MAKING MASTER GUITARS

Roy Courtnall

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ROBERT HALE · LONDON
STEWART-MACDONALD · OHIO

Contents

1 Antonio de Torres (*1817–92*)

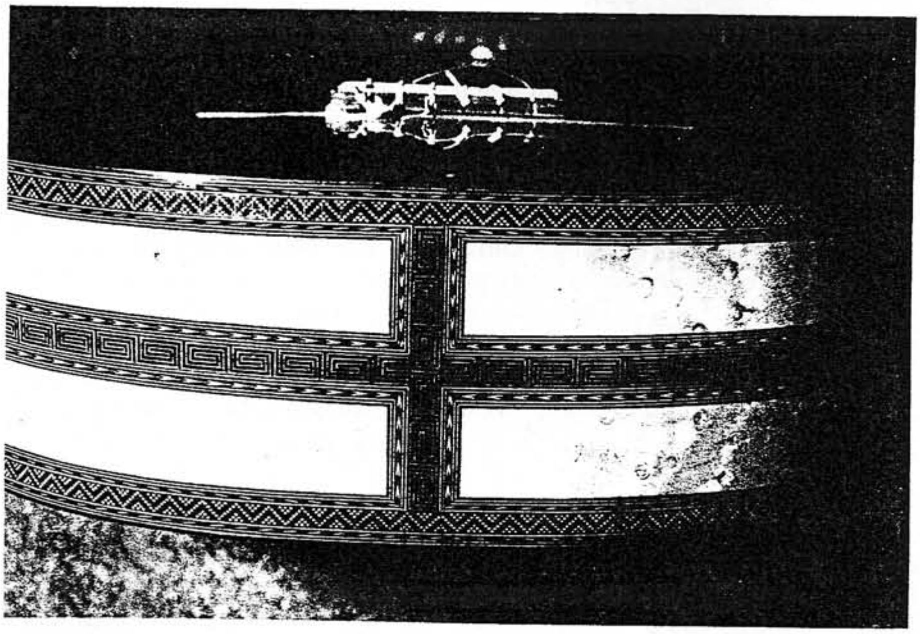
Background

1-1 Guitar by Antonio de Torres

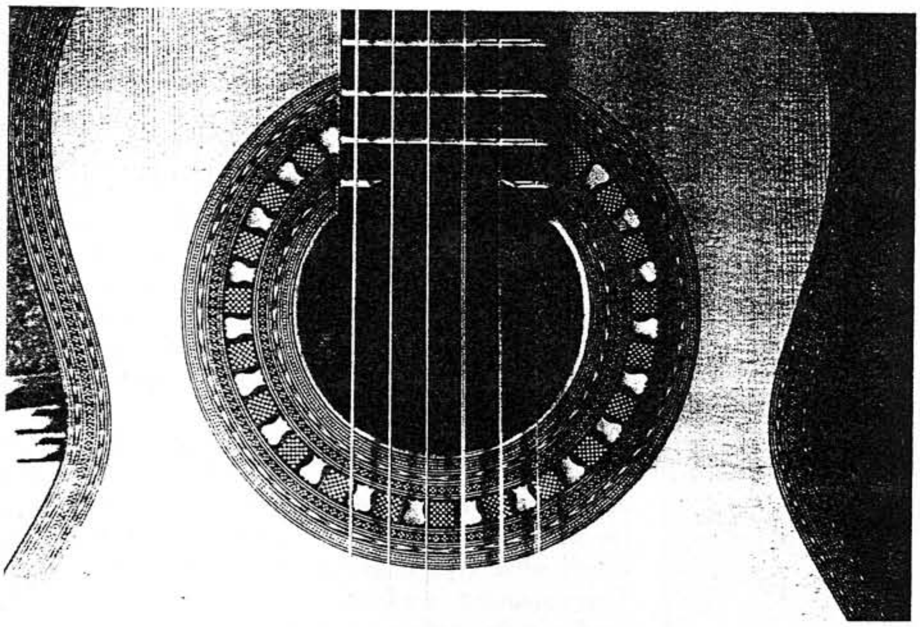
The legendary figure of Antonio de Torres has created much controversy in the guitar making world. His followers are convinced that the Torres contribution to guitar design is paramount, and that his reputation is more than justified. His critics view Torres much more as being one maker amongst many, and not all contemporary makers would acknowledge him as a major influence on their work. This is especially true of the most recent experimenters in guitar design, who are attempting to discard virtually all preconceived ideas in the hope of making radically new instruments. They are utilizing scientific data as their major source, rather than any historical or intuitive references.[1]

Any important historical figure attracts a certain amount of mythology; about their life, their work and their ideas. This is especially true in the absence of any well-documented records on which to draw. Until recently the life of Torres was shrouded in mystery. Many stories about him could not be substantiated. The English-based guitar maker, José Romanillos, has to a large extent rectified this problem by undertaking a thorough research into the life and work of Torres.[2] He has pieced together a vast amount of documentation and has catalogued and examined some sixty-five Torres guitars which could be traced. The result is that there is now a much clearer picture, not only of the life and times of Torres, but also of the contribution he made to guitar design. The sixty-five guitars provide what must be a substantial summary of his work, and it is now possible to see just how his work developed – different body shapes; the method of strutting; the range of decorative inlays, and we also have an insight into his method of construction.

Torres made his first guitar around 1840. By 1854 he had a workshop in Seville, which was located in a district occupied by a number of other guitar makers. He would have seen the guitars made by José Pernas, which were typical of the design currently in use. This consisted of a smaller body shape, a bridge with fixed saddle, rather wide struts, and an elaborate, scrolled head design. Torres, however, was already producing guitars that were radically different from this earlier pattern – his instruments had larger lower bouts, and incorporated the seven radial fan struts that were to become the hallmark of modern strutting design. At that time, most strutting consisted simply of three large transverse bars. Torres must have had an intuitive grasp of the acoustic properties of wood – he selected his materials more skilfully than many of his contemporaries, who often produced instruments as decorative items of beauty rather than as functional musical instruments. Although some of Torres' guitars exhibit elaborate marquetry and other decorative features, many are relatively simply



1-2 Detail of rib inlays on Torres' most decorative guitar, made in 1858 (FE 08)



1-3 The rosette on FE 08

adorned, and his main obsession was clearly with the functioning of the instruments. When he did make use of decorative techniques, they were carefully controlled so as not to become overpowering.

