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PART 1

Visual and Documentary Testimonies



The Medieval Glazier at Work

Sarah Brown

The (re)discovery in the mid-19th century of the complete 12th-century text now widely known as *De Diversis Artibus*, by the pseudonymous author, priest and monk “Theophilus”, triggered scholarly interest in the manufacturing techniques of the medieval glazier in exactly the period in which the Gothic Revival in stained glass was reaching its height.¹ All subsequent art-historical perceptions of the technical aspects of the medium have been dominated by the most coherent medieval description of glass making and glazing practice in the medieval period, contained in Book 2 of Theophilus’s text. Until very recently, the numerous modern descriptions of how a medieval window was made were augmented by assumptions derived from craft practice of the later 19th century. Recent scholarship, much of it under the aegis of the international *Corpus Vitrearum*, founded in 1952, has encouraged revisionary studies of medieval glazing technologies. Scholars have now revisited the seminal texts on which our understanding of medieval glazing technique has been founded, while conservators have observed and documented the physical evidence of glaziers and glass-painters at work.² This paper will revisit the evidence for medieval glazing practice from these new perspectives.

1 Theophilus and the Historiography of the Medieval Craft

For the English-language readership, Theophilus’s treatise first became accessible through Robert Hendrie’s 1847 parallel Latin and English texts of all three books. However, the most important edition was that published as part of Charles Winston’s seminal history of the stylistic development of medieval stained glass in England, a two-volume work with meticulous, archaeologically correct illustrations, in which Book Two of Theophilus’s text was translated, with extensive notes.³ The full title of Winston’s book, *An Inquiry into the Difference of Style Observable in Ancient Glass Painting, especially*

in England with Hints on Glass Painting, makes it clear that Winston’s intention was not only to provide a classified typology of medieval stained-glass design, but also to influence contemporary glazing practices. Hendrie’s critical notes are those of an historian and literary scholar. Winston’s are those of a man who had examined medieval glass at close quarters, who knew the workings of a glass-house and the practices of a glazing workshop.

Winston considered his text to be an important source book for those engaged, like himself, in the promotion of a revival of manufacture of “antique” glasses and authentic medieval painting styles. For this reason, he provided parallel extracts from other authors, ancient and modern, including Heraclius (10th century) and Bontemps (19th century). Frustrated by what he recognised as inconsistencies and omissions in Theophilus’s text, Winston was the first writer to test his reading of Theophilus against both his own experience of medieval windows and a reading of medieval glazing accounts and contracts.⁴ The dichotomy between an emphasis on literary and linguistic scholarship and the implications of the text for an understanding of practical application, can still be seen in the contrasting approaches of the two modern editions of Theophilus in English translation: C.R. Dodwell’s scrupulous 1961 edition of parallel Latin and English texts; and Hawthorne and Smith’s 1963 English translation with its many modern technical drawings.⁵

Despite the critical examination of other significant textual sources (notably that of Italian glazier Antonio da Pisa), the 12th-century treatise has continued to dominate the discourse, even though Theophilus was writing before the development of complex stone tracery (in the 13th century), before the age of silver stain (introduced in the early 14th century), before the widespread adoption of abrasion and etching techniques (predominantly in the 15th and 16th centuries), and before the use of paper in the preparation of designs (from the second quarter of the 15th century); all processes relevant to window production in the later Middle Ages. From the middle of the 20th century a new generation of scholars began to redress this balance by enquiring into glazing practice beyond

1 See Raguin, “The reception of Theophilus”, pp. 11–28.

2 See Kurmann-Schwarz, Ch. 20 in this volume.

3 Winston, *An Inquiry*, pp. 311–41. Although aware of earlier German scholarship, Winston worked from l’Escalopier’s 1843 French edition.

4 Winston, *An Inquiry*, pp. 342–50.

5 All citations here will refer to the Dodwell translation, *The Various Arts*.

Theophilus. Glimpses can be gleaned from examining the full gamut of texts and treatises, but also from wills, contracts and medieval glazing accounts, and from the windows themselves, all of which provide a pragmatic and material counterpoint to the literary sources, although not without their own challenges of interpretation.

Thanks to the indefatigable archival research of L.F. Salzman, a scholarly overview of the documentary evidence for medieval glazing practice in England became accessible.⁶ In the last decade of the 20th century the fruits of documentary and archival research began to make their mark on a rising tide of studies of medieval glazing practice, while the *Corpus Vitrearum* promoted international collaborations involving art historians, glaziers, scientists and conservators.⁷ Strobl's doctoral research, published in 1990, carried particular authority because of the author's dual training in history of art and craft and conservation practice.⁸ In 1991, Brown and O'Connor contributed a book on medieval glass painters to a British Museum series of nine titles on medieval craftsmen, and in the same year Marks contributed on window glass in one of 15 chapters of a study of English medieval industries.⁹ The Antonio da Pisa project, published in 2008, not only provided a new scholarly edition and commentary of Antonio's rather overlooked technical treatise (juxtaposed with invaluable translations of all other relevant texts), but brought together a team of craftsmen, conservators and scholars who not only subjected the texts to rigorous scrutiny, but also tested and reflected upon the processes described by Antonio, known to have been a practising glazier.¹⁰ In Belgium technical research has focused, among other things, on the production techniques involved in the manufacture of roundels and unipartite panels.¹¹ *Corpus Vitrearum* researchers in Germany and the USA have reassessed the historical evidence for the use of acids to etch the surfaces of coloured flashed glasses.¹² Conservators and scholars working in the USA, Britain, and Switzerland have observed evidence of sophisticated methods for the transfer of designs from the cartoon to the glass, discussed more fully below. Interdisciplinary collaboration

between art historians and materials scientists is providing the social and historical context for observation on the chemical composition of medieval bulk glasses, with exciting implications for our understanding of networks of stained-glass manufacture and distribution.¹³

2 Building the Walls of the Heavenly Jerusalem

While Theophilus opens his discussion of window-making processes with a description of the medieval glass-house, it is clear that glass-making and window-making were quite distinct and separate processes.¹⁴ The glazier was thus always once removed from the manufacture of his most important raw material, and in some ways in thrall to his supplier for the qualities and colours of his palette of materials. Antonio da Pisa's discussion of the making of pot-metal coloured glasses is thus, perhaps understandably, flawed, as he is describing the expertise of others. Modern research into the composition and manufacture of medieval window glass has shown that a remarkable array of glass colours were made from a very limited range of compositional elements. The only metallic oxide described as having been added deliberately in order to colour glass, is copper. The other key colouring agents were manganese and iron, both of which were present coincidentally, as part of the composition of the sand and the wood ash (especially in the ash of beech wood advocated by Theophilus) of which typical medieval potash-lime-silica glasses were made. While the medieval glass-maker had no control over the presence of these compositional elements, it has been suggested that he may have had some empirical control over the degree of oxidation of the materials during the melting process.¹⁵ Recent research has demonstrated that this may have been particularly critical in the manufacture of translucent ruby glasses, challenging the assumption that they were always manufactured through the lamination process commonly known as "flashing".¹⁶

It is clear that glaziers and their patrons were sensitive to the properties and qualities of glass from different sources, and may have sought them out for these very reasons; Antonio singles out the flashed ruby glasses of Germany as being particularly good for the application of acid etching.¹⁷ The fabric accounts of English projects are especially helpful in this regard, as no coloured glasses

6 Salzman, *Building in England Down to 1540*, published in 1952. Also see id., "The glazing of St Stephen's Chapel"; and id., "Medieval glazing accounts". Now see Brooks and Evans, *The Great East Window*, pp. 11–16 and 33–36.

