The one-pull press

Alan May

In December 2006 Wavelength Films, an independent film company working for the BBC, approached me about the possibility of building an early printing press such as might have been used in the mid-fifteenth century. They were interested in filming the making and using of such a press for a programme commissioned by BBC 4, entitled 'The machine that made us'. It will be presented by Stephen Fry and is due to be broadcast early in 2008. It is about the 'why' and 'how' of Gutenberg's success in using and adapting then current technologies in order to take printing forward from an essentially 'one-off' process into something capable of both high-quality mass production and commercial usefulness.

Wavelength Films knew already that I had recently completed an eighteenth-century common press for Le Musée de l' Imprimerie in Lyon and assumed initially that the new press would be similar. I pointed out that this was not the case and that any attempt at such a reconstruction was likely to involve a good deal of speculation, as what little we do know indicates that Gutenberg's press was significantly different from the 'two-pull' presses which appear in the earliest printed illustrations. Wavelength Films were not put off by this and in mid-February 2007 agreed to fund an experimental machine to be completed by the end of May. Furthermore, they stipulated that the machine was to be a working model capable of demonstrating the technical challenges faced by Gutenberg and his team, rather than a museum piece. They also indicated that they wished to film the press both under construction and in a final printing experiment.

From the beginning I was well aware that other attempts at replicating Gutenberg's press had been made in the past, and that a number of these had relied heavily on illustrations made so long after that their value is open to question. Very little evidence about printing in the earliest period exists. No illustrations or equipment have come down to us. There are some documents relating to a lawsuit between Gutenberg and his partners in Strasbourg in 1438 (the Dritzehn papers) in which one Konrad Saspach built a press for them, but whether this was a printing press is not clear.[1] Worse, the documents concerned appear to have been written in a way which deliberately obscures the nature of the enterprise in which Gutenberg and his partners were involved. Accordingly, my reconstruction

1. Albert Kapr, *Johann Gutenberg: The man and his invention*, trans. by Douglas Martin (Aldershot: Scolar, 1996), pp. 74–7.

is based wherever possible on the evidence to be found by looking at Gutenberg's printing and by trying to understand the practical engineering problems he faced. Post-Gutenberg depictions of the printing press have been viewed as secondary sources. This account starts by reviewing what we know about these early presses and what can be deduced from this. This is followed by a description of the reconstruction sponsored by Wavelength Films.

INSIGHTS INTO THE FIRST PRESS GAINED FROM EARLY PRINTING

One- and two-pull presses

A significant difference between the presses that were used in the first decades of printing and those that followed was that on the earliest presses, including Gutenberg's, only one impression was possible at each visit to the press. Such presses are referred to as 'one-pull presses'. This is believed to be the case because the vast majority of the earliest printed books are folios; that is, they are made up from sheets folded in half thus providing four pages. Occasionally in these, including an example in one copy of the Gutenberg Bible, one of a pair of conjugate pages is missing. This omission is likely to arise only on a press which has only one page on its bed, i.e. is a one-pull press. The printing forme on the bed of a 'two-pull press', which is thought to have arrived around 1470,[2] would consist of two pages. On such a press, each of the two pages of type for the double spread would be inked together but printed one after the other, providing no opportunity for the accident of a missed page. This modification of the early press from one to two pulls would have been introduced in order to be able to print the whole side of a sheet at each visit to the press.

Initially it must have seemed that the easiest way to do this would be to simply impose the two pages transversely on an enlarged press with a bigger platen (the flat block that delivers the pressure of the screw to the type) so that two pages could be printed with one pull. This change, if it had been possible, would have brought with it significant economies in the time taken with make-ready, printing, sheet handling and drying. However, it turned out not to be feasible as the text area (approximately 200 × 290mm) of a single page of a Royal folio such as the Gutenberg bible was already very close to the maximum area that a person could print using a wooden screw press. This is borne out in my reconstruction. When printing a replica Gutenberg Bible page we found that we were just able to apply sufficient pressure to make a good print; but if we attempted to apply even greater pressure the friction on the wooden thread almost

2. Lotte Hellinga and J. B. Trapp, eds, *The Cambridge History of the Book in Britain*, volume 3 1400–1557 (Cambridge: Cambridge University Press, 1999) pp. 79–80.

While accepting Hellinga's evidence in this passage for the date of the emergence of the two-pull press, I find that I don't quite agree with her on the technical differences between the earliest presses and those which followed. She argues in this same passage that the early press had a fixed bed and that the significant change was the introduction of a movable carriage. I would argue on practical grounds that in order to achieve accurate positioning of the paper over the type and the avoidance of smudging while inserting the type, paper and packing under the platen, a movable carriage would have been essential from the start.

immediately increased under the extra load to the point where the thread simply locked up. With enlargement of the platen not possible, the two-pull principle became the next best option for increasing the speed with which printed sheets could be got off the press (referred to here as riddance). This change from one to two pulls will have required substantial modifications to the structure of the press. Understanding what these changes must have been should provide useful insights into the structure of the one-pull press.

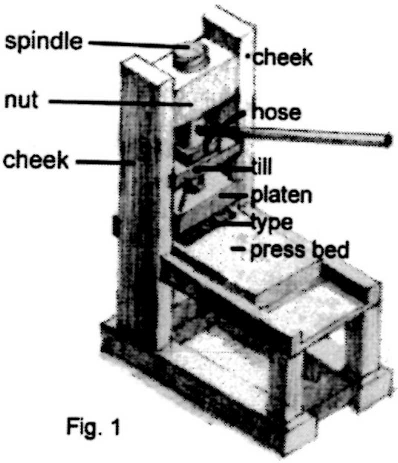


Fig. 1

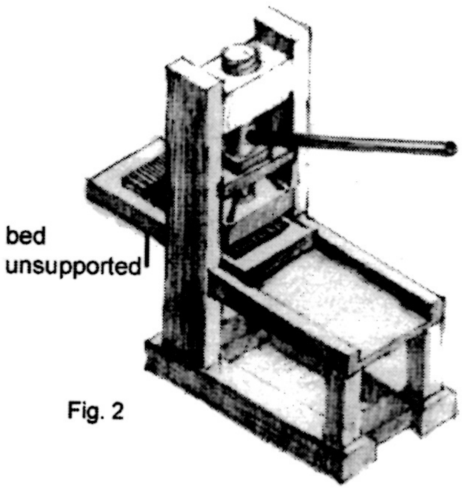


Fig. 2

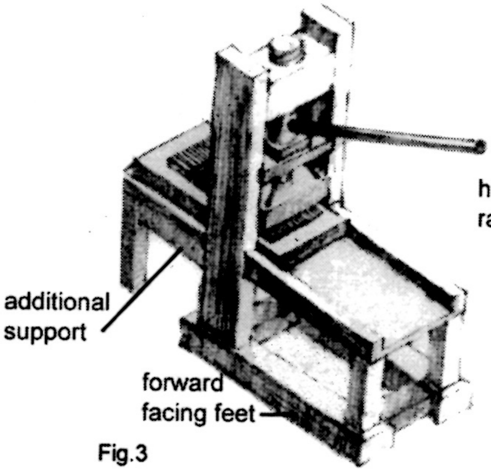


Fig.3

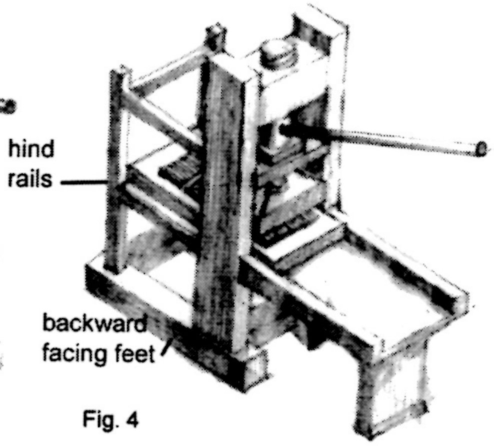


Fig. 4

Figs 1–4 are an attempt to throw light on what these changes may have been. For simplicity details such as tympan and frisket have been omitted. Fig. 1 represents a printing press at its simplest. It consists of a stout bench with a sliding top on which the type and press bed can be mounted. At one end two uprights (the cheeks) are attached. These support the impression mechanism consisting of a threaded wooden spindle rotating in a wooden nut. At the base of the spindle is attached the platen which bears down on the type when the spindle is rotated. The platen itself is prevented from rotating by means of the hose and till.[3] Such a press should print one page effectively but would be incapable of a second, because in order to get the second leaf under the platen the press bed would have to pass out beyond the point where its whole weight is supported by the cheeks. This situation is illustrated in Fig. 2. Furthermore, the problem is compounded by the need to accommodate not one but two pages of type on the press stone (the flat stone surface on which the type rests) which has to be more than twice the size required on a one-pull press. A press stone of this size would weigh perhaps 50kg[4] and to this must be added the weight of the plank, coffin, two pages of type, and the tympan and frisket.[5] The total weight would probably be not much short of 100kg so some means of supporting this weight at this stage in the printing cycle would need to have been made. Perhaps the first solution would be simply to provide some additional support at the back of the press: Fig. 3 illustrates a possible arrangement. (Intriguingly Albrecht Dürer's 1511 drawing of a press shows features which almost exactly duplicate this interim solution: see Fig. 8.) Eventually, however, a more structurally satisfactory solution was found by turning the feet of the press so that they pointed backwards rather than forwards and by introducing what we now refer to as hind rails (which would have had no function on a one-pull press). These changes are depicted in Fig. 4. The press has now evolved into a two-pull or common press. It is probable that the rounce was added at this stage (the winch used to wind the bed in and out) as they now needed to move a much heavier press bed over a longer distance and to start and stop it accurately at two points in the printing cycle. A rounce could have been employed on a one-pull press but would probably have been unnecessary. On my reconstruction I have not fitted one as the bed has to travel only about 450mm and can be readily moved with one hand. It can be stopped when at the correct place under the platen by means of a simple limit strap.