By 1860 Torres had exhibited his guitars at major exhibitions, and was well established as a maker. Nevertheless, guitar making was not a lucrative business, and he stopped making instruments in favour of opening a retail shop which sold china. It is thought that the general depression in Spain was responsible for his increasing financial difficulties. Guitar makers generally produced two types of instrument – basic student models for the amateur player, and elaborate versions for professional musicians. The large amount of time that it took to produce the finest guitars must have made it very difficult to charge a price that would reflect the true amount of labour that went into their construction. By 1875 Torres had once again started making guitars, producing about six instruments a year. This modest output doubled to twelve a year from 1883 to 1892. It is, however, the guitars produced earlier on in his career which were the most successful. The later instruments did not produce the same quality of sound. Torres died on 19 November 1892. The majority of his work was carried out between 1852–69, and then between 1875–92.

shaped to a 'gable-end' on the earlier guitars, but later they were gently rounded off. The harmonic bars are not gable-shaped in the way that later became popular, but are left rectangular in section along their entire length, so that the full section of the bar makes contact with the rib.

On the majority of instruments, Torres joined the ribs to the back with continuous lengths of kerfed linings, rather than the individual blocks which were in use at the time. This is still an aspect of guitar design that varies from one maker to another, as it is unlikely that either method has any acoustic benefit over the other. The thin soundboards were to a large extent strengthened by Torres' use of a 'solera'. This is a workboard which has been cut to the outline of the guitar, and on which the instrument is assembled. Rather than being left flat, Torres shaped the lower bout area of the solera, below the soundhole, so that the required concavity would be built into the soundboard – it would appear as a dome on the outer surface of the instrument. The fan struts could be glued down on to the soundboard, which in turn was positioned on this shaped board. The result was that the struts and soundboard would be fixed permanently into the domed shape, resulting in a more rigid and strengthened structure.

Torres made several guitars in which the lower harmonic bar (running transversely across the soundboard, below the soundhole) had openings cut in it, so that the bars are not in continuous contact with the soundboard. The soundboard is vulnerable to shrinkage and expansion across its width, as temperature and humidity levels alter, and this is a way of allowing more scope for the wood to move, than if the bars are fixed rigidly right across their full width. It also extends the vibrating area of the soundboard, rather than cutting this off suddenly at the position of the bar. Torres then extended the outer fan struts through these openings, so that they ended up quite close to the soundhole. This feature of open bars combined with longer fan struts passing through them is often thought of as being the innovation of the French maker, Robert Bouchet. As Bouchet himself has confirmed that he took his model from Torres, whose instruments he had examined, it is difficult to understand how this myth arose.

Plantilla

Torres produced guitars that were often about one fifth larger in soundboard area than the instruments commonly in use at the time. Although larger bodied guitars had been made at various times prior to this, it seems that Torres was the first maker to carry all the other aspects of the design along with this change – the strutting, the plate thicknesses, and the doming of the soundboard all contributed to the new design. His instruments were so successful that his design immediately superseded the old patterns. As a carpenter, Torres would have understood the basic geometry needed for setting out many common items produced in the workshop. Attempts have been made to analyse his plantillas (the outline shape of the instrument) in geometric terms, but it is most likely that he arrived at the shapes intuitively.

It used to be thought that every instrument made by Torres had a different shape. This must have been due to the lack of any accurate comparison of a large number of his guitars. More recent research now shows that Torres used five shapes in all. Like any maker, he must have spent some time experimenting with different sizes and shapes in an attempt to find the perfect outline. He may have been restricted by financial considerations and the lack of ideal wood supplies, which could itself guide the maker to suit the shape of the guitar to the given material. Even within the range of different sizes, the plantillas have a uniform aesthetic quality, which identifies them with this maker.

Neck

Compared with more modern instruments, the necks of Torres' guitars are rather narrow, often being 47 mm to 49 mm wide at the nut. The thickness of the neck at the nut is typically about 20 mm, increasing to 22 mm at the 9th fret. The neck and ribs are joined by the traditional method of cutting slots into the neck, into which the ends of the ribs are located. The heel is laminated from several pieces of wood, sometimes as many as six. The end of the heel is almost a semicircle, rather than the more angular design favoured by many later makers.

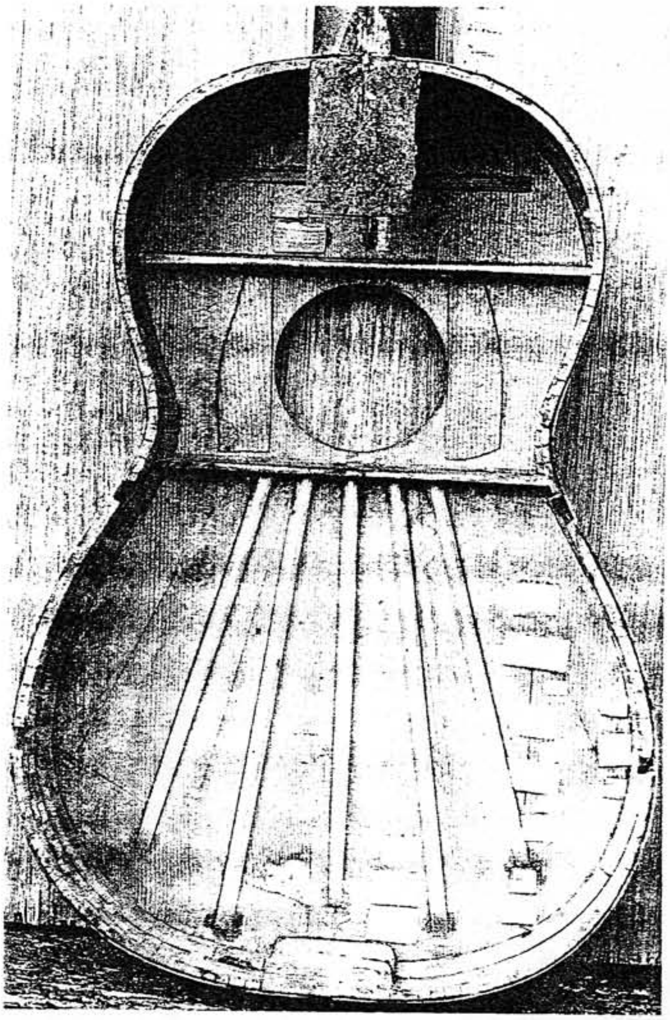
Head

Torres maintained the same head motif for most of his instruments, although the proportions varied according to the size of the guitar and the width of the fingerboard. It consists of three arches, the central one being the largest. He used machine heads on some guitars, and tuning pegs on others. The head is joined to the neck with a spliced joint.