7 Signaled in Boulanger and Hérold (eds.), *Le vitrail et les traités*; Pilosi, Shepard, and Strobl (eds.), *The Art of Collaboration*.

8 Strobl, *Glastechnik des Mittelalters*.

9 Brown and O'Connor, *Glass-Painters*; Marks, "Window glass".

10 Lautier and Sandron, *Antoine de Pise*.

11 Caen, *Production of Stained Glass*.

12 Scholz et al., "Beobachtungen zur Ätztechnik"; Pilosi et al., "Early acid-etching".

13 Freestone et al., "Multi-disciplinary investigation".

14 Theophilus, *The Various Arts*, pp. 37–43.

15 Royce-Roll, "The colors of Romanesque stained glass".

16 Kunicki-Goldfinger et al., "Technology, production and chronology".

17 Lautier and Sandron, *Antoine de Pise*, p. 73.

were manufactured in England until the late 15th century, meaning that the glaziers needed to be specific about their sources of supply. References to coloured glass from Burgundy, Hesse, Lorraine, Normandy, and even Venice are found in English accounts.¹⁸ The executors of Richard Beauchamp specified a wide range of coloured glasses that were to be used for glazing the Beauchamp Chapel: blue, yellow, red, purple, sanguine, violet, green, and white, of the finest quality and foreign manufacture. The use of English glass was expressly forbidden!¹⁹

3 Patrons and Patterns

Frustratingly, the first, and in some respects the most intriguing, stage in the creation of a window, the negotiation between the patrons and their craftsmen, is omitted from Theophilus' instructions. We are not told how glaziers were instructed to fill their windows, nor are the few surviving medieval contracts especially helpful in this regard, referring only obliquely to a design process that had already been determined. John Thornton, commissioned to make the Great East Window of York Minster between 1405 and 1408, was instructed merely to fill the window "with historical images and other painted work", a rather impoverished description of one of Europe's largest and most ambitious windows.²⁰ The accounts for the glazing of the collegiate church of the Holy Trinity at Tatteshall in Lincolnshire do describe the subjects of the windows, albeit briefly: the Legend of the Holy Cross, St. James, the Creed, the Magnificat, and the Seven Sacraments. But this seems to have been intended to distinguish the windows assigned to each of the five teams of glaziers entrusted with the work, rather than to invoke the appearance of the windows themselves.²¹ Reference to other prestigious and well-known projects underpinned the discourse. At Westminster glaziers had other useful drawings to inform their understanding of their patron's requirement, for in 1509 "pictures" of "Stores, Ymagies, Armes, Bagies and Cognissaunts" had been delivered to the master of the royal works at Westminster, in accordance with Henry VII's will.²² Executors charged with the commissioning of memorial windows were sometimes provided with testamentary instructions and even drawings that reflected the wishes of the deceased.²³

In France in the same period, there is plentiful documentary evidence for the existence of small scale "patterns" (variously called *poutraict*, *patron au petit pied* and *gect*) provided by the patron for the use of the glaziers. These sketches carried legal weight and were appended to the contract, which was thereby free to define costs, specification of materials, timescales, and penalties.²⁴ A small number of sketch designs for late-medieval windows have survived, shedding light on the process of negotiation between the patron and the glazier. Sometimes called a "*vidimus*" ("we have seen"), these preliminary drawings are remarkable for the variety and diversity of information they convey.²⁵ One late 15th-century example preserved in the British Library (Figure 1.1), was probably drawn by the donor himself and concerns the appearance of the donor images of Sir Thomas Froxmere and his wife, which were to be positioned at the base of an unidentified window then under discussion.²⁶ However, most sketches are actually the work of extremely competent professional artists. Some have a grid superimposed to assist in scaling up the design to full size, and some are marked with the position of structural window bars. Few are fully coloured and none indicate the internal leading pattern essential in the actual construction of a stained-glass panel.

The small-scale sketch had serious shortcomings in conveying complex heraldic information for monumental glazing schemes. While patrons could probably expect experienced glaziers to be familiar with all but the most unusual or novel iconographic formulae, they seem to have been less confident in leaving details of heraldic display to chance. Thomas Froxmere's *vidimus* is almost exclusively concerned with heraldic detail, perhaps understandably, as the heraldry of a minor country gentlemen is unlikely to have been well-known. In 1505 Lady Margaret Beaufort, mother of King Henry VII, paid the London artist William Hollmer 20 pence for a drawing of a heraldic yale, to be sent to the Peterborough glazier John Delyon, who had depicted the beast incorrectly as "a common antelope" in the glazing of the great hall of her manor house at Collyweston. Delyon received 7s to correct his mistake.²⁷ This may explain why a number of designs for monumental stained-glass projects – for example Hans von Kulmbach's design for a window (c.1522) for Jacob Welser and Ehrentraud Thumer in the Mariakirche in Nuremberg – leave the coats

18 Brown and O'Connor, *Glass-Painters*, pp. 47–48.

19 Myers, "The contracts for the making of the tomb of Richard Beauchamp".

20 French, *The Great East Window*, pp. 153–54.

21 Marks, *Holy Trinity, Tatteshall*, pp. 30–58.

22 Marks, "Henry VII's chapel", p. 190.

23 Marks, "Wills and windows", pp. 248, 250.

24 Leproux, *Recherches sur les peintres-verriers parisiens*, p. 35.

25 Wayment, "The great windows".

26 London, British Library, Ms Lansdowne 874, fol. 191; Goodall, "Two medieval drawings", pp. 160–62.

27 Salzman, *Building in England*, p. 178.

of arms of the kneeling donors blank.²⁸ The drawing is a highly finished clean copy that was very little altered in translation into stained glass, but additional heraldic drawings would have been required in order to complete the commission. In summary, we are forced to conclude that sketch designs served different purposes, represent different stages in a process, and above all reflect the wishes of different kinds of patrons whose personal priorities and budgets varied a great deal.

