THE WINSTON CHURCHILL MEMORIAL TRUST OF AUSTRALIA

Report by Gavin Merrington – 2014 Churchill Fellow,
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To research the latest heritage stained glass conservation/restoration techniques and isothermal protective glazing systems.

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Signed,

Gavin Merrington
13/07/2015

Contents

Pages

Introduction

The project to research the latest developments in stained glass conservation/restoration and advancements in isothermal protective glazing was successfully accomplished.
The professional people and studios contacted proved to be the correct choices, as evidenced by the exemplary information contributed and gathered, and wonderful site visits experienced.

Conservation and protection of Australia's precious high quality stained glass is currently not at the forefront of many heritage projects, yet is aesthetically, historically and architecturally a very important part of the church's fabric and culture. If lost through inaction, neglect or ignorance, it will have a dire impact on the heritage values of irreplaceable windows, and therefore the buildings that contain them are likely to be devalued. Church's contain some of the most inspiring and accomplished works of art, in the form of stained glass in Australia, and are an integral part of its architecture.

European conservation and restoration practices have continually developed over centuries. Australia must use the lessons learnt from overseas studios and take advantage of the proven techniques, to protect and enhance our precious, and in some cases, irreplaceable glasswork.

Acknowledgements

- I would firstly like to acknowledge the Churchill Fellowship Memorial Trust for providing the once in a lifetime opportunity to enable me to travel to overseas destinations and sites that would not have been possible without their assistance.
- I would like to thank my highly regarded referees, who have provided encouragement and mentorship over many years.
- Mr Peter Spratt - Heritage Engineer
- Gerry Cummins and Jill Stehn – Stained Glass Consultants and Practitioners

- I would also like to thank the studios we were warmly welcomed into and the directors and staff for the discussions and tours of various studios and sites. Their willingness to see advancements for the whole industry in general, and further the preservation of stained glass in Australia was inspiring.
- I wish to thank my wife Anja for her support and continued interest in the project, and her companionship through foreign countries on our pilgrimage of glass.

Executive Summary

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Project Description

To research the latest developments in stained glass conservation/restoration and advancements in isothermal glazing techniques.

Fellowship Highlights

The highlights of the trip include fulfilling a lifelong dream of visiting international stained glass studios and sites. Viewing medieval windows in their original openings, and in studios at various stages of conservation and with a variety of protective glazing.

Meeting highly skilled practitioners with qualifications and accreditation specific to stained glass conservation. Having valuable discussions with some of the highest internationally regarded custodians and directors on current techniques, materials and philosophical approaches concerning conservation, restoration and protection.

Particularly valuable in providing information for the project, and valuable sites visited in order on itinerary were:

- Sam Kelly, Salisbury Cathedral
- Leonie Seliger, Canterbury Cathedral
- Sarah Brown, York Minster
- Keith Barley, Barley Studios
- Chartres Cathedral and International Centre Vitrail
- Troyes Cathedral
- Reims Cathedral
- Lamberts Glass Factory
- Cologne Cathedral
- Metropolitan Museum of Art
- St Patrick's Cathedral

Major Lessons Learnt and Conclusions

- That my studio practice rates well with international counterparts and I am confident of my skills and ethics when compared to overseas studios. Improvements can be made, including purchasing new equipment and accessing formal training for employees.

- Professional international studios have state of the art safety equipment and protocols, in-studio and on-site. These include extraction filtration equipment and separate rooms and zones for the individual processes required during restoration.
- New materials and their use. Evaluation criteria and use of computer programs for documentation and analysis of paint loss.
- Isothermal glazing is used to protect fragile and vulnerable stained glass and its paint against the elements – wind, rain and hail, pollution and vandalism. It is common practice in Europe and the USA but not in Australia. Consulting with custodians and heritage groups to inform them of the valuable cultural artistry held and best methods of protection.
- Isothermal glazing is a system whereby a new protective glass, plain or leaded, is inserted externally to protect the existing stained glass and vented internally to avoid moisture on the fragile glass paints. There has been a proven advantage to windows protected and a long term cost benefit to the custodians by prolonging the period between restorations. Improvements have been made concerning the changed external appearance of the protective glass and its relationship with the architectural stonework. Each aspect of the building must be assessed individually and each window's paint condition and translucency assessed as it may require a separate solution. No one system can be seen perfect for every situation.
- Condensation in the interspace between the protective layer and the stained glass is the main concern. I have investigated various ventilation systems and monitoring equipment, new UV glasses and thermoformed glass protectors, along with non ferrous framing techniques for the internally mounted stained glass.
- In an ideal world no protection would be needed, and indeed a lot of significant European windows are not protected. History is proving that many of these precious windows without protection are now in a perilous state.