Rosette

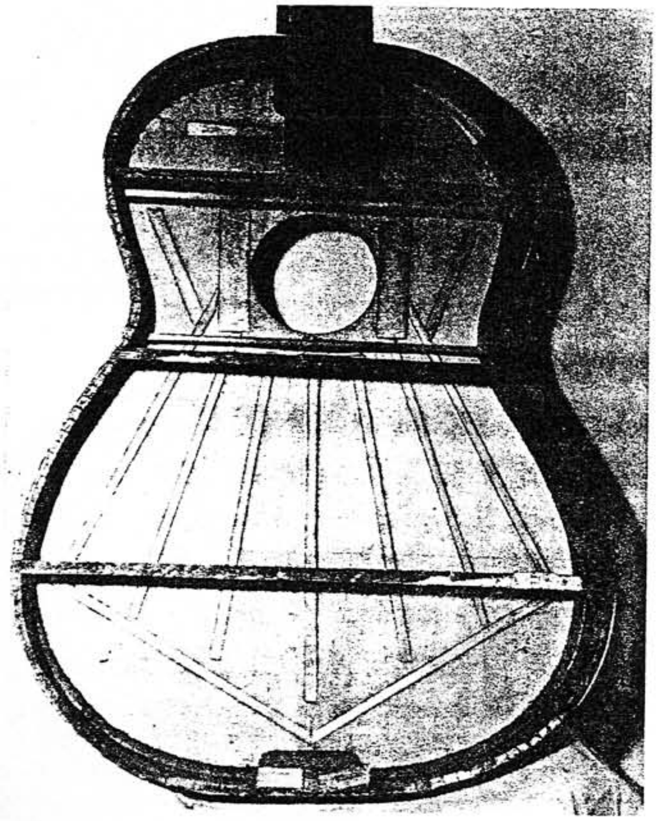
Prior to Torres, the decorative aspect of guitar design was quite different – instruments were often lavishly embellished with mother-of-pearl, as well as wood inlays, and this decoration was not confined to the peripheral areas of the instrument, where there would be little influence on the acoustic functioning of the wood. Many instruments, having their soundboards covered with inlays, must have been adversely affected in this respect. Torres is largely

Soundboard and Strutting System



1-4 The inside of a Torres guitar made in 1888. The struts are not original – pencil lines mark the positions of the original struts. This guitar has now been restored to its original strutting layout by José Romanillos. The second set of plans provided at the end of this chapter is based on this instrument

Torres thought of the soundboard as the single most critical component of his guitars – he was careful to select suitable spruce, which he thicknessed according to its characteristics of stiffness and annual ring growth. In fact, his fascination with the soundboard was so great that he was motivated to produce his now famous papier-mâché guitar in which the back and ribs were constructed from cardboard, thus demonstrating the overriding importance of the soundboard in tone production. As this instrument is not in a playable condition, it is impossible to determine whether the experiment supported his idea about the relationship between the soundboard, and the back and ribs. In general, his soundboards are thickest in the central area; around the bridge and above the soundhole (2.5 mm), thinning out in the peripheral areas to as little as 1.4 mm. The papier-mâché guitar has a peripheral soundboard thickness of only 0.4 mm. All measurements of plate thicknesses on old instruments must be treated cautiously, as repeated repairs and re-finishing, in which there is a temptation to sand away all dents and scratches, may result in considerable thinning of the surface. Most contemporary makers are unlikely to reduce any area of the soundboard to much below 2.0 mm.



1-5 The inside of a Torres guitar made in 1884. The transverse back bars have remained in place after the back was removed. Note the rib strengthening bars

The fact that Torres wanted a much larger soundboard than was currently in use meant that he required a stronger method of supporting this vulnerable span of wood. The idea of using struts laid out like a fan was not entirely new – a gradual development towards this pattern was occurring during the eighteenth century, but Torres is certainly responsible for establishing its use and for perfecting its symmetrical design. Romanillos' research shows that Torres set out his struts geometrically, being based on two isosceles triangles which are joined at their bases. This creates a 'kite' shape, in which the strut positions are set out symmetrically. Torres was the first maker to use this system. He varied the dimensions of the 'kite' according to the overall size of the guitar, so as to avoid the outer struts being too close to the ribs. Having established this method of strutting, Torres maintained its use on all his guitars, although the number of fan struts was reduced to five on the smaller instruments. The fan struts were

From outer circumference:

Outer border:
0.25 black
0.25 white
1.0 brown
0.25 white
1.0 white and brown squares
0.25 white
1.0 brown
0.25 white
1.75 black
0.25 white
1.0 brown
0.25 white
0.25 black
0.25 white
1.0 white
1.0 green } with black squares
1.0 white
0.25 white
0.25 black
0.25 white
1.0 brown
0.25 white
0.25 brown

Central section:
1.5 green and white herringbone

Inner border:
0.25 brown
0.25 white
1.0 brown
0.25 black
0.25 white
0.25 white
1.0 white
1.0 green } with black squares
1.0 white
0.25 white
0.25 black
0.25 white
1.0 brown
0.25 white
1.75 black
0.25 white
1.0 brown
0.25 white
1.0 white and brown squares
0.25 white
1.0 brown
0.25 white
0.25 black

Torres 2

This rosette is 16 mm wide.