Only rarely do we glimpse the research that had preceded the commissioning of the preliminary design. A late 12th-century illuminated Life of St. Cuthbert from the monastic library of Durham Cathedral priory was loaned to Archbishop Richard Scrope of York (1398–1405), presumably to inform the devising of the version of the saint's life destined to fill the south-east transept of York Minster (SV7).²⁹ In the early 16th century the newly-built chapel of the Observant Friars at Greenwich (consecrated c.1494) also served as the chapel for Henry VII's Greenwich Palace. Two rolls preserved in the British Library record the results of preparatory research undertaken in anticipation of the instruction of glaziers soon to be entrusted with the creation of a new five-light east window.³⁰ The window was to include half-length figures of Henry VII and Queen Elizabeth, the princess Margaret and the king's mother, Lady Margaret Beaufort. The saints to be depicted flattered the newly established Tudor dynasty by reflecting the devotional interests and political preoccupations of the royal family, but were also appropriate for a Franciscan community. The coats of arms of the saints to be included in the window, carefully chosen to underline the King's lineage, required particularly careful research, as many of the shields were rare and unknown in London. The compiler of the roll intended to provide small sketches of all of the coats of arms, and while the more familiar English royal arms are all carefully described and drawn, many of the other shields remained blank.

The rise of print and the wider availability of affordable paper had a significant impact on stained-glass design, introducing patrons to new images and ideas that could be lifted directly from new graphic sources with little mediation through other designers. At the collegiate church of Holy Trinity, Tattershall in the last quarter of the 15th century and in the west wall of St. Mary's,

Fairford, c.1500, for example, the block-book *Biblia Pauperum*, devised in the Netherlands c.1464–65, was used as a source for stained-glass design, presumably at the behest of the patron.³¹ A remarkable interpretation of 1502 of the Tuscan poet Petrarch's *Triumphs* in stained glass, for the church of Saint-Pierre at Evry-le-Châtel (Aube), has been shown to be indebted to both early printed books of hours and to even more cheaply printed tarot cards, used in a popular game originally known as *Ludus Triumphorum*.³²

Perhaps the most remarkable evidence of the power of print to transform stained-glass design is the speed and degree to which designs by Nuremberg artist Albrecht Dürer circulated throughout Europe. The Apocalypse window in the church of Saint-Georges at Chavanges (Aube) of 1526 is clearly indebted to Dürer's Large Passion of 1498, one of several windows copying this same source in the Champagne region.³³ Three scenes in the east window of Balliol College, Oxford, including the *Ecce Homo* (Figure 1.2), dated only three years later, are also based on Dürer's engraved Passion (1507–13), while the Carrying of the Cross is indebted to the Great Passion. The window was given by Laurence Stubbs, almoner and buildings administrator in the household of Cardinal Thomas Wolsey, whose brother Richard was master of Balliol College.³⁴ Wolsey is known to have owned an engraved copy of Dürer's Passion. Perhaps not surprisingly, some of the closest interpretations in glass of sources circulating in engravings were in the form of small-scale roundels, often destined for secular and domestic settings. A single sheet of clear glass could very easily be placed over an engraving in order to paint a direct copy. Glaziers collected these engravings to copy, adapt and share with their clients, and probably made several sets of the most popular series in anticipation of easy sales, as, unlike monumental stained-glass panels, roundels could easily be accommodated into plain glazed surrounds.³⁵

Armed with these preliminary drawings, or engraved sources, the patron could enter into negotiations for the actual making of the window with his or her chosen glazing workshop. A shared experience of other glazing schemes provided a bedrock on which these discussions were undoubtedly founded. This is implied in the

28 Scholz, *Entwurf und Ausführung*, p. 181, figs. 258–62; Butts, Hendrix, et al. (eds.), *Painting on Light*, p. 172.

29 Now London, British Library, Yates Thompson, MS 26; Marner, *St Cuthbert*, pp. 36–37. The window was eventually given by Thomas Langley, Bishop of Durham (1406–37).

30 London, British Library, Ms. Egerton 4631, rolls A and B; Rogers, "A pattern for princes", pp. 318–38.

31 Marks, *Holy Trinity, Tattershall*, pp. 191–200; Brown and McDonald, *Fairford Church*, pp. 64–66.

32 Riviale, "Le vitrail et le jeu des Triomphes".

33 For other Dürer-inspired Apocalypse windows in the region, see *Vitraux de Champagne-Ardenne*, pp. 24, 70–72, 80–85, 111–13, 247–57, 262–70.

34 Jones, *Balliol College*, pp. 48–49; Wayment, "Wolsey and stained glass", pp. 126–27.

35 Husband, *Silver Stained Roundels*, pp. 17–21.

contracts for the windows at Kings' College, Cambridge, where the glaziers are directed to the earlier royal glazing scheme in Westminster Abbey's Lady Chapel.³⁶ Such experience is nowhere better illustrated than in the extraordinary correspondence of Birgittine nun Katerina Lemmel, widowed member of the wealthy and influential Imhoff clan of Nuremberg, who entered the cloister of Maria Mai at Mailhingen in 1516.³⁷ Through her spirited correspondence with her cousin Hans Imhoff V, she exhorted her family to assist financially in the provision of windows for the newly extended cloister of her nunnery. In order to engage their enthusiasm and allay their anxieties about cost, she invoked a shared experience of other glazing schemes in the city and vicinity of Nuremberg, and assures them that the windows will be, above all, spiritually compelling rather than showy and costly. Hers is the only contemporary account of a meeting between a patron and a glazier, in this case Veit Hirsvogel, glazier of the city of Nuremberg, for a meeting that took place in her monastery in May 1518. While the glazier may have brought samples of the subjects favoured by Sister Katerina to the meeting, it is also possible that she had already researched the subjects she wanted, probably in the engravings and devotional woodcuts in the nunnery's library. She was also very demanding concerning the use of abraded ruby glass and metal, rather than wooden window frames, to ensure the longevity of her windows. Sadly, none of them have survived.

Some surviving drawings actually reveal the dialogue between patron and glaziers. Sketch designs believed to have been prepared for Cardinal Thomas Wolsey – a drawing of a 13-light window depicting the Crucifixion and Resurrection now in Edinburgh (Figure 1.3), and 24 drawings outlining a narrative cycle from the Annunciation to the Coronation of the Virgin, accompanied by standing saints (now in Brussels) – all bear annotations that suggest a discussion concerning alternative arrangements of subject matter.³⁸ The annotations have been attributed to the hand of glazier James Nicholson, the glazier employed on all of Wolsey's building projects, and the drawings have been assigned to the chapel of York Place in London and the chapel of Hampton Court respectively. For the Hampton Court east window, Wolsey was even offered two versions of the Crucifixion.

