Historic England

Traditional Windows

Their Care, Repair and Upgrading

Summary

The loss of traditional windows from our older buildings poses one of the major threats to our heritage. Traditional windows and their glazing make an important contribution to the significance of historic areas. They are an integral part of the design of older buildings and can be important artefacts in their own right, often made with great skill and ingenuity with materials of a higher quality than are generally available today. The distinctive appearance of historic hand-made glass is not easily imitated in modern glazing.

Windows are particularly vulnerable elements of a building as they are relatively easily replaced or altered. Such work often has a profound affect not only on the building itself but on the appearance of street and local area.

With an increasing emphasis being placed on making existing buildings more energy efficient, replacement windows have become a greater threat than ever before to the character of historic buildings and areas.

This guidance covers both timber and metal windows and is aimed at building professionals and property-owners. It sets out to show the significance of traditional domestic windows by charting their history over centuries of technical development and fashion. Detailed technical advice is then provided on their maintenance, repair and thermal upgrading as well as on their replacement.

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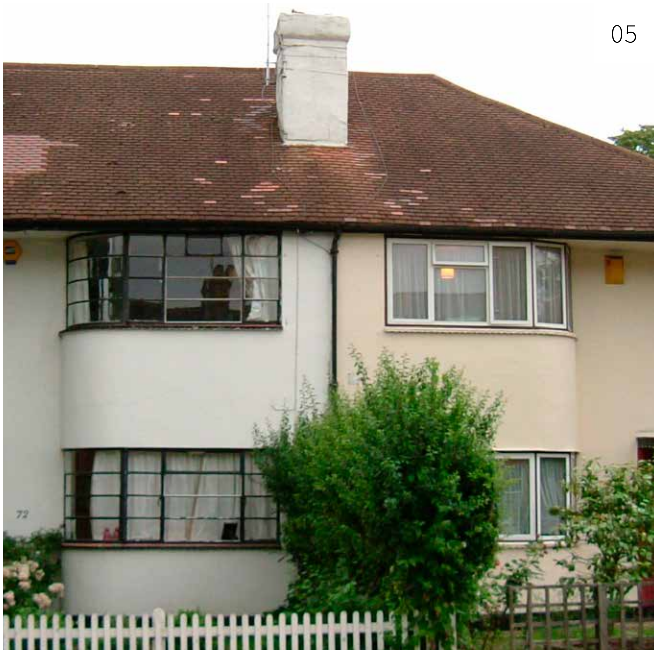

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Images 01-05

The loss of traditional windows from our older buildings poses one of the major threats to our heritage.

Contents

Image
Tying a lead 'mouse' and string to the new sash cord.

Introduction

Twenty years ago, a campaign called *Framing Opinions* (English Heritage 1994-7) was launched to highlight the increasing loss of traditional windows from older buildings and historic areas. Other initiatives have since continued to highlight the issue. Research on measuring change in conservation areas (Booth and Pickles 2005) documented the change to key building elements and recorded the widespread replacement of traditional windows, despite additional planning controls being in place to prevent such loss. In 2009, the Heritage at Risk campaign on conservation areas also raised the loss of traditional windows as a cause for concern, stating that unsympathetic replacement of windows and doors represented the number one threat and affected no less than 83% of conservation areas.

The pressures for change

The pressures that threaten traditional windows come from many different sources. Probably the most significant of these is the replacement window industry that relies on PVC-u windows for almost all of its business. The industry has invested heavily in marketing over a long period and as a result has persuaded many home-owners that their old timber windows are rotten, draughty, and beyond economic repair, whereas in most cases minor repairs and some upgrading would have allowed them to remain fit for purpose and serviceable for years to come.

Replacement plastic (PVC-u) windows pose one the greatest threats to the heritage value of historic areas, particularly in towns and villages. Despite attempts at improving the design of these windows they are instantly recognisable because they cannot match the sections and proportions of historic joinery. According to the English Housing Survey (2011) commissioned by the Department for Communities and Local Government, more than 52% of dwellings built before 1919 now have PVC-u double glazed windows.

The 'one stop shop' installation offered by PVC-u window companies can appear an attractive option. Windows on an entire four-bedroom house can be removed and replaced within a day, without having to involve and co-ordinate other trades. If the installer is a member of a Competent Persons Scheme such as FENSA (fenestration self-assessment scheme) then approval under the Building Regulations is taken care of through self-certification. Although many timber-window companies are registered with a Competent Persons Scheme, the timber-window industry has not been able to match this level of service, though sash window refurbishment companies are now much more common than ten years ago.

Home ownership provides a huge potential market, especially in areas where properties are frequently changing hands. New ownership invariably leads to some upgrading work, which often involves replacing windows because they are ‘worn out’. However, the idea that old windows are ‘worn out’ is driven largely by a culture of replacement and fashion rather than by an actual assessment of their condition and performance.

Traditional windows are often completely replaced to improve a building’s energy efficiency when many simple thermal upgrading options, such as draught-proofing or secondary glazing, are usually available at much less cost. In the case of listed buildings and those in conservation areas, owners can often be under pressure to adapt windows to accommodate double glazing, which in most cases ends up in their complete renewal or inappropriate adaptation.

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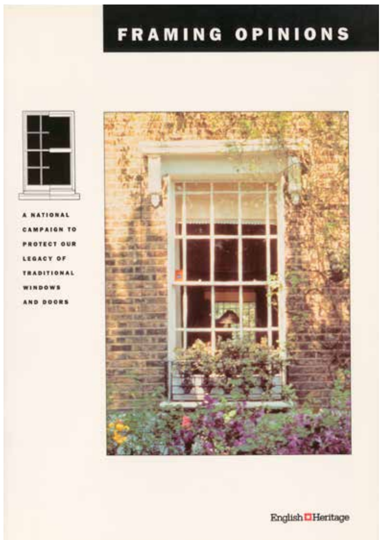

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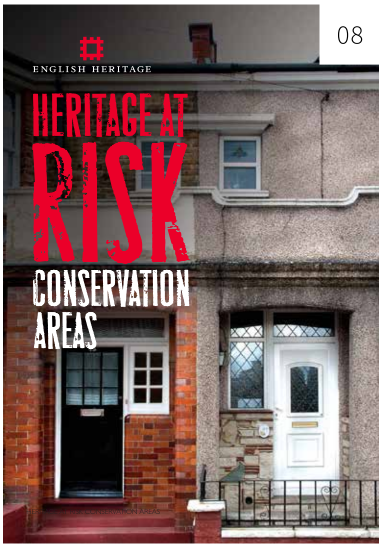

Images 06-08

06. The Hanger Hill Conservation Area in Ealing formed the pilot study in the research into erosion of key features.
07. The English Heritage Framing Opinions campaign was launched in 1994.
08. The English Heritage Heritage at Risk campaign on conservation areas was launched in 2009.

Why preserve historic windows?

Windows are the eyes of a building - they let in light and give views out - and profoundly affect its appearance. In addition, traditional windows bear witness to the artistic, social, economic and technological developments of past ages. Their design and detailing were influenced by contemporary architectural fashion, and reflected the status of a dwelling (and often the individual rooms within it). They were further shaped by factors such as methods of taxation, building legislation and craft advances, particularly in glass manufacture.

An assessment of the significance of a window or windows and the contribution they make to the overall significance of a building is the key first step in deciding the right course of action. Surviving historic fenestration is an irreplaceable resource which should be conserved and repaired whenever possible. The significance of a historic building, both as a whole and in terms of its constituent parts, can be assessed by considering its heritage values, using the framework set out in *Conservation Principles* (2008).


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Images 09-17
Surviving historic fenestration is an irreplaceable resource which should be conserved and repaired whenever possible.

Determining significance

“The significance of a place embraces all the diverse and natural heritage values that people associate with it, or which prompt them to respond to it. These values tend to grow in strength and complexity over time, as understanding deepens and people’s perceptions of a place evolve.”

Conservation Principles, Policies and Guidance for the Sustainable Management of the Historic Environment (2008)
Principle 3.2

The values that give significance to heritage assets are wide-ranging and interrelated: buildings and places provide material evidence about the lives of past generations. For example, they may offer insights into developments in construction technology, reflecting the distribution of materials, skills, ideas, knowledge, money and power in particular localities and at particular points in time.

Evidential value

Evidential value reflects the potential of a building or its fabric to yield information about the past. Rarity adds to evidential value. If the fabric of the window is old it will probably have considerable evidential value. In contrast, a modern standard ‘off the peg’ window in the same opening will have no evidential value.

Historic value

Most historic windows will illustrate, in varying degrees, the materials and technology, the craftsmanship and the architectural taste of the period from which they date. A shop window in a domestic building may carry considerable historic value indicating the development of the function of the building.

Aesthetic value

Fenestration often forms an integral part of the design of the building and contributes to a building’s visual interest. If later in date, its aesthetic qualities may add to or detract from the interest of a building. Replicas or recreations of fenestration of aesthetic quality will maintain this value. In contrast, much off-the-peg joinery and modern glazing does not replicate historic appearance and so can detract from the aesthetic value of the building.

Communal value

This value will not usually be affected by changes to windows unless they contain commemorative glazing, as sometimes found in public buildings and places of worship.

Significance

Significance is the sum total of heritage values.

Why is repair better than replacement?

Traditional windows can often be simply and economically repaired, usually at a cost significantly less than replacement. For timber windows this is largely due to the high quality and durability of the timber that was used in the past (generally pre-1919) to make windows. Properly maintained, old timber windows can enjoy extremely long lives. It is rare to find that all windows in an old building require new sections. Many historic components continue to give service after 150, 200 or even 250 years. Traditional metal windows can also usually be economically repaired and their thermal performance improved, avoiding the need for total replacement.

The whole-life environmental costs of replacement will be much greater than simply refurbishing. It will take many years before savings on heating offset the large amounts of energy used to make PVC-u windows in the first place. Repairing traditional windows rather than replacing them is not only more sustainable but makes better economic sense, particularly when the use of shutters or secondary glazing to improve their thermal performance is taken into account.

Crucially, retaining historic windows of significance is an important part of good conservation.

Can old windows be made energy efficient?

An increasing focus on energy efficiency makes older windows particularly vulnerable. Windows are generally presumed to account for 10-20% of the heat loss from buildings, although this will vary greatly from one building to another, depending on the size and number of openings in relation to the external wall area. In many older


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Images 18 and 19

The thermal performance of single glazed traditional windows can be improved significantly by draught-proofing or secondary glazing.

buildings, windows are small relative to wall areas so the cost of double glazing will seldom be covered by energy savings within the lifetime of the insulated glazed units.

The thermal performance of traditional windows can be improved significantly by draught-proofing or secondary glazing. Further benefits can be gained simply by closing curtains, blinds and shutters - measures that can produce the same heat savings as double glazing. Measures to improve the thermal performance of windows are described in more detail in Section 5 of this guide.


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Why are plastic (PVC-u) windows unsuitable?

The different appearance and character of PVC-u windows compared to historic windows is highly likely to make them unsuitable for older buildings, particularly those that are listed or in conservation areas. PVC-u is short for *Poly Vinyl Chloride un-plasticised* and these windows are assembled from factory-made components designed for rigidity, thermal performance and ease of production. Their design, detailing and operation make them look different to traditional windows. Manufacturers have been unable to replicate the sections/glazing bars used in most


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Images 20-22

PVC-u windows stand out as they cannot match the sections and proportions of historic joinery and slim metal sections.

Images 23 and 24

Research has shown that houses in conservation areas have added value and the retention of key elements such as traditional windows contributes to this.

timber and steel windows due to the limited strength of the material and the additional weight of the secondary glazing units. False 'glazing bars' which are thin strips of plastic inserted within the glass sandwich of a double glazed unit change the character of the window.

Repairs can be a major problem. Because of the nature of PVC-u, complete replacement is often the only viable option, which makes them a very unsustainable solution when compared to timber and steel.

The frames of PVC-u windows need cleaning every six months to prevent discolouration from dirt and ultra violet light. They also need to be lubricated and adjusted annually and weather-seals and gaskets renewed at least every ten years. Paints are now available for some of the early varieties of PVC-u windows that have since faded or discoloured.

Although recycling does exist for PVC-u windows this is limited to waste sections left over in manufacturing rather than for complete redundant windows. Discarded windows end up in landfill sites with the potential for releasing some of the most damaging industrial pollutants.

Can replacement windows affect property values?

Home improvements are big business. The installation of replacement double glazed windows closely follows new kitchens and bathrooms as the most popular improvements, often in the belief that such work adds value to a property.

Estate agents suggest that using poor facsimiles of historic features can actually *reduce* the value of a property. A survey of UK estate agents carried out by English Heritage in 2009 showed that replacement doors and windows, particularly PVC-u units, were considered the biggest threat to property values in conservation areas. Of the estate agents surveyed, 82% agreed that original features added financial value to homes and 78% thought that they helped houses sell more quickly.

This is a significant issue for homeowners, particularly those in conservation areas, because houses in these areas sell, on average, for 23% more than houses elsewhere. This has been shown by research carried out on behalf of English Heritage by the London School of Economics (Ahlfeldt, Holman and Wendland, 2012).

1 A Brief History of Windows

1.1 Window frames

Throughout the early medieval period, the great majority of windows were unglazed. In timber-framed buildings they were simple openings in the structural frame. Wider openings were often sub-divided into two or more 'lights' with plain or moulded mullions. Vertical wood or iron bars were inserted to keep out intruders. Taller windows might be sub-divided horizontally with transoms. Glass was extremely expensive and rare and was not considered a fixture. Timber shutters were widely used for security, privacy and to reduce draughts. In England, they were often internal and either hinged or slid in runners. Although these early shutters have rarely survived, the runners sometimes remain. Windows were also often covered with oiled fabric, nailed directly to the frame or stretched over a thin timber lattice.

Much of the plain glass and most if not all of the coloured glass used in England during the medieval period was imported from the continent and thus prohibitively expensive for widespread domestic use. By the late medieval period and into the 17th century, windows became more sophisticated with wooden tracery, moulded mullions and deep projecting cills. As glass was no longer quite as expensive it started to be used for ordinary domestic buildings.


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Images 25-27

25. A reproduction medieval shutter sliding in a groove in the timber framework at the top and an attached rail at the bottom.

26. Late 15th-century mullioned window (with 19th- and 20th-century glazing). The mullions and traceried heads are integral with the timber frame.

27. A 17th-century mullion and transom window planted onto the structural frame and secured by pegs.

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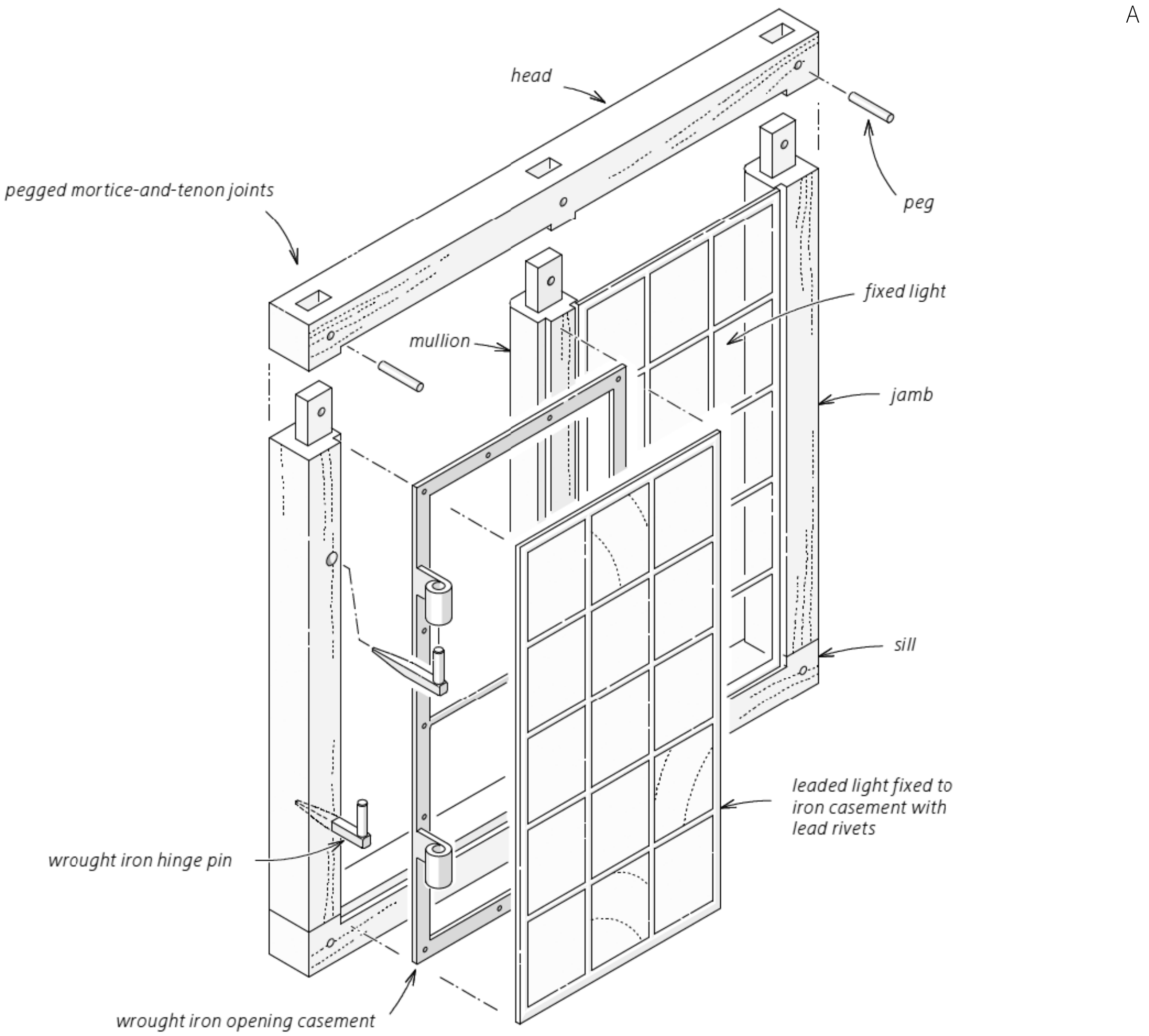
Images 28-31

28. Leaded glazing set within stone mullions with a later steel casement to the central bay.
29. Late 17th or early 18th-century oak framed window with an opening side hung iron casement.
30. Early 18th-century mullion and transom window with opening iron casement. This would have originally been glazed with leaded lights.
31. A late I7th-century/ early 18th-century wrought iron casement window set within its oak frame (from the Brooking Collection).