From outer circumference:

Outer border:
0.9 black
0.25 white
0.9 black
0.25 white
0.9 red
0.9 brown
0.9 red
0.25 white

Central section:
0.9 green
0.25 white
0.9 brown
0.25 white
0.9 green
0.25 white
0.9 brown
0.25 white
0.9 green

Inner border:
0.25 white
0.9 red
0.9 brown
0.9 red
0.25 white
0.9 black
0.25 white
0.9 black

Materials

Torres used a great variety of materials, unlike most modern makers who tend to use only a narrow range of established woods. Cypress, maple, rosewood, walnut, mahogany and cherry were all used for the backs and ribs, although his preference does seem to have been for Brazilian rosewood. The soundboards were invariably of spruce, but he appears to have had difficulty obtaining matched sets. Cedar was always used for the necks.

soundboard:	European spruce
back and ribs:	rosewood, maple or cypress for the best instruments
neck:	cedar
fingerboard:	ebony
bridge:	rosewood, inlaid with mother-of-pearl
internal struts:	European spruce

Soundboard Thickness

2.5 mm in the central area; 1.4 mm around the periphery

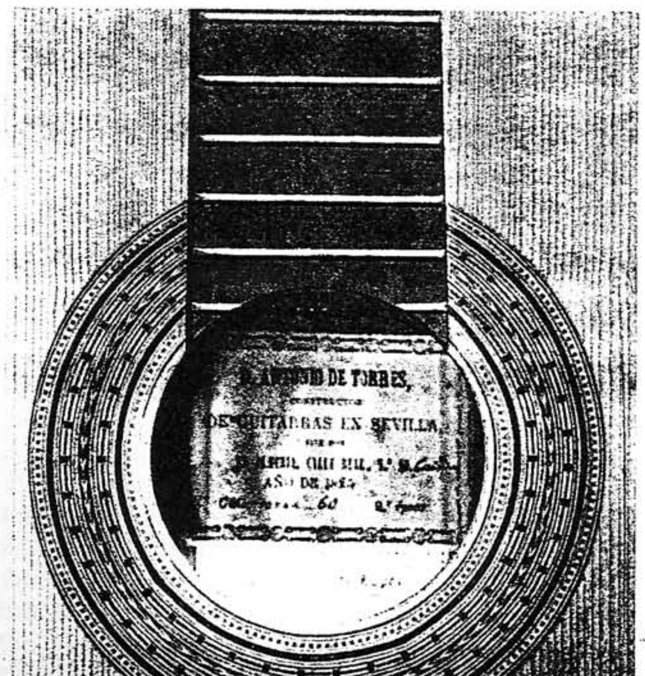
1-6 The rosette on a Torres guitar made in 1859. The central motif was later used by Hermann Hauser as the basis for his own rosette designs.

responsible for creating a new aesthetic in the decorative side of guitar design – the style became much more restrained, and often quite austere. The kind of musical instrument whose function was more that of a decorative object which would enhance its owner's surroundings, so popular during the eighteenth century, gave way to a desire for an improved sound and resonance. Nevertheless, the rosettes that Torres constructed were often quite complicated and he found ways of making extremely fine motifs, including herringbone, intertwining rope, and chequered patterns, which must have been difficult to construct, given the lack of modern woodworking machines. Unlike many later makers, who produce rosettes in bulk, Torres must have made each one individually since, although he often uses similar motifs, the overall rosettes are mostly different. The cheaper instruments may simply have a number of strips of different coloured woods laid into a groove cut in the soundboard. The important guitars gave expression to his finest marquetry techniques. He usually avoided stained woods, mostly using a range of naturally coloured veneers, except for green, which has traditionally been obtained by staining sycamore or satinwood with a solution of ferrous sulphate. A design he often used consists of a rectangular chequered motif for the central pattern, surrounded by borders of herringbone. Sometimes there are additional borders of a cross motif. (This cross motif was used by the German maker, Hermann Hauser, for the main part of his rosette design.) These various patterns are separated from one another by numerous long, thin strips of veneer which have been inserted all the way round the circumference. Torres constructed the rosettes by first making up the component parts, and then setting them into grooves cut in the soundboard. Each constituent circle of design was inserted separately. (This is the method described in Chapters 13 and 14.) Most makers after Torres worked with much the same kinds of designs that he had used, which helped establish the visual impression of the modern concert guitar.

Details of two different Torres rosettes follow.

Torres 1

This rosette is 27 mm wide.



1-7 The rosette on a Torres guitar made in 1884 (SE 60); see (1-11)

Back Thickness

1.2 mm to 2.2 mm; thickest in the centre

Scale Length

650 mm on the best instruments, others were between 645 mm and 602 mm

Comparison of Dimensions of Two Torres Guitars

(measurements in millimetres)

(Torres made several different sizes of guitar. The larger 1864 instrument is typical of his most successful guitars.)

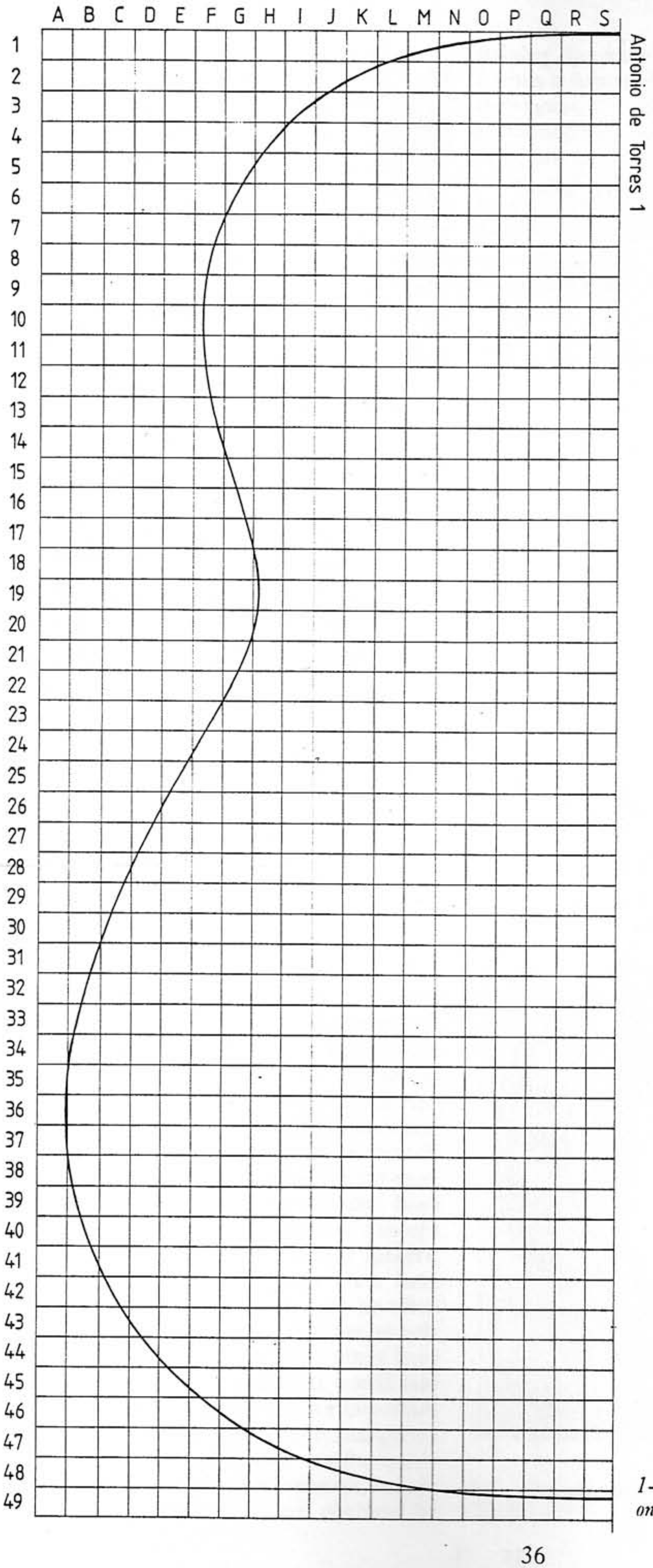
year	body length	width at upper bout	width at waist	width at lower bout	body depth at end-block	body depth at heel
1864	483	272	235	360	95	90
1888	425	220	178	283	78	72

