typically the result of attack by a mild form of sulfuric acid, such as acid rain. This corrosion appears as a dark gray patina on the surface of lead and is self-sealing similar to the green patina that forms on copper that is exposed to the elements. This corrosion does not need to be treated, is not harmful to the lead and is commonly accepted as being more esthetically pleasing than the look of bright new lead. Solder joints take longer to acquire the same patina due to the high tin content of the alloy.

Organic acid attacks can result in myriad surface corrosion results but the most common is a white powdered appearance on the surface of the lead. As the corrosion continues, the white powder grows into larger white chunks and falls away from the window. The corrosion can attack the hidden surfaces of the lead came as well as those that are visible. One must be very careful when assessing lead came matrices that have been *tinned* (floated with a thin layer of solder), such as those found on Tiffany windows. The surface may look solid due to the corrosion-resistant tin in the solder alloy, while the underlying lead comes have corroded away. This type of attack is not self-sealing and will eventually destroy or diminish the strength of the lead comes to the point that they will suffer catastrophic failure.

There are a number of microenvironments that will encourage attack by organic acids. English oak, and certain other wood species, release a high level of tannic acid as they age. If leaded glass is set in this type of frame, the leads near the perimeter will be attacked. Acid-cure silicone caulk releases acetic acid (vinegar smell) that will attack the lead. If silicone is used, it must be a neutral-cure type that release alcohol during curing. Moisture tends to collect in the interstitial space of unvented protective glazing systems. Carbon dioxide, a common component of our atmosphere, can dissolve into the moisture and form carbonic acid. This can attack the lead matrix.

If the level of corrosion is minor (a light, smooth layer of white, covering portions of the window), and the agent producing the organic acid is removed from the proximity of the window, the corrosion can be cleaned off the window with stiff, natural bristle brushes in situ; however, this white powder will not continue to corrode the window and may be left in place. The condition should then be closely monitored. If the corrosion is severe (heavy accretion of powder throughout, large chunks of salt falling off the lead) the matrix may be approaching failure. A portion of the window should be removed to facilitate closer inspection of the lead comes. If corrosion has seriously weakened the came, releading is in order. Abrasive techniques should never be employed to remove the corrosion. Regardless of the level of intervention to the panels in question, the source of the acid must be found and ameliorated.

Corrosion resistance of the lead came alloy is increased with the addition of tin.





**Metal Fatigue** Metal fatigue is a weakened condition induced in the lead comes by repeated stress from the expansion/contraction cycle and the flexing of the lead came matrix due to wind or other localized loading conditions. Metal fatigue results in fracturing of the lead comes under forces much weaker than those necessary to fracture new material. Metal fatigue in lead comes is evidenced by irregular, jagged cracks in the lead came perpendicular to the came's long dimension. The cracks are first seen at the perimeter of solder joints. As came continues to fatigue, cracks occur throughout the lead, away from the solder joints. A precursor to the cracking of the lead comes is a change in the surface character of the lead. The lead acquires a rougher texture and a series of small bumps form, possibly the result of internal cracking and oxidation. This condition is very severe and is irreversible. It cannot be solved by soldering over the broken area of lead, recementing the window, rubbing the lead with linseed oil or adding support bars. It is a systemic condition and will eventually result in the catastrophic failure of the lead came matrix. If it is found in less than 5% of the leads, and the remaining systems appear to be in good condition, the failure is not yet at emergency levels but should be closely monitored. The resistance of the lead came to fatigue failure can be greatly enhanced by adding trace amounts of copper and/or silver to the alloy during manufacture. The presence of these elements as the lead cools from a molten to a solid state encourages the formation of equal-sized crystals within the lead. The forces imparted onto the lead during its lifetime are then more evenly distributed and fatigue failure is delayed.

**THE GLASS** Esthetically, the glass is the most important part of any stained glass window. The more important the window, the more important it is to save and reuse as much of the original glass as possible. Glass should only be replaced for compelling reasons. When chemically stable, glass is very durable and will last many millennia. The applied decoration (vitreous and unfired paint) is sometimes less durable. The following are the most common forms of deterioration that may be found when inspecting the glass and applied decoration of the window.

**Broken Glass** Broken glass falls into two major categories, impact damage and stress fractures. A minor category is *crizzling*. Crizzling is the breakdown of the chemical nature of the glass, often due to an excess of alkali in the original *batch*, or dry mixture of compounds the glass was made from.