Side elevations of these changes in the structure of the press are shown diagrammatically in Figs 5–7. My speculations about these changes are based entirely on what I perceive to be the design considerations governing the early press. I see no way round the fact that a one-pull press would need to have had its feet and supporting framework at the front.

The only early illustration of a press of which I am aware, which shows these features, is the Dürer drawing of 1511. Relative to the date of the changes which I am discussing, the drawing is rather late and is almost certainly not a one-pull press. However, because it does show features which I regard as being at an interim stage

3. The hose is a square wooden collar from which the platen is suspended. The till is a horizontal wooden plank fitted between the cheeks of the press. It has a square hole in its centre through which the hose passes. Its purpose is to prevent the hose and therefore the platen from rotating when the press is operated.

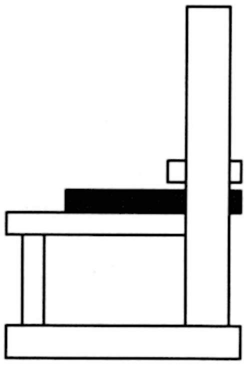
4. My estimate for the size of a two-pull press stone is based on the dimensions given by Moxon. The weight was calculated by weighing a litho stone of the correct thickness but of somewhat larger area, and then interpolating.

The weight of the type for two bible pages is 24.5kg.

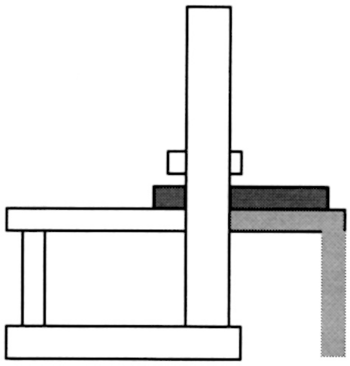
The stone used on this one-pull press reconstruction weighed 21kg.

5. The plank is a large flat board on which the stone rests. Its under-surface is fitted with runners so that it can operate like a sledge. The stone is surrounded by a substantial wooden frame, the coffin, which is nailed to the plank. The upper surface of the coffin is made level with the top surface of the stone except at its corners, where its height is increased to provide a means of wedging the type securely in place on the stone.

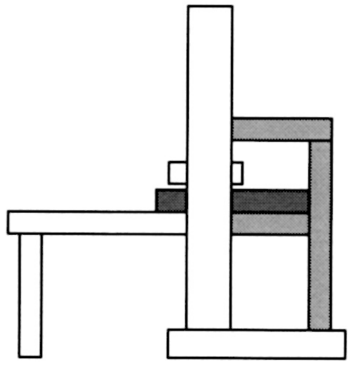
between the one- and two-pull press, I wish now to look at it in more detail.



5. Projected structure for a one-pull press.No hind rails required.Feet face forward.



6. One-pull press adapted to print two pulls. Hind rails absent but support provided for bed during second pull (shaded). Feet still face forward. Compare with Dürer drawing (1511).



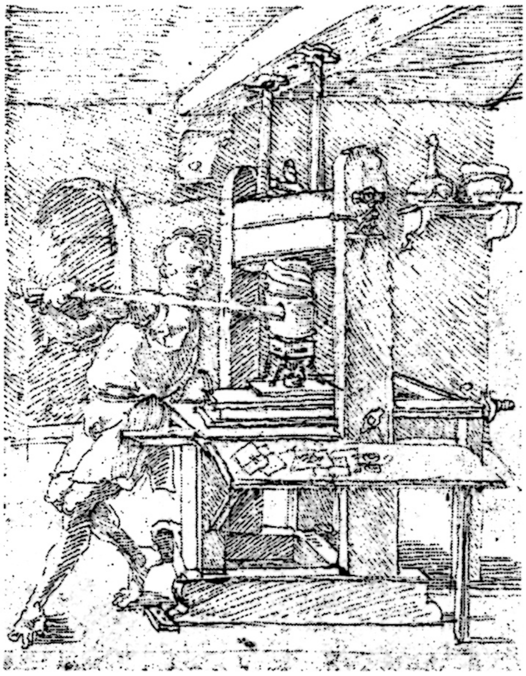
7. Two-pull press. Hind rails fitted (shaded). Feet now face backwards. Cheeks, hind rails and feet joined together in an integrated structure. Typical two-pull 'common press' structure.

The Dürer drawing of a printing press 1511 (Figs 8–9)[6]

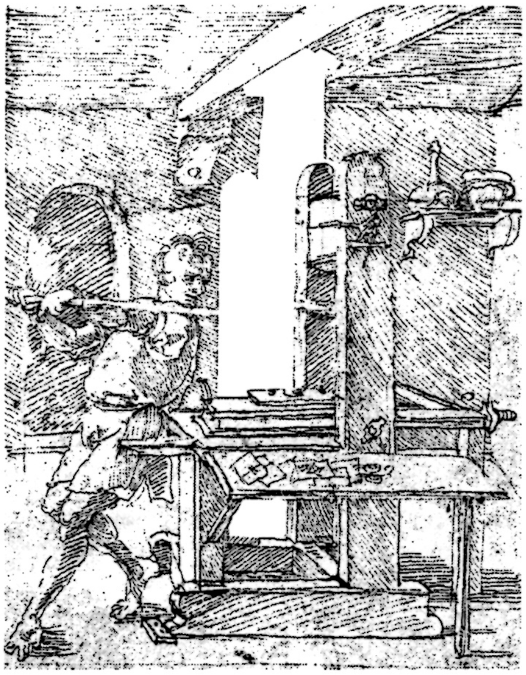
Apart from the front-facing framework this drawing has a number of other unexpected features. The platen appears to have its long side parallel to the sides of the press (contrary to normal practice) and the carriage appears too short to run out the bed from under the platen. There is a hose but no till and the spindle has its thread going round the wrong way. Most surprising of all is that Dürer, who we know made an intensive study of perspective, seems to have got even this wrong in this instance. Collectively these ambiguities have resulted in the drawing being regarded as a somewhat unreliable source, and this view is intensified by the drawing's context. The press drawing is sandwiched into the middle of a set of three, the other two having connections with blacksmithing and baking. The drawings appear to be describing some form of activity in which all three are involved and was probably satirical in intention. Erwin Panofsky describes this drawing under the title 'A Satirical Allegory on the Profession of a City Clerk'[7] and suggests that its purpose was to lampoon the work of the artist's friend Lazarus Spengler, City Clerk of Nuremberg. Whatever the reasons, there is much that can be said in its favour, both as a drawing and as a source of information about the early press. It also shows a number of small details within the drawing which convince me that Dürer had a detailed knowledge of this press. I would instance in particular the drawing of the platen pan, which can just be seen at the base of the

6. Ray Nash, *Dürer's 1511 drawing of a press and printer* (Cambridge, Mass.: Harvard College Library, 1947).The drawing is in the Musée Bonnat in Bayonne.

7. Erwin Panofsky, *Albrecht Dürer* (Princeton: Princeton University Press, 1943), 1943 vol. II, p. 98 (no. 945).

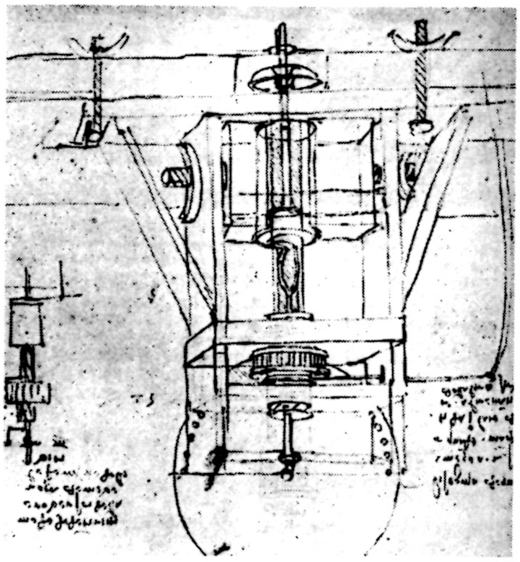


8. Dürer's drawing of a printing press (1511).



9. Drawing modified to correct perspective.

spindle, and the inclusion of the tiny chock under the front foot to prevent the press rotating in use. This sort of detail is visually insignificant but important to someone using a press on a regular basis. The drawing of the hose is also clear and includes details such as the lines on each of its faces which are the equivalent of a garter. This detail would have become obscured by the till if this had been added. All of this suggests that this is a rapidly executed memory drawing. Dürer is constructing the press in his mind as he works, adding bits and then modifying by overdrawing. Probably it was done quite quickly and with light-hearted intention. (In the accompanying text Dürer calls his drawing a 'cake' which he could not quite finish because he was too busy.) The perspective distortion turns out to be deliberate: Dürer has adjusted his drawing part way through in order to present a near frontal view of the screw. The two reproductions of the drawing in Figs 8 and 9 make this clear. Fig. 8 is an unmodified reproduction of his drawing whereas Fig. 9 has been modified in Photoshop so that the top of the drawing (all those parts of the press that are above the bed) have been brought back to the position that Dürer must have intended for them before deciding that what he had drawn did not look sufficiently like a press. This repositioning of the top half of the press has been determined by aligning the top part of the cheek furthest from the viewer with that part of the same cheek that can be seen under the table, which must have been drawn first. My apologies to Dürer! The modified drawing looks much less iconic, indeed the screw can no longer be seen, but the perspective is corrected and the press now has a carriage large enough to be able to operate the bed. Drawing the spindle with its thread going round the wrong way is very easily done particularly when drawing from memory. (I have done it on two occasions during the preparation of this paper.) The drawing of the platen appears to have been completed after the perspective changes so we cannot assume that its apparent longitudinal mounting is deliberate. It appears to be very thin, which probably indicates that it was made of metal. The absence of the till must be because Dürer simply hadn't got round to drawing it in, particularly as the hose is depicted in such detail that I have been able to use it as the model for my reconstruction. A hose without a till is a nonsense: neither has a function without the other.