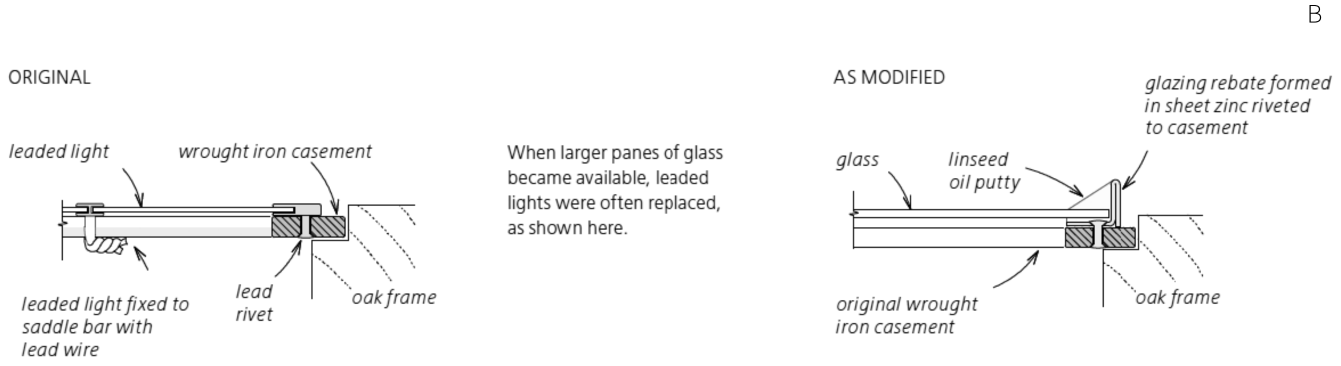


Image 32

A. Typical oak-framed casement window with leaded lights.

B. Typical glazing details.

Types of plain glass

Broad glass

A method of producing sheet glass, widely used by the 12th century; it is an early form of cylinder glass (see below). The glassmaker swung a bubble of molten glass back and forth whilst blowing to produce an elongated balloon. This was then laid on a very smooth surface; the two ends were cut off to leave a tube, which was then sliced along its length with a pair of shears and flattened to form a small rectangular sheet of glass.

Crown glass

A method of producing sheet glass in which a bubble of molten glass is transferred onto a metal 'punty rod' or 'pontil rod' which can be spun between the hands of the glass- blower. The spinning causes the molten glass to blow open into a disc. The earliest known crown glass in England dates from the 1440s; crown glass was widely used for windows until the mid-19th century, when taxation by weight ceased and cylinder glass became cheaper. Crown glass has not been manufactured since the early 20th century.

Cylinder glass

A more developed form of broad-glass manufacture. Early examples were small but by the end of the 19th century the cylindrical bubbles could be as much as 1.5m long.

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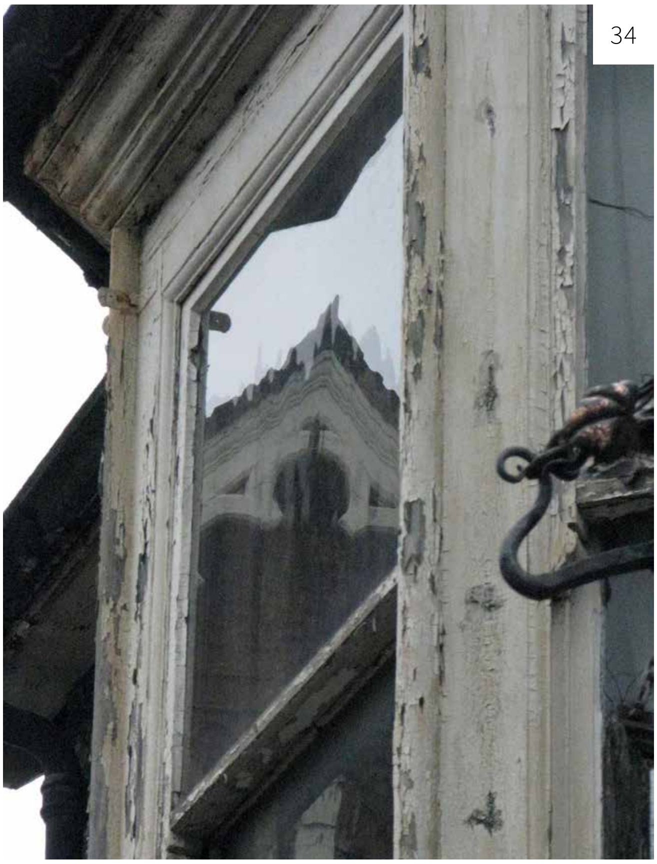

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Images 33 and 34

33. An example of crown glass which is now very rare but was widely used for windows until the mid 19th century.

34. An example of drawn sheet glass which was produced from early in the 20th century.

As with broad glass, the rounded ends were cut off and the glass was annealed and flattened. Also known as 'muff glass' and 'castle glass'.

Polished plate glass

The glass was cast onto a highly polished table of copper or cast iron. It was then ground and polished until flat and crystal clear. Developed in France, the process was used in England from the late-18th century until mechanisation in the mid-19th century made large sheets of highly finished plate glass much less expensive.

Drawn flat sheet glass

This started to be produced from early in the 20th century and involved drawing molten glass through a die into a flat continuous sheet rather than a slab or cylinder

Float glass

Float glass was invented in the late 1950s and involves flowing the molten material over a bath of molten tin. It is completely flat and therefore lacks the varied surface interest of earlier glass.

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Image 35

Windows with horizontally sliding sashes are often called Yorkshire' sliding sashes though they were used widely.

From the late 16th century, developments in glass making became more significant to the appearance of windows. Early window glass was in the form of leaded lights, which were either mounted directly in the window frame or on hinged wrought iron casements. Small areas of broad glass were cut into 'quarries' then fixed together by strips (cames) of soft metal, usually lead. Plain glass quarries were usually diamond shaped. Windows were often divided into smaller opening lights by mullions of wood or stone and sometimes also by transoms. They rarely had more than one window that opened. Windows to service or low status rooms were not commonly glazed until well into the I7th century.

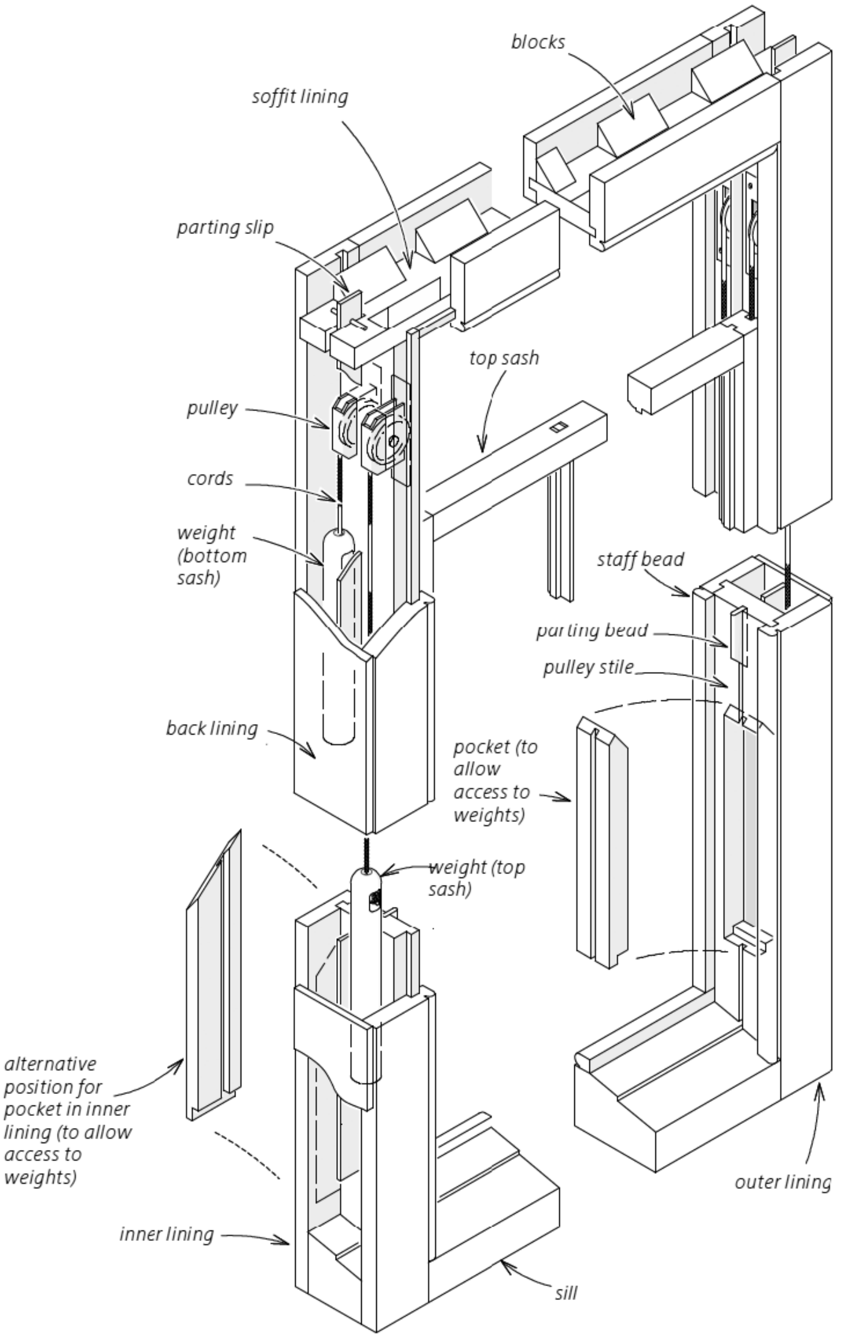
By the I7th century, larger windows in timber-frame buildings were often 'planted' onto the structural frame and fixed with pegs. The side-hung hinged casement window was common throughout Europe during the 17th century, but by the end of that century wooden casement and windows with vertical or horizontal sliding sashes were becoming more fashionable as larger and clearer sheets of glass became available. These allowed glass to be placed within rebated timber frames and glazing bars rather than within lead cames. The glass was laid in a bed of putty and pinned using glazing 'sprigs'. More putty was then applied to waterproof the joint before it was painted. This form of glazing gradually superseded leaded lights.

Horizontally sliding windows, commonly known as Yorkshire sliding sashes, had been in use from at least the I7th century and were not just restricted to Yorkshire. The great advantage of sliding windows is that they can be left slightly open even in poor weather without being damaged or letting in rain.

The earliest vertically sliding sash windows had a fixed top sash; the lower sash slid upwards in a groove and was either wedged in position or held by pegs inserted into holes drilled in the frame. They were probably introduced from France sometime in the mid-I7th century. The double-hung sash with a counter-weighting mechanism, however, appears to have been a British invention. This was an ingenious technological breakthrough that enabled a far more subtle and sophisticated system of ventilation to be achieved than was possible with the old, side-hung casement. It used a system of hidden, counterbalanced weights to allow both top and bottom sash frames to be moved independently. The earliest surviving double-hung sash appears to date from I70I; however, by I720 double-hung sashes had spread as far as Holland and the British and Dutch colonies.

As a precautionary measure against the spread of fire, the 1709 Building Act stipulated that the corners of a sash box frame be hidden behind the face of the brick or stone masonry and that 'no door or window frame of wood shall be set nearer to the outside face of the wall than four inches'. In 1774 this distance was increased to nine inches, and nearly the entire frame had to be hidden behind the face of the wall. While this legislation was only applicable to the cities of London and Westminster, the styles they produced became fashionable and spread throughout England within about twenty years.

While windows of the late 17th century could be quite large, in the early 18th century they were relatively small, sometimes with a curved top, with thick glazing bars and small panes of glass. By 1730 gauged-brick arched windows had largely been replaced by square-headed varieties that were cheaper to make. The glazing patterns inserted into these frames often took the form of six panes over six, although this was by no means the rule. Nor were the dimensions of each pane necessarily dependent on the principle of the golden section (a system of proportion used by the ancient Greeks and rediscovered during the Renaissance). In some cases, individual panes were broader than they were tall. The overall size of the window was, nevertheless, usually kept in strict proportional harmony with the rest of the facade.



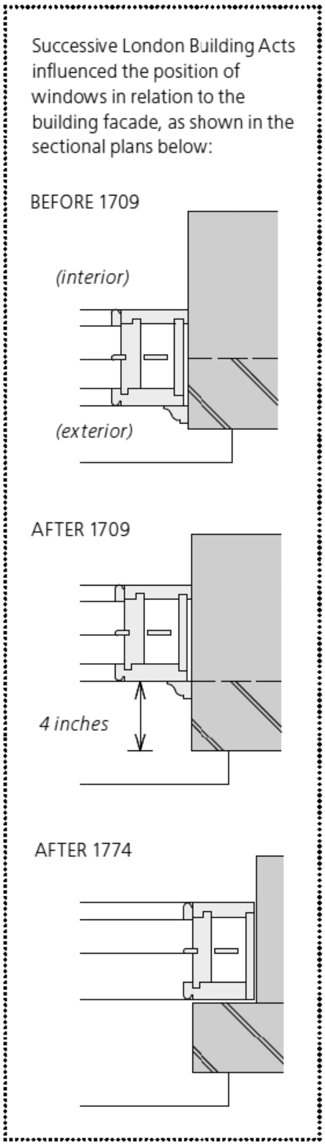


Image 36

Typical details of sliding sash window with cased frame.

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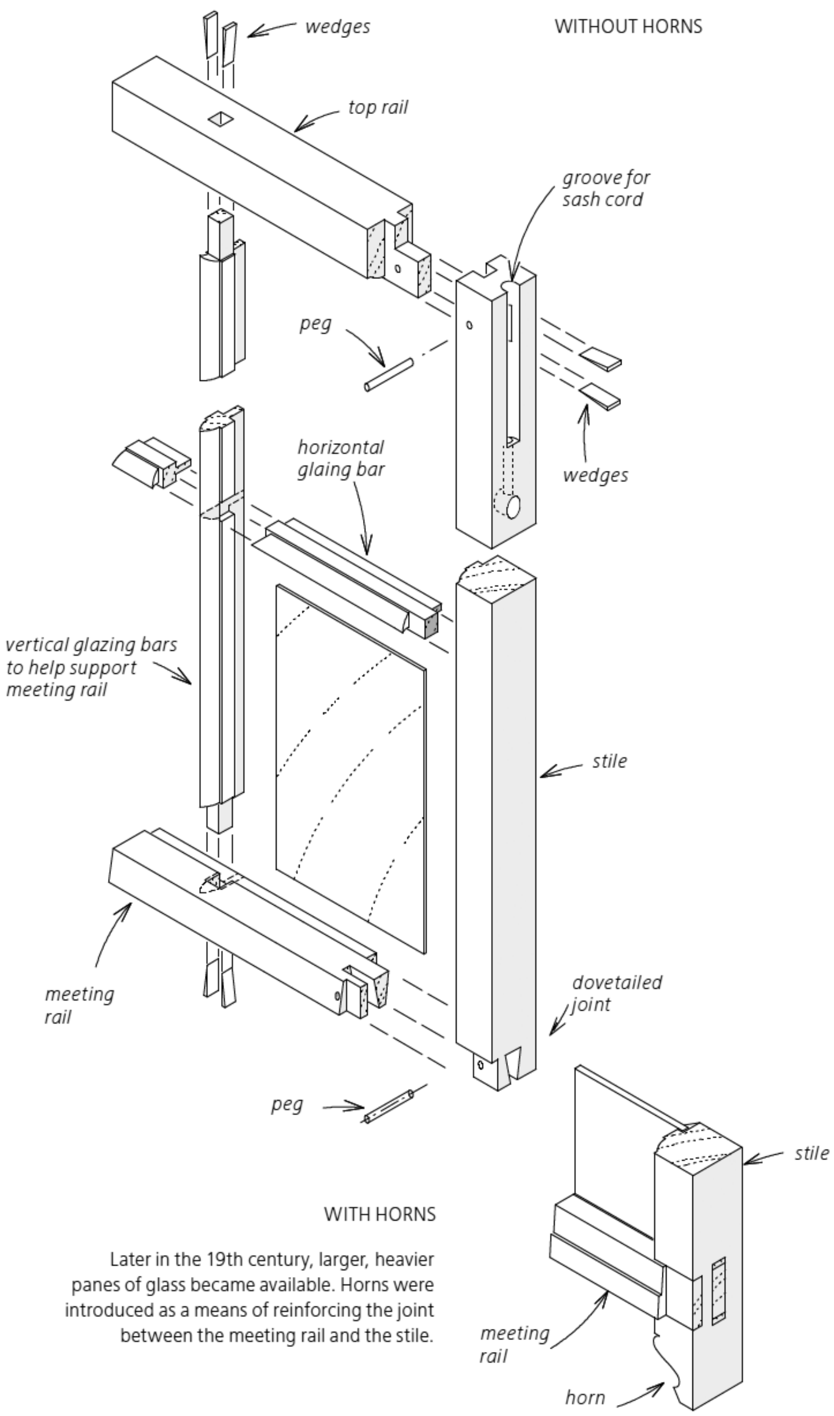

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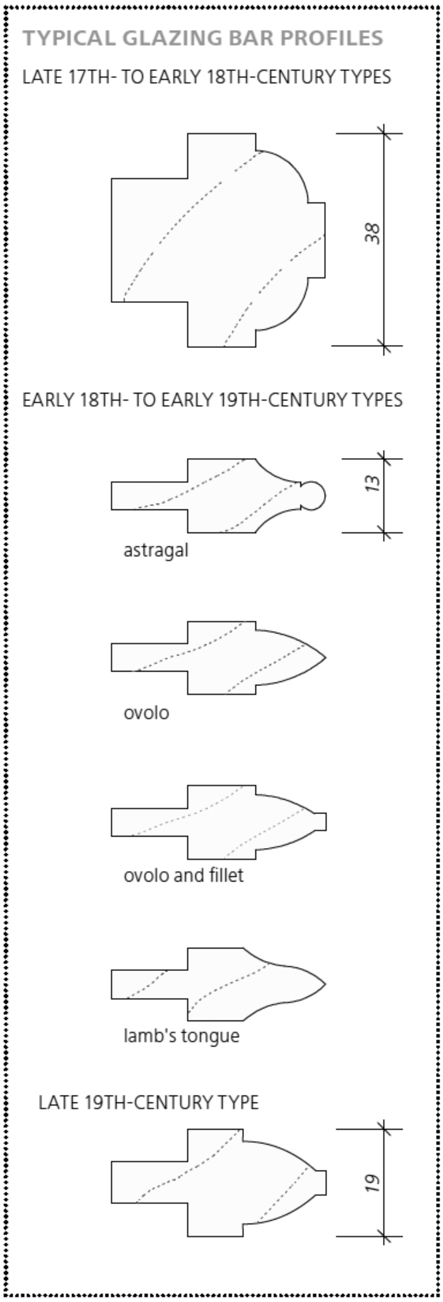

Image 37

A. Sliding sash windows: typical top sash.

B. Typical glazing bar profiles (dimensions in millimetres) showing the early ovolo profile (top)

Early glazing bars were thick and robust, usually made of native oak or a similar hardwood. They were often almost 40mm thick to support and protect the fragile glass. However, the increasing use of oak for shipbuilding coincided with the growing availability of cheaper softwoods from Scotland, the Baltic States and Scandinavia. Most late 17th and early 18th-century glazing bars were based on the ovolo, or quarter-circle moulding and used 'deal', a generic term for pine or fir softwood. Crown glass was used for glazing; being lighter it lent itself to larger sashes. Thinner, finer glazing bars, with pointed (gothic) and lamb's tongue mouldings became popular. By the early 19th century some glazing bars were only 12mm wide (although, to provide lateral strength, they could be up to 38mm deep).