By the end of the Middle Ages there is strong evidence of an increasing separation of the role of the designer from that of the craftsman entrusted with the

execution of the design in glass, a process undoubtedly facilitated by the greater availability and affordability of paper. In the *Kunstabuch*, composed in the second half of the 15th century in the Dominican nunnery of St. Katherine in Nuremberg, it is recommended that a preliminary sketch "*auf papier*" be sought from a painter.³⁹ In 16th-century Paris, Jean Chastellain was instructed to execute stained glass after "*portraits et patrons*" made by master painter Noel Bellemare.⁴⁰ The rise of the "celebrity" artist undoubtedly encouraged this process, while the increasing affordability of paper, mentioned in the *Kunstabuch*, meant that even full-size cartoons could be commissioned from artists rather than specialized glaziers. The Tuscan artist Cennino Cennini implies that by the late 14th century it was already common practice for Italian glaziers to commission full-scale paper cartoons from well-known artists.⁴¹ Paper cartoons could also be stored more easily, meaning that a monumental design could be far more easily preserved across generations. In 1503, York glazier Robert Preston bequeathed "all my scrowles" to Thomas English, while in 1508 glazier and lord mayor of the city John Petty left his "scroes" to his younger brother Robert.⁴² Outside Italy most of the evidence points to the creation of the full-scale cartoons within the orbit of the glazing workshop, and it is to this process that we turn next.

4 Making the Window

4.1 The Glazier's Table

As discussed above, none of the preparatory drawings of monumental windows to have survived would have been suitable for immediate translation into a window. It is clear that this process was entrusted to the glazier. This is made explicit in the contract of 1447 for the glazing of the chantry chapel of Richard Beauchamp at St. Mary's church in Warwick. Patterns on paper detailing "the matters, images and stories" required in the windows were to be delivered by Beauchamp's executors to the King's Glazier, John Prudde in his workshop within the royal palace of Westminster. Prudde was required to see to it that they were "newly traced and pictured by another painter". The Beauchamp Chapel vidimuses do not survive, but a comparison of those prepared for King's College chapel and the windows as made, reveal that the glaziers did not slavishly copy them, but made

36 Wayment, *King's College Chapel*, pp. 123–24.

37 Schleif and Schier, *Katerina's Windows*, pp. 277–84.

38 Wayment, "Twenty-four vidimuses"; id., "Wolsey and stained glass", pp. 117–18.

39 Lautier and Sandron, *Antoine de Pise*, p. 332.

40 Leproux, *Vitraux parisiens de la Renaissance*, p. 124.

41 See discussion in Thompson, Ch. 21 in this volume.

42 Brown and O'Connor, *Glass Painters*, p. 55; Knowles, "Medieval methods of employing cartoons".

adjustments to the original designs as they translated them into a monumental cartoon.⁴³

For much of the Middle Ages the main vehicle for the full-size working drawing was the glazier's whitened table, as described in some detail by Theophilus. The table was a multi-functional component in the process of design and manufacture, for it served successively as a cartoon, a cut-line drawing and a work-bench on which to lead-up and solder the finished window. In a 1443 inventory of the materials stored at the royal residences at Westminster and Sheen, for example, two "portreying tables of oak, two tables of poplar and 11 trestles used for glazing works" are listed.⁴⁴ They were valuable commodities, and in 1458 York glazier Robert Shirley's father bequeathed to him his "tables and trestles [that] belong in any way to my craft".⁴⁵ Even in the 18th century, Pierre le Vieil, a member of a glazing dynasty, placed the glazier's table at the top of his list of essential equipment for a glazier's workshop.⁴⁶

The glazing accounts for St. Stephen's Chapel, Westminster, make explicit the value placed on the preparation of the glazier's table and the status accorded to those who fulfilled the role. Master glazier John de Chestre consistently received the highest wages of all the glaziers. He worked with five others, also termed master, all of them defined by their role in "designing and painting on white tables", which were washed with ale at regular intervals throughout the project, allowing new designs to be drawn up on their whitened surfaces.⁴⁷ In the hierarchy of payments made to the glazing team employed at Westminster, the designing on the white tables was always entrusted to those termed "master" and was most generously rewarded, at 12d per day. Glass-painters were paid only 7d per day, while those engaged in "breaking and fitting glass" were paid 6d. Just over 50 years later, in 1405, master glazier John Thornton of Coventry was obliged entirely "with his own hands to portrature [*portreiabit*] the said window", although he was allowed to delegate glass-painting tasks to others. It is not hard to see why this process was so highly prized, as it was the glazier's table that determined the relationship of the window as made to the sketch designs authorized by the patron. It also controlled all the other technical processes leading to the creation of a satisfactory monumental window, a sequence of processes that would involve several workshop members.

Only two medieval glazing tables have been found and both display some of the characteristics described by Theophilus. One, made of walnut and now cut into two lengths (Figure 1.4), was used to make panels of c.1340 that survive in the choir clerestory of Girona Cathedral (Catalonia), and are preserved in the Museu d'Art de Girona; here, it is the fact that the tables *and* the windows *both* survive that makes this a unique phenomenon. The other example, preserved in Brandenburg Cathedral, is of late 14th century date and originated in Bohemia. It is by comparison very poorly preserved, having been used to reinforce the predella of a medieval altarpiece. Both had escaped international notice until 1986.⁴⁸ In 2013 the Girona table was reexamined, using UV light, digital infrared reflexography, and X-ray imaging.⁴⁹ The whitened upper surface described by Theophilus as being made of chalk and water was found at Girona to have been made of a surprisingly resilient mixture of chalk and a proteinaceous binder (perhaps egg or casein). The darkened area immediately below the canopy drawn out on table A was known from earlier UV examination to have originally borne the cartoon of a figure of the Virgin Annunciate.⁵⁰ The most clearly visible outline is of a geometric design used in several panels in the choir clerestory. Contrary to some assumptions, the table was found not to have been resurfaced between designs but has only a single layer of its chalky coating, meaning that the earlier figure of the Virgin had simply been washed off, allowing another design to be marked in its place, the process alluded to in the Westminster accounts.⁵¹ The mapping of the patterns of square holes, which were left by the glazing nails used to hold glass in place during the leading-up of the painted and fired glass pieces, confirm that the tables had been used for making several different panels; while some nail holes closely followed the lines of the most visible drawings, others followed earlier patterns that had been washed away. The orientation of the drawings and the nail holes, especially on table B, suggest that more than one person had worked on the table at the same time, an observation with interesting implications for working practices in the medieval workshop.

The reexamination of the table also challenges earlier assumptions derived from Theophilus's description, which implies that *all* details required to make the stained-glass panel were supplied on the table. The

43 Boon, "Two designs for windows by Dierick Vellert", pp. 153–56, 204–05; Wayment, *King's College Chapel*, plates 129, 135, 137.