Impact damage can be caused by any number of objects. This type of damage is easy to identify in a window. There will be a pattern of relatively straight cracks or breaks radiating from a clear point of impact. Sometimes the point of impact is on the lead matrix, between two or more pieces of glass. To state the obvious, the greater the force exerted, the more severe the damage will be. With severe impact, the glass at the point of impact may be crushed into powder. Most often, broken glass found in stained glass windows is not the result of impact damage. The stewards of windows must be very careful to resist the urge to cover stained glass windows with exterior glazing when isolated incidents of impact breakage are found. This approach will typically result in creating a microenvironment that is much more damaging over time for the window than the occasional accident or act of vandalism. Unless the windows in question are of the highest level of complexity and value, it is usually more cost-effective to execute the rare repair than spend money on protective glazing systems.



Stress breaks have several causes. *Thermal stress breaks* can be the result of quickly cooling hot glass (like dropping cold water on a hot light bulb) or heating glass quickly and unevenly. Thermal stress breaks can be identified as single, meandering cracks that twist and turn through the broken piece, following the internal path of least resistance. Sometimes these cracks only partially extend through a piece of glass, and are referred to as *runs*. They are usually very well-defined cracks that run at right angles to the glass surface, with little or no powdering of the glass. This type of damage is often seen in windows that were very close to fires in buildings. Thermal stress breaks also occur when glass was not annealed properly during the manufacturing process. This builds stress into the glass. When additional stress is added at a later time from heat, vibration or tension, the glass breaks. Before thermal stress breaks occur, one can determine if internal stress due to improper annealing exists by inspecting the suspect glass with a series of polarizing filters.

*Tension stress breaks* occur when glass is stressed beyond its tensile strength limitations. Think of a force pushing against the middle of a long, thin piece of glass. As the force increases, the glass will bend slightly. Once the glass is pushed beyond its tensile strength, the glass will break, usually at the point at which the pushing force was centered. Tension breaks tend to be straight and can often have splinters of glass expelled from the area under greatest stress. In typical stained glass windows, this type of force is exerted on glass when an operating ventilator (the section of the window that opens) is forced closed or slammed shut. Tension stress breaks also occur when a window deflects. As a window bows away from its flat plane, the edges of glass are retained by the lead comes, thereby forcing the glass to bend. Eventually, something must give and the glass breaks.

When broken glass is seen in a window, it is important to determine the cause and time period in which the breakage occurred. If it is the result of a single incident, it can be stabilized or sometimes repaired in situ. If the cracks are the result of systemic failure, such as severe deflection, the situation becomes more serious and the window should be removed and addressed quickly. Further, glass has a very high *modulus of elasticity* (resistance to bending). This physical characteristic helps to make the stained glass panel more rigid. As more glass breaks, it weakens the overall matrix of the window, accelerating the rate of deterioration.

It is important to stabilize cracks or repair cracks, especially if they are found on painted glass or irreplaceable types of glass. If a crack is left to its own devices, edge damage will occur along the line of the crack. When the window flexes or vibrates, the edges of the glass along the break work against each other, resulting in conchoidal fracturing of the glass surface. This will chip paint off the piece and make the crack more noticeable and more difficult to restore in the future.

**Paint Problems** The process of applying painted and fired decoration on glass objects was documented as early as the 15<sup>th</sup> century B.C. in Egypt. Examples of glass painting on architectural glass as we know it today date back to the 9<sup>th</sup> century A.D. The process has remained basically unchanged since the 11<sup>th</sup> century A.D. Concurrent with the advent of this process was the beginning of problems with paint stability. Most of the stained glass windows in the United States have some degree of glass paint on them. Most of this paint is *vitreous* or paint that is fired in a kiln and fuses with the glass substrate. The paint is made from ground glass, metallic oxides and a flux, used to lower the fusing temperature of the paint.



Problems with the applied painted decoration that may be encountered: missing trace lines; degradation of the matte or applied stencil work; lifting of enamels; accretion of dirt; or loss of cold (unfired) decoration. The painted pieces can appear as though they have faded, but this is not the case. Virtually all visual problems with paint are the result of the particles of the paint separating and/or falling off from the glass surface.