The window tax, a property tax based on the number of windows in a house that was introduced at the end of the 17th century and eventually repealed in 1851, often resulted in *trompe l'oeil* fake painted sashes or plain masonry recesses where windows had been blocked up. However, not all blocked windows can be attributed to the window tax.

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Images 38 and 39

38. In the cities of London and Westminster, legislation came into force in 1709 which required window frames to be set back from behind the wall face.

39. Late 17th to early 18th-century glazing bars were considerably thicker than later profiles.

The introduction of cheaper and stronger plate glass from the I830s reduced the need for glazing bars, thus allowing uninterrupted views to the outside. However, the increased weight of the glass and the absence of any internal supports necessitated the introduction of 'sash horns' on the upper frame, extensions of the stiles that helped to strengthen the vulnerable frame joints at either end of the meeting rail.

Although wooden sashes dominated the window trade, metal windows did not entirely disappear and by the 18th century accurate methods of casting had made metal casements and fixed lights much more economical to produce. Cast-iron windows were more fire resistant than timber and so were often chosen for industrial buildings.

The development of hot rolled steel in 1856 meant that inexpensive window frames could be produced in mild steel rather than wrought iron. However, it was not until the late 19th century that glass could be produced in sheets large enough to fill sizeable opening such as shop windows. Meanwhile, windows with side-hung wooden casements continued to be used for small houses and rural buildings, as well as larger Queen Anne revival and 'Arts and Crafts' style houses, well into the 20th century.

At the end of the 19th century the 'Queen Anne' revival led to a renewed interest in windows with small panes and thick glazing bars, particularly in the upper sash. Window design is as important to the character of these later buildings as it is to Georgian ones, even if it may sometimes be more idiosyncratic.

After the First World War firms such as W F Crittall revolutionised the worldwide use of the metal casement. Crittall was responsible for the development of the 'universal suite' of hot-rolled steel sections that formed the basis of what we now regard as the classic metal windows

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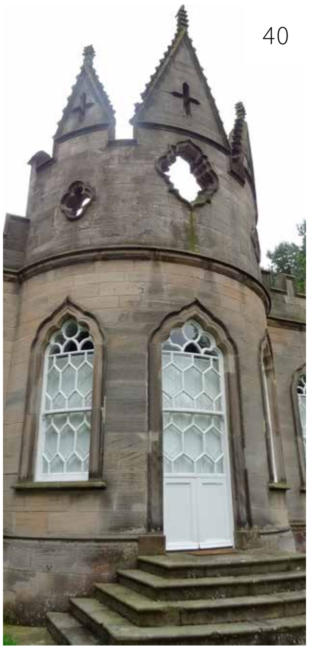

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Images 40-43

40. Elaborate mid18th-century 'Gothick' windows.
41. In 1774, further legislation in London led to sash boxes being hidden within a rebate formed in the brickwork surrounding the window opening. This, combined with very slender glazing bars gave windows a much lighter and more delicate appearance.
42. Bow windows are curved rather than polygonal in plan.
43. Oriel windows are confined to the upper storeys so that they jut out from the wall.

of the I920s and 30s. Residential windows were produced to standard sections known as the 'F-range', first introduced around 1914, and to modular imperial dimensions in a wide variety of designs. Widely used by the pioneering architects of the Modern Movement, these windows were in keeping with the new vogue for healthy, outdoor living that swept Europe in the I920s and I930s. Steel windows were strong, slim, cheap, and fire-resistant, factors that made them highly competitive with traditional softwood sashes. Since steel casements could open wider than traditional wooden sashes, they were preferred in buildings in which plenty of fresh air and light was suddenly a major priority.

From around 1945 it became the practice to galvanise steel windows after fabrication. This involves dipping the windows in a bath of molten zinc so that the zinc forms a molecular bond with the steel. Galvanising protects against corrosion without the need for further painting.

In the mid1950s, galvanised steel 'W20 sections' were introduced in lightweight and heavyweight versions. Most of the W20 sections remain commercially available though only in the lightweight version. By the 1970s, many firms were applying a tough polyester powder coating on top of the galvanising to give a decorative finish. This coloured coating is applied in the factory by electrostatic spraying followed by stoving in an oven. The initial coat lasts much longer than site-applied coats of paint.

During the inter-war years non-ferrous metals such as bronze and aluminium started to be used for windows, although bronze had been used in the 19th century for fine glazing bars. By the 1950s, aluminium become cheap enough to be used as a material for windows. It was widely used for curtain walling, which became an established form of construction in the post-war years.


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Images 44-48

44. A rare surviving awning.
45. Remains of cases for external blinds and awnings still exist on some Victorian buildings.
46. Bay windows have foundations and may be one or several storeys high.

47 & 48. In the late 19th-century vertically sliding sash windows began to make use of larger and heavier panes of glass. The weight of the glass, coupled with the disappearance of the glazing bars that had given support to the horizontal meeting rails, led to the development of 'horns' which strengthened the joint between the meeting rail and the stiles.

Window colour

During the early 18th century white or stone-coloured (white broken with yellow ochre and a little black) oil paint appears to have been the popular finish for sash windows. Only the wealthiest homes could afford more ostentatious finishes; by 1740 the internal window joinery at Chatsworth, Thoresby Hall, Holkham Hall, and Wentworth Woodhouse was gilded with gold leaf. By 1770 more modest homes were beginning to experiment with alternative paint finishes: green, grey, brown, black, and grained. These dark colours were particularly popular against light-coloured stucco or stone facades. During the 1820s John Nash stipulated that the sashes of his stuccoed Regent's Park development were to be repainted every four years with oak graining, and analysis has recently confirmed the use of black for sashes at Sir John Soane's London home in the 1820s. By the end of the Georgian period, green was very commonly used for more rustic homes, but white was still held to be the most appropriate colour for grander dwellings. However, by the middle of the 19th century purple-brown paint (first recorded as early as 1803) was popular for window joinery. Brunswick green was also widely used for external window frames and doors, while graining, usually to resemble oak, remained a popular internal and external finish.


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Images 49 and 50

49. A simple I9th-century timber side-hung casement window. The uniformity of the frame proportions is maintained by the split mullion.

50. An early I9th-century casement with a later steel metal casement central light.


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Images 51-59

51. Cast iron windows in a lattice pattern were used widely for estate cottages in the mid I9th-century and many still exist.

52-53: Small pane cottage windows became popular towards the end of the 19th century for model workers housing as shown here at Port Sunlight and New Bolsover.

54. Early 20th-century Crittal window dating from 1904 (from the Brooking Collection).

55. Steel windows became a feature of inter-war suburbia.

56. 1930s ‘Modern Movement’ style steel windows with balcony railings.

57. During the inter-war years non-ferrous metals such as bronze started to be used for windows largely for the non-domestic market.

58. Steel windows combined with leaded lights in a block of I930s flats.

59. A rare three light steel sliding sash window dating from the early I950s.

1.2 Shutters

Window shutters in English buildings are usually an internal feature, but there are exceptions in all periods. For example, medieval shop fronts were secured with demountable shutters or shutters hinged on timber dowels. This custom persisted well into the 19th century and traditional shop-fronts were usually designed with a discreet recess into which external shutters would be mounted for protection at the close of business.

Early shutters made of plain boards were superseded by framed and panelled versions constructed in the same way as doors. In towns, windows on the ground floor of houses were often fitted with external shutters as a security measure. Most of these have now been lost, but evidence, sometimes subtle, of their former existence can often be seen in the details of ground-floor windows or in the remnants of associated ironmongery.

From the 17th century, frame and panel construction was also used for internal window shutters and their housings or shutter boxes. The shutters usually consisted of a series of narrow leaves, which were hinged together so as to fold into the shutter box. The outermost segment, the 'back-flap', was sometimes a plain board, which could be easily cut to the exact width required on site. Counterbalanced internal shutters that slid vertically into a housing below the window cill were sometimes installed but are a comparative rarity. They can also be difficult to recognise as a result of having been sealed up.


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Images 60-65

60-62. Double hung sash windows with internal shutters which fold into recesses on each side of the window. When fully closed the shutters are secured tightly with iron shutter bars.

63. External shutters from the 18th -century divided into upper and lower leaves to give greater flexibility in balancing requirements for light, ventilation and security.

64. These internal shutters which are divided horizontally have a security bar which locks the lower panels in place.

65. A holdback for external shutters.

1.3 Window ironmongery

Window fittings can provide an intriguing insight to the history of a building and give clues to the lifestyles of past occupants.

In the early 17th century, window catches, latches and casework stays were usually integral parts of the wrought-iron opening light. Early timber-framed casement windows, with glazing bars or leaded lights, usually had wrought-iron H or HL-shaped hinges and spring catches.

The arrival of the sash window in the mid-17th century created a need for a far wider range of ironmongery, which by 1800 had become enormously diverse and multi-patented. The basic fittings for Georgian and Victorian sash windows were brass or hardwood pulleys, lead (and later cast-iron) weights, shutter hinges and knobs, and some form of fastener to help secure the sashes.

The sash pulley can sometimes be a useful dating guide, especially when the more obvious period details have been lost and frames have been replaced. The earliest forms of sash pulley date from the late 17th century and comprised either a brass wheel set directly into the pulley stile without an outside case (to facilitate removal) or, more commonly in less expensive work, oak or boxwood wheels with iron pins. By the early 18th century, pulley wheels were set into their own removable blocks, and by the middle of the century they were, at least in first-rate work, set into wrought-iron frames with brass face plates. As casting techniques improved, it became possible to use cast-iron for the pulley cases and to introduce sophisticated axle pulleys.

The use of brass, rather than wrought iron, for sash handles and early forms of sash fastener became more widespread during the late 18th century. By 1800 the sash fastener had evolved into the familiar, lever-arm pattern that we see today. By this time, too, sash, fasteners had become increasingly elaborate and were often finished with ceramic, ebony, or glass knobs. However, it is important to remember that throughout the 19th century traditional hinges and window fittings were used in humbler buildings. By the mid-19th century cast iron was used for even the smallest window fittings, including latches and sash fasteners.

Sash lifts, which during the 18th century had been restricted mainly to grander houses with large windows, became essential after the introduction in the 1830s of cheaper plate glass and the consequent manufacture of larger, heavier windows. They also became heavily ornamented. Indeed, the various design revivals of the 19th century led to the introduction of many more exotic designs into standard ranges of window furniture.

Sash weights were generally cylindrical and made of lead or cast iron; occasionally, rectangular-sectioned weights were used. Sash cords were made of cotton during the Georgian period, but by the later 19th century these were sometimes replaced in substantial houses by linked chain robust enough to operate the very large plate-glass sashes then in use. In 1930 the spiral sash balance was patented. Housed in grooves in the sides of the sashes, each balance comprised a cylinder containing a torsion spring and a spiral rod. The rod was threaded through a bush attached to the spring and caused the spring to be wound or unwound as the sash was lowered or raised; the mechanism could be adjusted, within limits, to suit sashes of different weights.

By the end of the 19th century a vast selection of window ironmongery was available, ranging from Regency patterns that are still in production via the revived Stuart and Georgian forms so popular with the Arts and Crafts Movement to the new, Art Nouveau designs, some of them superbly crafted. Many manufacturers continued to produce Victorian window-fitting designs well in to the 1930s.

A modest range of sash-window fittings was still available up to the Second World War. By the 1950s, distinctly modern aluminium fittings were being displayed alongside older styles, most of which had become unpopular by the 1960s. The range of sash pulleys and fasteners was cut drastically, with only a few firms supplying them by 1970. Today, the revived interest in old homes is bringing new life into this area of window furniture.


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Images 66-75

66. A window hinge made up of a pintle and gudgeon.
67. A 19th-century lever catch for a sash window.
68. A cockspur catch consisting of a piece of metal bent at right angles to form a flat latch and a handle.
69 & 70. The loop to fasten the stay which was usually on the handle. Early hook stays were attached to the frame.
71. A spring catch which has a notch to take a bar of sprung wrought iron fixed to the frame, which will hold the window shut.
72. Simple quadrants could only secure the window fully open.
73. A sprung quadrant can hold a window open in almost any position.
74 & 75: Brass fastener and adjustable stay to a 1930s steel casement.

2 Maintaining Windows

All types of windows require regular maintenance to avoid the need for repair or replacement. Ideally, windows should be inspected every year to check for typical problems. Many windows have been discarded unnecessarily because they have not opened properly, whereas some basic maintenance or minor repair would have restored them to working order.

2.1 Timber windows – recognising problems

These are some of the problems to be looked out for when inspecting older windows:

- Any evidence of structural movement which is deforming the opening and damaging the window – but note that some signs of movement may be so old that they have long since been stabilised or repaired, leaving the window in working order: its deformation expresses its age and character

- Evidence that the pointing between the frame and the wall opening is cracked, loose, or missing, allowing moisture and draughts to penetrate around the sash-box or window frame

- Sashes that do not move properly, or at all. This may be due to:

  - over-painting of the joinery
  - stop beads that have been fitted too tightly
  - pulley wheels that have seized up because of over-painting or lack of lubrication
  - broken sash cords
  - swelling due to water absorption (see below)
  - inadequate lubrication between the sash and the pulley linings
  - thicker and heavier replacement glass
  - failure of hinges on casement sashes

- Evidence of water absorption, indicating possible wood decay (wet rot). The signs to look for are:

  - interior paint failure caused by condensation
  - exterior paint failure
  - opening of the frame joints
  - degradation of the wood surfaces (where paint has flaked off) or depressions in the wood surface
  - cracked, loose, or missing putty
  - standing water, especially on the cills.
  - Faults with flashings or water shedding features associated with windows

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Key to Image 76

1. Holes drilled in frame for cable entry may admit water and cause decay.
2. Deformation of window caused by structural movement in wall; sashes no longer fit or slide properly.
3. Broken sash cords.
4. Breakdown of paint and putty caused by lack of regular maintenance; this allows water to penetrate and become trapped, causing decay.
5. Glass displaced or broken due to deformation of sash.
6. Failure of joints, caused by timber decay due to water penetration.
7. Opening parts of window jammed due to accumulation of paint.
8. Worn or damaged beads, causing rattles and draughts.
9. Decay of stile (or jamb) and outer lining at junction with cill due to water penetration.
10. Decay of cill caused by water penetration after breakdown of paint. Water may also creep into the joint between the timber cill and the masonry sub-cill.

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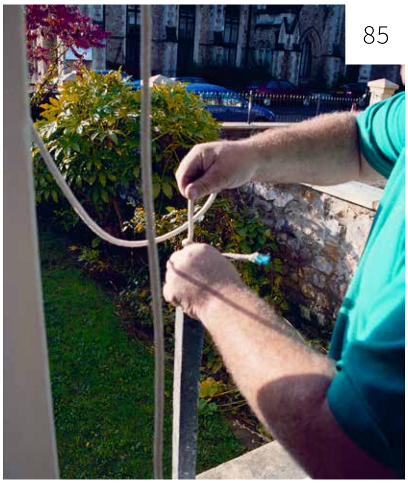
Images 76-78

76. Some of the problems to look out for when inspecting older windows.
77. A double hung sash window lacking maintenance but still easily capable of being overhauled.
78. Lack of maintenance has resulted in lost putties to glazing and rot at the base of the window frames all capable of repair. Cables fed through the base of the frame have allowed water to enter and contribute to the rot.



Images 79-87 Replacing a sash cord and adjusting window operation.

79. Removing the staff bead to free the lower sash.
80. Opening the sash pocket.
81. Accessing the weights.
82. Adjusting the weight as necessary to balance the sash.
83. Tying a lead ‘mouse’ and string to the new sash cord.
84. Running the mouse over the pulley into the weight box.
85. Knotting the weight to the new sash cord.
86. Fixing the cords to the grooves in the sides of the sash.
87. Chains are replaced in much the same way being screwed into the special fitting in the sash.

It is important to ensure that water does not enter crucial joints, such as in the lower parts of cills or jambs, where deterioration most often occurs. Joints should be kept tightly closed. In addition, it is helpful to seal end grains with paint before assembly. A watch should also be kept for any putty failure (which encourages water to sit on the horizontal surfaces of the glazing bars and meeting rails) and for deterioration in the protective paint finish.

If the timber has been affected by rot, the underlying surface will be soft and fibrous. Vulnerable areas should be probed with the point of a sharp knife or bradawl. It is easy for an experienced carpenter to repair affected areas by cutting out the rotting wood and replacing it with a piece of sound, treated timber. Epoxy resins are sometimes used as a substitute for treated wood in these patch repairs. However, it is important to paint over the repaired area as soon as possible, as resin degrades in ultra-violet light (see Section 3, Repairing Windows, for more detail on epoxy resin repairs).