Dissemination and Implementation of Findings

- I will use the knowledge gained in my own studio practice, and keep in contact with my overseas counterparts to keep up to date with changing approaches and improvements in this field.
- Liaise and consult with heritage organisations, architects, engineers and church committees.
- Be accessible to advise stained glass and leadlight studios and encourage the highest quality techniques and philosophical approaches to restoration.
- Promote as standard use in conservation the international benchmarks of ICOMOS, The Corpus Vitrearum, Burra Charter and Practice note 15 – Tasmanian Heritage Council.
- Continuation of studio restoration and church visits for custodians and parishioners.
- Power point presentations to interested groups.

Program Itinerary for Churchill Fellowship 2015

England

May

12th – St Martin in the Fields church – London
13th – St Paul's Cathedral – London
15th – Salisbury Cathedral – meeting with Sam Kelly (head restorer of the Salisbury Cathedral stained glass restoration team)
16th – St Thomas Church – Salisbury
16th &17th – St Mary & St Nicholas Church – Wilton
17th &18th – Salisbury Cathedral including service
20th – Chartwell – Home of Winston Churchill
20th – All Saints Church – Tudeley Kent – Marc Chagall windows
21st – Canterbury Cathedral – meeting with Leonie Seliger
22nd – Canterbury Cathedral conservation studio/workshop team
22nd – Evening Lecture and exhibition –"Before the Ancestors" with Professor Sandy Heslop in the Canterbury Cathedral chapter house and archives
23rd – Kings' college chapel and exhibition – Cambridge
23rd – St Mary's Church – Cambridge
24th – Ely Cathedral and Stained Glass Museum – Ely
24th – Lincoln Cathedral -Lincoln
25th – St Helen's Church – York + All Saint's North Street - York
26th – York Minster- meeting with Sarah Brown - the Yorks Glaziers Trust and Bedern conservation studio - site visits
27th – Guided tour of York Minster with Sarah Brown and the restoration project of the Great East Window
28th – Keith Barley studio visit and discussion. Dunnington, York
28th – St Nicholas' Church – Dunnington, York
29th – Parish of All Saints Pavement - York
29th – York Minster exhibition of medieval stained glass and site photography

France

31st – St Vincent's Cathedral – St Malo

June

1st – Mont St Michel
3rd – Saint Gatien Cathedral – Tours
4th – Basilique St Martin – Tours
5th – Chartres Cathedral and tour with Mr Malcolm Miller
6th – Vitrail museum international glass centre and contemporary glass exhibition and Chartres Cathedral
7th – St Aignan and St Pierre – Chartres
8th – Cathedral of St Pierre and St Paul – Troyes

9th – Eglise St Urban and Eglise Sainte Madeleine and Museum de Vitrail– Troyes
10th – St Chappelle – Paris (early morning) and St Mary Cathedral – Reims
11th – St Merri and Notre Dame Paris

Germany

13th – Church of our Lady Dom – and St Lucas – Munich
14th – St Ulrich – St Moritz – and the Dom – Augsburg
16th – St Vitus Cathedral – Prague Czech Republic
17th – Lamberts Glass Factory – Waldsassen – Meeting with Manfred Milsk and staff – Restauro ® UV protective glass and mouth blown painting glasses
18th – Lamberts Glass Factory – Waldsassen - Glass blowing demonstrations
20th – Cologne Dom
21st – Grobe St Martin and St Maria and Cologne Dom service
22st – Cologne Dom and St Minoritenkirche

USA – New York

24th – St Patricks Cathedral – protective glazing inspection
25th – MOMA – Museum of modern art
26th – The Cathedral of St John the Devine
28th – Guggenheim museum
29th – Metropolitan Museum of Art – including Louis Comfort Tiffany collection
30th – Metropolitan Museum of Art – Cloisters medieval glass exhibition and Frank Lloyd Wright installation

<u>July</u>

1st – Grace church and St Francis of Assisi New York
3rd – Airport – JFK to Tasmania

Main

A Basic Overview of The Materials Used for Stained Glass and Schedule of Work Processes in Conservation and Restoration for Heritage Stained Glass

Materials

Stained glass is art like no other, in that it relies on natural transmitted light to illuminate the artistry and skill of applied vitreous paints and enamels to coloured and clear glass to create its effects.

Coloured glass, called pot glass, is coloured throughout the glass with metallic oxides, and is the most commonly used. Differing recipes for the making of the hand made mouth blown glass has varied through the centuries, with nineteenth century glass proving to be the most stable.

Flashed glass was developed by applying a thin layer of coloured glass, usually red or blue over clear, to vary the translucency within the sheet, and create a variety of tones within the glass. Various techniques can then be used to manipulate the flashed surface to enhance areas required if the artist desires. Abrasion with engraving and acid etching on selected areas of the flashed layer can create dynamic outcomes.

The application of silver stain (silver nitrate bound in clay or ochre) was discovered around the fourteenth century and the application to the glass created colours from pale orange to deep orange amber. Mostly used on clear glass, silver stains created never before seen effects, because it stains the glass as opposed to vitreous paint that fuses into the glass surface.