10. Metal threads and nuts similar to those seen in the Dürer drawing in a depiction of a polishing machine by Leonardo da Vinci.

These points taken together imply that what is represented here is a real press and not just a pictorial invention. It is perhaps a press of rather archaic form but this would not be unreasonable in the workshop of someone specialising in the printing of woodblocks. After all many obsolete nineteenth-century iron presses continue to give good service in contemporary printmaking studios. Before leaving Dürer's illustration it is worth drawing attention to two other unusual features about this press. The first is that although by its size the press spindle is clearly made of wood there are several metal threaded bolts used in the press's construction and these are tightened by means of wing-nuts. These bolts appear to have very steep threads and were probably made by heating and then twisting a square bar of iron. A similar technique can be seen in use today on decorative ironwork. Exactly similar bolts and nuts appear in a

Leonardo da Vinci drawing of a grinding and polishing machine (see Fig. 10). This method of making screw threads was probably unsuitable for the spindle screw because it would provide only very rudimentary control of thread pitch.

The top of the spindle screw in Dürer's drawing includes a feature not seen in any of the other early press drawings. There appears to be a much smaller screw sticking out at the top. If this really is a screw an intriguing possibility arises. Is it the means of adjusting the length of the impression mechanism? Unlikely, perhaps, but all platen presses require some means of adjusting the spindle to bed distance in order to ensure that the bar is able to travel through its full arc from cheek to cheek. Two possible ways of achieving this have occurred to me. They are of course both mere speculation but I cannot see any other means of making this adjustment.

A wooden or a metal screw?

Earlier in this paper I alluded to the fact that the employment of a press with a wooden screw would have limited the maximum size that could be printed to about that of a single page of the Gutenberg bible. It is conceivable, therefore, that the change from a one- to a two-pull arrangement of the press can itself be seen as an argument for the use of wooden spindles on the earliest presses, as the limitations of pressure and platen size which a wooden spindle imposed would not apply to the same extent if iron spindles had been employed.

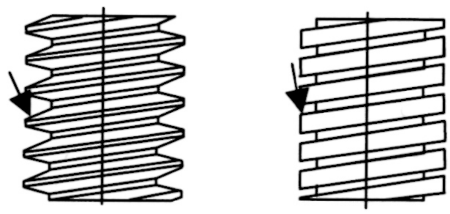
Some authorities believe that iron spindles were used from the beginning. Frans Janssen says 'It is questionable if a wooden spindle can make the platen move up and down with sufficient perpendicular force and with enough precision to produce a clear impression.'[8] Against this, I would claim that the practical experiments associated with this reconstruction have established that the use of a wooden spindle is perfectly capable of producing numerous good-quality impressions up to Royal folio size. Indeed, with two people working the press, printing speeds of around forty impressions per hour were easily achieved. Furthermore, contemporary depictions of wine and olive presses of this period, which are often regarded as the models for the printing press, all have screws which by their size are almost certainly made of wood. These presses, which must have been familiar objects throughout medieval Europe, will have required repair and replacement. It is not unreasonable, therefore, to suppose that artisans specialising in this type of work will have appeared, particularly as several of the tasks involved were probably outside the remit of the non-specialist carpenter.

8. Frans A. Janssen, 'Reconstructions of the common press: aims and results', in *Techniques and design in the history of printing: 26 essays by Frans A. Janssen*, ('t Goy-Houten: HES & De graaf, 2004), p. 275. Albert Kapr also suggests that Gutenberg's presses employed iron screws: *Johann Gutenberg* (note 1 above), p. 183.

In particular, the setting out of the correct thread pitch for a given press onto its wooden spindle blank and the cutting of the female counterpart of the threaded spindle (the nut) so that it fits this thread are not trivial jobs. In view of this, would not the prospective customer for a new type of press (a printing press) have sought out the help of those with expert knowledge? I believe they would have, and so on balance I think that a wooden spindle is the most likely on the very earliest presses; this is borne out in the earliest illustration. This is not to say that a wine or olive press could be simply acquired and adapted. This is very unlikely to have been possible, as the design considerations governing these presses are very different. On a printing press, the amount of downward movement imparted to the platen and the arc through which the thread can be turned are both tightly constrained. On a wine or olive press the platen continuously compresses the fruit and the rotation of the thread can be carried on again once the bar meets the press frame by inserting another bar through another hole in the spindle. The likelihood of a thread from such a press fortuitously meeting the printing press specification is remote.

Large wooden threads such as those used for crushing fruit were marked out and cut by hand. This practice continued until the nineteenth century. The problem of making a nut for these threads would vary, depending on whether the particular thread had been made before. If it had been made before, a nut for this thread would exist and could be used to generate another. If it was a new thread which the workshop had not had to make before, some sort of temporary nut would have to be devised. The procedure for doing this was first described by Hero of Alexandria about AD 64. He suggested enclosing the screw in an open-ended wooden box. Holes were then drilled in the sides of the box and pegs inserted which engaged with the threads of the screw forming a temporary nut. On first reading this I was very sceptical about its chances of working, but in fact it works very well and produces a nut more accurate than the screw that generated it, as any slight irregularities of the screw thread tend to be averaged out by the many pegs which comprise the nut. The rest of the procedure which is the same whether a temporary or a proper nut is used is outlined later when I come to describe the building of a one-pull press.

Without doubt iron spindles possess advantages over wooden ones and will have been adopted by press makers as soon as the technology for making them had developed sufficiently. Iron threads would have first to be marked out and then cut by hand using cold chisels and files. A description of the process entitled 'The Rules and manner of Cutting Worms upon great Screws' appears in Joseph Moxon's *Mechanick Exercises or the Doctrine of Handy-Works*, Volume 1 in the section dealing with Smithing.[9] Large metal threads continued to be cut by hand until the industrial revolution. They can be made with square threads and because of this produce less friction. They are stronger and less bulky and importantly their nuts can be cast in bronze around the original iron screw. Wooden screws are normally made with threads having a V-shaped section. There are a number of reasons for this. With wood it is important to make the base of each thread as wide as possible in order to guard against the thread splitting off the central core. The sloping surface of the thread also helps by ensuring that the forces that are tending to sheer off the thread are not acting parallel to the grain direction. V-section threads are also easier to cut. These arguments apply equally to the cutting of the wooden nut. However, V-section threads develop more friction than square ones and so are less efficient at generating power.[10] This additional friction arises because the thread load does not act parallel to the screws axis and so causes a wedging action against the nut. Fig. 11 is an attempt to clarify this point.



11. Arrows indicate the direction of the thread load on V-sectioned and square threads.

Registration

The need to provide a reliable means of getting the type and the paper or parchment into and out of the press cleanly and efficiently and to ensure that while on the press the two stay correctly located relative to each other must have been one of the major challenges that Gutenberg faced, though probably one which tends to get overlooked in light of his other more impressive developments. The page registration in the Gutenberg Bible is remarkably accurate, far better than is found in many of the incunables which followed it. On a one-pull press each folio sheet would have had to be repositioned on the press four times thus doubling the possibility of mis-registration compared with a two-pull press and with it the consequent loss of time and material. Furthermore, on some of the first pages of the Bible Gutenberg attempted a second printing in red, identifying the start of each book. This second printing was abandoned quite quickly presumably because it was found to be uneconomic. Instead

9. Joseph Moxon, *Mechanick Exercises or the Doctrine of Handy-Works* (Morristown, N.J.: The Astrigal Press, 1989), pp. 34–8.
10. A detailed account of the mechanics of power screws appears in: Joseph Edward Shigley, *Mechanical Engineering Design* (Singapore: McGraw Hill, 1986), pp. 294–300.

spaces were left in the black text for completion by a rubricator. This early abandoning of the second printing is not surprising when one considers that in the worst case a single folio sheet would have had to be presented to the press no fewer than eight times. Any mistake in registration, inking or strength of impression on just one of these visits could result in the whole four-page sheet having to be rejected.

At its simplest, the means of moving the type and paper in and out from under the platen would have been to place the type on a tray sliding on a press table, one end of which was under the platen. The type could then be inked while out from under the platen, the paper placed upon it and some packing placed on top of the paper. The whole could then be slid under the platen for printing and then removed. In practice such a simple arrangement would have caused problems if a number of identical impressions were required. Registering the paper consistently and ensuring that the packing did not jar against the platen would both be difficult. An improvement in registration could be affected by attaching the paper to a frame hinged or accurately located in some other way to the back of the sliding tray. Provided that the paper was always at the same place on this framework and the type not moved on its tray, the relationship between type and paper would stay consistent.