It is important to identify precisely the nature and causes of defects so that the correct treatments can be selected.

2.2 Overhauling timber windows

The purpose of overhauling timber windows is to correct defects caused by general wear and tear. Typically works include:

- freeing jammed casements or sashes and removing build-ups of paint which interfere with their effective operation
- replacing broken sash cords
- lubricating pulleys and hinges
- replacing broken glass and defective putties
- cleaning and repairing ironmongery and replacing missing or broken items
- easing sticking sashes and casements
- adjusting/packing hinges
- replacing missing or worn beads
- preparation and redecoration of previously painted surfaces (5-8 year cycle)

2.3 Metal windows – recognising problems

It is important to first understand the type of metal used for the window – whether ferrous (iron, steel) or non-ferrous (bronze and aluminium) – as this will determine the right treatment. These are some of the problems to be looked out for when inspecting older windows.

- Any signs of structural movement which is deforming the opening and damaging the window – but note that some signs of movement may be so old that they have long since been stabilised or repaired, leaving the window in working order: its deformation expresses its age and character
- Evidence that the pointing between the frame and the wall opening is cracked, loose, or missing, allowing moisture and draughts to penetrate around the window frame
- Corrosion of metal framing or signs of rusting
- Distortion of the frame
- Casements that do not move properly, or at all. This may be due to an excessive build up of paint, failed hinges and fittings, rust or distortion of the frame

Metal windows which at first may appear to be beyond repair can often be satisfactorily repaired (see Section 3, Repairing Windows)

2.4 Overhauling metal windows

The purpose of overhauling metal windows is to correct defects caused by general wear and corrosion. Typically works include:

- freeing jammed casements and removing build-ups of paint which interfere with their effective operation
- replacing broken glass and defective putties
- cleaning and repairing ironmongery and replacing missing items
- easing sticking sashes and casements
- preparation and redecoration of previously painted surfaces (5-8 year cycle)
- annually clean bronze, brass and copper frames that are protected by wax coatings using a small amount of water with a little non-ionic detergent added, followed by re-waxing as necessary
- rubbing down areas of superficially corroded steel and treating them with a zinc-rich metal primer before repainting

2.5 Maintaining the window-wall junction

Joints between the window frame and walling were traditionally filled with haired lime mortar or, sometimes, a mixture of boiled linseed, driers and sand. Aerosol foam fillers should not be used, as they are unsightly and can trap moisture. If frames have been removed for repair from masonry walls regularly exposed to driving rain, it may be desirable to insert a damp-proof membrane to isolate the timber from the masonry. A proprietary pre-compressed, open-cell polyurethane foam tape, impregnated with a hydrophobic polymer resin, can be inserted into the junction. Once unrolled, the tape slowly expands as it tries to regain its original uncompressed size and, in consequence, seals the gap. The tape is black in colour and it is preferable to recess it at least 25mm behind the face of the frame to allow the junction to be pointed with lime mortar. Modern mastic sealants can be particularly disfiguring if carelessly applied or if joints are overfilled, so should only be used where they can be applied unobtrusively. Caution should be taken if aerosol foam fillers are used as they can be unsightly and can trap moisture.

2.6 Decorating windows

With the exception of early unpainted oak-framed windows, traditional windows were always painted, both to protect the timber and for aesthetic reasons. If paintwork is allowed to deteriorate it is not only the appearance of the windows that suffers; water penetrating the paint film can cause the underlying timber to decay.

Putty also becomes brittle and prone to cracking after a time. These problems are best avoided by regular inspection and redecoration of the painted surfaces.

Modern timber windows are often coated with wood stains. However, the appearance and character of this type of finish can make it unsuitable for use on traditional joinery in listed buildings and conservation areas which were usually painted or occasionally grained.

Although the same coating is often used on both the interior and exterior of the window, this does not have to be the case. Exterior paints must be able to cope with what may be very hostile conditions. The problem with most modern exterior ‘plastic paints’ is that they form an impervious surface that over time starts to crack with movement of the substrate. Moisture is then able to seep in beneath the waterproof film and is trapped so that decay rapidly occurs. Even very tough coatings will split at the joints of the frame, at the meeting point of glass and frame and around fittings; elasticity is usually more important than strength.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Images 88-93

88. A steel window showing signs of corrosion with paint blistering.

89. It is important to maintain the joints between the window frame and wall junction to prevent water entering.

90-91. Preparation of a steel window for repainting- all loose paint must be removed along with any corrosion such as rust. Deep losses should be filled to stop water collecting leading to corrosion.

92. If paintwork is allowed to deteriorate on timber windows this can lead to decay of the timber as shown here to the lower more vulnerable parts of the window.

93. The decayed parts of the window being filled and primed ready for repainting.

Paint analysis

Many surfaces in historic buildings have been over-coated many times during their history without stripping of the layers beneath. These layers form an important archaeological record.

Often, it is possible to remove a fragment of the surface coatings that contains all of the accumulated layers. This composite piece can be sent away for analysis in a specialist laboratory, where the material and colour of each layer can be analysed. This can reveal a wealth of information about the history and presentation of the building. In the past, these techniques have led to the discovery of wall paintings hidden beneath plain surfaces. More frequently, they provide the evidence to justify changing a modern paint scheme to a traditional scheme which has proven historical precedent. Fragments of coatings sent for analysis need only be very small and should only be taken from an inconspicuous section of the window or door.

Choosing a suitable paint

There is a bewildering range of options available for the painting of timber and metal windows. Traditionally, lead-based paints (still available under licence) were used for timber and metal windows but new paint systems have since been developed for specific applications.

Issues to consider when selecting a paint system include:

- compatibility with existing finishes is important, for instance acrylic paints will not adhere well to an oily substrate
- performance and maintenance requirements
- aesthetic considerations

Whatever paint system is used it is important to use good quality materials that are specifically formulated for exterior use and the type of substrate to be painted. It is important also to recognise that many paints are intended to be applied as a system (for example, primer, undercoat and finish) and that manufacturer's recommendations should always be followed on this, particularly regarding preparation and the number of coats at each stage.

Good results on timber windows have been obtained with linseed oil paints and 100% acrylic resin paints.

Preparation of surfaces

For good adhesion a coating must be applied to a clean, dry surface. Any areas of loose paint or rust and decay need to be removed. It is rarely necessary to strip back to bare wood. Not only does this destroy any earlier paintwork but it can damage the surfaces and profiles of the window joinery. There are also potential health hazards associated with removing old paint layers that may contain lead. Heat strippers should be avoided where historic glass is being retained *in-situ*.

Once loose or blistering paint has been removed the surface can be sanded lightly to improve its key.

On ferrous metal frames, active corrosion products such as rust should be removed as completely as possible using mechanical methods.

The areas to be painted should then be cleaned with sugar soap as this improves the key.
A thorough rinsing and drying is essential, particularly for frames made of ferrous metal; these should be primed to prevent flash rusting.

Priming

Ferrous metal windows that have not been galvanised should be painted first with a zinc phosphate-rich primer to prevent rust. A bare hot-dip galvanised finish also requires a zinc phosphate-rich primer because brush paint coats will not otherwise adhere to the treated metal.

Filling

Cracks and other irregularities can trap water and need to be filled before painting. Fillers need to stay elastic in order to cope with expansion and contraction of the substrate. Fillers should be sanded smooth after they have set or cured.

Repainting

Painting needs to be carried out in the appropriate conditions for the particular coating being applied. Ideally it will be carried out in workshop conditions and with the glazing removed, but this may not always be practicable. Care needs to be taken to ensure that no paint gets onto fixtures such as window sash cords and pulleys. In the case of puttied windows, the paint should cover the putty to prevent it drying out and be taken very slightly onto the glass to ensure that the joint is waterproofed. New putty needs to be allowed to cure before being painted, otherwise it will shrink.

Speed of drying depends on the thickness of the paint layer and the weather. For linseed-oil paints, the speed of drying will also depend on how much oil the surface absorbs from the paint.

Lead paint

Lead-based paints are often found on older buildings. They can be harmful to health, particularly that of children. Sometimes these paints have been buried beneath later layers. If there is any uncertainty about the presence of lead paint on windows that are to be stripped, it should be assumed that it is present and that precautions should taken accordingly.

The use of lead paints has now been generally banned because of the hazard to health. However, there is an exception to the ban that allows them to be used on Grade I and Grade II* listed buildings. On such buildings, the traditional appearance of the lead paint, together with its longevity and its fungicidal and insecticidal properties, mean that it is sometimes still used. However, it should only be applied by professional decorators using appropriate protective equipment and is not recommended for use where it may be in the reach of children.

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Image 94

The new putty to this steel casement hasn't been allowed sufficient time to cure before being painted. Consequently the paint has blistered.

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Images 95 and 96

95. In a double hung sliding sash window each sash has its own pulley and cord. The parting bead separates the sashes and holds them in position. The cord and pulley need to be kept in good working order.
96. A Fitch pattern sash fastener.

2.7 Overhauling window ironmongery

Original ironmongery such as sash lifts and sash fasteners should be retained and restored. A window latch or stay coated in cream paint may seem unremarkable, but when the layers have been removed the fine quality of its craftsmanship and construction becomes apparent. The temptation to replace such items should be resisted until they have been cleaned down so that their true condition can be appreciated.

Repair of damaged items is also possible. Reproduction fittings are widely available if the original ironmongery is missing or beyond repair. However, care must be taken when choosing replacement ironmongery, particularly for sash windows, because some ranges of fastener are particularly compatible so that they perform adequately, as well as being historically correct for the period. For example, the Fitch pattern sash fastener was designed where space was limited for a fastener but not introduced until the late 19th century. It therefore would not be historically accurate when used for Georgian sash windows.

Sash cords can be cotton, jute or nylon, although sashes from the later 19th century may have a metal chain instead. The cord or chain must be taut. Waxing keeps cords flexible and prevents them from rotting. New cord is fed over the pulley wheel by attaching it to a piece of string (with a small weight at one end) which is guided over first. A sash may sometimes not work properly because the pulley has broken or has been blocked with paint, or rubbish has accumulated under the weights.

Pulleys are of importance in dating a building, and original ones should be kept. Pre-1760 examples have wooden cases. They were not mass-produced until about 1780, when they could be iron, brass, or a combination of the two. Later Victorian pulleys could be partly of steel, with small idler wheels to take some of the extra weight of the plate glass.

A simple and inexpensive set of ironmongery called Simplex hinges can transform the bottom frame of a vertically sliding sash window into a side-hung casement that is easier to clean and repair where access is difficult.

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2.8 Improving window security

Traditional windows can be made secure. Modern materials and designs are not necessarily more secure than traditional models.

A variety of ironmongery can be added to improve security, most of it unobtrusive. Window locks, dual screws, anti-lift devices, mortice bolts and sash chains can be fitted, while still allowing the window to be opened for ventilation and cleaning. Traditional sash-window catches on their own are insufficient as security fittings, as intruders can easily hammer the catch out of its screwed mounting.

Where windows have very low cills, internal barriers can be fitted to help prevent accidents and to achieve compliance with applicable technical standards.

Original window shutters can provide excellent protection against intruders, as well as keeping warmth in and noise out. Fastening bars on shutters can help to prevent a break-in, providing that they are fixed to the structure of the building as well as to the shutter woodwork. If no shutter bars survive, modern facsimiles or approximations can be obtained. A remarkably low-tech, late-Georgian alarm system that has been rediscovered by householders involves the installation of small bells on the inside of the shutter. Its rather more advanced modern counterpart is the vibration detector, which activates an alarm when the shutter is disturbed.

Images 97 and 98

97. Height restrainers allow a degree of ventilation without compromising security.
98. Bolts inserted into the meeting rails of a sash window keep the two sashes firmly locked in place.

3 Repairing Windows

3.1 Repairing timber windows

The purpose of repair is to replace or reinforce those parts of the window that have decayed so badly that they can no longer function as intended.

There is a widely held perception that repairs are shortlived, especially those to external softwood joinery, and that the result is inferior to a new window. There is no doubt that repairs will fail quickly if they are poorly designed executed or carried out with unsuitable materials. However, properly carried out repairs can extend the lifetime of a window for many years.

Wherever possible, repairs to window frames should be carried out *in-situ*, particularly when the frame is built in and cannot be easily removed without damaging either the window or the surrounding wall. Sashes and casements can usually be removed without damage for repair either on site or in a joiner's workshop.

Recording

Before windows are removed for repair they should be carefully recorded, at least with photographs and some basic measurements. Sashes, casements and other parts should be labelled to ensure that they go back in the correct positions. Before stripping many layers of accumulated paint, think about having a paint analysis. This might reveal information about the previous colour schemes that could inform future painting. If possible, leave a small section of existing paint layers *in situ* for future analysis. Any historic glass and its characteristics should also be recorded.

Where several windows have to be dismantled in the course of repair, it is important always to mark and record the identity of the components before dismantling.

Decay in timber windows resulting from moisture penetration can be prevented by thorough painting, regular maintenance and prompt repairs. Wet rot in windows is recognisable by cracked and wavy paintwork, the timber beneath having become very soft. Replacement sections can be scarfed or pieced-in, taking care that the original profile is accurately reproduced. At the same time it is essential to remedy the cause of the dampness.

Sash windows were usually constructed from slow grown deal (pine); only in the most prestigious houses and a few early examples, was oak used. Repairs and replacements should be of the same type of timber as the existing to avoid differential movement. Hardwood is generally used for the cill as this is the most vulnerable part of the window. Where glazing bars of iron, lead, brass or bronze have survived every effort should be made to retain them.

Open joints

Open joints allow moisture to enter and cause decay. Loose joints should be re-secured by cramping, glueing, re-wedging and pinning. Decayed joints should be taken apart and defective members repaired by piecing-in. New wood and as much of the existing as possible should be treated with a solvent-borne preservative before fitting. Metal angle-repair plates, let in flush, may be used as a temporary repair to the corners of sashes.

Cills

Timber cills are particularly susceptible to decay. New cills should be made of durable hardwood, such as oak, thoroughly primed and painted and where appropriate incorporating a drip. To avoid removing the whole window, the outside half of the cill alone can be replaced; the butt joint between new and old work should be covered by the bottom rail of the sash when it is shut.

Spliced repairs

Spliced repairs should be made by cutting out rotten wood and splicing or scarfing-in timber inserts which are shaped to obtain the maximum strength and to match the existing profiles. The new timber should always be worked to the line of the existing and should follow any existing deformations in the line of the window. Excessive trimming of the existing timber should be avoided. Spliced repairs should be designed so that water is directed towards the outer face of the timber and cannot lie on or enter the repair joint. Inserts should be made from good-quality wood similar in species and moisture content to the parent timber. They should be fitted with the grain orientated to match the existing. This reduces the risk of the insert and the parent timber moving at different rates during damp and dry conditions, which could in turn cause the repaired joint to fail by splitting. Just as for any other joinery work, timber with defects such as shakes, resin pockets, knots or sapwood should be avoided for use in repairs. Modern softwood has poor resistance to decay and should be double-vacuum impregnated with preservative by the supplier.

When repairing window joinery, always rectify the source of the problem first - such as where damp is getting in. If you need to apply preservative treatments, these can be brushed onto the affected area after the decayed wood has been cut out. A more sophisticated method is to pressure-inject organic, solvent-based preservative into the timber through non-return valves that are later filled. This is best done by a specialist and is not really economical for fewer than five windows. The insertion of preservative rods containing water-soluble chemicals (usually boric acid) that diffuse into the surrounding timber is also highly effective, but again is best carried out by an experienced person.

Resin-based repairs

Proprietary polyester or epoxy resin repair products can also be considered. Where the window is to be painted, small areas of loss can often be made good with fillers based on wood dust mixed with a two-part epoxy resin or polyester resin. The worst decay is first cut away, but not back to sound wood; instead, weakened areas are strengthened with a resin consolidant. Removed material is then replaced with a filler or a combination of filler and timber. This is a very effective way of maximising the amount of original fabric retained.

The most likely area of failure is at the timber/filler joint, where cracking results from differential movements in the timber and resin and insufficient adhesion between the two materials. Moisture admitted through these cracks is likely to be trapped behind the repair where it could create conditions for further decay. Although the long-term performance of resin-repair systems is uncertain, such systems can postpone the replacement of a traditional window so that it survives to be repaired another day. If traditional joinery repairs are not possible, it is better to use resins and extend the life of the original window.

Timber quality

Many 18th and 19th centuries sash windows continue to provide excellent service thanks largely to the high quality timber used in their manufacture. Most were made from heartwood of imported Scots pine *(Pinus sylvestris)* grown slowly in natural forests. However, by the early 20th century, trees cultivated on plantations were an increasingly important source of timber. Plantation grown trees are encouraged to grow to a marketable size in the shortest possible time. As a result, they contain a larger proportion of sapwood than slow-grown trees. Sapwood is more permeable than heartwood and contains sugars and starches that provide an excellent food source for fungi; this makes it susceptible to decay and unsuitable for external joinery. Nevertheless, in the post-war years, it became common practice to use timber containing a high proportion of sapwood for many joinery tasks. The results of this can be seen in the large number of timber windows, dating from the 1960s and 70s, which now require replacement. Therefore, it makes good sense to retain old joinery wherever it is sound. When repair or replacement is required, heartwood of one of the more durable softwood species, such as Scots pine/ European redwood *(Pinus sylvestris)* or imported Douglas fir *(Pseudotsuga menziesi)*, should be used. As it is very difficult to ensure that timber is entirely free of sapwood, pre-treatment with preservative is generally recommended. An alternative would be to use chemically modified ‘acetylated’ softwood which is exceptionally durable, and dimensionally stable.