Glass paint consists of ground glass mixed with copper and iron metallic and mineral oxides, liquid or oils, and is applied to the surface of the glass as a combination of trace lines, shading, matting, and washes.

A matrix of H shaped lead cames that can be of numerous profiles, are inserted in between the glass pieces to create a framework, which is designed to structurally and aesthetically hold the individual glass pieces. The lead cames follow the design of the composition producing a mosaic style image. The lead cames are soldered together at their intersections and puttied under the leaves, or flanges, of the lead to make the panel watertight.

The amalgamation of the lead and base glasses, stains, vitreous paint and coloured enamels fired in the kiln, are the fundamental materials for the stained glass artist.

Why the need to Conserve?

Like all materials, those used in stained glass windows break down with the passage of time. The glass and glass paints may last for centuries but the leads, solders and putties break down faster if the window is unprotected and can become structurally unstable. The lead deteriorates becoming fragile, soldering joints crack, and putty

dries out and washes away allowing water to penetrate through the window and onto the surface of the glass paint. If the structure of the window is compromised, bowing and slumping occur which exerts stress on the glass leading to breakage. This can be the loss of historically and sometimes irreplaceable material. The main criteria for conserving a stained glass window, is to ensure its long-term survival and retain its cultural significance including its artistry. Moisture and condensation are the greatest threat to glass paints.

A regular inspection and programmed maintenance schedule is the best ongoing practice to attempt to preserve windows in their existing state, and to guard against deterioration. Regular written and photographic recording of a windows condition provides a comparable rate of decay over a given time.

In-situ works can be carried out to prolong removal. Physical protection of the window externally, if possible, could be achieved by inserting removable protective glazing, vented to the exterior, or securing wire screens depending on the reasons cited for protection.
Specialised sensitive cleaning of the internal glass paints where deemed stable, to remove hygroscopic material from the painted surface, with cotton swabs and de-ionised water. No wet cleaning in areas with soft detail should be attempted on site, only light dusting with a squirrel hair brush or equivalent.

Resoldering key broken joints in the lead matrix and some hand puttying with standard traditional linseed oil putty externally, to prevent further water ingress, may be possible. Puttying in-situ against paintwork is not recommended.

Restoration, Reconstruction and Adaption

Restoration is to reassemble the components that exist the window's earlier state without the introduction of new material, and removing and replacing previous poorly produced replacements (Stop-ins).

Reconstruction requires the introduction of new materials to return the window to its known earlier state. This usually requires dismantling and re-leading with lead alloy came to the exact same profiles removed, unless proved to be structurally inadequate in some areas.

Adaption is taking a course of action whereby the window is modified to suit a new or improved frame. This may require new sacrificial borders to be added replicating removed ones, or adding extra border leads.

Inspection and Initial Condition Report

The first process is to establish the overall history of the window, previous repairs, restorations and interventions, and most importantly the studio and artist that has been responsible for the work. Determining the artistry and quality of the window is paramount before any action is taken. This can be a great advantage to the custodians, as an experienced restorer will most likely have encountered similar windows from the same maker. This knowledge could sound warning bells or shouts of joy for all, but a plan and course of action should become obvious.

A detailed inspection on site must be undertaken to assess the paint condition and structural condition of the window. Close examination of the frame and the fit of the window within it, corrosion to ferramenta and supporting saddle bars and attachment of the ties is necessary.
Inspection minimally requires intimate access internally to the window with a ladder, scaffold or EWP (elevated work platform). If possible, it is an advantage to carry out an inspection of the paint in both transmitted and reverse light on site with a magnifying glass. Overall photographs and detailed close-ups, especially irregularity's of paint condition, must be taken prior and during removal. The condition report should include both written and photographic documentation.

The openings, usually stone in churches, need to be assessed and often need remedial works. Many sandstone frames in Tasmania have a high clay content meaning they are quite porous and therefore can become unsound with age. Consultation with a stonemason and engineer are often required at this stage.

Timber and metal components may also require expert tradesman to be employed, or to seek advise from. Supporting ferramenta frames and saddle bars and metal screens can have nonferrous tips attached to prevent spalling when in contact with the stonework.
Following all these considerations, costing estimates can be formulated.

Pricing estimates should be possible after the onsite inspections however it is often interesting after the window is removed, and on the light box in the studio, to finally realize what you are dealing with and the task ahead.

Project Brief and Commissioning the Works

The commissioning of the works to an experienced and proven contractor with a good standing relationship with the committee is usually unproblematic providing consultation with a committee continues.

If multiple quotations are required, a professional and written detailed brief of the project should be provided by the proponent, and reviewed by a person with knowledge of stained glass restoration, history and evaluation. Equitable skills in reviewing the proposals and being able to differentiate between works are essential.
Works applications and works exemptions need to be sought from the relevant Heritage Council, and often the local council.
Ensure that all works are to the principals and guidelines set out by ICOMOS, The Corpus Vitrearum, Burra Charter and Practice Note 15 – Tasmanian Heritage Council.