Painted decoration can become unstable as a result of one or more of the following:

*Insufficient firing of the glass* Temperature controls and apprentices were not always accurate. If the glass was under-fired, the paint would fail to properly vitrify and remain unstable.

*Incompatibility* This is more common with enamels and certain types of glass such as opalescent. Enamels are fired at lower temperatures and usually adhere to themselves better than they do to the glass. If the coefficients of expansion of the glass and the enamel differ enough, they may become unstable, peeling off the glass in sheets as the window experiences changes in heat gain or loss. This may also occur on a smaller scale with trace and matte paints. The loss of enamel is common problem in Tiffany windows.

*Composition of the flux* It is thought that a number of late 19<sup>th</sup> century glass painters used borax as a flux in their paint. Borax lowers the firing temperature of the paint, allowing the painter to more easily apply multiple layers of trace, matte and enamels during the painting process. However, it appears that the addition of this flux results in a painted surface that is very susceptible to deterioration by water.

All paint loss is further accelerated by the attack of water. Condensation that is allowed to sit on the glass promotes corrosion. The glass and the paint adsorb water resulting in the loss of free alkali ions. This leads to the breakdown of the molecular matrix of the glass. If the paint is not composed of a durable glass base, it will quickly deteriorate. If unstable paint is found or suspected, it is critical to engage the services of a professional who has had experience with fragile paint to determine the extent of the problem.

**Dirt** There is often an accretion of dirt on all surfaces of the glass. This may be a combination of soot from the furnace, candle smoke and other air-borne contaminants. The dirt mixes with the petrochemical components and forms a varnish like substance that adheres to the glass. Depending on the exact chemical composition of the deposit, it may become hygroscopic, absorbing moisture from the air. Localized concentrations of moisture on the windows can result in deterioration of applied paint or the surface of the glass itself.

**WEATHERPROOFING** This process is often referred to as *cementing* in the trade. The phrase is a bit misleading. The cementing process is one whereby the window is waterproofed by forcing a putty compound under the leaves of the leads to fill any void that may be left between the lead comes and the glass. Putty should be used on lead or metal came windows only. The space between copper-foil and glass is too small to adequately waterproof with putty, (although it is large enough to allow for the passage of wind-driven rain). While the process of cementing a window will lend it additional structural integrity, the primary function of this process is the prevention of the infiltration of water and wind through the panel.



The major portion of the structural integrity should be derived from a properly designed lead matrix; careful cutting of the glass; skillful leading and a well-designed support system. The use of a hard-setting putty to make up for deficiencies in the above-described areas is akin to wearing hard socks instead of shoes. It works for a while, but indicates a basic misconception on the part of the wearer.

To be successful, the cementing compound should form a skin on the surface and remain pliable below to allow for the independent movement of the glass and the lead. The properties of the compound should be limited to: an organic oil (such as linseed or soybean); calcium carbonate (whiting); and a coloring agent such as lampblack or other tinting agent that is compatible with the particular oil being used in the mix. In the past, oxides of lead were added to enhance adhesion. These are no longer available due to environmental concerns.

Failure of the waterproofing system occurs over time as the binding oil leaches out from the putty or fully polymerizes, leaving the dried out calcium carbonate behind. The dry material powders and falls out from under the leads. As the condition worsens, the panel will rattle when lightly tapped with the fingertips. When the condition becomes severe, water and wind begin to blow through the window and leak onto the floor. In the early stages, waterproofing failure can be addressed by the spot application of new putty. However, this should be understood to be a stop-gap and not a solution. Ultimately, the window must be removed. Proper waterproofing can only be accomplished with the panel flat on a bench. The old putty must be removed and new material forced under the leads. The panel should remain in a flat position for at least 14 days prior to reinstallation to allow the initial skin to form on the new waterproofing. If the lead matrix is failing, waterproofing, no matter how expertly done, will never strengthen the panel sufficiently enough to avoid releading. Unfortunately, it is a common practice by unknowing studios to promise otherwise.

**SUPPORT SYSTEM** Proper support is the result of the careful execution of many individual facets of the window fabricating process. There are three primary elements of the traditional support system. Tee bars provide lateral (wind) resistance and serve a load-bearing capacity. Tee bars must be firmly attached or inserted into the perimeter frame. Failure to do so greatly diminishes the positive effect they may have to support the window. The horizontal web of the Tee should face to the exterior. In this way, it sheds water more effectively than if it is turned to face the interior. Windows should not be removed simply because the Tee bars are installed incorrectly. However, if the Tee bars have begun to rotate and the horizontal web is no longer horizontal, a serious condition has developed. The stained glass panels can now slip off the Tee bar and serious damage will result. This condition should be remedied if the windows are removed for any reason.