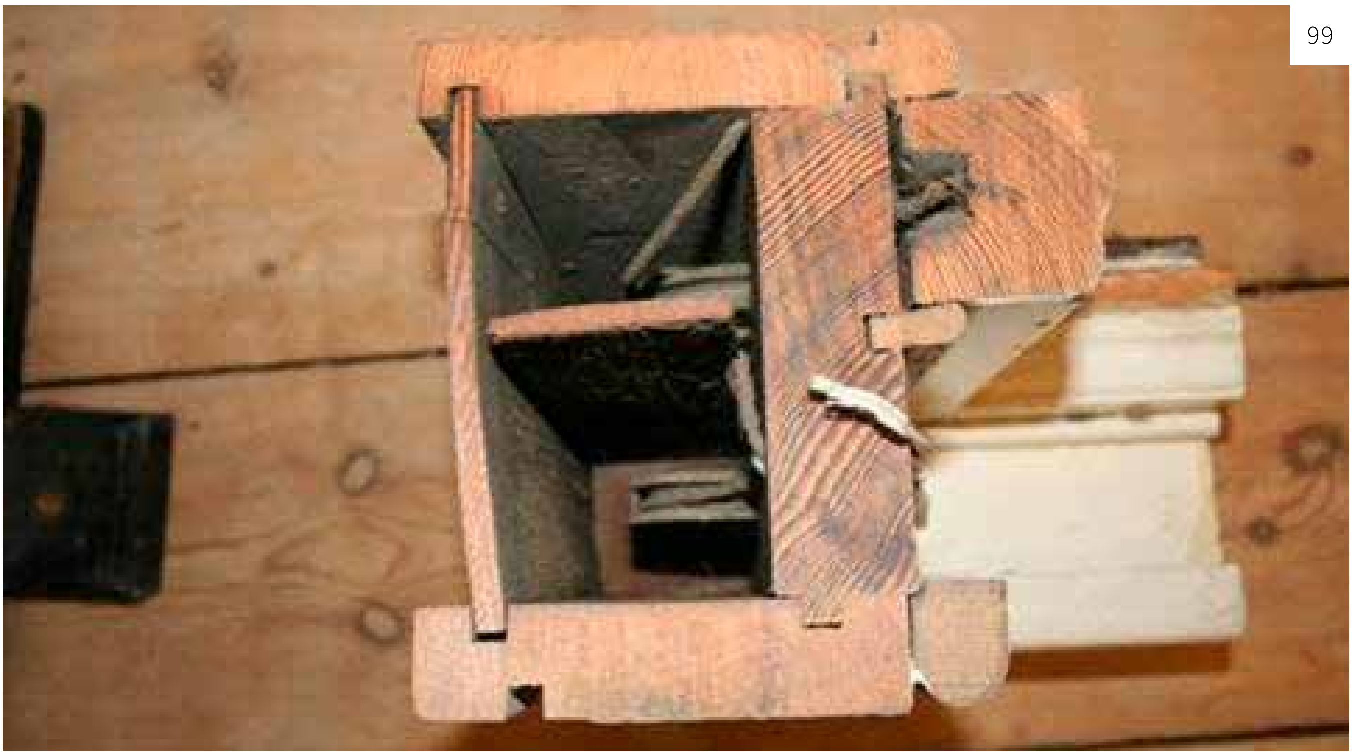
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Image 99

This section through a sash box shows the high quality of the timber used during the 19th century.

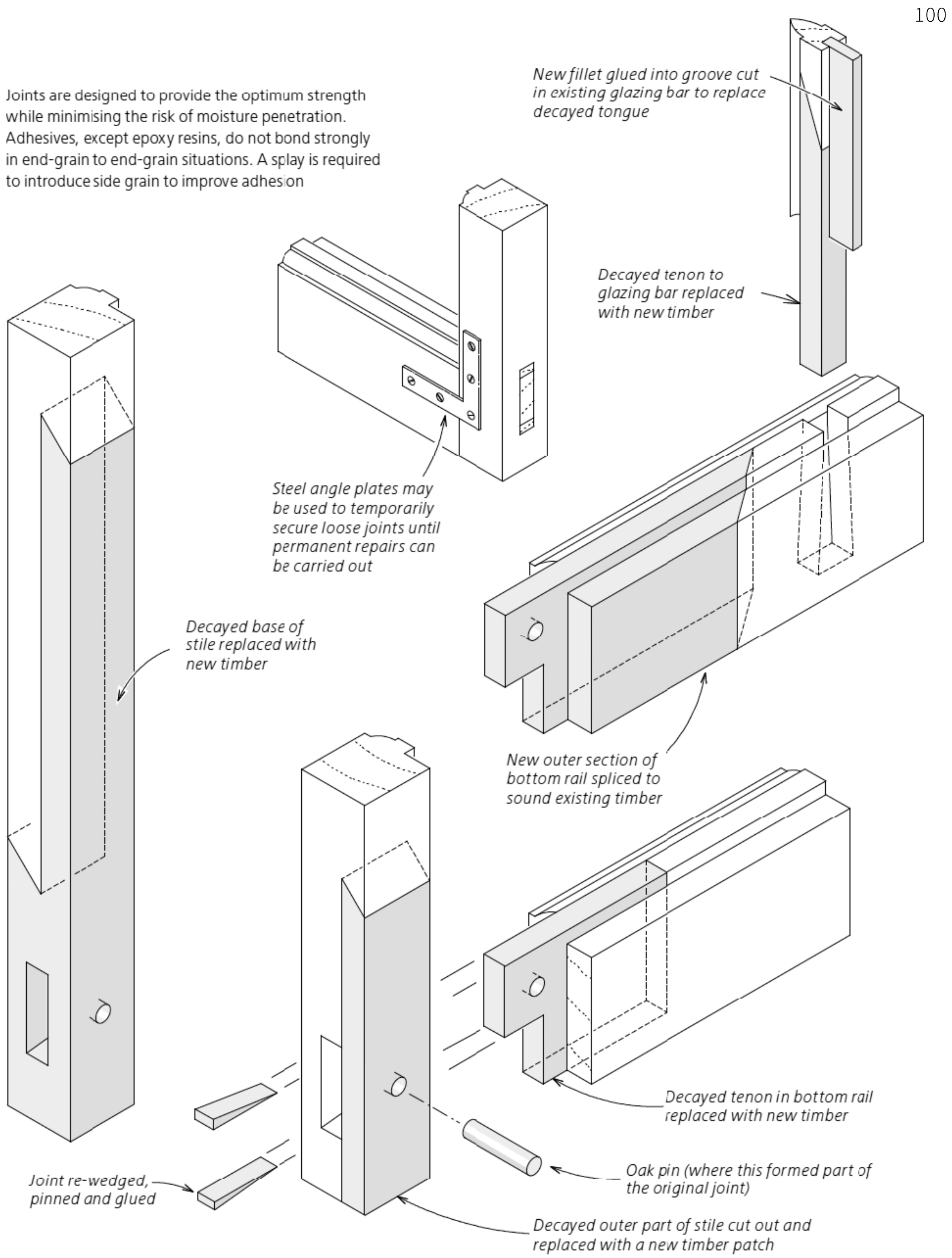

Image 100

Typical timber-to-timber repairs to sash and casement components.

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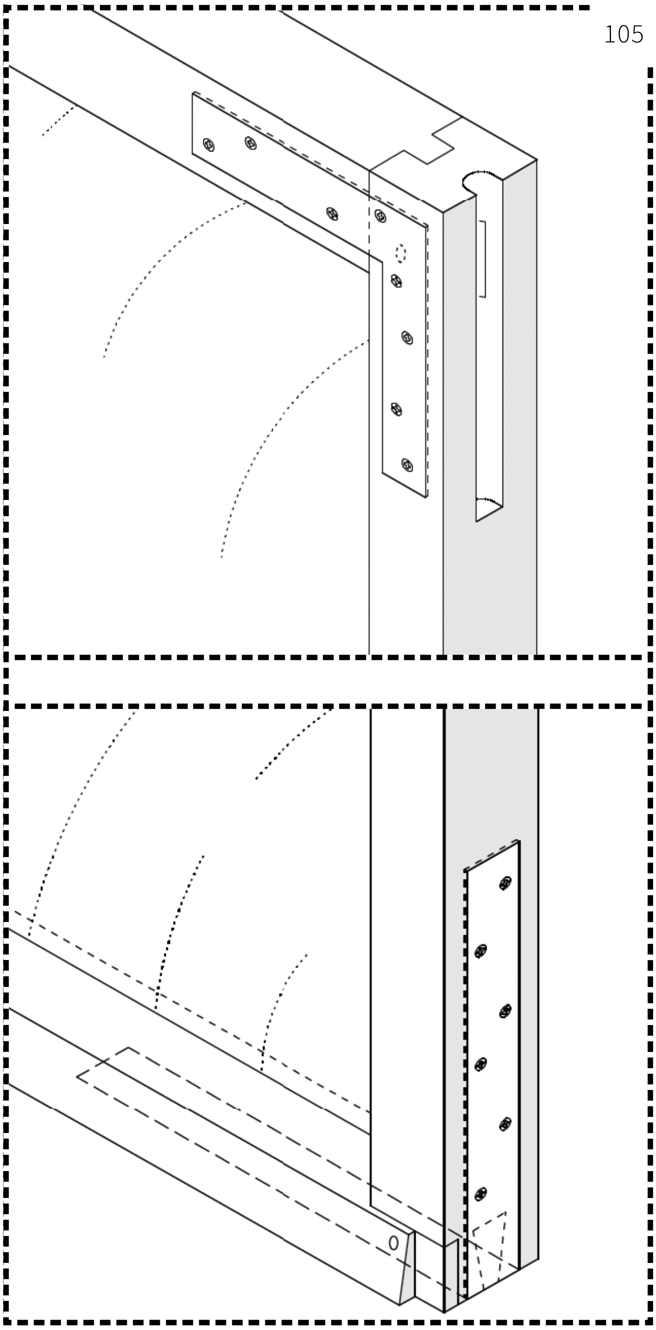

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Images 101-105

101. Decayed timber at the base of the pulley stile, the outer lining and the exterior of the cill has been cut out and new timber inserts have been pieced in.
102. Careful piecing in of new timber has saved this window whilst retaining as much historic fabric as possible.
103. Splicing in new timber
104. An example of skilled joinery repair in the workshop where the central mullion and cill have been replaced.
105. Metal angle brackets are one of the least invasive ways of reinforcing damaged timber casements and sashes. They are more obtrusive than carpentry repairs, and should therefore be positioned on the interior of the frame, but they have the great advantage that the glass does not need to be removed to make the repair.

3.2 Repairing metal windows

The best way of repairing a metal window will depend on the type of metal used. Ferrous metals pose different problems to non-ferrous metals such as bronze and aluminium, and within the ferrous metals wrought iron will need to be treated quite differently to cast iron or steel. The original method of production is also a consideration. For example, pre-l950s steel windows were generally not galvanised so are prone to corrosion, which often appears as rusting of the horizontal glazing bars and the bottom members.

Ferrous metal windows can suffer from surface rust, distortion, excessive build-up of paint and failed hinges and fittings. Rust expands up to seven times the volume of un-oxidised metal, so corrosion can often look much worse than it really is. Even windows that appear in a very bad state at first sight can often be repaired.

Rust and paint can be removed by acid pickling or flame cleaning. Firms specialising in this are found in many towns. Any necessary repairs to wrought iron or steel windows, including welding in replacement sections, can be made by a professional metalworker. Cast iron windows cannot generally be welded (limited welding in-situ might be a possibility) because they tend to crack when heated, but they can be repaired using a technique known as 'cold stitching'.

Traditional metal windows can often be economically repaired and made energy-efficient (see Section 5, Thermal upgrading) rather than be totally replaced. Many firms undertake this type of work. Renovation can be done either on site, using tools such as wire brushes, files, and small grinders to remove rust and scales, or in the factory, where the windows can be grit- or-shot blasted and galvanised (or, in the case of more fragile specimens, zinc-sprayed). What may look thoroughly rusted and unusable may have decades of life left in it, if in doubt, call in a metal windows expert, particularly if the windows need straightening or the glazing is damaged.

Distortions

Distortions should be left if at all possible, but if they are interfering with the operation of the window, or the safety of the glass they will need to be corrected.

With the exception of cast iron, which is brittle and tends to crack, the metals used for windows remain fairly malleable, so slight distortions can usually be corrected by carefully easing the frame back into alignment without the window being de-glazed.

To correct significantly distorted frames it will usually be necessary to remove the glass first, which can sometimes be difficult. It may then be possible to pull the frames back into alignment; otherwise the bent section can be strapped to a stiff wooden framework using ratchet straps, which are slowly tightened over a period of days.

Corrosion

Superficial corrosion of steel can usually be dealt with by rubbing down the rusted areas with a wire brush, wire wool and wet-and-dry paper before treating them with a zinc phosphate-rich metal primer and then repainting. Deeper losses that have not compromised the structural stability of the window should be raked out as thoroughly as possible, primed, and then replaced with a metal filler before repainting. Whenever possible, corrosion should be prevented by excluding water; this means making the building water-tight and ensuring that any sensitive metals are protected by a suitable paint or other coating (see Decorating Windows).

Cast and wrought iron windows

If the casement and frame require repair, an assessment needs to be made of the glass to find out whether it will have to be removed to facilitate the repair or can remain *in-situ*.

Wrought-iron frames can be repaired with rivets, bolts and tenon joints. Alternatively, sections of a ferrous non-corroding alloy can be arc-welded or MIG-welded into place. The optimum way of repairing wrought iron it to use salvaged wrought-iron sections. The weld must extend through the full depth of the metal, to ensure that all parts are connected together. Surface welds have very little structural strength. Cast iron must always be repaired by cold stitching. Welding is technically possible but risks fracturing the metal. The surface of wrought iron should be cleaned back to sound metal, primed, repaired and painted.

Metal windows with leaded lights are found in buildings from many periods. Their repair can be a specialist task and should be approached with caution, particularly if the windows are of historic significance. It may not be sensible even to attempt to repair leaded-light windows to draught-free levels, but secondary glazing can often be added to provide protection and draught-proofing.

Steel windows

The main problem associated with ungalvanised steel windows is rusting and corrosion. Rust is iron oxide formed by the reaction of iron with water and oxygen. As the metal corrodes it exfoliates and expands. This expansion often then cracks the glass.

Corrosion or rust begins whenever moisture is able to penetrate the protective paint that coats a rolled-steel window. Neglected decoration is perhaps the most obvious cause of corrosion, but defective putty can lead to even worse symptoms, allowing corrosion to eat away at the metal section beneath. A faulty weather-seal around the perimeter of a metal frame is equally damaging, allowing rust to develop.

Flaking or blistered paintwork is often the first sign of corrosion. Probing the affected area with a pointed tool will detect the degree and extent to the rust, which in turn determines the required treatment.

Steel windows made from the mid-1950s onwards will probably be galvanised. This can be ascertained by looking for a tough silvery finish below the layers of paint.

If the window has been galvanised, repair should be relatively straightforward. Remove excess paint, including from the hinges and other moving parts. Care should be taken not to damage the galvanised finish. Wire-brush any loose paint and if hinges or other fittings are damaged they can be replaced. The window can be upgraded thermally at the same time. (see Section 5, Thermal upgrading)

Corrosion in un-galvanised steel windows is likely to be more severe and the decision will need to be taken as to whether to remove the window for repair in the workshop or in-situ. The windows need first to be recorded. It may be necessary to cut out and replace severely corroded sections of frame, provided matching sections can be found or made by a steel fabricator. Welding should only be used off-site, so this is an option only for elements that can be safely demounted, transported and reinstalled.

Where repair is neither technically or economically viable, steel windows of a very similar pattern are still available and can be supplied in a durable powder coated finish.

Non ferrous metals

Frames of copper or copper alloys such as bronze can be repaired by brazing, soldering and welding. They can be repaired *in situ* by stitching, riveting or screwing the pieces together.

3.3 Glazing repairs

Removing and saving glass during repairs

Sometimes a window may retain its original crown glass or cylinder glass. This is not completely flat and may have slightly curved ridging or air bubbles that give depth and character to a facade. Historic glass should always be retained in place and great care taken to protect it while work is in progress. Crown glass is no longer manufactured (although there are various forms of cylinder glass available) so original pieces are now very rare. Chipping away at the putty to remove the glass involves a very significant risk of cracking it. Putties become very hard with age but can be softened by prolonged contact with solvent or caustic alkali type paint strippers or infrared heat treatment.

Solvent (non-caustic) paint strippers should be applied in accordance with manufacturer's instructions and covered with polyethylene film to prevent drying out. A dwell time of up to 24 hours may be needed to soften putty sufficiently to enable it to be removed by careful scraping. Further applications may be required to treat the full thickness of putty.

Old putty may also be softened by heating. This requires great care and should only be carried out using a proprietary 'putty lamp'. This device produces a focused, linear beam of infrared radiation which heats and softens the putty but largely passes through the glass. Localised thermal stresses in the glass are thereby minimised and the risk of cracking the glass is reduced. Flame-producing torches and hot-air strippers should not be used.

This work can be carried out by a specialist contractor and requires great care. If the putty has perished it can be cut out by patiently running a knife or sharp chisel between the timber and putty - but not between the putty and glass.

Removing historic glass from leaded lights is easier as the lead cames are flexible, allowing the glass to be taken out with relative ease.

Glass analysis

It is possible to establish the age of window glass through chemical analysis. The raw materials and recipes used to make window glass have changed over time. Phosphorus is present as an impurity in most window glass made before the 1830s but is virtually absent from later glass. This is because early glass was made using plant ashes, all of which contain at least some phosphorous. The type of plant ash can also sometimes be identified using chemical analysis -for instance, the use of seaweed ash in 18th century window glass can be detected through the presence of strontium.

Re-glazing windows after repair

Whether the frame is metal or timber, the approach to re-glazing is much the same. The rebate must be cleaned, dusted and given a thin coat of primer, before new linseed-oil bedding putty is applied for wood windows and metal casement putty for metal frames. The glass pane can then be pressed into place and fastened with fixings that replicate the original system. Finally, more putty is used to seal the joint between the frame and the glass.

Cylinder glass has recently become available again from specialist suppliers. A good and cheap substitute is colourless 2mm or 3mm 'horticultural' glass. Alternatively, glass which has been heated and deliberately distorted can be obtained.

The sash mechanism relies on the weight of the window-sash and its counterweights being almost the same, although for efficient closing it is suggested that the weights should be a little heavier than the upper sash and a little lighter than the lower sash. If by re-glazing you increase or decrease the weight of the window you will have to carefully adjust each counterweight.

For leaded lights, effective replication of the original panel will depend as much on the thickness and height of the heart of the cames as on the shape and width of the flanges. Whenever possible, the original cames should be reused, though this might be very difficult for anything other than single pieces of glass ('quarries'). Prior to dismantling it is important to record the positions of the glass by taking rubbings. The panel should be sealed after re-leading, either on both sides for plain glass or on the unpainted side if the glass is decorated and could be damaged by the sealing.