44 Salzman, "Medieval glazing accounts", p. 27.

45 Knowles, "The Chamber family", pp. 127–28.

46 Le Vieil, *L'Art de la peinture sur verre*, p. 137.

47 Salzman, "St Stephen's Chapel".

48 Vila Grau, "La table de peintre-verrier", pp. 32–34; Maercker, "Überlegungen zu drei Scheibenrissen".

49 Santolaria Tura, *Glazing on White-Washed Tables*.

50 Ainaud de Lasarte et al., *Catedral de Girona*, pp. 74–79.

51 Caviness, *Stained Glass Windows*, p. 50.

evidence of the Girona table shows that a significant degree of autonomy was afforded the individual glazier, even after the skeleton of the window design has been determined by the master. While the table is marked with letters that might refer to the colours of glass to be used, these do not readily correlate with the wide array of glass colours found across the six canopies that derived from the design on table A, while the only painted element to have been drawn in detail is the vine leaf motif that decorates the gable of only two of the six canopies. This suggests either that detailed instructions on glass colour and exact positioning of the painted line were available to the glazing team in another form, or more likely, that in a close-knit experienced team, a level of decision-making was delegated to individual craftsmen and painters.

The designs on the table do not actually indicate all the lead lines at all, and, indeed, leave out some lines that would be critical to the cutting of glass for a viable stained-glass panel. The master therefore allowed the individual glazier to judge where to place subsidiary lead lines and thus how best to cut a piece of glass, ensuring that sheets could be cut economically and without waste. This realization has important implications for our understanding of working relationships within the team, but also for the status of individual components within the whole glazing scheme. While based on a single design “template”, the Girona canopies are anything but a mass-produced product. Each one is, in effect, unique, a version of the master’s cartoon rather than a replica of it, and this is borne out by close comparison of the glazier’s table with the surviving stained glass presumed to have been made on it. The superimposition of the actual cut-line of the glass of several of the canopies onto the lead lines indicated on table A shows that glass was cut and leaded in a variety of different combinations. Hérold arrived at similar conclusions based on close examination of panels of the same design, apparently indebted to the same cartoons, in a number of churches in the Champagne region.⁵²

This adaptive approach to manufacture goes a long way to explain the ambiguous “glaziers marks”: discreet and barely visible marks usually painted on or wiped off a fired paint layer, and predominantly found in the more “anonymous” areas of a panel, including architectural frames and backgrounds.⁵³ While some glaziers’ marks may have indicated the order of assembly, this cannot explain the large numbers of the same mark scattered

widely across a single panel, usually all orientated in the same direction. Once the bespoke nature of the cutting of the glass for each panel is appreciated, it can be seen that after firing the glaziers needed to reassemble the pieces belonging to each specific “jigsaw puzzle” of painted and fired glass with speed and precision. While large, distinctive pieces belonging to unique figures or narrative compositions could probably be recognized easily, repeated elements within a scheme could be less quickly distinguished from one another, and although there were superficial similarities, glass pieces were not readily interchangeable from one panel to another, even if prepared on the same glazier’s table.⁵⁴

4.2 *Cutting the Glass*

Both Theophilus and Antonio da Pisa provide descriptions of glass-cutting techniques, and yet only recently have these been subjected to critical examination. Both writers assume that the cutting of glass is done directly on the glazier’s table without the intermediary of a template. Light-coloured glass could be laid directly over the dark lines drawn on the table, but for cutting dark glass, marks were first outlined on a piece of white glass, which could then be held up together with the dark in order to allow the necessary outlines to be seen against the light.

Theophilus outlines two processes, the cutting of glass with a heavy, hot iron (“thin throughout but thicker at one end”) and the shaping of glass with a flat, notched grozing iron (“a hand’s-breadth in length and curved back at each end”),⁵⁵ a tool that crops up in the St. Stephen’s chapel accounts on numerous occasions, and was apparently supplied to the glaziers from a common store of tools.⁵⁶ The hot iron (known in German as the “dividing iron”) was very similar to the tool used for soldering: were these tools used interchangeably? The dividing iron or soldering iron is represented arranged in saltire (with the more distinctive grozing iron) in the borders of the 16th-century ordinances of the Guild of St. Luke in Antwerp.⁵⁷ Before the advent of the diamond cutter, only the dividing iron could be used to cut glass into two or more pieces without any great loss of material, for the grozing iron shapes glass by reducing it in size. It was long assumed that its apparently cumbersome size and shape meant the dividing iron could be used for cutting glass only to very approximate shapes, but experimentation conducted during the Antonio da Pisa project

52 Hérold, “‘Cartons’ et pratiques d’atelier”.

53 Armitage Robinson et al., “Marks on the glass at Wells”; Wayment, “The glaziers’ sorting marks at Fairford”; Vila Delclòs, “Les marques d’assemblages”.

54 Cothren, “Production practices”.

55 Theophilus, *The Various Arts*, pp. 48–49.

56 Salzman, “St Stephen’s Chapel”, (1926), p. 32; (1927), pp. 38, 40.

57 Caen, *Production of Stained Glass*, pp. 301–03.

revealed the sophistication of this tool when wielded correctly, allowing glass to be cut at angles impossible to achieve with the diamond.⁵⁸ The large size of the iron's head is required in order for it to be heated to a red-hot temperature (750°C) and then to retain this heat for the duration of the cutting process. The glass is not cut so much as divided, by a crack generated by thermal stress (Figure 1.5), and the skill lies in encouraging the crack to flow across the sheet in pursuit of the head of the hot iron. The resulting cut edge is far softer and more congenial to work with than the sharp edge cut by the diamond or modern cutting wheel.

The same can also be said of the edge produced by the grozing iron, which nibbles back the glass in a series of small shales that results in a scalloped and slightly chamfered edge that is far less sharp than a modern cut (Figure 1.6). The grozing iron can be used with great speed and precision, and one of the hall-marks of a medieval stained-glass panel is the closeness of the fit of its complex and tightly interlocking pieces. The visually distinctive grozing iron was widely used as a heraldic device in the armorials adopted by glaziers and their guilds (Figure 1.7), and yet despite the numerous contemporary images of them, they had little intrinsic value and very few have survived.⁵⁹

Antonio additionally describes the use of a range of hard stones, including the diamond, which had been widely adopted as the main tool for cutting glass by the early 17th century.⁶⁰ The diamond glass-cutter was a more costly tool than the grozing iron and, as it responds to the pressure of the hand of the individual, it became a far more prized and personal tool than the grozing iron, and consequently less likely to appear in a general workshop inventory. It may therefore have been in use at an earlier date than the surviving inventories suggest. However, it is also clear from the illustrations published by Diderot (1751–77) and Le Vieil (1774) that the grozing iron continued in use alongside the diamond glass-cutter well into the 18th century.