Flat bars and saddle bars provide resistance to lateral pressure only; they do not act in a load-bearing capacity. Saddle bars are round, or less often, square iron, steel or bronze bars that are firmly attached or inserted into the perimeter frame. Failure to do so greatly diminishes the positive effect they may have to provide support to the window. Saddle bars are attached to the lead matrix of the window with copper tie-wires that are soldered onto the matrix. Upon installation, the wires are pulled around the saddle bar, twisted snug, cut to a uniform length and folded over



the bar. This system is a thousand years old. The weakest point of this system is the connection between the tie-wire and the matrix. Most common failure is the wire pulling out from the solder joint. Rarely does the copper wire break. One or two failures intermittently found in the window are of little concern. When over 10% of the wires separate, it is a more serious affair and bears close monitoring. As more wires break and the panel begins to deflect away from the bar, the situation is serious and may result in glass breakage and ultimate failure of the panels.

Flat soldered bars are of a more modern age, and are soldered with their wide dimension perpendicular to the panel directly at the solder joints in the studio prior to installation. Again, the weakest point in the system is the connection between the bar and the matrix at the soldered joint. As the system breaks down, the lead at the perimeter of the solder joints tears and allows the panel to deflect away from the bar. This condition cannot be remedied in situ. While it may be possible to effect a temporary repair in place, the panels must be removed to complete a proper, long-term repair. Tie-wires should not be used with flat bars. Saddle bars should not be soldered directly to the panel. Horizontally installed panels (domes, skylights) should always have the support bars attached to the underside. This way gravity tries to pull the panel through the bars, rather than away from them.

**METHOD OF INSTALLATION** An important concept to understand at this juncture is that we are dealing with a system, not an isolated or singular material. The installation system is comprised of the sealant, the material of the frame, the design of the frame, and the panel to be installed. Other factors, such as the degree of roof or building overhand, the orientation (North, South, etc.) and the degree of exposure of the window and drip detailing of the building will also affect the success or failure of the installation system. It is crucial to view the window as a moving part of the living fabric of the building, and not an isolated, static element.

Stained glass windows are installed in a variety of ways. Stone settings in grooves are the most difficult and arguably the best way to install stained glass windows. Some stone settings are into rebates in the stone, greatly simplifying the process. When inspecting stone installations, look at the condition of the stone and the mortar. Open mortar joints allow water to enter around the stained glass and into the building. The best time to repoint is when the windows are removed for conservation. This installation will have saddle bars and possibly Tee bars. Make sure all support bars firmly engage the stone and are not just floating in the groove. Traditional stone settings were done with putty. Due to the absence of lead oxides in modern putty and the developments with flexible caulks, a caulk/backer rod system is the best for stone settings. This system also allows for the easy removal of panels from the stone down the road with little risk of damaging the stone surround.

Metal frames have to be checked for corrosion and deformation of the metal members. Galvanic corrosion can be the result of dissimilar metals coming into contact. This can occur when the wrong type of fasteners are used, or within the flashing details of the window. This can only be remedied by replacing the offending fastener with one of the proper type or insulating the dissimilar metals.



Wood frame and sash installations are quite common. Due to lack of maintenance, many are in poor condition. The paint is flaking off, sills are split and checked, an overall deplorable appearance. However, it is important to resist the apparent obvious replacement of these frames with new aluminum or new wood. It is difficult to get a smooth transition from a wood window to an aluminum one. It is unlikely, even with proper maintenance that the aluminum frame will be in good condition 70 to 100 years from now, especially if the aluminum is exposed to a marine environment. To the contrary, properly maintained wood has been proven to last centuries. If the quality of the original wood was good, restoration is usually better than replacing with new. They don't grow trees like they used to, literally. Old growth lumber has tight growth rings and is more resistant to rot and deflection than new forced-growth trees.