As a general rule, historic glass should not be rearranged, nor should later additions and repairs to the glazing be removed as these too can contribute to the significance of the window, unless there is a strong conservation argument for doing so.

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Painting timber/metal windows

See Section 2, Maintaining Windows.

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Image 106

Steel window showing severe corrosion to the bottom rail of the frame and distortion from 'rust jacking' which has cracked the glass.

Image 107

A putty lamp should be used where old putty needs to be renewed as this reduces the risk of cracking the glass.

4 Thermal Upgrading

Energy efficiency is now a major priority for most building owners, for comfort, fuel economy and to limit the waste of natural resources and reduce carbon emissions. The thermal efficiency of historic buildings can be greatly improved without replacing windows that contribute to their significance. Rather than focusing entirely on windows, it is better to consider energy conservation measures that address the thermal efficiency of the whole of the building. This should include not just physical measures, such as loft insulation and draught-proofing, but also the efficiency of heating systems and controls and the way these are used. In every case, the aim should be to strike an appropriate balance between energy conservation and building conservation. Adopting a 'whole building' approach can help in understanding where energy goes, and identifying less harmful options to achieve energy savings.

Image 108

Testing windows in the climate chamber at Glasgow Caledonian University.

The heat loss from windows can vary considerably, depending on the size of the windows and their ratio to the external wall area. Heat is exchanged through windows in a number of ways: by *conduction* through the glass and materials of the frame, by *convection* through gaps and openings, and by *radiation* from the surfaces. All of these are important for thermal comfort; draughts will replace warm indoor air with cool air from the exterior, and radiant heat loss can make people within a room with large windows uncomfortably cold, even if the windows are completely sealed. A brisk winter breeze cooling the exterior glass can set up convection currents that make the room feel draughty, even if there is no exchange with the exterior.

Where a window is clearly 'leaky' (with gaps around the frame and rails where sash windows meet) research has shown that repairing and draught proofing it can reduce air infiltration by over 80%. Further benefits can be gained simply by closing curtains, blinds and shutters and these can produce the same heat savings as double glazing. The addition of secondary glazing can also reduce heat loss by nearly 60% (and is also effective in reducing sound transmission). In multi-paned windows, secondary glazing will generally be more thermally efficient than replacing the existing glass with double glazing due to thermal bridging through the frame and glazing bars. It is also usually less expensive. Some of these measures enable buildings that retain historic windows to be *more* energy efficient than buildings whose windows are simply replaced with double glazed units.

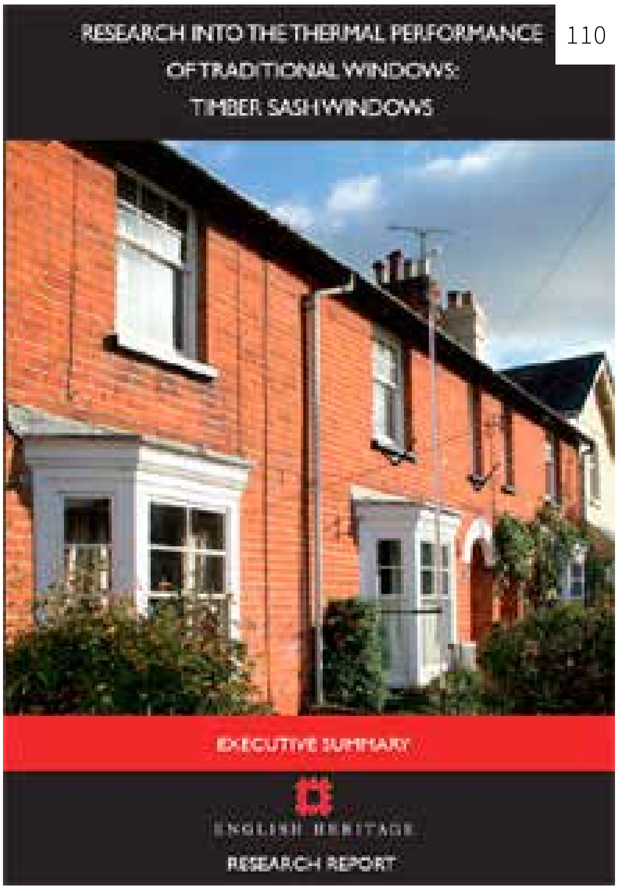

Image 109

Testing windows in the climate chamber at Glasgow Caledonian University.

Image 110

The English Heritage research report on the thermal upgrading of windows was published in 2009.

Historic England/Historic Environment Scotland windows research

Historic England and Historic Environment Scotland decided to commission research into the thermal performance of traditional windows as they were concerned that calculated U values were not giving a true picture of actual thermal behaviour.

These complex factors are very hard to measure, not least because they are so dependent on exterior conditions. Thermal transfer through building materials is commonly expressed in terms of overall heat transfer coefficient, or U-value (the rate of heat transfer through a given area of a building element when exposed to different temperatures on either side; the lower the U-value the more slowly the element transfers heat).

Timber sash windows

The main series of tests looked at the behaviour of two timber vertically-sliding sash windows of about the same size. The sashes of one were divided into six panes (6-over-6 window) as was common in the Georgian period; the other had a more typically Victorian configuration, with each sash divided into two panes (2-over-2 window). The 6-over-6 window was in good condition but the 2-over-2 example was deliberately chosen as it was in poor condition, so that the improvement in air leakage due to simple repairs and refurbishment could be assessed.

The main round of testing looked at the reduction in conductive heat loss due to a series of common improvements, including installing roller blinds, lined curtains, shutters and secondary glazing, and using glass with a low-emissivity coating.

Results

Effect of maintenance

Simple maintenance to mend cracks and eliminate gaps can significantly reduce the amount of air infiltration or draughts. On the window that was tested air infiltration was reduced by more than 33%.

Draught-proofing

Draught-proofing was found to reduce air exchange through the window by as much as 86%.

Reduction in heat loss

Simple measures were found to have a dramatic effect on conductive transfer through the window: thermal roller blinds alone could cut heat loss by 57%. Secondary glazing was especially effective if made from glass with a low-emissivity coating, cutting heat loss by around 60%; shutters performed almost as well. The best results were achieved by multiple systems – shutters or secondary glazing combined with curtains or blinds for example. This was, indeed, the traditional approach and it has the added bonus of allowing flexibility, in that the system can easily be adjusted for different seasons.

Heat loss through contact with the glass and frames can be significantly reduced by adopting simple measures like closing thick curtains and plain roller blinds. In the test, heat loss was reduced by 41% and 38% respectively

More elaborate measures reduce heat loss even more and can improve windows to meet modern building regulations, which target a U-value for new windows of 1.6 or below. In a test with good quality secondary glazing this value was 1.7. Well-fitted, closed shutters produce similarly good results. The best result is when the two methods are used together, yielding a 62% reduction in heat loss and a U-value of $1.6Wm^2K$.

Metal windows

The tests looked at the behaviour of two metal-framed casement windows, one with a steel frame and 3x4 rectangular panes leaded together, and the other a 2x3 steel window. Unlike timber, metal has a very low thermal inertia, and unsurprisingly the frames and leading were found to contribute strongly to the heat transfer through the window.

The main round of testing looked at the reduction in conductive heat loss from a series of improvements, including installing roller blinds, lined curtains or secondary glazing using glass with a low-emissivity coating and replacing the single glass with thin IGUs (slim-profile double glazing). Shutters were not tested.

The results were then compared with other tests by the same researchers, which looked at the improvements delivered by secondary glazing and by a number of different slim-profile double glazed units.

Results

Draught-proofing

Draught-proofing was found to reduce air infiltration by over 95%. This agrees with the results of independent tests on an in-situ cast iron window which had badly failed the British Standard test for weather tightness and air permeability, but with later draught-proofing easily passed the same test even in gale force winds.

Reduction in heat loss

As with timber windows, simple measures such as adding roller blinds and secondary glazing produced dramatic improvements, cutting heat loss by as much as 54% and 62% respectively.

Comparison with slim-profile double-glazing

The heat transfer through the frame greatly limited the improvement that could be gained by replacing single glass with slim-profile double glazing.

See also Section 7, Further Reading, for references on thermal-upgrading research

4.1 Draught-proofing windows

Draught-proofing is one of the most cost-effective and least intrusive ways of improving the comfort of occupants and reducing energy used for heating with little or no change to a buildings appearance. It has the added benefit of helping to reduce noise, rattling and keeping dust out. Recent research has shown draught-proofing can reduce air leakage in windows by between 33 and 50%, significantly reducing the energy requirement needed for heating.

A number of companies offer a repair and upgrading service for windows, using a variety of weather-stripping systems. One system for timber sash windows replaces the existing staff and parting beads, which are usually sacrificial elements, with modern equivalents that incorporate brush seals of woven polypropylene pile. Others rout out slots in the sides of the frames and the meeting rails to receive push-fit, flexible Z and V strips or variously shaped brushes, which are concealed when the window is closed.

Repair first

All types of windows will decay over time so regular inspection and maintenance will always be a good investment. Before installing any draught-proofing it makes sense to identify and make any repairs that are needed first. Straightforward repair can reduce air infiltration and heat loss by up to a third.

Draught-proofing products

Choosing the right products for draught-proofing can be difficult. When windows are distorted, many products will not work effectively as they can only deal with a specific range of gap widths. Some products are also applied to the surface of a door or window frame, while concealed solutions are generally more suited to historic buildings.

When choosing a draught-proofing product consider the following:

- How big are the gaps to be sealed?
- How variable is the width of the gaps?
- Does allowance need to be made for seasonal expansion and contraction of the door or window?
- Is it important that the draught-strip is not seen? What about when the window is open?
- Does the draught-strip need to match the colour of the frame? Painting the flexible part of a seal is not recommended as it changes the characteristic of the product
- Will the draught-strip be renewed every time the door or window is redecorated? If not, it will either need to be capable of being removed and reinstalled after decoration

There is a British Standard (BS7386) that covers the quality of draught-proofing products. Specifying and purchasing products that meet that benchmark will help ensure minimum standards are met.

There are two main types of draught-proofing seals:

- compression seals
- wiper seals

Compression seals

Compression seals are used where the moving part of the window closes against the frame. Typical applications include around the sides and top of a door or around the entire edge of a casement window. Compression seals can also be used along the bottom and top rails of a sash window and are normally quite cheap and easy to install. They are most appropriate for sealing narrow, even gaps. They require some compression to be effective, but cannot be compressed too far, so a given size of seal therefore only works on a narrow range of gaps. This makes them difficult to fit to casements and doors with some warping because of the variation in gap thickness. Since compression seals are typically mounted to abut the face of a casement or door they are relatively unaffected by seasonal expansion and contraction of doors and windows.

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Compression strips are available in a range of materials. The simplest to install are self-adhesive strips of rubber (EDPM). These are available in a variety of profiles and thicknesses to cater for different gap widths. Foam strips are cheaper still but have a short life. Silicone and rubber 'O' tubes are available in a variety of diameters. Some attach to the frame using an adhesive others come on a carrier strip that is either attached to or cut into the frame.

V-shaped silicone and rubber seals are an alternative that can bridge a greater range of gap sizes. Silicone is taking over from rubber as the material of choice for compression strips because it is available in a range of colours, including white. Brush pile seals, more typically used as wiper seals and described below, can also be used as compression seals.

For metal windows, particularly those with irregular gaps, a silicone gel or polymerised rubber can be used to create a compression seal. The gel is applied from a tube onto the frame. Non-stick tape, or more usually grease, is applied to the meeting surfaces of the window, which is then immediately closed to squeeze the sealant into a perfect fit. When the sealant is dry, the window is opened, the seal trimmed, and the release tape or grease removed.

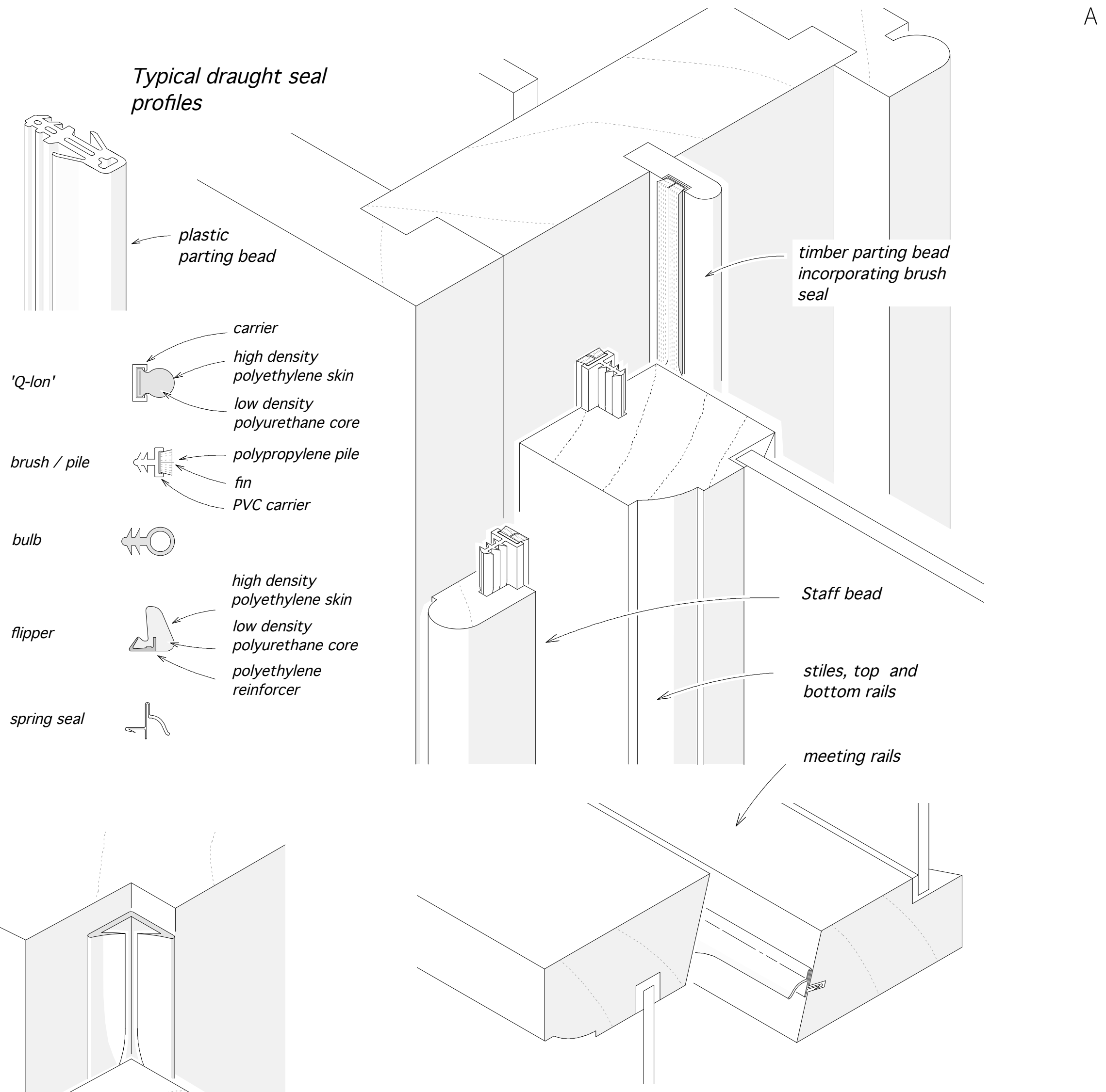
Wiper Seals

These are used when the moving parts slide past each other. Wiper seals are the only way to seal the sides and meeting rails of sliding sash windows.

Wiper seals can also be fitted to the edges of casement windows. Here they can still work, even when the window is moderately warped.

Images 111-113

111. Nylon brushes being inserted into the sash as draught-proofing.
112. Silicone being injected into gaps between the frame and casement to exclude draughts. The casement is first painted with a releasing agent. The silicone is then left to cure with any excess trimmed back.
113. A sash window with draught-proofing brushes installed.



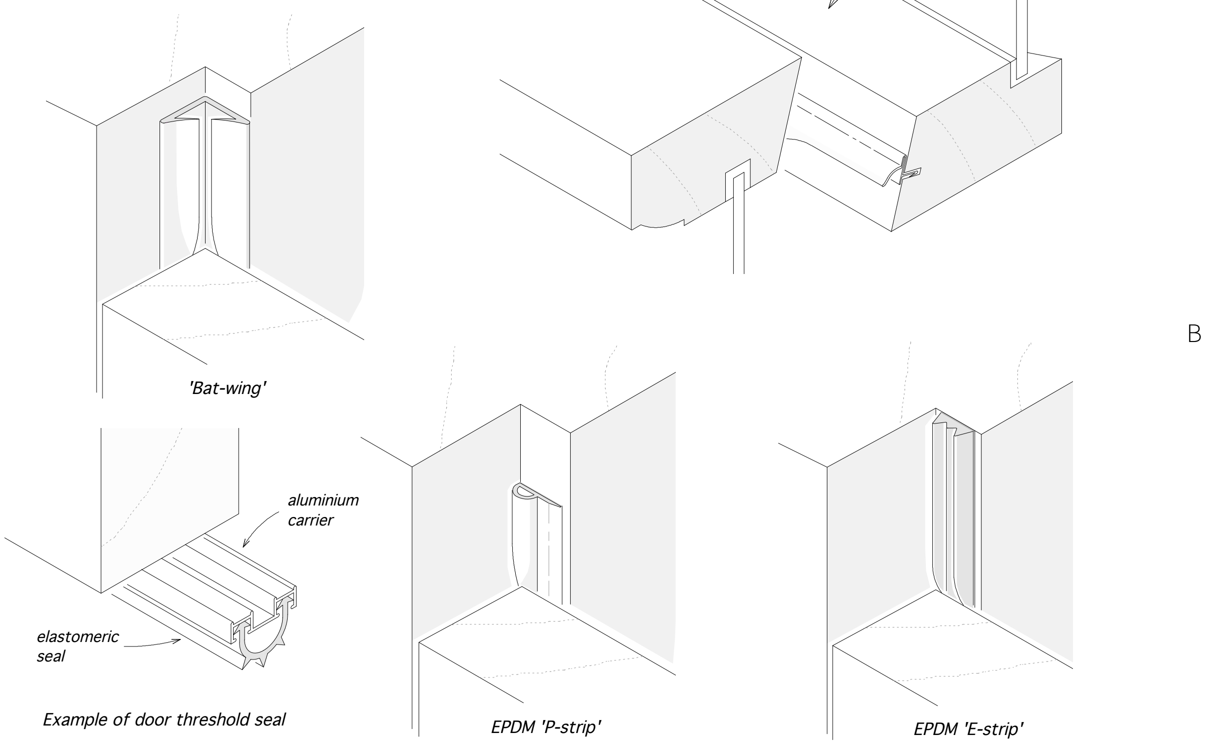


Image 114

A. Example of draughtproofing for sash windows.
B. Examples of draughtproofing for casements or doors.

The most common wiper seals are brush pile seals. These are capable of sealing a range of gap sizes, and adapt to fill uneven gaps well. Some include a thin plastic fin or fins in the centre to make a better seal. Other wiper seals are made of silicone or thermoplastic strips where a heavy-duty seal is needed. V-strip wiper seals are also available, and can be used between the stiles and boxes of sliding sashes. Some wiper seals are supplied with a simple backing strip for gluing or pinning to a window frame. Others require a narrow groove cut into the wood into which the base of the seal is pushed.