The Plans

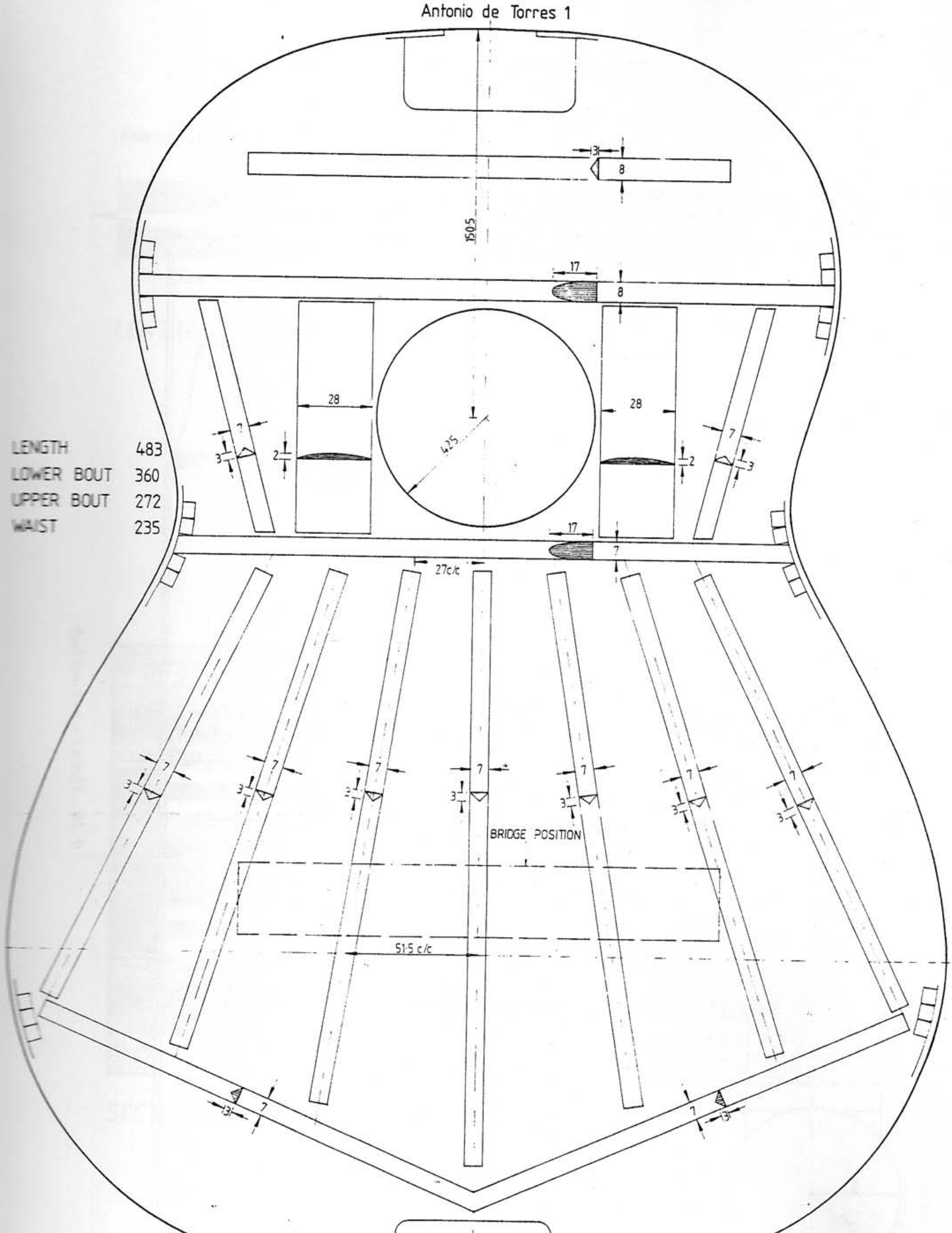
Two different sets of plans are provided for Torres. The first is based on one of his best instruments, and is typical of the larger bodied guitar that he developed. The second is a much smaller guitar, with a scale length of 604 mm.