Metal Screens

Metal screens are often attached as protection to prevent air borne projectiles from hitting stained glass. They work if positioned far enough away from the glass surface so the force of impact does not bend the wire to the window. They are certainly better than no protection at all, however if the screen is low enough for human access they are practically useless if a delinquent is determined to get through and into the

building, or simply push an implement through the wire and into the stained glass for ‘fun’. Unfortunately this is common.

Screens made from non- ferrous materials with extra supports, can be professionally produced and installed. Brass, or powder-coated stainless steel is recommended. Fixings for wire screens into stone were commonly ferrous material often leading to spalling and unsightly stains at the point of contact. If the screen is made from ferrous wire, or the coating has disintegrated with age, the sandstone sill badly stains.
Wire screens have the disadvantage of being seen through stained glass when in direct sunlight, creating an annoying distraction of the legibility of the design. Wire screens are cheaper to produce than the installation of protective glazing, but only deter projectiles, not wind load or moisture.

Removal

Removal of stained glass is a specialised process that should only be carried out by experienced tradespeople and supervised by an expert to ensure the windows safety and the safety of the trade staff. Removing lime mortars can be relatively straightforward, but often windows set in stone have been installed or repointed with inappropriate – and unacceptable - cement based mortar. The window components, when removed, can be structurally weak and susceptible to breakage if handled incorrectly. Painted glass should never be taped.
Custom made crating, made to the window size, is essential for transportation.

In-Studio Inspection and Consultation

Once removed from the crate in the studio, the window can be fully laid out on the light box. Under constant and even light, a detailed inspection utilising a magnifying glass is made. Details of any paint defects are recorded, along with notations of previous interventions and unusual leading techniques.

Photographic documentation in transmitted and reverse light is standard procedure prior to any intervention. This provides valuable reference material on which decisions can be made during works, and documentation for comparison to the finished restoration for the studio and custodians. The condition of the window must be fully documented before any intervention, so that any interventions that are made can be identified if there is a decision to reverse the change in the future.

When dealing with the glass, the conservator often has to make judgements of an aesthetic nature when trying to represent the artistic legacy of the maker. This may entail discovering and reinventing unusual styles of painting, and attempting to match unobtainable base glasses.

Consultation with a committee of professionals with knowledge of heritage issues and a sound understanding of stained glass, and a representative from the building or church is essential. Several meetings during the project may be necessary to achieve the correct outcome for all. Progressive decisions need to be made as the works advance.
Major decisions should not be made in isolation.

Patterns

Patterns, or cartoons, can now be made. Three rubbings are made to record the original pattern of the lead cames. One pattern is used for reassembly and one for the laying on of dismantled glass. The third pattern is created on PH neutral archival paper for long-term retention, and includes a legend to identify changes and interventions. A sketch plan of the entire job, and individual numbering of each panel relating to the sketch, make for an orderly flow during the work and on site.

Cleaning

Over the years dust, grime and soot accumulates on the surface of the window, restricting light and attracting moisture. The hygroscopic (dirt attracting moisture) process accelerates the deterioration of the glass paints. Great skill and care is required when cleaning fragile paints. The principal method of cleaning paint from the glass is with de-ionised water and if necessary PH neutral surfactants, applied with cotton swabs and poultices while the glass sits on the light box, allowing an even light to illuminate the glass. The glass is frequently inspected in transmitted and reverse light with a magnifying lens to ensure no damage is occurring to the glass paint. Cotton buds are used to gently abrade the dirt from the paint. Often countless cotton buds! The panel or pieces are then placed on edge, rinsed with de-ionised water and gently patted dry.

Retaining and Repairing Original Damaged Glass

As much as possible of the original glass must be retained and repaired. This is particularly important where the studio painters have used an idiosyncratic style, which some studios may find difficult to reproduce. Sometimes the visual repairs to an individual piece may be deemed to be detrimental to the artistic integrity of the overall panel, so after much consideration a decision to copy could be taken. If the painter is skilled, in the case of painting shattered faces or hands, it is likely the window will again read as intended. All broken pieces that have been replaced must be retained in an orderly fashion for archiving.

Leonie Seliger director of the Canterbury Cathedral workshop and studio showed us an innovative computer programme for identifying paint loss. When some pieces are sighted in-situ with heavy paint loss, it becomes immediately apparent how much guesswork this could save. This is a fantastic innovative use of new technology aiding replication of the historic original artistry.

There are many techniques in a glass restorer's "box of tricks" that can be used to repair broken, or even shattered glass pieces. These methods and materials are not seen in any other trade and require special training, skill and patience.

Museum grade non-refractive Hextal – NYL-1 epoxy,
Araldite 20/20 and high-grade silicon are three adhesives used for edge gluing broken glass. Fine copper wires are often fashioned as physical supports in the event the glue may fail.