Ventilation control

Significantly reducing the ventilation of a room can create moisture problems, particularly in areas with a high moisture content such as a kitchen or bathroom. Controllable ventilation in the form of extractors or trickle ventilators can be used. However, the incorporation of such methods of ventilation in listed buildings should be very carefully considered as they can affect the special interest.

Low cost draught-proofing

Many of the most cost-effective solutions for improving the insulation of windows, such as blinds, timber shutters and awnings were commonplace in the past and were only abandoned when energy became cheap and readily available.

Curtains and blinds

Heavy curtains not only reduce heat loss by conduction but are also an excellent way of preventing draughts. Well-designed blinds can almost match the effectiveness of double glazing, especially when made of materials which reflect radiation. Tests have shown that heavy curtains or well-fitted ordinary roller blinds will cut heat loss by around 40%; honeycombed roller blinds (made of much lighter materials, but with a cellular structure that traps air) cut losses by more than 50% and roller blinds with reflective surfaces on the window side have been found to cut losses by as much as 57%.

Shutters

Well-fitted external or internal wooden shutters dramatically decrease heat loss from both draughts and conduction through the window. Conduction losses alone are cut by 60 %. Redundant shutters should certainly be brought back to use wherever possible and if missing, consideration given to reinstating them. Where there is no clear evidence of shutters the merits of installation will have to be weighed against the impact on the significance of the building.

4.2 Adding secondary glazing

Secondary glazing is a fully independent window system installed to the room side of existing windows. The original windows remain in position in their unaltered form (without draught-proofing to prevent possible condensation).

Secondary glazing is available as open-able, removable or fixed units. The open-able panels can be either casements or sliding sashes. These allow access to the external window for cleaning and the opening of both the secondary glazing and external windows for ventilation. Other secondary glazing is designed to be removed in warmer months when its thermal benefits are not required.

Recent research has shown heat losses by conduction and radiation through a window as a whole can be reduced by over 60% by using secondary glazing with a low emissivity (low-E) hard coating facing the outside. The research has also shown that further savings can be made if the secondary glazing uses insulating frames or incorporates double or vacuum-glazed units (vacuum glazed units can achieve a U value of $0.6Wm^2K$ with single glazed windows).

Although the primary purpose of secondary glazing units in older buildings is to improve the thermal performance of windows by draught-proofing as well as reducing the conduction of heat through glass, secondary glazing can provide a number of other benefits including insulation from noise, improved security and protection from ultra-violet radiation.

Before carrying out secondary glazing work to listed buildings or buildings in conservation areas, check first with the local planning authority if any consent is required.

Thermal benefits

Heat loss from a room through a window during the heating season is complex because three main mechanisms are in play:

- by convection and conduction, from the warm room air to the colder surfaces of the glass and the frame
- by the colder surface of the window absorbing infrared radiation from the room
- by uncontrolled air leakage, which can either bring in cold air from the exterior or take warm air out from the interior; often called air infiltration, this can occur even when the window is closed

Heat loss through the glass and frames

Whether it leaves the room by convection, conduction or radiation, the lost heat all passes through the glass and the frame as conduction. The glass is the most conductive part of the window but heat is also lost through the frame, albeit at a lower rate for timber windows. Single glazing is a poor thermal insulator and readily conducts heat. A typical 4mm-thick glass has a typical U-value of 5.4W/m^{2}K. The thermal loss through a single-glazed window will depend on the total area of glass, the conductance of the frame material and the quality of the fit of the framing and glazing materials. A typical value of a timber framed single glazed window is 4.8W/m^{2}K.

- U-values measure how quickly energy will pass through one square metre of a barrier when the air temperatures on either side differ by one degree
- U-values are expressed in units of Watts per square metre per degree of temperature difference (W/m^{2}K). The lower the U value the slower the rate of heat transfer through the barrier and therefore the better the insulation quality

For thermal performance, the optimum airspace between primary and secondary glazing is 50-60mm. A larger air space allows convection currents to develop within the cavity and more heat to be lost. The positioning of the secondary unit is usually dictated by the window reveal and can often only be fitted at a distance of about 100mm from the primary glazing. However, a significant proportion of the thermal benefit of secondary glazing comes from decoupling the frame from the primary timber window frame and this can reduce the U-value to approximately 2.5W/m^{2}K. The use of low emissivity glass for the secondary glazing can further improve the thermal performance to less than 2.0Wm^{2}K. To maintain this figure it is important to keep the coating clean – the standard is 'visually' clean.

Heat loss through air leakage

Heat losses from a typical traditional window are predominantly through gaps around the window. With larger windows, the proportion of heat lost by conduction through the glass tends to be greater. Since draughts caused by convection and air infiltration make people feel colder, the occupants may turn up the heating and also run it for longer. Purpose-made secondary windows, with efficient perimeter sealing and brush or compression seals on the opening panels, form an effective seal over the whole of the frame of the original window and can significantly reduce excessive draughts.

Noise insulation

Windows are one of the most vulnerable parts of a building to noise transmission due to their relatively lightweight construction. Depending on the number of openings and the quality of the seals between the openings, a single glazed window without seals may only achieve a noise reduction of l8-25dBA. When closed, sealed double glazed units perform little better than single glazing because the two panes of glass are rigidly connected with a minimal cavity so the two panes resonate together. A secondary window with an air space of 100mm or more de-couples the movement of the two panes of glass and reduces the resonance between the two. Sound insulation of up to 45dBA can typically be achieved. Higher levels of sound insulation are obtained as the gap increases, particularly if the reveals are lined with an acoustic material, though minimal improvements occur with cavities beyond 200mm. The use of thicker or acoustic laminate glass within the secondary window also improves the acoustic performance of the installation.

Protection from ultra violet light

Ultra violet (UV) light from the sun can cause extensive damage to paintings, fabrics, furnishing and other objects. The use of a film either in laminated glass in the secondary glazing unit or applied as a film to the primary window, will absorb UV light and reduce this risk of damage. However, this type of film will degrade overtime and although unlikely to cause harm to the glass surface unless it is decorated, damage may be caused by attempts to remove it. Highly reflective films are best avoided in a historic context due to their visual impact.

Solar gain

Windows can admit large amounts of solar energy leading to overheating. Secondary glazing can make this worse if it restricts summertime ventilation. However mid-pane blinds, glare coatings and summer ventilation of the air space can be used to help make the room cooler. A number of secondary glazing systems can be taken down in the warmer months.

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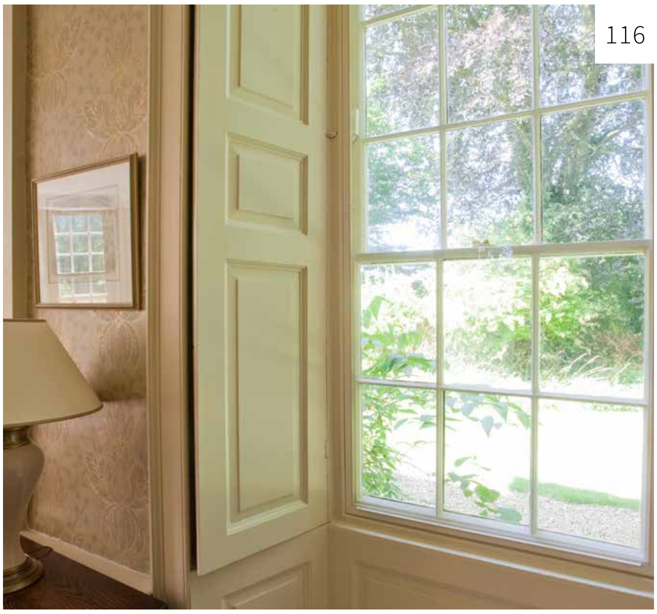


116

Images 115 and 116

115. Failing plastic coated aluminium double glazed windows to this listed terraced house were replaced with single glazed timber casements to the correct historic pattern with secondary glazing incorporating Low E glazing giving a centre pane U-value of 1.6w/m^{2}K.
116. A very thin secondary glazing unit fitted alongside working timber shutters.

Materials

When selecting secondary glazing units it is important to use a system in keeping with the design and materials of the room. There are several proprietary secondary-glazing systems available that provide installations that are configured to suit the particular needs of the building.

Proprietary systems normally have painted aluminium frames. This allows the design of slim-line systems that can fit within the depth of the staff bead of a typical sash window, so shutters and window cills can be retained. Systems with more substantial framing sections are stronger and can accommodate seals, fixings and counterbalancing. The systems may use an aluminium outer frame fitted to a softwood ground or seasoned hardwood surround depending on the design and fixing details. Easily removable lightweight systems that use acrylic glazing and are fixed by magnets are also available. The suppliers of these systems provide design, manufacture and installation services.

Alternatively, a bespoke system can be designed comprising a sub-frame, commonly of timber, into which opening casements or sliding sashes are fixed. Individual glazed windows can be hinged so that they fold up like shutters or operate like sash windows.

4.3 Adding insulating glass units (double or triple glazing)

Installing double-glazed windows has been one of the most popular and fashionable home improvements over the past 25 years.

Repair, draught-proofing or secondary glazing is likely to be more cost-effective than replacement with double glazing. In multi-paned windows, double glazing will generally be less efficient than secondary glazing, due to the thermal bridging through the frame and glazing bars, particularly for metal frames.

It may be possible to consider re-glazing to cut heat transmission with low-emissivity coated glass or even insulated glass units. However, it is advisable to see physical prototypes in order adequately to assess the visual impact of such proposals.

Low-emissivity glass

The transmission of radiant energy through window glass can be decreased by applying coatings that reflect infra-red wavelengths while letting visible light pass. In winter, heating is reflected back indoors; in summer, heat from the sun is reflected away, keeping the room cooler.

Types of double glazing

Like secondary glazing, insulated glass units (IGUs) rely on multiple layers of glass to cut heat transfer, but the glass sheets are positioned much closer than in secondary glazing. In order to cut heat transfer the gap must be either evacuated or filled with an inert gas such as argon, krypton or xenon to reduce the rate of heat transmission. Low-emissivity coatings are sometimes applied to the inner pane of glass to reduce thermal transmission still further.

Conventional double glazed IGUs are 22 - 28mm thick overall. ‘Slim-profile’ double-glazing (also known as ‘slimline’ or ‘slim-cavity’) has a narrower gap between the panes of glass and ranges in total thickness from l0mm to l6mm. A more recently developed type of IGU is 6.5mm thick and has a miniscule cavity from which the air is removed to create a vacuum.

Modern single glazing is normally 4 to 6mm thick, but historic single glazing can be as thin as 2mm. In comparison, slim-profile IGUs at 10-16mm are significantly thicker, and the whole double-glazed unit can be many times heavier than single glazing.

The function of IGUs depends on the seals that prevent air and moisture from entering the gap; when these fail, the units will become much less thermally effective and are also likely to fog because of internal condensation. The lifespan of current IGUs is estimated to be between l5 and 25 years.

In energy terms IGUs have pay-back periods that can greatly exceed their design life, especially for units filled with inert gases. When the seals fail and let in water vapour this then condenses on the interior of the glass. They are difficult to repair and also much more difficult to recycle than plain glass - discarded double-glazed windows have become a major contributor to landfill. The energy required in manufacturing and transportation can also be significant in the overall equation. Special glazing compounds need to be used when reglazing with IGUs because standard linseed oil putty can damage the seals to the units.

Adding double glazing to traditional windows

In practical terms, it is often impossible to replace existing glass in multi-paned historic windows with double glazing - even where 'slim-profile' IGUs are used - without having to alter the frames and glazing bars to accommodate the increased thickness and weight of the glazing. In double-hung sash windows without glazing bars, the sashes are often replaced but the sash boxes are retained and heavier weights added to balance the increase weight of glass.

If used in multi-paned windows, IGUs will generally be less efficient than secondary glazing since even the most efficient units will not overcome thermal bridging through the frame and glazing bars. This is particularly an issue when IGUs are added to steel windows. For this reason and for cost effectiveness, many replacement windows are made instead with a single IGU with timber glazing bars or leaded lights applied to the surface. This loss of historic fabric and detailing and change in appearance are likely to reduce the significance of the window and the host building.

Timber windows that are more than 150 years old will often have been weakened through general wear and tear and distortion from the weight of glazing and any movement of the building. Experience has shown that where slim-profile IGUs are inserted, window sashes often have to be replaced. For this reason, and because of the potential loss of any surviving historic glass, the installation of IGUs in historic windows is likely to seriously harm their significance.


117

Image 117

This slim profile IGU comprises 3mm outer glazing a 3mm gas filled cavity and 4mm Low-E inner glazing giving a total thickness of 10mm.

Double glazing could be considered in these circumstances:

- where a historic window retains no significant glass, and has sufficiently deep glazing rebates and is robust enough to accommodate the increased thickness and weight of IGUs without significant alteration (for example, late Victorian of Edwardian 'one-over-one' sash window or a simple casement)
- where an existing replacement window of sympathetic design is to be retained and is capable of accommodating IGUs
- steel windows sections that are able to accommodate a slim IGU

The introduction of slim-profile IGUs has made it possible to produce new double-glazed windows in traditional materials which may be more sympathetic to the character of older buildings than earlier types of replacement window.

(See Section 5, Replacement Windows)

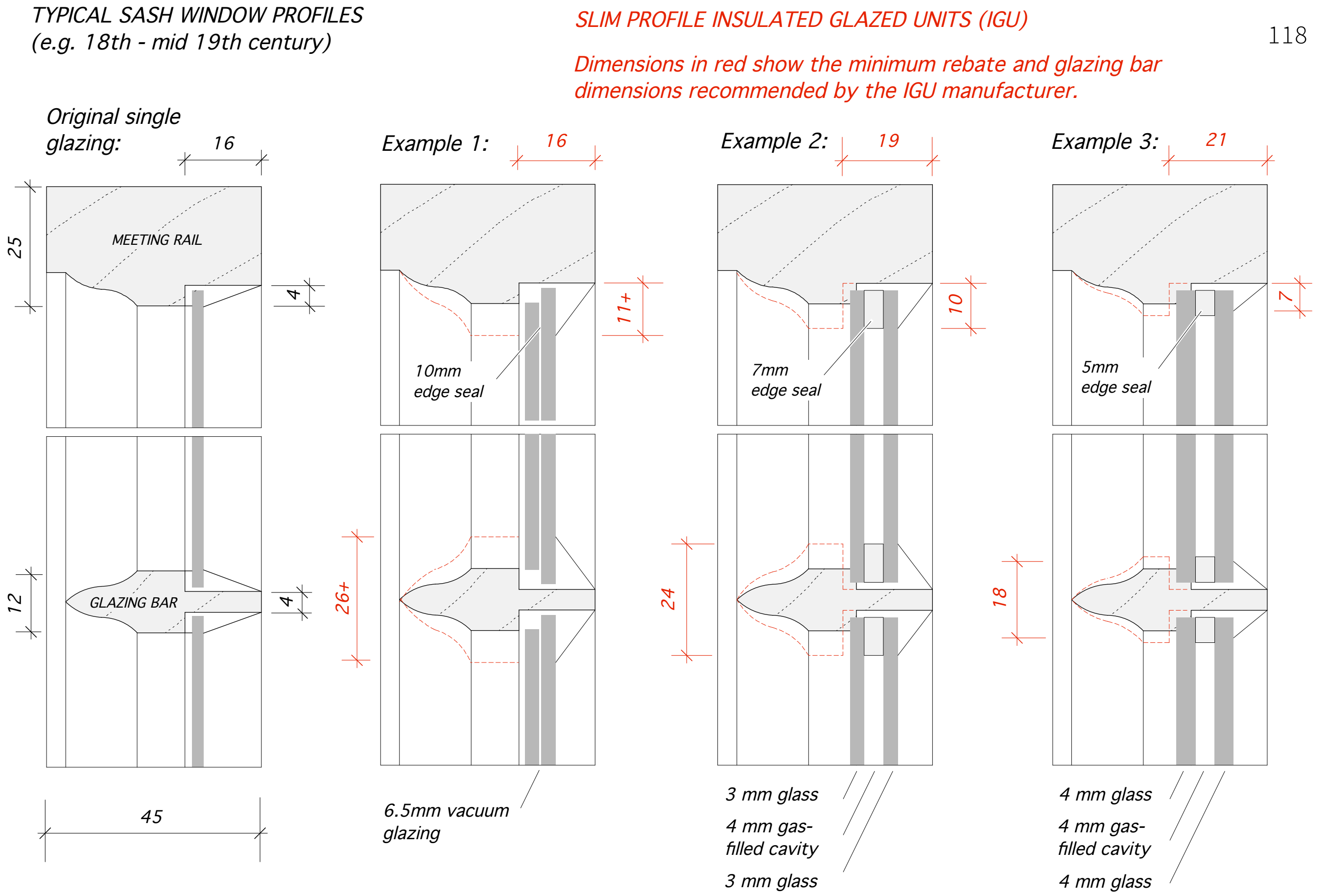
In cases where the significance of a building has been harmed by the installation of replacement windows of non-historic design, consideration may be given to the installation of new slim-profile double-glazed replacement windows where:

- the new windows are of a more sympathetic design and the net impact on significance will be neutral or positive
- no incidental damage to the building fabric will result from the removal of the existing windows

Acrylic double glazing

To overcome the weight problems of double glazing and to avoid the need to remove existing glazing, systems have been developed that use precision-cut acrylic rather than glass; although the gap cannot be evacuated or filled with special gases to cut heat transfer, plastics have a much higher thermal inertia than glass. Tests have confirmed that this hybrid form of double glazing can cut thermal transfer by more than 40%. The plastic must be well sealed to prevent moisture building up in the gap; this is backed up with a specially developed dessicant material.