Many commentators have noted the existence of pinholes around the periphery of most early folios including the Gutenberg Bible. Irvine Masson is I believe the first to suggest that the existence of these pinholes is evidence for the use of a frame by the earliest printers and that this was fitted with pins on which the paper was impaled before being placed over the type and printed.[11] His argument for the existence of this frame is that the consistency of the pin-hole positions in relation both to each other and to their occurrence on each leaf implies such a device. His work on pinholes is perceptive, carefully observed and worthy of study, but this assumption is I think unwarranted and takes insufficient account of the sheer impracticality of what is being proposed. Imagine the difficulty in placing a large sheet of damp paper on a set of six widely spaced pins (ten pins in the early pages of the Bible) each of which is located within 2mm of the edge of the paper. Worse, after printing, the sheet must be removed from these pins so that the next sheet can be printed. Subsequently the first sheet must be impaled on the pins again at its other end so that its conjugate page can be printed. This procedure has to be gone through four times for each sheet. It might appear that an alternative is to assume that the paper is impaled only once on the frame which is then turned and inverted to make the four

11. Irvine Masson, *The Mainz Psalters and Canon Missae 1457–1459* (London: Bibliographical Society, 1954), pp. 16–22.

impressions; but this will not do either as the framework would be needed for the next impression. Such a solution would imply multiple identical frameworks. In fairness to Masson it should be said that he himself was uncertain how such a frame could be used.

There are in any case other ways of achieving accurately located pinholes which conform equally well to the observed facts. One such method is outlined below, but before describing it I must first list a number of features about the pinholes in early folios which Masson and others have noted and which have a bearing on the problem.

Masson makes the following points:

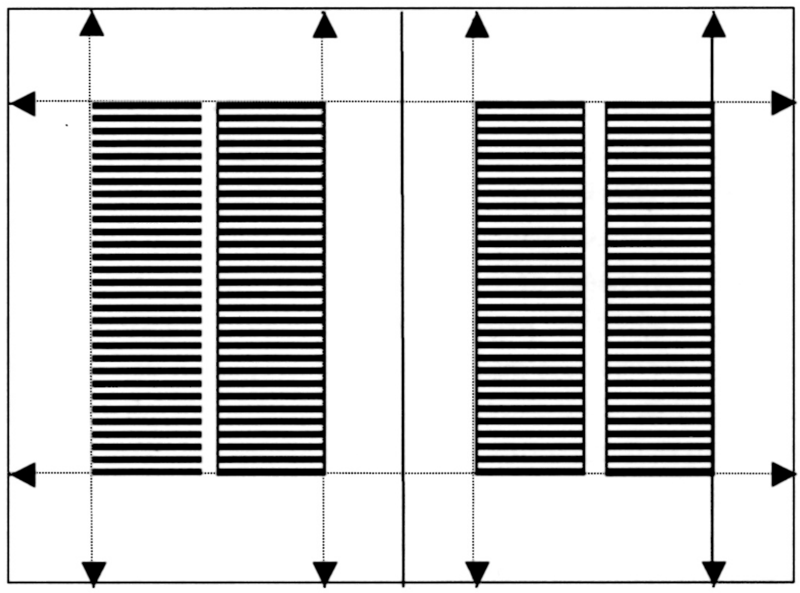
— The Gutenberg Bible has two pinhole patterns: a 10-hole pattern for the pages with 40 and 41 lines (not shown) and a 6-hole pattern for the pages with 42 lines.

— The Gutenberg Bible and the Mainz Psalter are the only two folios that exhibit this 6-hole pattern which is portrayed below (Fig. 12). The rulings show how the pinholes relate to the text columns.

— The number of pinholes per page on other early folios becomes fewer over time.

— Pinholes are always near the paper edge.

Other important observations concerning pinholes in early folios are made by Paul Schwenke, Konrad Haebler and Martin Boghardt.[12] Haebler states that pinholes are always pierced from the recto side to the verso. This is confirmed by both Schwenke and Boghardt. Boghardt notes also that the holes are particularly neat and that ragged and double puncture holes are absent, which is not the case later.

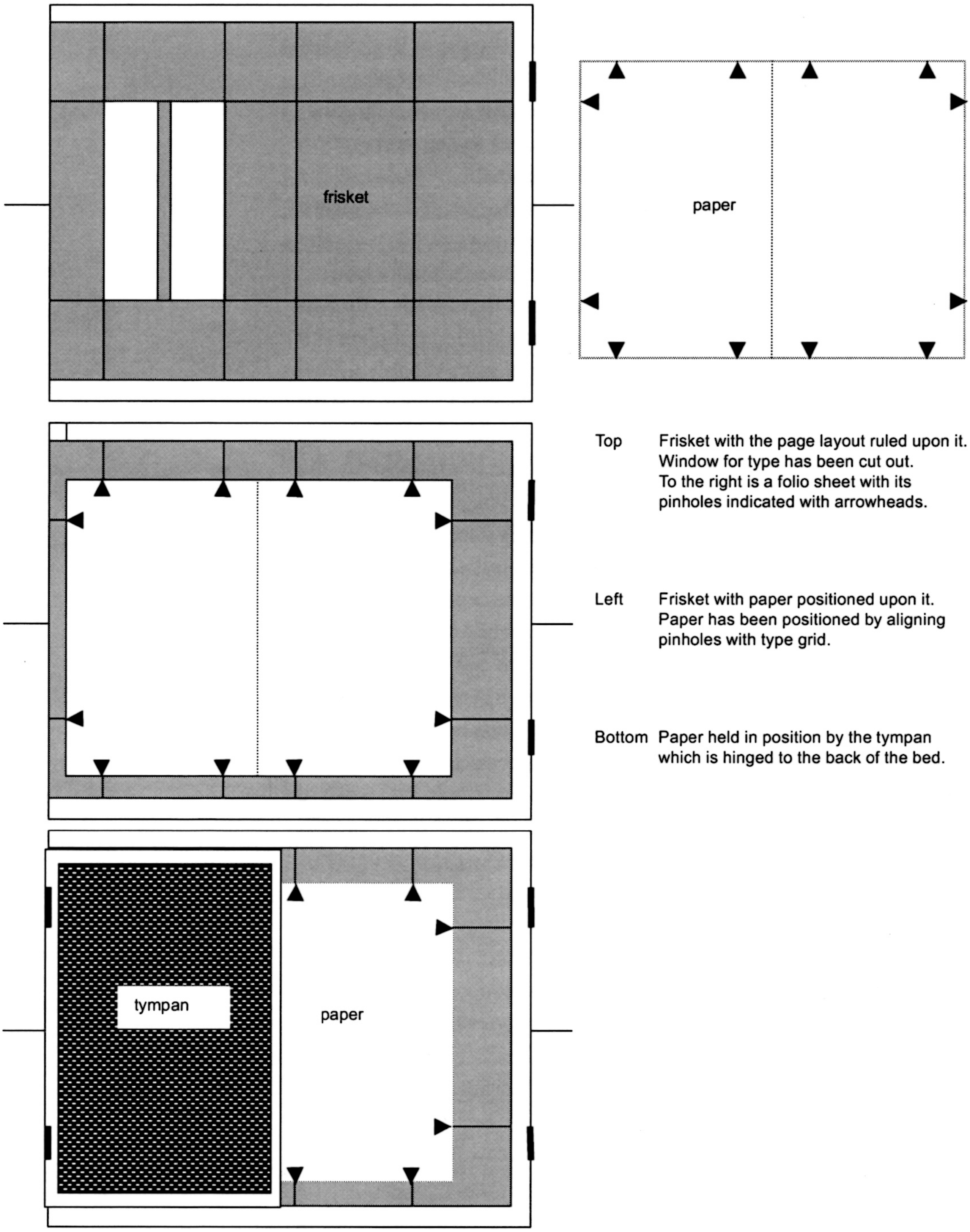


12. The arrowheads indicate the pinhole positions. They are about 2mm from the paper edge.

12. *Faksimile-Neudruck der zweiundvierzigzeiligen Bibel von Johannes Gutenberg, Mainz 1450–1453*, ed. by Paul Schwenke (Leipzig: Insel, 1923); Konrad Haebler, *Handbuch der Inkunabelkunde* (Leipzig: Hiersemann, 1925), p. 27; Martin Boghardt, 'Punkturmaster in grossformatigen Inkunabela und die Datierung des Mainzer 'Catholicon', *Gutenberg Jahrbuch* 1999, pp. 75–88; Boghardt, 'Pinhole patterns in Large-Format Incunabula', *The Library* 7 series 1998, pp. 263–89.

Masson's framework hypothesis assumes that pinpricks in the paper are evidence for pins being used to hold the paper in position during printing. He appears not to have considered that pinpricks can also be simply a means of discreetly marking a particular position on that paper (a technique frequently used in the preparation of manuscripts). It has already been noted that the pinholes in the Gutenberg Bible are in line with the edges of the text and are within 2mm of the paper edge, so that by joining up opposite pinholes the position in which the text block must be printed can be plotted (see Fig. 12). Pricking the sheets could have been done with a bodkin before taking the paper to the press using a pre-drilled template as a guide. In order to minimise this work the paper was probably folded in half first so that both half sheets could be pierced together. This arrangement would bring with it the advantage that the folded edge would provide a straighter reference edge against which to lay the template than could be found on deckle-edged paper. It would also help to ensure that the pairs of rectos and versos were always pierced symmetrically and in the same direction. It is unlikely that the paper was printed while folded: if it had been we would see evidence of this in the Bible. Probably, once a quantity of paper had been folded and pricked in this way, it would have been opened out again and then damped. This would help to flatten the paper and reduce the fold.