Edge gluing, and being exposed to the elements, is still largely unproven over time, so is recommended as a more compatible technique used in conjunction with protective glazing employing newly developed UV inhibiting glasses.

Fine copper foiling is a technique for joining glass that can work well but shouldn't be used on fragile glass paint.

Conservation grade Paraloid B72 acrylic glue used in tiny diluted amounts to stabilise fragile and flaking paints can be useful. Re-firing and chemical coatings are damaging methods that should not be considered for the fixing of loose paint.

Fine "spaghetti" leads are a good solution, and do define themselves as repair leads by width, because they are markedly different to the surrounding lead.

Strap leading can be used as a temporary repair by cutting and fashioning the repair lead on both surfaces of an in-situ broken piece of glass, puttied to stop water and light penetration, as a temporary repair.

Plating techniques are used to replicate paint loss on a host glass and sealing to the original lead. It is especially useful for important details features and inscriptions. Highly developed skills are imperative for successful back plating. This procedure is very useful, but can be problematic if the host panel continues to deteriorate, or if condensation becomes trapped between the glasses and organic growths begin.

Cold enamelling is used as a reversible and often temporary measure to replicate the original design on the exterior of the glass. This process can substantially rectify the reading of a window and if necessary be applied in-situ. Recipes and development have improved over recent years.

Removal of Old Putty

Removal of the old putty can be a nerve-wracking task if it is very hard and bound to fragile glass. Softening with deionised water usually helps and reduces the toxic dust. The use of putty knifes anywhere on the glass apart from the immediate putty residue line will obviously risk damaging the paint however sound, and is to be avoided. Personal protective gear and extraction equipment, and a clean designated dismantling area are a must to prevent inhalation of dust and the consequential risk of lead poisoning. Yearly blood tests for males and six monthly tests for females of reproductive age are a must. I did see some surprising and innovative methods being experimented with overseas to remove difficult putties on fragile glass.

Reassembly and Putty

Exactly the same lead profiles used by the original studio should be replicated, as this forms an integral part of the construction and aesthetics of the window. Rare or unusual leading techniques used are noted and are carefully reproduced during re-assembly. When re-leading heritage windows our studio only uses lead made to specific international restoration standards, which include antimony, copper, tin and silver. The alloys included ensure there is less "creep" in the lead, so the windows

longevity is greater and less likely to bow. It is a harder lead and more difficult to fashion than soft leads normally used by lead lighters in residential windows.

After the window has been re-leaded or repaired, a propriety standard brand of black linseed oil putty is forced into the interspace between the edge of the glass and the leaf (or flanges) of the lead on both sides of the window. A sharpened wooden stick is used to run against the edge of the lead and remove the excess putty. When dry, this both waterproofs and stiffens the window. It is critically important that residue putty on the glass, and particularly the painted surfaces, is carefully and completely removed, as linseed oil can attack glass paints. In the final stage of the putty process, a fine brush and whiting is used to remove particles of putty and to darken the lead and solder. At no stage are chemical polishes or patinas used on the lead fabric, as they are likely to be detrimental to the paint. The finished window is installed into its stone, timber or metal frame, and supportive saddle bars attached

Re-Installation

Re-installation and removal are physically demanding jobs, requiring care and co-operation of a small experienced team. Saddle bars, either the original bars or new non- ferrous stainless steel, or brass bars, are fitted into the reveals. The ties are systematically and neatly twitched to the bars when the panel alignment and overlap leads sit soundly. Traditional lime mortar is pushed into the stone reveals, and great care is taken to remove any residue from stonework and the window. The correct lime based recipe, appropriate sized washed aggregate and sand colour choice for the reveal are essential. A close final detailed inspection is taken to ensure all surfaces are clean and everything is perfect before packing away materials and access equipment.

Recording of works and Final Condition Report

A final condition report should include a written description of all processes used during the restoration. It should include pre and post detailed photographs of both the interior and exterior of the window, so comparisons can be made. The fragments of any glass replaced, together with the archival rubbing and legend of notes, need to be stored and made available.
When we were in York, we met Phillipa, a PhD student. She was completing her project of digital layering documentation. The task she set herself was complex, however, she had simplified the amount of layering which gives a valuable history of the window and its interventions. If a diocese could afford this type of documentation it would be a perfect compliment to paper archival coded rubbings.

The Workshops and Studios

The workshops and studios we were fortunate enough to visit overseas all had one thing in common. They were all very well organised, and run as professional businesses. Everyone had their role, and the tasks seemed well defined and directed. The teams ranged in number of staff from four to fifteen. The studios and workshops had clearly defined workspaces, and rooms for particular processes, equipped with state of the art analytical tools and safety extraction systems. Dedicated rooms for the work of photography, fireproof safes for storage of windows pre and post restoration documentation material, painting room, kiln room, metalworking shops for screens

and frames, dismantling room, puttying room, design and drawing studios, library, tool and safety equipment sheds, offices and tearooms!