Notes

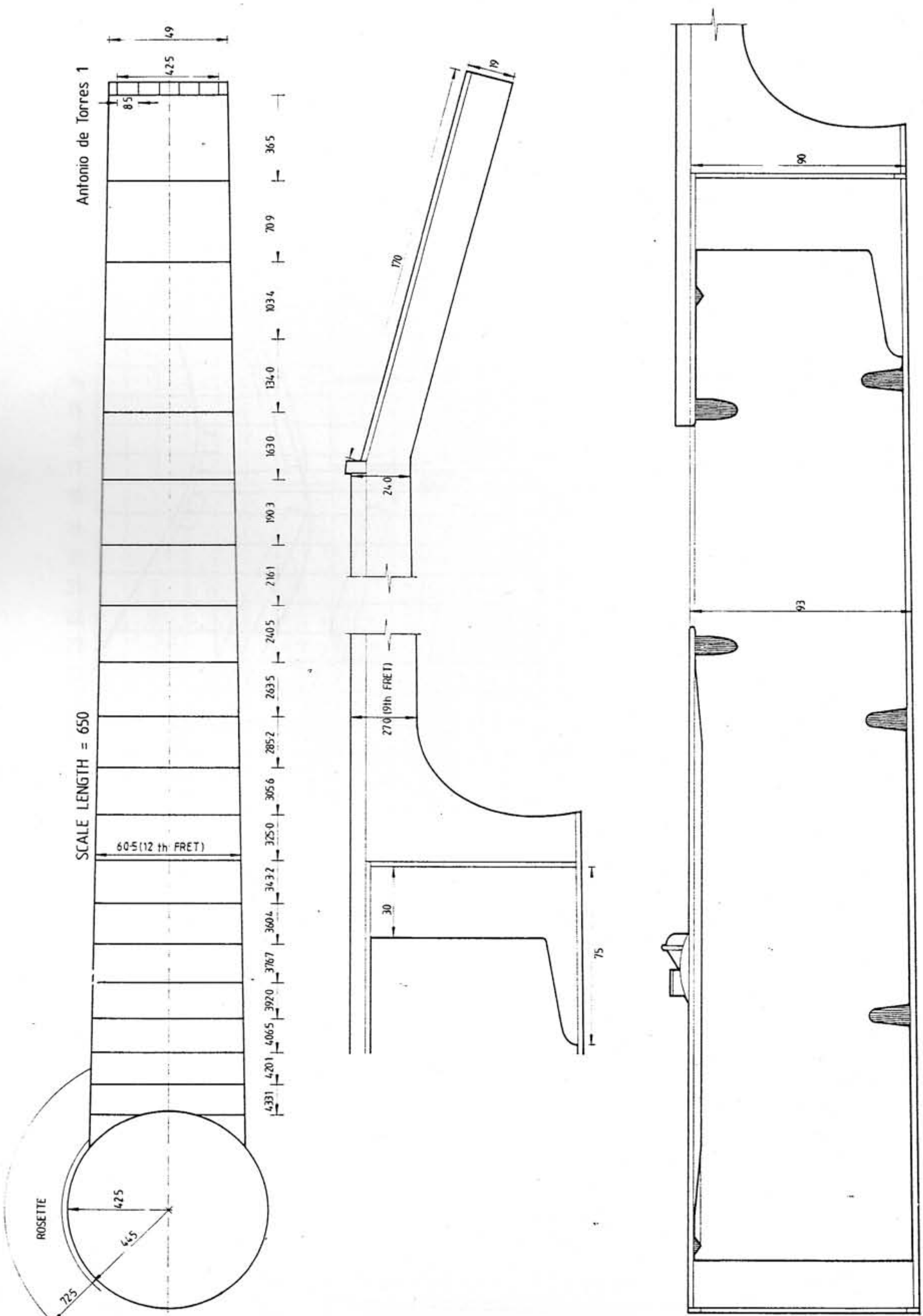
1 A good example of the modern trend in guitar design can be seen in the Kasha method (see *Guitars* by T. and M. Evans and *American Lutherie*).
2 Romanillos, José, *Antonio de Torres – Guitar Maker – His Life and Work.*



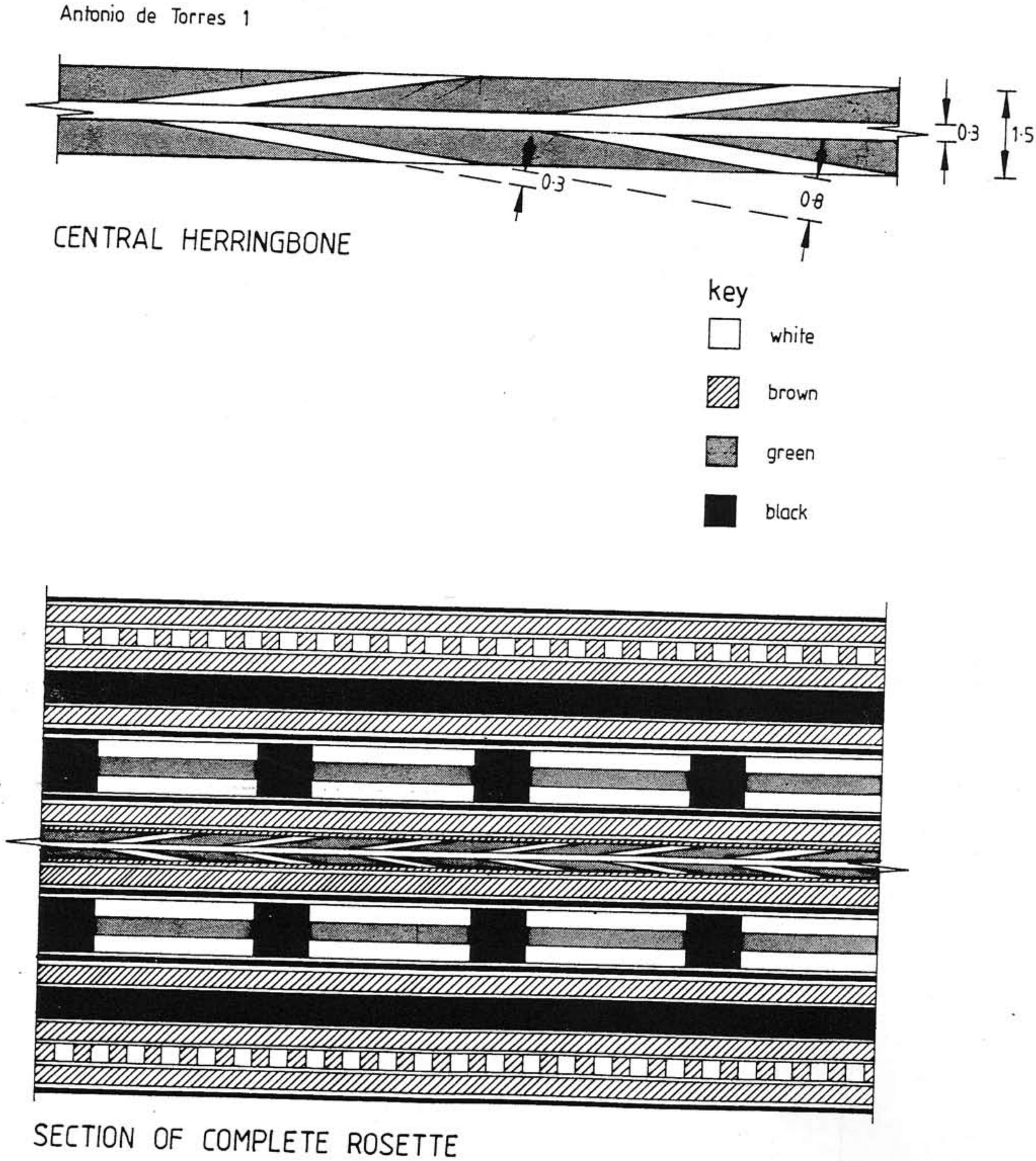
1-8 Torres 1 – plantilla (each square represents one square centimetre)