We now need to consider how this paper can be positioned on the press so that its single page of type prints accurately in the position determined by the pinholes. The solution involves the use of a frisket, a metal frame hinged to the press bed which has a parchment membrane stretched over it. A window is cut through this membrane to permit the type to print through it. However, in this case the frisket is mounted not on the top of the tympan as it is on later common presses but directly on the front of the press bed. Mounted in this way it serves its usual purpose of keeping clean the non-printed areas of the page but in addition provides a flat surface on which the paper can be positioned before printing. In effect the frisket becomes the equivalent of Masson's framework but without the pins. Instead of the pins a grid is drawn on its upper surface which indicates the position of the type underneath. After the type has been inked, the frisket is laid down so that it rests just above the type. Next the page to be printed is positioned on this grid using the pinholes as a visual guide. This arrangement is represented diagrammatically in Fig. 13. Visually positioning the paper on the frisket is extremely simple with twelve reference points available. Even if one or two of the pinholes miss the paper because of an uneven deckled edge there are always more than enough to ensure accurate



Top — Frisket with the page layout ruled upon it. Window for type has been cut out. To the right is a folio sheet with its pinholes indicated with arrowheads.

Left — Frisket with paper positioned upon it. Paper has been positioned by aligning pinholes with type grid.

Bottom — Paper held in position by the tympan which is hinged to the back of the bed.

Figure **13.**

placement, and it is not surprising to learn that the number of pinholes became fewer over time.

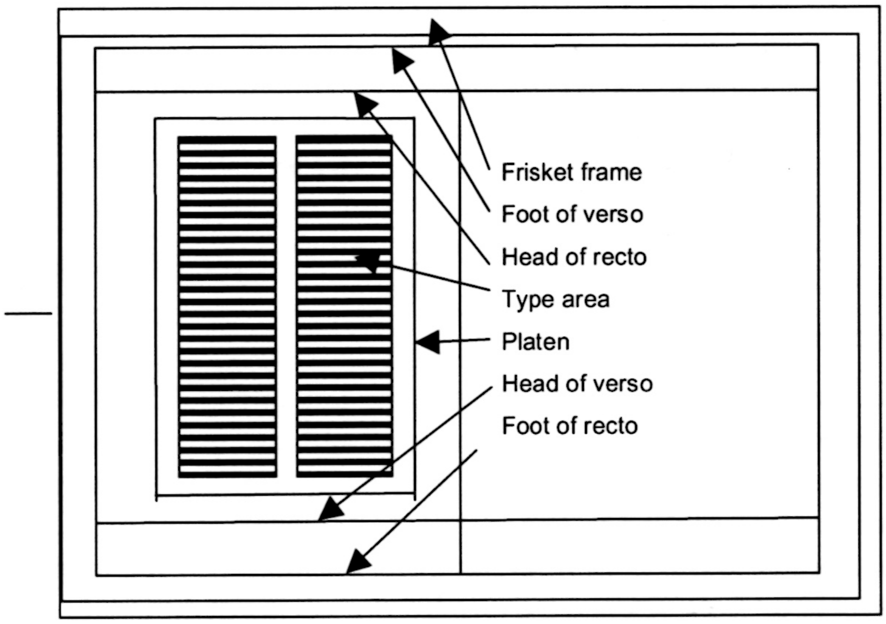
It should be possible to check whether the pages of the Gutenberg Bible were in fact positioned visually by measuring the distance from any particular pinhole to its nearest adjacent text on the same page of different copies of the Bible. If this visual method was used, one would expect to find small but random differences in these distances. There should also be similar differences in the text-pinhole relationship between recto and verso. These random differences of position between different copies should not occur if a mechanised method of registration by fixing the paper to the press with pins had been used. Also in cases where the recto and verso do not back up, we should expect to see double pinholes if a mechanised method had been employed. In 1923 Paul Schwenke published the following observations on pinholes in the Gutenberg Bible which I believe lend support to the notion of a visually based registration system even though he appears not to have had such a system in mind when he wrote it:

> 'The punctures were not only to fix the leaf but also to ensure exact backup on the other side. This is however only possible if the tympan and the type forme are always fixed in relation to each other or can be adjusted in the right position. This capability seems not to have been accomplished for the printing of the bible. Already, on the printing of the recto, the printing shifts up, down or sideways. Sometimes they are slightly skewed. This is more often the way on the verso but without the punctures showing any difference. In some cases the mistake can be found in the same place in different copies but it is mostly the case, as far as can be judged, that the mistake is particular for each separate leaf.' (Schwenke, *Faksimile-Neudruck*, p. 40; translated from the German)

BUILDING A ONE-PULL PRESS

It was apparent from the start that the task of building the press broke down naturally into three separate sub-structures. These were the impression mechanism, the press framework and the carriage and bed assembly. The last of these had to be tackled first: it was important to know just what size a one-pull press bed and carriage should be, because upon it depended the spacing of the cheeks and the length of the front rails. Before I could start on this I had to make some assumptions. The first was that the press that printed the Bible was built specifically for that purpose and so would be the minimum size necessary to accommodate its page size. The second was that although there are good grounds for thinking that the Bible pages were folded in half before printing to facilitate the pricking of the six or more pinholes which occur on each of its untrimmed pages, I thought it unlikely that they would have remained folded during printing: if they had, evidence of this would be apparent in the printing.

My starting-point therefore for estimating the bed size was to make a full-size drawing of the opened out sheet (604 × 414mm) and mark on it the area occupied by type. Next I drew a rectangle on the left-hand page somewhat larger than the type area (230 × 350mm) representing the platen. This was centred over the type area and overlapped its edges by a sufficient amount to avoid accidental misprinting. In the interests of obtaining an even impression the platen and the type had both to lie across the press centre-line but because the type area is not centred on the page the paper has to be offset towards one or other side of the press in order to print it in its correct location. Which side it is displaced towards will depend on whether a recto or verso is being printed. Because of this offsetting of the paper away from the centre-line the press bed must be widened on both sides by rather more than this offset so as to avoid the paper brushing against the press cheeks during printing. In addition some space needs to be added to all sides to allow for the frisket and tympan frames (see Fig. 14).



14. Determining the dimensions of the press bed.

The dimensions which emerged were used to construct an experimental carriage and bed. This was used to check that the whole arrangement would work and also to find the distance that the bed needed to travel from under the platen to the point where the type could be inked; it also enabled the length of the front rails to be determined. Once made, a number of other differences between the one- and the two-pull press became evident. The most significant was the weight of the bed which turned out to be less than half that on a two-pull press. This is because the area of the stone required