Education

A recently created course based at Holmesglen TAFE in Victoria is currently the only one available in Australia - Diploma of Stained Glass and Lead lighting. Courses specifically for the conservation and restoration of stained glass in Europe are administered by The Institute of Conservation - ICON and include (PARC) Professional Accreditation of Conservation Restorers and the MA course for Stained Glass Conservation and Heritage Management. These courses are not available in Australia and therefore there is no benchmark for competency when contracting work for heritage windows. High quality accredited courses have required investigation into new ideas, better ways of working, improved studio practices and development of new materials.

Protective and Isothermal Glazing

The protection of Australia's nationally and internationally significant stained glass is of prime importance if this nation genuinely treasures its cultural and artistic heritage. Many exquisitely designed and painted historic windows currently have no protection, or are only protected by flimsy wire screens and prayer.

Protective glazing is the general term used for protecting stained glass. The systems can include mixed ventilation (both internal and external), internally ventilated, externally ventilated and no ventilation.

Externally vented protection is often cost effective and is simple to install if the stained glass stays in its original rebate. Laminated glass or toughened glass can be fixed with non-ferrous fixings and venting provided. If necessary, it is simple to remove if designed and installed correctly. Low iron glasses of a less reflective nature are a good choice. This system will not necessarily stop condensation and still leaves the exterior open to pollutants. The big advantage is relieving the window of wind stress, soaking rain and vandalism.

"Double-glazing" is also often used as a term, but in the context of this study and method of this application system, is technically inaccurate because it normally relates to sealed units with dry air in the interspace.

Isothermal glazing is the current term used when the protective glass is sealed into the rebate where the stained glass previously sat. It can use internal or external systems of venting or both. Normally it is sealed to the exterior atmosphere and vented to the interior of the building. This is generally the most widely used system and considered the most successful to keep the stained glass dry.

The stained glass is moved to the sandstone profile on the interior of the building in a specifically constructed U channel manganese bronze frame bent to correspond to the windows individual shapes with the supporting saddle bars attached. Lead flanges can

be added to diminish any distracting light seepage around the boarders of the frame. Brass T-bars divide the separate panels, a practical and sensible system, but historically rarely used in Australia.

The ever-inventive Mr Keith Barley and the York Glaziers Trust first developed the internal frames for windows at The York Minster. Barley Studios and The York Glaziers Trust have continued to improve and enhance this proven system. It is an exemplary method for stained glass preservation, in effect allowing the glass to be housed in museum conditions. The dynamic Sarah Brown, director of the York Glaziers Trust and Nick Teed head conservator, have developed a system of corner brackets and screws to further compliment the framing. This was instigated primarily in response for the quantity of frames needed in the restoration of the Great East Window at York Minster. The window consists of over three hundred separate panels and is the largest window in England.

Depending on the system chosen and position where the window is sited, a specifically designed vent arrangement is often necessary to allow airflow, and primarily to stop dust and insect access. Vents utilising stainless steel and other non-ferrous materials can be designed to be virtually unnoticeable. We saw some ingenious solutions in England. Mr Sam Kelly, the head stained glass conservator at Salisbury Cathedral was inspiring in his practical approach and solutions in the area of mesh for venting. Yearly cleaning or vacuuming is necessary to remove dust deposits.

The airflow is most successful when designed as a chimney, i.e. bottom to top and top to bottom, depending on air temperature. This allows a continuous airflow between the protective outer layer and the stained glass. When correctly designed, it keeps the stained glass dry on both sides. Internal support bars in the interspace have been proven to reduce the airflow and create microclimate areas if the interspace is not wide enough. A minimum interspace of 25mm is crucial, and allowing a wider space normally provides greater improved airflow.

Slightly tilting both the top and bottom panel of a large set to the interior of the building, is utilized to increase air flow and has proved successful, enabling the majority of the window to sit close to its original reveal. We saw this in English Cathedrals, and it was easily viewable in Cologne Cathedral, which also has a long history of protecting its precious windows.

History

Protective glazing is not new to the protection of stained glass. York Minster and Canterbury Cathedral have a long history of protecting their precious windows. The oldest known double-glazing was installed in Canterbury Cathedral and York Minster around 1861. Cold temperature was the main reason for the installation of large green toned machine rolled textured panes into convenient sandstone profiles on the exterior of the exterior to the stained glass in Canterbury. The sheets were firmly mortared creating tension and no room for flexibility. The consequence during the preceding decades was fractured glass. The glass looked reasonably unsightly from outside but was not in a highly viewed position. Some distraction from the artistry of the original panel was evident. The subsequent removal and inspection after more than a century

revealed the glass had protected the window internally and externally, and had no deleterious effects compared with companion windows unprotected. The interspace, although unvented, was approximately one hundred and fifty millimetres, a generous amount and likely to help avoid problems.