4.3 *Painting the Glass*

As we have seen, the painting of the glass, that process that distinguishes stained glass from a purely mosaic process, was not ranked as highly within the workshop hierarchy as the process of design. It remains, however, the aspect that most enchants and engages the viewer. The extraordinary monumental windows with figures of

prophets painted after 1132 for the clerestory of Augsburg Cathedral (see Figure 2.5), reveal a glass-painting craft already fully mature and perfectly mastered.⁶¹ By 1140, Abbot Suger of Saint-Denis was able to call on glass painters from several countries to work at his abbey church.⁶² The materials used in 12th-century Germany for painting the glass are described by Theophilus as a finely ground mixture of burnt copper filings and a flux of green and blue glasses. In late 14th-century Italy, Antonio da Pisa also recommends copper-filings but advocates the use of yellow glass rosary beads for the glass flux. In both the 12th-century text and the late 14th-century one, the proportion of the paint mix is specified as one-third copper to two-thirds glass, and produced a brown or black paint.⁶³

Glass paint can be diluted but not dissolved, and the choice of binder determines the consistency, flow, and workability of the painting medium. The paint remains slightly granular, even after thorough grinding. Theophilus advises the use of wine or urine as a binder for the powdered glass-paint, while Antonio recommends a tempera binder mixed with sap from the fig.⁶⁴ The St. Stephen's Chapel accounts refer to glass paint as "geet" and "arnement", and also include payments for the gum arabic that helps the paint to adhere to the glass before it can be fired.⁶⁵ The organic binders necessary to carry the fusible pigment are burnt away in the firing process (stained glass is usually fired at 600–500°C), and so do not survive to be subjected to modern analysis. Nonetheless, the development of glass-painting techniques in the later Middle Ages, resulting in a complex and multi-layered approach to the application of paint, means that more than one binder must have been used to avoid one layer running into and dissolving another. One layer can be applied with a watery binder – wine, water, or vinegar – and another with an oily binder, such as lavender or clove oil. Close examination of multi-layered paint applications confirm that medieval glass-paint was fired only once, as highlights can be seen to have been cut through all the layers of paint to the underlying base glass, impossible to achieve once a paint layer has been fired (Figure 1.8).

Throughout the Middle Ages the predominant painting technique was to begin by laying down a thin overall

58 Lautier and Sandron, *Antoine de Pise*, pp. 97–104.

59 One is preserved in the Germanisches Nationalmuseum in Nuremberg. Azzola, "Das historische Handwerkszeichen eines Glasers".

60 Lautier and Sandron, *Antoine de Pise*, pp. 91–96.

61 Becksmann, "Die Augsburger Propheten", pp. 84–110. Also see Dell'Acqua, Ch. 2 in this volume. For even earlier archaeological evidence see Balcon-Berry et al. (eds.), *Vitral, verre et archéologie*.

62 Abbot Suger, *On the Abbey Church*, p. 73.

63 Theophilus, *The Various Arts*, p. 49; Lautier and Sandron, *Antoine de Pise*, pp. 107–09, 307–38.

64 Theophilus, *The Various Arts*, p. 49; Lautier and Sandron, *Antoine de Pise*, p. 112.

65 Salzman, "St Stephen's Chapel", (1926), p. 14.

glaze or wash of paint, to which subsequent layers were applied in order to modify the passage of light through the glass. Glass paint dries quickly and so needs to be applied with spontaneity and confidence. It can be matted, stippled, and textured with a variety of brushes and tools. The layered painting technique means that error cannot easily be corrected, as glass painting is both an additive and a reductive process. Glass paint applied with a brush can also be etched and scratched out to create piercing highlights. Nuremberg glass-painters of the 16th century could buy brushes made of silver wire for this purpose, although more mundane objects such as quills, needles, and the sharpened ends of brush handles were also used.⁶⁶ The semi-opaque contour lines (trace lines) are applied last of all, in a process that seems to be counterintuitive and is extremely difficult to achieve. Its great advantage lay in the fact that this technique required only a single firing.

Only in recent years, and through the close observations made by conservators and art historians, have the ways in which the medieval glass painters worked become clearer. On the exterior surfaces of painted glass dating from the late 13th to the early 16th century, faint and sometimes partially expunged lines, coinciding with the outlines painted on the interior surfaces of the glass, have been observed.⁶⁷ These represent temporary guidelines, traced off the glazier's table or cartoon, allowing the glass painter to remove the individual glass piece from the table so that the painting could be carried out against the light, working with an exterior outline of a design that would only take its final form on the interior surface of the glass with the final application of the trace line. The glass painter would normally erase these temporary guidelines before firing the glass, but in some cases failed to remove them adequately so that, having also been created using fusible glass paint, they were inadvertently fired onto the finished piece.⁶⁸ Glass painters also deliberately took advantage of the fact that glass can be painted on both of its surfaces, allowing a play of optical effects to be achieved.

From the years around 1300 it was also possible to add a yellow colouring to glass through the application to the exterior surface of a window of a silver nitrate or oxide compound derived from ground silver filings (Figure 1.9).⁶⁹ Given the alacrity and enthusiasm with which it

was adopted in the course of the 14th century, becoming ubiquitous and even dominant in the 15th century, the late adoption of silver stain by stained-glass artists is rather surprising. It is mixed with an ochre binder, and so was usually applied to the exterior of the glass to avoid damaging the painted details on the interior surface. By the end of the Middle Ages coloured vitreous enamels – transparent pigments created from a finely ground, low-melting coloured glass – provided a new range of colours that could be applied with the brush.⁷⁰ These were popularly used to colour the increasingly intricate charges of heraldic shields and to enliven small-scale panels and roundels designed to be seen at close quarters, freeing the glazier of the need to cut and lead-in small pieces of glass of different colours.

Guild prohibitions suggest that glass painters also used cold, unfired paint to augment their fired decoration, perhaps when they had omitted a fired detail, or had underfired their conventional paint or stain. Antonio provides a recipe for cold paint made of verdigris mixed with a liquid varnish, which when allowed to dry in the sun took on the appearance of a fired paint.⁷¹ A 15th-century English manuscript mentions an oil-based recipe for a paint suitable “To make curyus worke on glasse wyndowes after the be aneled”.⁷² The inherently poorer durability of unfired cold paint and the failure of careless restorers to recognise its antiquity, means that its use has been overlooked. However, prohibitions against its use demonstrate that it must have been recognised as a common enough technique, attested by significant survival in windows in Nuremberg and Berne.⁷³

4.4 Further Embellishments: Applied and Inserted Jewels, Abrasion

A small but technically demanding range of further embellishing techniques were available to the medieval glazier. Theophilus mentions one of these, the use of a thick application of glass-paint to the surface of a piece of glass of one colour as a means of fixing through firing a small piece of another colour to its surface.⁷⁴ This “appliqué” approach was used over a very long period, and is most frequently used to imitate the application of jewels to the hems of vestments and rich garments or to the brim of a crown or mitre (Figure 1.10). Examples dating

66 Butts, Hendrix et al. (eds.), *Painting on Light*, pp. 57–65.

67 Trümpler, “Rückseitige Vorzeichnungen auf Glasgemälden”; Ayers, *Merton College*, pp. lxxv, 25.

68 Cothren, “Production practices”, pp. 122–27.

69 Salzman, “St Stephen's Chapel”, (1926), pp. 32, 33, 34; Lautier and Sandron, *Antoine de Pise*, pp. 109–12; Also see Husband, Ch. 19 in this volume.