**Sealant Materials** The traditional material for setting stained glass has been linseed oil putty. This system still works, but it has its drawbacks. The putty may set hard and does not allow for the expansion and contraction of the panel, or the movement of the building. Look for cracking of the putty bevel and separation from the frame or panel where water can enter. As the original putty system failed in the past, it was common to caulk over the putty. This may have worked in the short term, but this approach is destined to fail. If the sealant system is failing, it must be completely removed, the panel and substrate carefully cleaned and a new system installed. If the stained glass is in good condition, there is no need to remove it to properly do this work. It is important to the long-term health and welfare of the window, and to the interior walls and finishes, that the perimeter sealant be checked on an annual basis.

**Protective Glazing** A very destructive force that adversely affects the lead came matrix of the window is heat gain from the sun. Numerous studies in Europe and in the United States have concluded that unvented protective glazing systems create a super-heated environment for the windows that they were intended to protect and actually accelerate the rate of deterioration of the windows. Condensation can form in the unvented interstitial space between the protective glazing and the stained glass. The condensation is conducive to the growth of microorganisms whose by-products attack the lead comes and the stained glass. In addition to the direct damage to the stained glass, the condensation rusts the steel support bars and encourages the rot of the wood frames.

When inspecting the installation, if protective glazing is installed, look at the possibility of removing it permanently. Ninety five percent of the stained glass windows in this country do not need to be protected. If the exterior covering cannot be removed, make sure it is copiously vented to allow a free flow of air into the interstitial space. If the covering is plastic, holes can carefully be drilled at the top and bottom of sealed chambers to ventilate them.



## Additional References

An informed steward will make better decisions when formulating a plan for the conservation and long term care of stained glass windows. In addition to the information contained in this paper, there are a number of sources for additional information.

Additional sources of information are:

1. "Conservation and Restoration of Stained Glass: An Owner's Guide," published by the Census of Stained Glass Windows in America, 1988.
2. "Stained Glass in Houses of Worship," Inspired Partnerships, Chicago, IL 312-294-0077
3. Preservation Brief # 33 "The Preservation and Repair of Historic Stained and Leaded Glass," published by the U.S. Department of the Interior, National Park Service, Cultural Resources Division.
4. "Protective Glazing Study," National Preservation Center in Natchitoches, LA 318-357-6464
5. "Conservation of Glass" by Roy Newton and Sandra Davison, published by Butterworths of London.
6. "Corpus Vitrearum Medii Aevi" This organization is concerned with the preservation of all stained glass with a focus on medieval stained glass. The website is <http://www.cvma.ac.uk/index.html>
7. "The American Glass Guild" This is an organization devoted to the dissemination of information about stained glass and its care. The website is [www.americanglassguild.org](http://www.americanglassguild.org)



## About Femenella & Associates

**Arthur Femenella** is the President of Femenella & Associates, Inc., a full service stained glass and historic window conservation studio. Mr. Femenella began as an apprentice in 1968 at the Greenland Studio of New York and later became co-owner. In 1993 he formed Femenella & Associates. The firm has expanded to include historic wood and steel window restoration. He has been responsible for the restoration of thousands of windows, doors, panels and artifacts, including hundreds of works by John La Farge, Louis Comfort Tiffany, Frank Lloyd Wright, Maitland Armstrong, Mary Tillinghast and other artists of equal importance. Mr. Femenella is active in a number of preservation groups. He has written numerous articles and lectures across the country. The firm is an approved provider of AIA/CES learning credits.

Mr. Femenella is a founder, past President and current Vice-President of the American Glass Guild, LLC; a past Chair of the Restoration Committee, former Board Member and former Treasurer of the Stained Glass Association of America. In this capacity, Mr. Femenella was the primary author of the booklet *Standards and Guidelines for the Preservation of Historic Stained Glass Windows*. Mr. Femenella sat on the Board of Governors of the Census of Stained Glass Windows in America, and was the primary author of the technical section of the booklet produced by the Census titled, *The Conservation of Historic Stained Glass: An Owner's Guide*. He is a member of APTI, the National Trust and the AIC, with a pending application for Professional Associate status.

Arthur Femenella has written over forty articles on subjects specific to stained glass and historic window restoration. He has presented papers at numerous international and national symposiums and conferences. Art was the consultant to the Protective Glazing Task Force. This was a group of architects, engineers, and preservationists charged by the Department of the Interior to develop national guidelines for the fabrication and installation of protective glazing.

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