For larger panes thicker acrylic is needed to prevent distortion; it does not address heat transfer through the frame. Potential problems include cleaning, the scratching of the acrylic and discolouration. However, the use of high-grade acrylics can minimise the risk of scratches and discolouration.



118

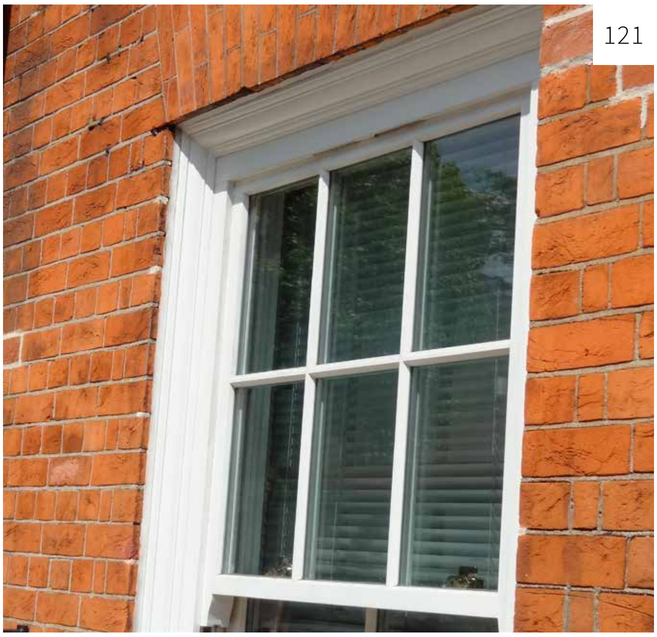
119

120

Images 118-120

118. This drawing shows the different thicknesses of insulated glass units currently available when applied to a window with slim glazing bars (Dimensions shown are in millimetres).

119-120. These existing windows had IGUs fitted but the width of the edge seals necessitated the painting of the glazing bars to be extended over the glass so that the seals are not visible.



121

122

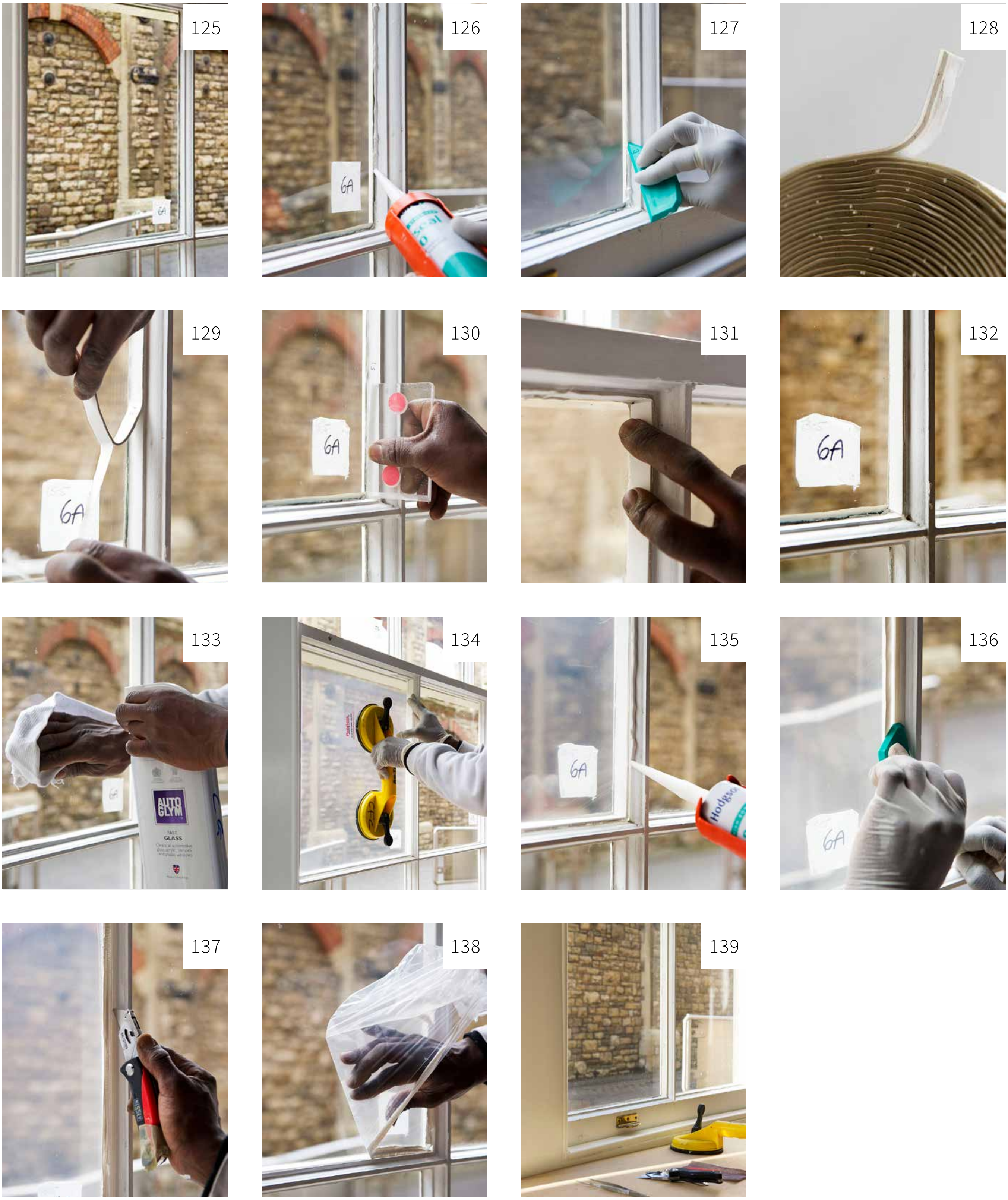
123

124

Images 121-124

121-122. All the double hung sash windows to this Victorian tenement were completely renewed with replica sash windows incorporating IGUs. The timber glazing bars have been applied onto the IGU. Although the workmanship is of a good standard the overall appearance lacks character.

123-124. Following a mock-up of secondary glazing units these steel windows in an older stone frame were fitted with slim IGUs as this solution had less impact on the significance of the window. There was no historic glass and the steel sections were able to accommodate the thickness of the IGUs.



Images 125-139

125-139. This sequence shows the addition of precision cut acrylic glazing to small paned windows. This allows the existing glazing to remain in place

The edges need to be carefully sealed to prevent moisture entering the cavity. This is backed up with a specially developed dessicant material inserted in the cavity to prevent condensation.

5 Replacement Windows

Replacing an historic window in a listed building will require listed building consent from the local planning authority.

This section sets out what to do if a window is really beyond repair, or if you are seeking to restore a traditional window in an opening that has had an inappropriate window inserted at a later date.

When a building element such as a window (which is classed as a controlled fitting under Building Regulations) is replaced, it will also need to comply with the requirements of the Building Regulations

(See Section 6, Consents: The Building Regulations)

5.1 Replacing a traditional window that is beyond repair and all the details of which are known

The replacement window should match the form, detailing and operation of the window to be copied. It will be necessary for the maker of the new window to accurately copy the profiles of all the window components including head, jambs and cill of the frame and the stiles rails and glazing bars of the sashes or casements. Old glass should be carefully salvaged and reused. Where practicable, ironmongery should be overhauled and reused.

Normally for replacement sliding sash windows counterbalancing springs should not be used in as a substitute for pulleys and weights as this significantly alters the detailing and appearance of the window.

Unfortunately, in many cases replacement products that claim to match historic designs do not do so. Exact reproduction is possible, and many firms of builders, carpenters or joiners can provide a bespoke service for timber windows. For steel windows, many traditional designs are still available as mass-produced items.

CE marking

From July 2013 the Construction Products Regulation (2011) made it mandatory for manufacturers to apply CE marking to any products that are covered by a harmonised European Standard. CE marking indicates that a product conforms to its stated performance. For new windows, this covers components such as double-glazing units, safety glass and window safety devices. CE marking is not related to Building Regulations or any planning legislation.

Image 140

Windows of the original size and pattern have been reinstated in this south London conservation area which has involved reinstating the original masonry openings.

5.2 Replacing a window of inappropriate pattern or material

Where a window that diminishes the significance of the building, such as a PVCu window or an 'off the peg' timber window of an inappropriate pattern, is to be replaced the new window should be designed to be in keeping with the period and architectural style of the building. It may be possible to base the design on windows that survive elsewhere in the building or it may be necessary to look for examples in other buildings of the same period and style close by. The local planning authority may also be able to offer advice. In some cases this may involve reinstating the structural masonry opening to the correct proportions.

Where the objective is to sustain or enhance the significance of a building by introducing an accurate copy of a historic window which is multi-paned, then single glazing could be required as incorporating double glazing may not be possible due to the size of the glazing bars. Glazing each pane would also reproduce the broken reflections that may be needed. In such cases, draught-proofing or secondary glazing or other compensatory measures to enhance the energy efficiency in other parts of the building may need to be considered.

5.3 Reinstating missing glazing bars

Older buildings often incorporate numerous alterations that reflect changes in use and fashion over their lifetime. One particularly common change is the removal of glazing bars. As glass technology developed, larger sheets could be produced relatively cheaply. The fashion towards larger sheets of glass resulted in many windows having glazing bars removed.

When the alterations are in an elevation in which the harmony and uniformity of the design is significant then there may be an argument for the reinstatement of one or two windows that are damaging to the building's significance.

Images 141-144

141. Historically inappropriate windows in an early 19th century terraced house.
142. Windows of the correct pattern reinstated along with adjusted masonry openings. The window patterns were obtained from surviving examples in the same terrace.
143-144: The repairs and restoration works to this listed terraced house have included the accurate reinstatement of the 6-over-6 glazing pattern but this has involved the removal of windows, albeit in poor repair, dating from the late 19th century. The justification for restorations such as this are often finely balanced between the desire to recover the scale and proportion of the historic design and the loss of later historic fabric. These judgments can only be made on a case-by-case basis as often many other issues need to be considered.

6 Consents

6.1 Advice on the alteration and replacement of windows in listed buildings

All of our advice is formed within the relevant legal and policy framework. Section 16(2) of the Planning (Listed Buildings and Conservation Areas) 1990 Act), creates a legal duty to have special regard to the desirability of preserving listed buildings and their features of special interest. The National Planning Policy Framework promotes the desirability of sustaining and enhancing the significance of heritage assets (para.131). It says that when considering the impact of a proposed development on the significance of a designated heritage asset, great weight should be given to the asset's conservation (para.132). It notes that the more important the asset, the greater the weight should be and that significance can be harmed or lost through alteration or destruction of the heritage asset. It states that as heritage assets are irreplaceable, any harm or loss should require clear and convincing justification.

A small proportion of the country's building stock is listed and a relatively small proportion of historic windows survive within that stock. Historic windows are often of considerable importance to the significance of listed buildings. They can contribute to significance through their design, materials and workmanship. The strength of that contribution depends on a range of factors including the age, style and historic function of the particular building. Traditionally- produced glass is fragile and thus increasingly rare and where it survives it contributes to the significance of listed buildings. Historic windows on principal elevations will generally, but not always, make a greater contribution to the significance of the listed building than windows elsewhere.

Where a proposal to replace historic windows is based on a desire to improve thermal performance, we would advise that there are other means of securing such improvements which may have less impact on the significance of the building. Our detailed advice can be found at www.HistoricEngland.org.uk/energyefficiency and in Section 4 of this guidance.

In the light of the above we therefore encourage the retention of windows that contribute to the significance of listed buildings. When alteration or replacement requires listed building consent, our general approach is set out below:

1. Where historic windows, whether original or later insertions, make a positive contribution to the significance of a listed building they should be retained and repaired where possible. If beyond repair they should be replaced with accurate copies.

2. Where historic windows have already been replaced with windows whose design follows historic patterns, these usually make a positive contribution to the significance of listed buildings. When they do, they should therefore be retained and repaired where possible. If beyond repair they should be replaced with accurate copies.

3. Where historic windows or replacement windows of historic pattern survive without historic glass it may be possible to introduce slim-profile double-glazing without harming the significance of the listed building. There are compatibility issues to consider as the introduction of double-glazing can require the renewal of the window frame to accommodate thicker glazing, thereby harming significance. These issues are covered in Section 4 of this guidance.

4. Where historic windows have been replaced with ones whose design does not follow historic patterns, these are unlikely to contribute to the significance of listed buildings. Replacing such windows with new windows of a sympathetic historic pattern, whether single-glazed or incorporating slim-profile double-glazing, may cause no additional harm. It also provides an opportunity to enhance the significance of the building, which is the desired outcome under national policy.

5. Where a new window or re-glazing is agreed, the reflective properties of secondary and double-glazing as compared to modern, polished single-glazing, do not usually harm the significance of the building. But when new multi-paned windows are proposed, the desirability of reproducing broken reflections by individually glazing each pane should be considered. Where the aesthetic value of the building is high, then the impact on the whole of the relevant elevation should be considered, including the desirability of accurately matching other windows.

6.2 Obtaining permission for work to windows

Planning controls are designed to protect the built environment for the benefit of its residents and users. They aim to promote a responsible approach to old buildings while at the same time accommodating private and commercial interests. In many conservation areas, 'Article 4 Directions' enable the local planning authorities to manage change that otherwise could be harmful to their special interest. An Article 4 Direction is therefore targeted at specific types of alterations, which usually include windows.

Maintenance work, such as redecorating and repair of windows will not generally require consent for listed buildings or buildings in conservation areas. Work other than basic maintenance to listed buildings and buildings in conservation areas (which have controls over windows)is likely to require permission from the local planning authority. It is therefore advisable to discuss any proposals with the local planning authority in advance of any alterations taking place.

6.3 The Building Regulations

Under the Building Regulations a new window is a 'controlled fitting' and would need to meet certain standards covering heat loss, safety, ventilation and spread of fire.

A 'certificate of compliance' can be issued either by using an installer who is registered with a competent person scheme such as FENSA or by making an application to the relevant Building Control body.

Thermal Performance (Part L)

For existing buildings energy conservation upgrading is generally only required for elements that are to be substantially replaced or renovated or where there is a change of use. If windows are being renewed or if they form part of a building undergoing a change of use then they need to meet the requirements of Part L. The new window should comply with the current U-value in relation to the amount of heat that can pass through the glass and framework.

To help reconcile thermal performance and building conservation certain classes of historic buildings are expressly exempted from the need to comply with the energy efficiency requirements of the regulations where compliance would unacceptably alter their character and appearance.

These include:

- Listed buildings
- Buildings in conservation areas
- Scheduled monuments

The regulations also include 'special considerations' which can apply to the following categories:

- Locally listed buildings
- Buildings in national parks and other historic areas
- Traditionally constructed buildings

Additional relaxations can be considered for buildings in these categories which don't have exemption status. A local relaxation of the energy efficiency requirements may be possible to allow the restoration (in their original form) of previously lost elements of a building which are important to its overall character. Restoring windows might be considered as part of this relaxation.

More detailed advice on the application of Part L of the Building Regulations can be found in the Historic England publication *Energy Efficiency and Historic Buildings: application of Part L of the Building Regulations to historic and traditionally constructed buildings*.

Safety Glazing (Part N)

The need for safety glazing depends on any window glazing being within a 'critical area' such as the height of the window above floor level and the proximity to doors.

Ventilation (Part F)

The type and extent of ventilation required will depend on the use and size of the room. For example kitchens and bathrooms require higher levels of ventilation. The Building Regulations only require a trickle vent in a new replacement window if there was trickle ventilation within the window being replaced.

Fire Safety and Means of Escape (Part B)

Windows need to comply with fire safety regulations if they are close to adjacent properties or provide a means of escape in case of fire. If windows are between adjacent properties they may fall into what is defined as an 'unprotected area'. Whether a window is within this area depends on its proximity to the boundary of the adjacent property.

When replacing any window the opening should be sized to provide at least the same potential for escape as the window it replaces. If the original window that is being replaced was larger than necessary for the purpose of escape then the new window could be reduced down.

For more information on Building Regulations see: www.planningportal.gov.uk/buildingregulations

7 Where to Get Advice

7.1 Further advice

Amenity societies

Georgian Group www.georgiangroup.org.uk

Society for the Protection of Ancient Buildings www.spab.org.uk

Victorian Society www.victoriansociety.org.uk

Twentieth Century Society www.c20society.org.uk

Trade organisations

Draught Proofing Advisory Association www.dpaa-association.org.uk/

Steel Window Association www.steel-window-association.co.uk

Wood Window Alliance www.woodwindowalliance.com

British Woodworking Federation www.bwf.org.uk

Specialist help

Brooking Collection www.thebrooking.org.uk
Guild of Architectural Ironmongers www.gai.org.uk
Institute of Conservation (ICON) www.icon.org.uk

7.2 Further reading

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Leaflet 3 *Metal Windows* (1997)

Leaflet 4 *Timber Sash Windows* (1997)

Leaflet 5 *Window Comparisons* (1994)

Leaflet 7 *Energy Savings* (1994)

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8 Acknowledgements

Images

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116 Storm Windows; Cover (bottom right)

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Cover Images

top left: Surviving historic fenestration is an irreplaceable resource which should be conserved and repaired whenever possible.

top right: External shutters from the 18th-century divided into upper and lower leaves to give greater flexibility in balancing requirements for light, ventilation and security.

bottom left: Steel windows became a feature of inter-war suburbia.

bottom right: The addition of precision cut acrylic glazing to small paned windows allows the existing glazing to remain in place. The edges need to be carefully sealed to prevent moisture entering the cavity. This is backed up with a specially developed dessicant material inserted in the cavity to prevent condensation.

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