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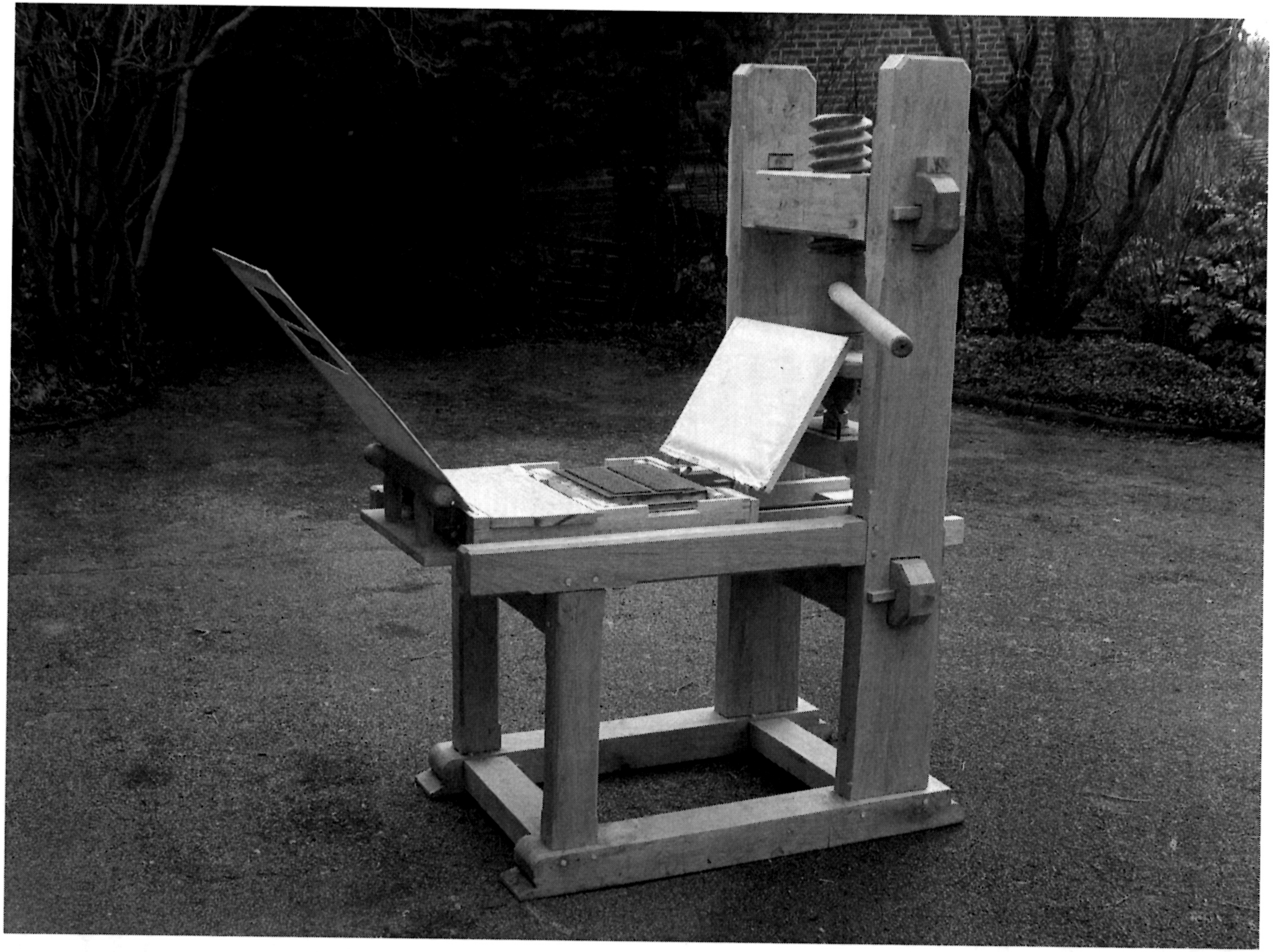
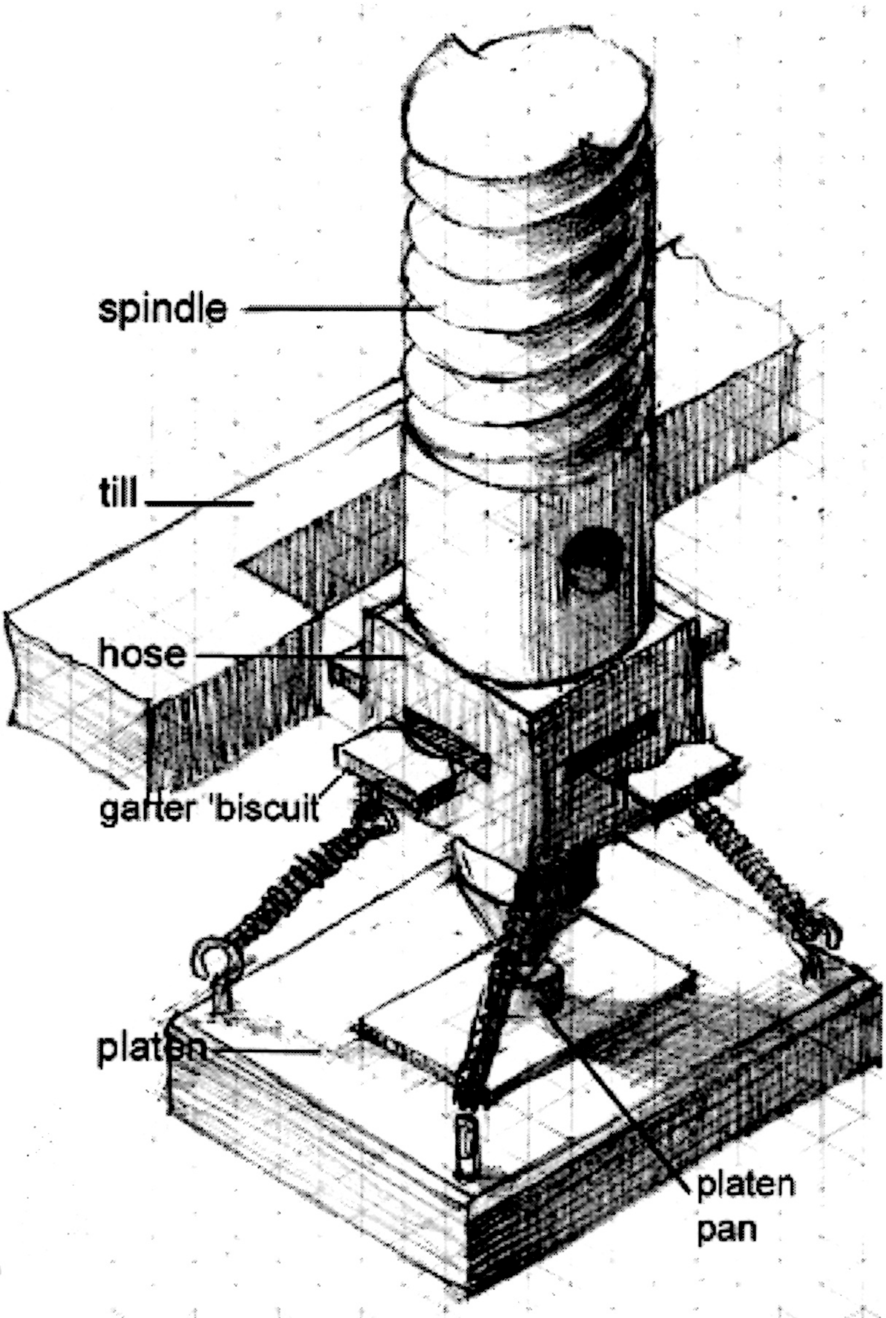
to support one page of type is halved and, as its area is reduced, its thickness can be reduced also. The weight of type on the stone is of course also halved as is the total distance through which the bed has to move. The method used to ensure that the bed slides easily was borrowed directly from the common press. It consists of an open wooden framework fitted between the cheeks and is supported at one end by the winter (the substantial cross-member located directly beneath the platen) and at the other by the front cross-rail. Two iron straps run down its length on which the plank slides. An even simpler arrangement occurred to me in which the front rails act also as guide boards for the plank which is simply allowed to run on battens attached to the winter and front cross-rail. In the end I chose the solution using a separate wooden framework because it made the job of taking the press apart easier. Two quarter-scale variants of the press were constructed before embarking on the full-size version.

The press framework was made in oak with pegged mortise and tenons used throughout. Once completed it occupied an area of 1.83 × 0.70m and stood 1.83m high. The head into which is cut the nut and the winter which supports the press bed while under pressure from the threaded spindle are both very substantial members. They are both fitted with large tusked tenons which pass through mortises cut through the cheeks and are then locked in position with wedges. These joints were used because they frequently occur in medieval illustrations depicting structural woodwork. The press uses a large wooden screw and nut which is turned by means of a metre-long wooden bar. Its principle is the same as that on a common press. The platen-to-nut distance, which has to be adjustable in order to ensure that the bar is able to utilise the whole of its arc between the press cheeks, is managed by moving the nut up or down in its tenons by means of wedges. There are neither cap nor head bolts. The spindle is fitted with a short wooden hose modelled on the one in the Dürer drawing. It is held in position on the spindle by a garter consisting of four small 'biscuits' of wood which are inserted into slits in each of the four faces of the hose. These 'biscuits' run in a groove cut round the spindle and are held in place by the till. From the hose is hung a wooden platen by means of hose hooks and lacings. The spindle has a steel toe which fits into a brass platen pan mounted in the centre of the platen.

The method for making the spindle screw and nut has already been alluded to briefly. It is perhaps the most demanding of the tasks associated with press building and in the light of this a more detailed account follows. The spindle in this case was made from a block of beech wood approximately 900 × 150 × 150mm. Beech was



15. The completed one-pull press reconstruction.



16. Exploded diagram of the impression mechanism. For clarity the nut and the front half of the till have been left out.

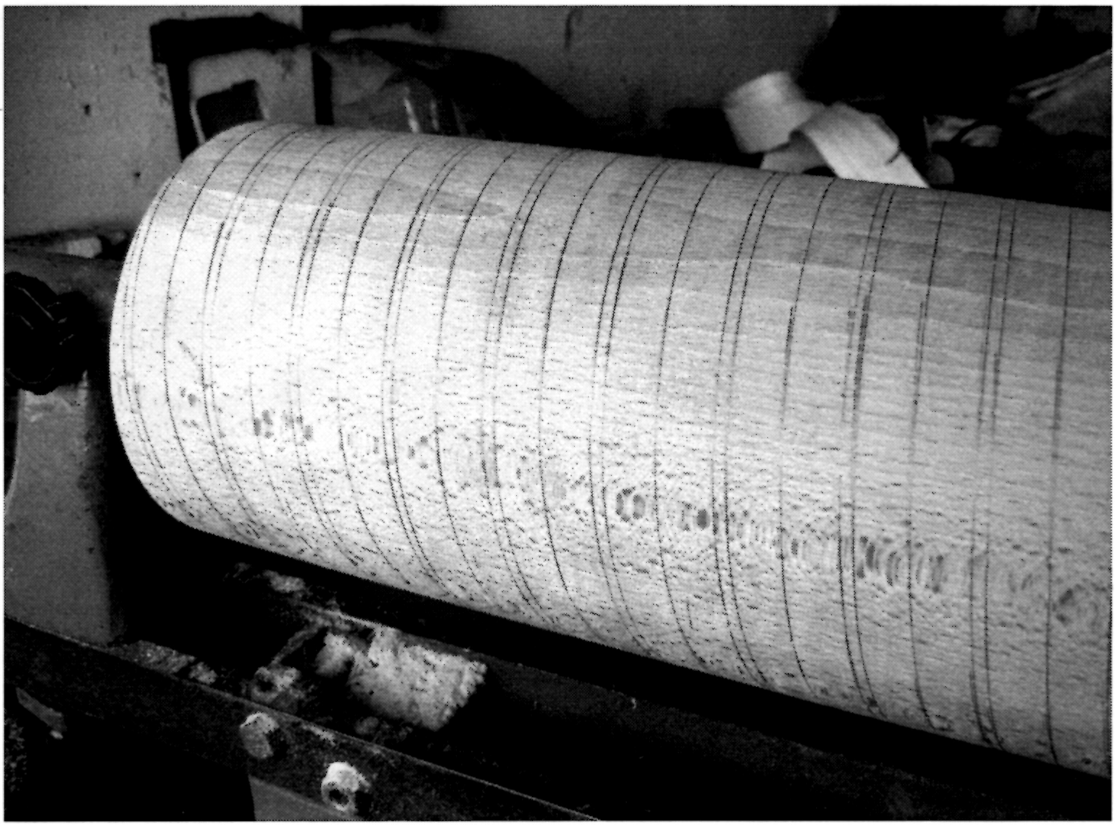
satisfactory but not ideal: its grain is very regular and consistent but it splits rather too easily. If available I would have chosen walnut, which was probably the wood of choice for work of this sort because it can be brought to a high polish. (Brunelleschi is recorded as having specified walnut for the making of the threads used on the cranes employed in the building of the Duomo.)[13]