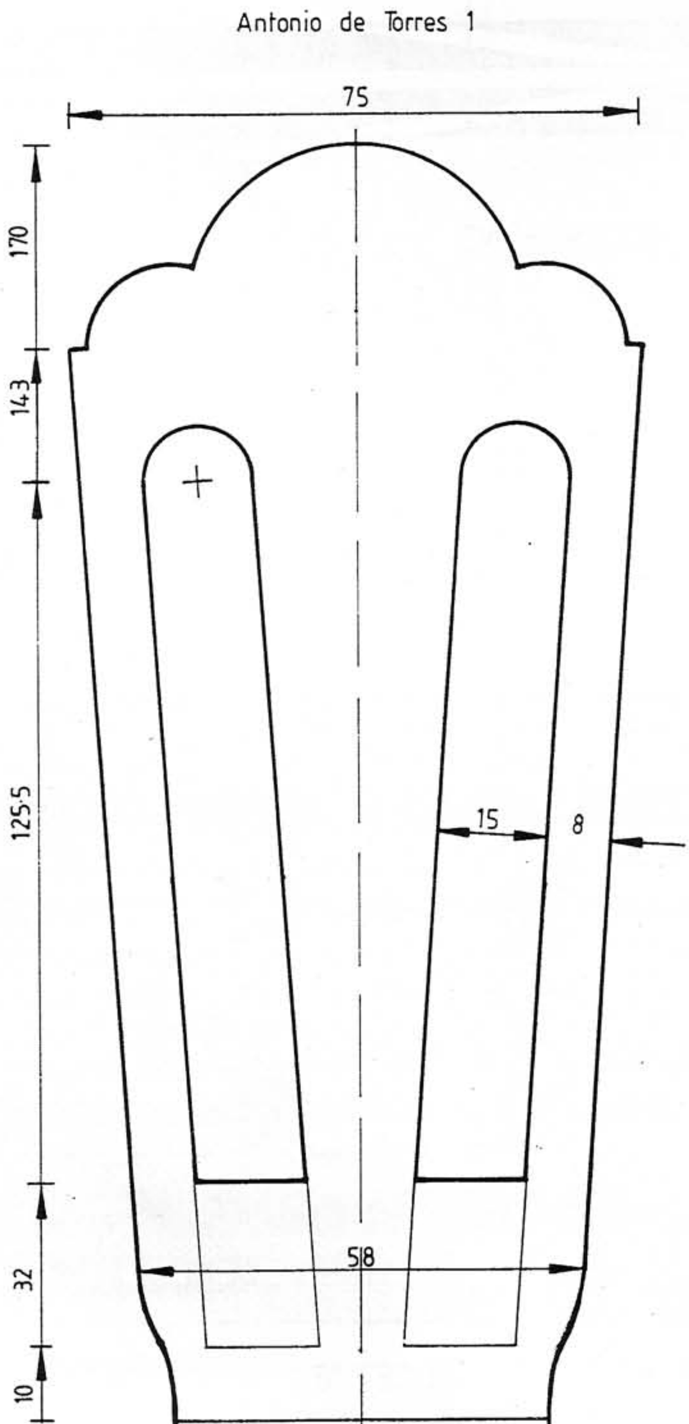
1-9 *Torres 1 – soundboard*



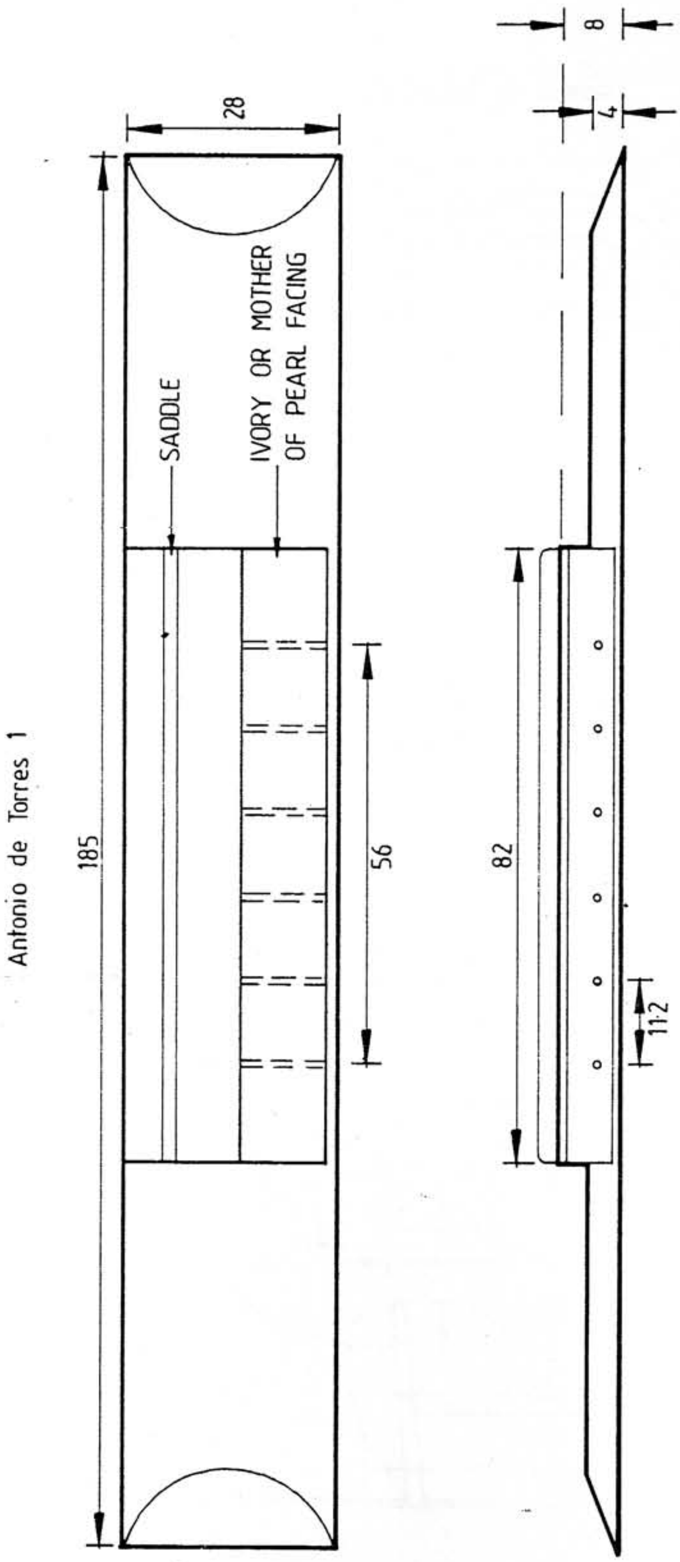
1-10 Torres 1 – neck and body