70 Caen, *Production of Stained Glass*, p. 139. The enamel layer can be as little as 5–100 microns thick.

71 Lautier and Sandron, *Antoine de Pise*, pp. 114–16.

72 Brown and O'Connor, *Glass Painters*, p. 61.

73 Marks, *Stained Glass in England*, p. 39; Hör, “Kaltmalerei auf Glasgemälden aus Nürnberg um 1500”; Trümpler and Wolf, “Cold paint on the late medieval choir windows of Berne Minster”.

74 Dodwell, *Theophilus*, pp. 57–58.

from the 12th to the 15th centuries have been identified with their jewels still attached.⁷⁵

A more permanent but even more demanding technique involved the introduction of small glass insertions, held in lead, introduced into holes drilled into the base glass, a highly risky procedure that, not surprisingly, became one of the tests of mastery of the glazier's craft, and is found in glass from the mid-15th century onwards. The treatises are almost entirely silent on this technique, in part because of its late adoption, but perhaps also because it was one of the "mysteries" of the profession. The 15th-century Nuremberg *Rezeptsammlung* implies the use of a lead drill of some sort, used with an emery grinding powder, and recent unpublished research has shown this to be a viable technique.⁷⁶ While these insertions are most commonly small and circular (Figure 1.11), once the base glass was breached, a small grozing iron could be introduced to enlarge and shape the hole ready to take a larger insertion of a more complex shape.⁷⁷

From the late 13th century onwards grinding or abrasion was also a technique widely employed to modify the upper coloured surface of ruby glass. No technical treatise addresses this technique, but the tiny scratches on the surface of ruby glass treated in this way show that a grinding tool was used to scratch away the thin surface layer of flashed red glass in order to create a decorative pattern or heraldic device. The white base glass revealed thereby could also be enlivened with silver stain. Antonio da Pisa describes a far less labourious method, involving a wax resist and the application of "water for separating gold and silver, some of the water that goldsmiths sell" with which the red coloured surface of a flashed ruby could be removed after 2 or 3 hours.⁷⁸ Recent research has not only uncovered a surprisingly large number of examples of early acid-etched pieces of stained glass (Figure 1.12), but has shown that

nitric acid will etch glass with a high lime content and that hydrofluoric acid may have been in use far earlier than hitherto supposed.⁷⁹

4.5 *Firing the Glass*

Only with the firing of the glass could the delicate painted detail be secured to the surface. This was the stage at which all the hard work of the glazing team could be lost, as the medieval kiln could not be easily controlled and poor firing could result in under-fired paint and/or broken pieces. The treatises, not surprisingly, devote a considerable amount of space to the construction of the small firing kilns and to the firing process.⁸⁰ While no temperature or firing duration is specified, it is clear that the glaziers understood the performance of different glass types and glass sizes inside the kiln. The careful preparation of the fuel, the management of the ventilation of the kiln interior, and the placement of glass on a kiln pan well-lined with an insulating layer of chalk and ash, would ensure efficient firing of the glass. Antonio advises "never put any red or yellow at the bottom, and don't put them too near the edges of the pan as both colours are very fearful of the fire; nor should you put large pieces at the bottom or near the edges of the pan".⁸¹ Both Theophilus and Antonio suggest that the glazier recognised a successful firing from the colour of the kiln interior and the pan on which the glass was laid out. For reasons of economy, glass was often stacked in layers in the kiln, and traces of paint and silver stain inadvertently transferred from one layer to another are often observed.⁸² The use of uneven and kiln-deformed pieces in some medieval windows, normally in subsidiary openings, underlines the glaziers' reluctance to dispose of expensive materials, but also suggests that accidents in loading the kiln did happen.⁸³

4.6 *Reassembling and Glazing the Panels: Lead and Solder*

After the firing and annealing of the glass, all the pieces were reassembled on top of the original glazier's table. It is now clear why Theophilus advocated a table large enough to hold two panels of glass, as the pieces could be laid out on one part of the table and then transferred

75 The 12th-century examples are said to survive in Regensburg Cathedral (personal communication, Sebastian Strobl). Early 13th-century examples were identified in the glazing at Heimersheim an der Ahr in Germany: Kowolik, "Choir windows of St Mauritius in Heimersheim". Unpublished examples can be found in the choir aisles of York Minster of c.1370 and c.1440 (windows sIV and sVII), while heraldic panels of the mid to late 16th century from Fawley Hall, in Northamptonshire, now in the Burrell Collection in Glasgow, employ a variation of this technique.

76 Lautier and Sandron, *Antoine de Pise*, p. 338; Stacey, "Artistic and technical dexterity".

77 At Fairford, both circular and quatrefoil insertions are found. See Brown and MacDonald, *Fairford Church*, plates 30 and 31.

78 Lautier and Sandron, *Antoine de Pise*, pp. 119–22. The 15th-century Bolognese manuscript seems to be referring to the same material: Merrifield, *Original Treatises*, pp. 494–95.

79 Piloni et al., "Early acid-etching".

80 Theophilus, *The Various Arts*, pp. 51–52; Lautier and Sandron, *Antoine de Pise*, pp. 135–41.

81 Theophilus, *The Various Arts*, pp. 52–53; Lautier and Sandron, *Antoine de Pise*, pp. 142–51.

82 Cothren, "Production practices", p. 123; Ayers, *Merton College*, p. lxxv.

83 In the tracery lights of n6 in the Chapel of New College, Oxford, for example. Observed 2009 by conservators of the York Glaziers Trust.

to the “cartoon” as the leading-up proceeded. In the efficient sorting of the glass pieces from the kiln pans back into their specific panels, the discreet sorting marks discussed above would have been invaluable. The glazier would then begin the process of leading the pieces together using H-profiled lead strips (usually called *comes*) to hold adjoining pieces together. Lead is the perfect material for this job, being malleable and capable of being cast into sections of different thickness, depending on whether a wider outer lead or thinner internal lead was required.