The Great East Window in York Minster was also protected in a similar manner in 1861 against the 'products of combustion' and later replaced with a plain leaded set. The new ultimate 'state of the art' protection is currently being installed. Other examples of protective glazing stretch back to this date in Germany, France and some other smaller European countries.

Pollution, Corrosion, Moisture and other Deleterious Threats

In recent decades the need for protection of historically valuable stained glass has become more urgent due to increases in aggressive pollutants and severe weather situations. Air pollution including sulphur dioxide combined with humidity, create sulphuric acid as acid rain and threaten the surface of the softer glasses. This corrodes the exterior surface of the glass and starts decomposition of the pieces and they appear to have a chalky surface, or so-called weathering crust or gel layer. The weathering crust absorbs water (hygroscopic) and therefore the destruction of the glass accelerates. Year by year the glass thickness reduces.

Companion windows that have been moved into museum conditions one or two decades before, show no increased acceleration of decomposition compared to their unprotected companion windows left in-situ.

Luckily, the majority of windows in Australia are from the Victorian period when the chemical composition of glass had improved significantly compared to medieval manufacturing. The glass is harder, but in many geographical situations is heavily exposed to aggressive and changing hazardous air pollutants. Monitoring of the glass surface on both sides is crucial to gauge any changes. The deleterious effects of excess moisture on the interior paint of stained glass are well documented. The moisture can eventuate from condensation and humidity. The corrosive effects of microbial growth can be deleterious. Direct water is likely to penetrate through the leads or frame if a window is in poor condition.

Windows that are unprotected are at continual risk from windstorms, hail, cyclic stress, temperature fluctuations, pollution, branches and wind borne debris from trees, bird strikes and their acidic droppings, lawnmower stones and deliberate violent interference from vandals.

Historic Cathedrals and churches usually are constructed with thick walls and timber, which absorb or release moisture. They are normally uninsulated, so the relative humidity over the centuries has not fluctuated greatly. The windows are the most poorly insulated part of the building. If the temperature of the glass reaches levels below the dew point, condensation will form on the glass surface. Modern heating in some churches can have a dramatic effect on the relative humidity, and condensation on the surface of the window can be problematic if the internal temperature changes quickly.

A church service or function may require heating to be turned on to full over a short space of time, creating marked temperature differences from interior to exterior. The condensation caused by the humidity settles on the poorly insulated glass if there is no protective exterior buffer. If glass protection is in place the moisture is likely to settle on the interior or exterior of the protective glass. Significant factors may be the heating source, the ventilation system or building orientation. Heritage engineers or architects may be able to offer solutions.

Different Techniques Viewed and Materials used

The protective glass relieves the stained glass of its original architectural function to seal the building from the elements. We viewed almost countless examples of protective glazing during the Churchill Fellowship. The majority were viewed through powerful binoculars and photographed. The multitude of varying finishes was new to Australian eyes. I viewed the windows from several vantage points, and many at various times during the day to gauge degrees of reflectivity and their relationship with the stone. Each finish has advantages either for the external reading of the building, or the internal reading of the stained glass. A compromise has been applied in some instances because both readings are important.

More than one system is often necessary because of the legibility of the stained glass. Examples of options were contained in one sample panel, placed in front of a window at Lincoln Cathedral, to gauge opinions for the finished outcome. Two other Churches were also trialling final options for their protective glazing.

The main glass finishes used are as follows:

- Clear commercial laminated glass
- 'Optiview', Low iron, low reflective glass
- Distorted 6mm Schott glass
- Commercial 3mm distorted leaded
- Kiln distorted 3mm leaded
- Kiln distorted 3mm leaded and painted
- Hand made mouth blown leaded
- Hand made mouth-blown 'Restauro ® UV' both 3mm leaded and 6mm laminated
- Thermoformed toughened plain or enamelled

The following observations are just my personal opinions from observations and not to be taken as recommendations.

Clear laminated glass and toughened glass. Condensation tends to be visible ' if ' it forms on the laminated glass.

The 'Optivew' low reflectivity laminated glass is a good option and a beautiful quality transparent glass, but it still shows reflectivity with full sun.

The French system of thermoformed glass is very clever and has applications especially where paint loss or glass breakdown are distracting the reading of the panel. The system allows the large protective pieces to be enamelled on specific internal sections of the kiln-fired impression. The lead impressed lines are often

painted in, making a legible reading from the exterior to look convincing to the casual observer. This system is easily viewable at Chartres Cathedral and Sainte Chappelle.

Kiln distorted glass leaded, and mouth blown leaded glass, cut and leaded to the major design lines of the panel behind, work well. The system seems more 'honest' than large sheets of glass as it replicates the major intent of the panel behind. The reflectivity is varied, and diverse as normal unprotected window glass behaves. The new mouth blown UV protective glasses perform similarly.