The block of wood had first to be made into a cylinder approximately 150mm in diameter. In my case most of this had to be done by hand, as at the start the wood was far too heavy and out of balance to risk rotating it on a lathe. Next, the details of the thread to

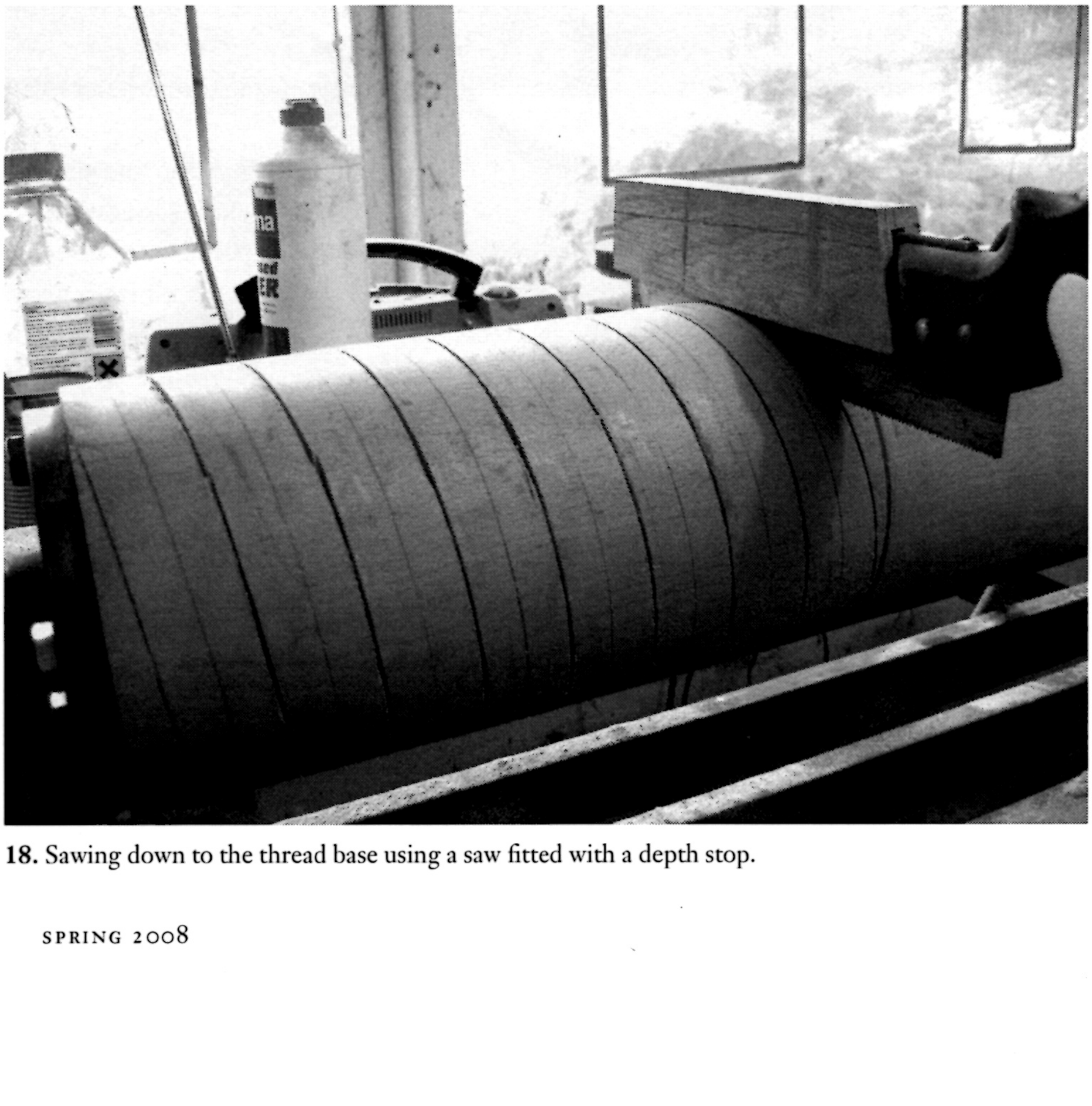
13. Ross King, *Brunelleschi's Dome* (London: Chatto & Windus, 2001), p. 68. King does not provide a specific reference for the information about the woods used but cites Frank D. Prager, 'Brunelleschi's Inventions and the Renewal of Roman Mason Work', *Osiris* 9 (1950), pp. 457–554.

be used had to be decided upon. The factors determining these were the arc through which the thread could rotate and the clearance needed to avoid the tympan striking the platen when being run in. Both were arrived at experimentally. The maximum rotation of the thread was about one-third of a revolution and the clearance needed for the tympan about 21 mm. This implied that the thread pitch (the distance that the thread would travel through the nut in one complete revolution) should be about 63 mm. In the event I chose 64mm because the even number made it easy to set the thread out as a 'two-start thread'. A two-start thread is not essential but does have strength advantages because the central core of the thread can be left thicker. It can best be thought of as two tapes wrapped around a pencil with their edges abutting. Two strips of paper, 32mm wide and about 2 metres in length, one for each of the two threads were prepared. Two lines 4mm apart were scribed down the centre of each strip. These two strips were then wrapped around the beech cylinder in a spiral with their edges abutting. The slope of the spiral was such that in one revolution the two paper strips progressed 64mm down the cylinder. The starting points for these strips were 180 degrees apart. They were wrapped round the cylinder for about 300mm. Next, the edges of the paper strips and the two ruled lines running down their centres were pricked through about every 50mm in order to mark the wood underneath. The papers were removed and the prick marks in the wood joined up producing a number of interlocking spirals. The spirals produced by the paper edges mark the position of the bottom of the V-cut threads. The two parallel spirals 4mm apart on each strip mark the top surface of the threads (which don't come to sharp points). These lines indicate where the cut downwards to the base of each thread on both sides must start. Once the thread has been marked out, the depth of the V-section cut has to be established. This is done by using a hand saw fitted with a depth stop set to the thread depth. In my case the spiral groove produced was too narrow and had to be widened by re-sawing with an improvised saw fitted with a double blade. Next the sloping sides of the threads had to be carved out using a chisel. Figs 17-19 show the various stages.