Medieval window lead was cast in moulds, a process described by both Theophilus and Antonio.⁸⁴ While a variety of materials for mould-making are mentioned, including an iron and copper alloy, wood, and a variety of stones, Antonio suggests that they should be procured from a master in the craft. He personally favoured those made of an alloy of copper and lead, describing them as both more durable and more responsive to thermal expansion. Wooden moulds would not have survived for long, while hard stones were prone to break when subjected to repeated heating during the casting process. In excavations at Saint-Denis and Reims in France, moulds made of chalk for casting window leads have been found, with associated lead strips.⁸⁵ The leads found in association with these moulds retain the vestiges of the casting flashes that would be planed off before use. Stone or chalk moulds could have been prepared by the glaziers themselves, while a metal mould would have to be forged by a blacksmith. Surviving medieval window lead, now relatively rare as a consequence of subsequent restorations (Figure 1.13), often displays a faceted edge to the “leaf” (or flange) of the lead, where it has been scraped clean of any casting flashes left from the mould. Pin-prick holes in the lead’s heart are evidence that air had been trapped during casting; Antonio proposed reducing this risk by greasing the mould interior prior to use.

After centuries of neglect and destruction, medieval window leads are now increasingly studied and prized.⁸⁶ Compared to modern milled and extruded lead, their strength and resilience is remarkable. Those in the windows of the choir clerestory of Cologne Cathedral are now over 600 years old.⁸⁷ They were usually far thinner

and finer than modern leads, often only 4 mm–6 mm across the flange, meaning that they could easily be bent around the most intricate and tightly-fitting of shaped glass pieces, an essential and symbiotic relationship in the most sophisticated stained-glass designs. Indeed, the glass and lead fitted together so closely that windows were watertight without the need for any waterproofing putty, which only became ubiquitous following the adoption of lead milling techniques from the later 16th century onwards. The Cologne lead nets are particularly interesting because their hearts have been packed with “withies”, which act as spacers when leads were doubled to give greater strength or greater visual emphasis to aspects of the design, but also served to give the panels greater resistance to wind pressure.⁸⁸

The glazier used “closing nails”, described by Theophilus, with which glass and lead is held in place during the assembly process.⁸⁹ Each intersection in the leading pattern was made firm by the application of solder on both sides of the panel, an alloy of tin and lead, cast into thin rods for ease of application. This low-melting material, for which Antonio provided several recipes, flows across and into the joints between leads, although care was required in moderating the temperature of the soldering iron so as not to melt the lead *comes*.⁹⁰ The application of a flux to the joint helped the solder to flow, and in the St. Stephen’s Chapel accounts, tallow (rendered beef or mutton fat) was purchased for this purpose.⁹¹

The lead matrix was given extra strength by the glazier’s skill in integrating the lead and the glass. Well-designed panels avoid too many vertical and horizontal straight lines, which provide weak “hinge” points in the lead matrix. Glass-painters frequently edged their glass pieces with a dense back trace-line. This registered the permissible limits that could be occupied by the lead flange, perhaps allowing the glaziers some leeway in grozing the painted pieces after firing to ensure a better fit. In unpainted geometric glazing, of a kind often associated with Cistercian patronage, the design relies entirely on the subtle relationship between glass and lead-line, and reveals the extraordinary precision in cutting and leading that the best glaziers could achieve.⁹²

84 Theophilus, *The Various Arts*, pp. 53–56; Lautier and Sandron, *Antoine de Pise*, pp. 123–28.

85 Deneux, “Un moule à plomb”, pp. 149–54; Meyer and Wyss, “Des moules à plomb”, pp. 105–06. For stone moulds, see Baker, *Excavations at Selborne Priory*, pp. 105–08.

86 Knight, “Researches on medieval window lead”; Cuzange and Texier, “Caractérisation des plombs anciens de vitraux”.

87 Brinkmann, “Die Verbleiung und Befestigung der mittelalterlichen Farbverglasung”.

88 Similar spacers have also been noted at Altenberg and Haina: Cortes Pizano, “Medieval window leads”, p. 27, n. 10.

89 Theophilus, *The Various Arts*, pp. 56–57. The Girona table bears the nail holes from the process of panel assembly.

90 Lautier and Sandron, *Antoine de Pise*, pp. 129–34.

91 Purchased from the appropriately named Peter Bocher: Salzman, “St Stephen’s Chapel” (1926), p. 35.

92 Zakin, *French Cistercian Grisaille Glass*; Brown, *York Minster*, pp. 18–19.

4.7 *Fixing the Windows: Stone and Iron, Masons and Blacksmiths*

In fixing a medieval window the glaziers, by necessity, worked closely with masons and blacksmiths. While this collaboration is largely passed over in the treatises, it is far more apparent in the glazing accounts. In the 12th and 13th centuries, before the advent of subdivided stone tracery, stained-glass panels were held in position in the window opening in a wrought-iron armature set into a wooded frame rebated into the stone.⁹³ Panels were held in place by projecting lugs through which wedges or curved pins were threaded. The Canterbury armatures are extraordinarily complex in their shape, and would have required close liaison between glaziers and blacksmiths to ensure a close fit.⁹⁴

Once window openings were subdivided by stone tracery, new fixing systems developed. Masons provided glazing grooves around the jambs and heads of their window mullions into which the stained-glass panels, made slightly wider than the visible opening, could be slotted directly, then mortared in place for a watertight finish. Horizontal iron support bars – lug bars or T-bars – were introduced at intervals in order to support the weight of the glazed panels. Additional vertical and horizontal bars were not load-bearing but provided additional strengthening. Lead ties, soldered at appropriate intervals across the stained-glass panels, allowed them to be tied to these bars, increasing their resistance to wind pressure. While the *ferramenta* could be set into sockets cut into the masonry, the window bars sometimes run through all the mullions of the window opening and so must have been introduced during the initial construction of the window, with implications for early project planning and the interactions between glaziers and masons. The relationship of the stained-glass panel to its fixing system could never be treated as an afterthought, but required careful planning to ensure that the *ferramenta* did not interfere with major design features. Some surviving medieval designs indicate the location of the *ferramenta*, and Antonio offers advice about the placing of the bars and ties.⁹⁵ There is even reason to believe that in some cases the masonry was designed to reflect the iconography of the stained glass it was to support, although this must have been at the stipulation of the patron.⁹⁶

93 This sort of fixing system continues in use in Canterbury, Lincoln, and Salisbury cathedrals.

94 Marks, *Stained Glass in England*, p. 38, fig. 29.

95 Lautier and Sandron, *Antoine de Pise*, pp. 49, 71.

96 The masonry of York Minster's Great East Window, for example, appears to have been adjusted deliberately to reflect the numerological significance of the window's stained-glass imagery: Norton, "Sacred space and sacred history".

5 "Walls Like Unto Clear Glass"

Stained glass is now one of the most important surviving manifestations of medieval monumental painting. Its status in the Middle Ages relied in no small measure on its capacity to turn the medieval church building into a foretaste of the heavenly Jerusalem described in John's vision (Revelation 21:18). While those who practised this craft remain elusive, collaborations between art historians, textual and documentary scholars, materials scientists, craftsmen, and conservators have transformed our understanding of medieval stained glass making, shedding new light on the role of the master, the autonomy of the craftsman and the relationship between patronage, design and execution.

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