The Manufacture of Stained Glass
Medieval Techniques and Materials

Glass was made by melting sand, potash（碳酸鉀） and lime together in clay pots. It was coloured by the addition of metallic oxides - copper for red, iron for green, cobalt (鈷礦；砷化物、氧化物、硫化物) for blue and so on. This is called pot-metal glass. Pot-metal glass, especially red glass, was often too dark to transmit much light. To overcome this, 'flashed' glass was made by dipping a lump of white glass on the blowpipe into a pot of red glass and then blowing, This provided sheets of glass with a thin surface layer of colour. Later, parts of this layer could be removed by grinding with an abrasive wheel; this produced two colours, red and white, on the same piece of glass.

Because paper was scarce and parchment very expensive, the full scale outline of the design for a stained glass window was drawn out on a whitened table top. The designer would indicate the principal outlines of his drawing, the shape and colour of the individual pieces of glass to be used, and the position of the lead strips that would eventually hold all the pieces of glass together. The panes of coloured glass were cut to shape with a 'grozing iron' and laid on top of the drawing. Through the glass, details of the drawing - faces, hands, drapery etc. - could be seen and these details were traced with an iron oxide pigment (氧化鐵顏料 Fe_2O_3) on the surface of the glass. After painting, the pieces were fired in a small furnace for sufficient time to fuse the paint to the surface of the glass, and then relaid on the table and assembled by the glazier, using strips of lead H-shaped in section, which allowed the glass to be slotted into the grooves on each side. The lead provided a strong but flexible bond. The intersections of all the lead strips were then soldered, and an oily cement was rubbed into all the joints in order to make them watertight. The panels were then held in place in the window openings by a grid of iron bars set into the masonry.

From the early fourteenth century a further range of colours varying from a pale lemon to a deep orange could be achieved on one piece of glass through the discovery of 'silver stain' (to produce the yellow, brown or amber shading), a silver compound painted on the back of the glass and then fired in a kiln. By the mid sixteenth century many different coloured enamels were being used. As a result, windows began to be painted like easel pictures on clear glass of regular rectangular shape, with lead calmes no longer an integral part of the design. These methods prevailed from the seventeenth to early nineteenth centuries. However, the earlier techniques were revived in Victorian times; the Museum's later displays show the survival, continuity and development of these traditional skills.

Modern Techniques

Every window starts as a full-size cartoon, either drawn in the studio or provided by an outside designer. Modern cartoons are drawn out on paper. The coloured glass is then selected to conform with the designer's conception and the position and purpose of the window. The glass is cut to size with a glass cutter. Awkward curves can be nipped ('grozed') with a pair of smooth-jawed pliers.

The design is applied as a black or brown paint which is a mixture of metal oxides, powdered glass and gum. The artist mixes it with water on a thick glass tile. Solid lines are painted thickly, carefully tracing the design from the cartoon. Thinner washes are left to dry and then dusted with a badgerhair brush to give fine shading effects. Finished pieces are then stored in glass racks to await firing in the kiln. The painted glass is laid on trays of whiting and loaded into the hot upper part of the kiln where it is fired at a temperature which fuses the paint to the glass. It is then left in the cooler part of the kiln to relieve the strains created in the glass by firing.

Leads of various sizes can be prepared from cast bars by squeezing them through a lead mill, either electrically powered or hand cranked. The window is assembled on a large table, each lead being cut and bent to fit its pane. As the work progresses, completed parts are held against battens by horseshoe nails tapped into the table. When the panel is complete, each joint must he soldered individually. Finally the whole window is sealed with mastic (乳香樹脂) which is brushed hard into all the joints.