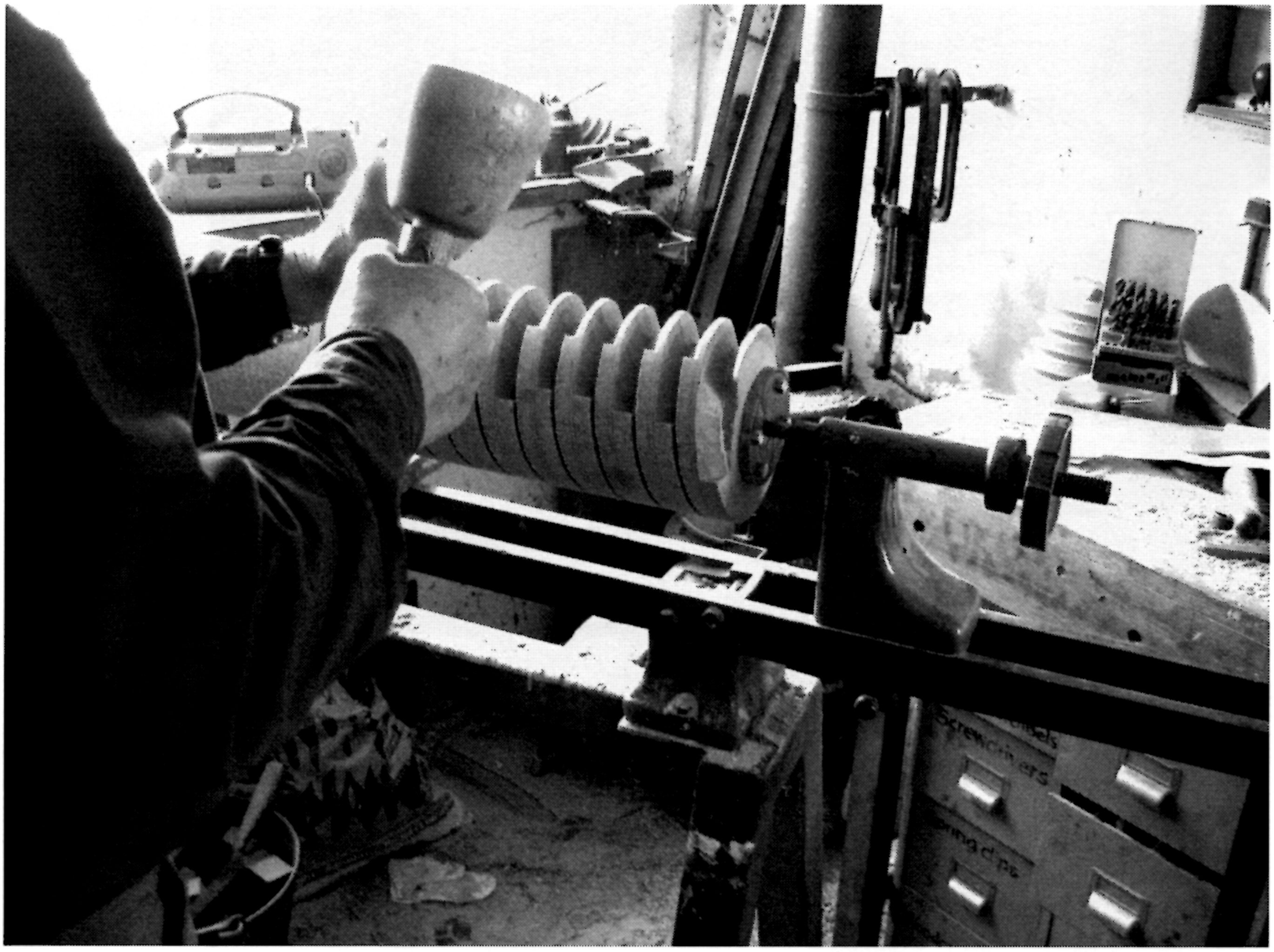
Once made, the cylinder with its thread at one end can be used to cut a nut which fits this thread. However, before this can be done about 300mm of the unthreaded end of the cylinder must be reduced to the diameter of the threads core (its minimum diameter). In addition a 50mm hole needs to be drilled through the middle of the cylinder so that a bar can be fitted to provide a means of rotation. Next it is necessary to make a temporary nut. This consists of a substan-



17. The cylinder marked out before cutting.



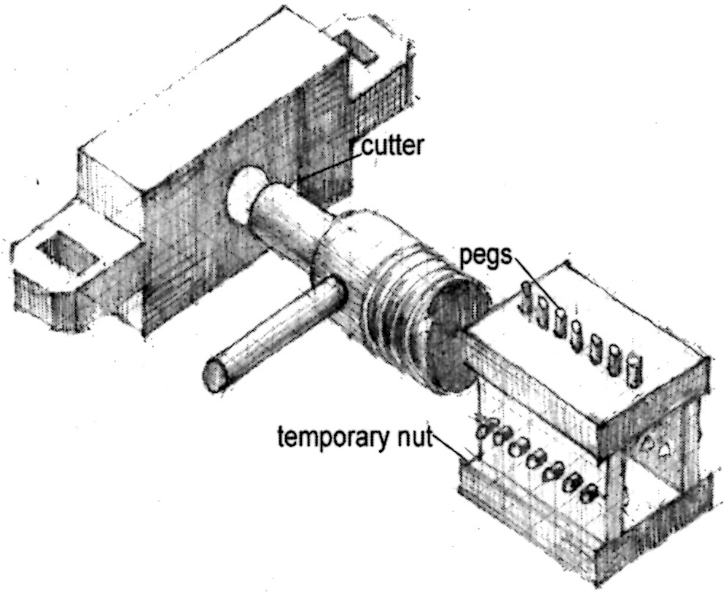
18. Sawing down to the thread base using a saw fitted with a depth stop.



19. Cutting out the thread with mallet and chisel.

tial open-ended wooden box made to fit closely round the thread. On the centre-line of each face of this box 20mm holes are drilled to coincide with the grooves in the thread. Into these holes are inserted sharpened wooden pegs. Next, the piece of wood which is going to become the press nut (its dimensions approximately 900 × 150 × 225mm) has to have a hole equivalent to the minimum diameter of the thread drilled through the centre of its wide face. Finally a cutter fashioned in my case from a worn-out file was fitted into a slot cut in the reduced portion of the cylinder about 50mm from the end. The various pieces were then mounted rigidly on the bench in the order depicted below (Fig. 20).

At the start the cutter is set so that only its tip is sticking out from the spindle. As the spindle is turned the cutter is forced into the new nut and cuts a spiral in the inside. Once through the nut the rotation of the spindle is reversed until the cutter emerges again. It is then set to cut a little more deeply. Only a very small amount of wood can be removed at each pass. The depth of the cut is measured after each cycle. Once down to depth the spindle is removed from the rig and



20. Diagram showing the set-up for cutting the nut.

rotated through 180 degrees before being fitted back again so that the second of the two concentric threads can be cut. Once the two threads for the new nut have been made it remains only to check that the thread runs through it satisfactorily. Tallow was applied to both to assist with this. Fig. 21 shows the inside of the completed nut. On completion of the job of making the nut the threaded cylinder can

21. The nut.

22. Drawing of the spindle.

now be modified so that it becomes the press spindle. To do this the end containing the cutter is sawn off and the remaining narrow portion is tapered as shown in Fig. 22.

At the top of the taper a groove is turned to accept the four wooden 'biscuits' which make up the garter. This is provided to prevent the hose from sliding down the tapered spindle. Finally a small steel point was fitted to the tip of the spindle to help prevent wear. A drawing of the spindle with the hose attached appears in Fig. 16. The hole through the hose has to be tapered to fit closely to the spindle taper.

The method of registering the paper on the press is the visual one described earlier. The tympan and frisket are mounted on the press in ways that do not correspond with later practice but which are, I think, quite logical on a one-pull press. They can be seen in Fig. 15. The frisket (which in area has to be somewhat larger than two leaves of the Bible because the folio sheets are to be printed 'opened out') is mounted directly on the coffin (the wooden frame that encloses the press stone) in the position which on a common press would be occupied by the tympan. The tympan, because on a one-pull press it needs to be only a little larger than a single page, has been mounted at the other end of the coffin.[14] This arrangement has a number of virtues. First, it holds the paper in position on the frisket which otherwise might move, as there are no locating pins with the visual registration described above. Second, if a conventional arrangement had been followed it would have been necessary to make the tympan twice as big even though half of it would never be used. Also, the awkwardness of having to mount the frisket on the top of the tympan frame 'on the fly', as is done on a common press, is avoided; the frisket can now do its normal job of keeping the white non-printing areas of the page clean and can as well support the paper above the type while it is being positioned. Before inking the type for the first time the frisket is so adjusted that its surface is parallel to but a few millimetres above the face of the type. The springiness of the frisket is such that it does not prevent the paper and type making contact when the platen is lowered to take an impression.

For the press's first printing trial, a page of the Gutenberg Bible set in a remarkably fine recutting of Gutenberg's type cast by the

14. At an earlier stage in my reconstruction I considered two alternatives to the tympan arrangement described here. The first was to dispense with it altogether and simply have the printer place loose packing on the back of the paper before running it into the press. The second was to attach the packing to the base of the platen. On reflection I decided that neither of these arrangements was good enough. The Gutenberg Bible involved a production run of close to a quarter of a million impressions. Each one of these had to be accurately positioned then printed to the highest standard achievable. Only a press developed to the point where production issues of this sort were properly addressed would have been good enough.

Dale Guild Type Foundry in New York was used. The type was set by Kitty Maryatt of Scripps College, Claremont, California. The job involved carefully identifying which of Gutenberg's many 'sorts' had been used in each location and then copying the inter-character spacing against an accurate photocopy of the original. The typesetting of this single page took more than forty hours. It was mounted on the press stone in a wooden tray closed on all four sides, not a galley, then held in position using wedges. Finally, the platen to nut distance was adjusted in order to ensure a good impression. The type was then inked up using inking balls and a pull taken on the uncut frisket. The printed part of the frisket was then cut out to provide a 'window' through which the type could print. This was done with the frisket still on the press to avoid losing position.

Finally the type was inked again and the first sheet of hand-made paper was positioned on the press. This had been prepared the previous evening by being cut to folio size, folded in half, pierced using a metal template then opened out and damped and left overnight. We were of course on camera for the final assembly and preparation, so that when it became time to take the first print there was a good deal of tension in the air. What a relief then, nay what a joy, when we saw that the print was good. I think I know now a little of how Gutenberg must have felt.

Acknowledgements

My thanks are due, first of all, to Wavelength Films for commissioning the building of the press here described. By doing so they turned a twenty-year-old daydream into what for me has been a fascinating practical experiment.

This account started out simply as a set of notes about the project. With the active encouragement of my friend and one-time colleague Margaret Smith it has grown into the present paper. Without her help it certainly would not have seen the light of day. She has worked tirelessly with the reading of drafts, the locating of references and in the provision of material from her own library. I cannot thank her enough.

My thanks are due also to all who have been prepared to discuss with me the historical and the practical engineering issues involved. I would mention in particular James Mosley and Lotte Hellinga who have both been generous with help and advice about early printing and Steve Boden who has helped me with his considerable engineering expertise. However, any factual errors which appear here are my own.

My thanks are due also to Ailsa Holland for her help in translating the German texts.