A very light application of correctly fired vitreous paint with close varying tones across several sheets can be applied before cutting the glass and leading it into the protective panel. This process reduces reflectivity and creates an impressive harmony with the stonework.

A criticism that was mentioned was that the lead lines can set up a so-called 'tramline' effect. The large amount of windows I saw did not display this, and one had to look really hard from the interior to see the protective panel. I would complement the decision makers for choosing the correct windows to protect in this manner i.e. with appropriately dark or obscure glass.

Monitoring the Interspace

The interspace and its ventilation are the most crucial components of the isothermal glazing system. The system is not a total guarantee and condensation can still form on the glass surface because of multiple factors, including the building, heating, ventilation and design of the isothermal system. The orientation of the building and the height a window is placed within it, determine elements of the configuration for the proposed protective glazing. If not correctly designed and monitored, increased damage can occur to the stained glass.

Monitoring can determine if the type of system proposed is suitable and effective. It can also determine if an existing system can, or should be improved before replication for following windows. Glass sensors can help determine the right choice of protective glazing. General trends can be detected, however to be certain, each model needs testing on a case-by-case basis.

Monitoring is a scientific procedure, which requires the results to be collated and analysed by experienced people. The surface temperatures of different coloured glasses in different parts of the window are tested and the surface temperature of the protective glazing in different positions internally and externally. The relative humidity and air velocity of the interspace are tested. The relative humidity of the building is measured internally.

Canterbury Cathedral were conducting studies while I was there, and I was fortunate to have the team's wonderful director Leonie Seliger show me the electronic equipment attached to the window and explain the computer modelling on her computer screen. The results were sent to a laboratory in Cambridge and returning almost instantly to Canterbury. It was calculating the changes every six minutes. A yearly cycle is imperative for accurate results.
When the graphs are explained, it is fascinating.

Testing can be carried out using several forms of equipment including Infra-red Spectroscopy or another set of equipment known as Thermistor sensors. The thermo-hygrometer, thermo-anemometer and kondens-indikator.

Another system routinely used is a system that stays firmly attached to the glass. The use of special sensitive glasses was developed in the mid 1980s in Germany and they are placed internally and externally in the interspace at chosen levels. The special slithers of sensitive glasses summarise the corrosive impacts that could be problematic. The glasses (or dosimeter sensors) are left attached for a full yearly cycle of seasons before removal and expert analysis.

Germany will not allow any work, restoration or protection to their precious windows to proceed unless the methods used are scientifically proven beforehand. Extensive ongoing studies with glass sensors and in-situ survey research have been professionally conducted in Cathedrals and Churches in England, France and Germany over the last few decades. The compilation of the tests and subsequent results conducted in Germany are outstanding.

Conclusions and Recommendations

England, France and Germany have a prodigious record for appreciating and valuing their centuries old and Victorian historic stained glass, as an important and crucial part of their cultural identity. The European countries and the USA are active custodians and embrace proven methods of conserving and protecting stained glass in the studio and with protective glazing if necessary.

Stained glass conservation and restoration needs defending against the unscrupulous and the untrained. Beautiful and treasured windows have been irreparably damaged very quickly when placed in the wrong hands in Australia.

Education and tiered training with accreditation needs to evolve. Young people who show dedication and passion for the trade should be given every opportunity to experience training with the limited major studios in Australia and then, hopefully, funded to gain experience in overseas master studios and attend their courses. This would be the best way to ensure a high benchmark for the profession into the future.

It is imperative Heritage bodies play an active role in preserving our cultural history. The safeguarding of important stained glass windows in the custodians care, with the necessary funding being made available, ensures they remain protected in the architectural setting they were designed for.

Dissemination and Implementation of Findings

- I will use the knowledge gained in my own studio practice, and keep in contact with my overseas counterparts to keep up to date with changing approaches and improvements in this field.
- Liaise and consult with heritage organisations, architects, engineers and church committees.
- Be accessible to advise stained glass and leadlight studios and encourage the highest quality techniques and philosophical approaches to restoration.
- Power point presentations to interested groups.
- Continuation of studio restoration and church visits for custodians and parishioners.

Acknowledgments of Local Custodians

I would sincerely like to thank and acknowledge the people who have helped and supported me in the pursuit of gaining the best technical and ethical outcomes for the preservation of stained glass in Tasmania over the past decades including: Mr Bob Bird, Brian Andrews, Grahame Corney, Ian Boersma and the Tasmanian Heritage Council, my family and friends and the caring custodians, wardens and ministers of our unique churches. Their support has been invaluable.

References and Interesting Reading

Practice Note 15 – Guidelines for Stained Glass and Leadlight Glass Conservation
-Tasmanian Heritage Council

Guidelines for the Conservation and Restoration of Stained glass
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Dr Bronwyn Hughes – Lights of our Past

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Jenny Zimmer – Stained Glass in Australia

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International Corpus Vitearum – Website

ICOMOS Guidelines – International Council of Monuments and Sites