1-11 Torres 1 – rosette

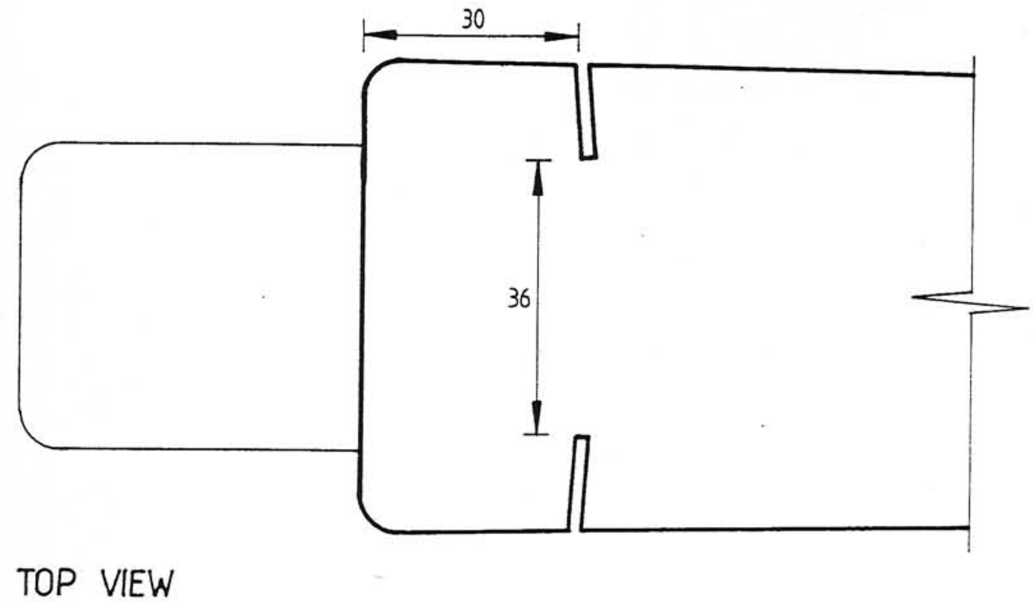


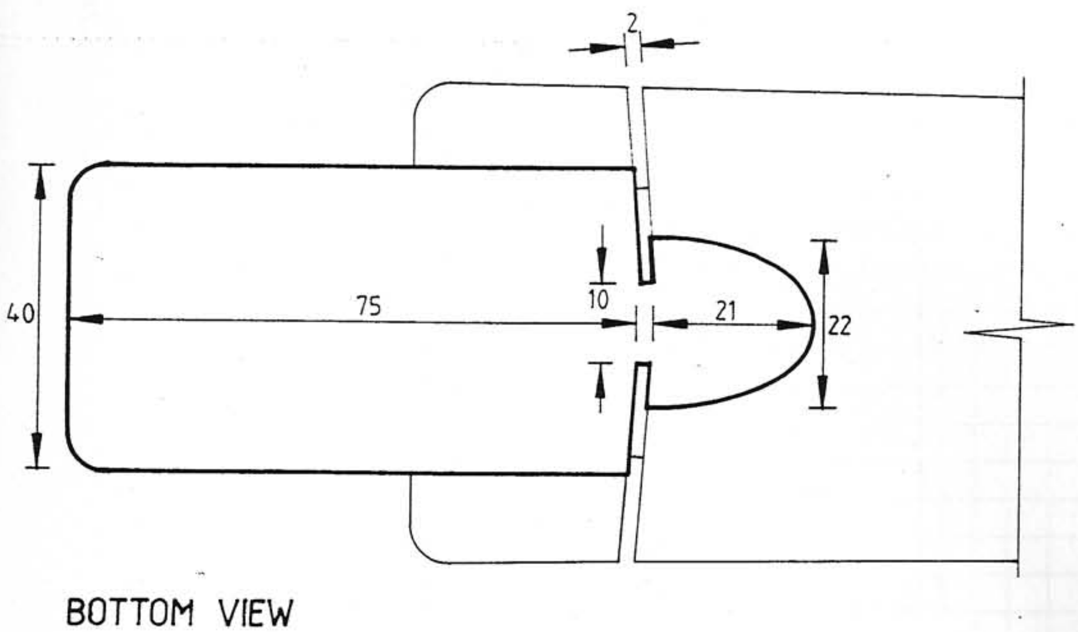
1-12 Torres 1 – head



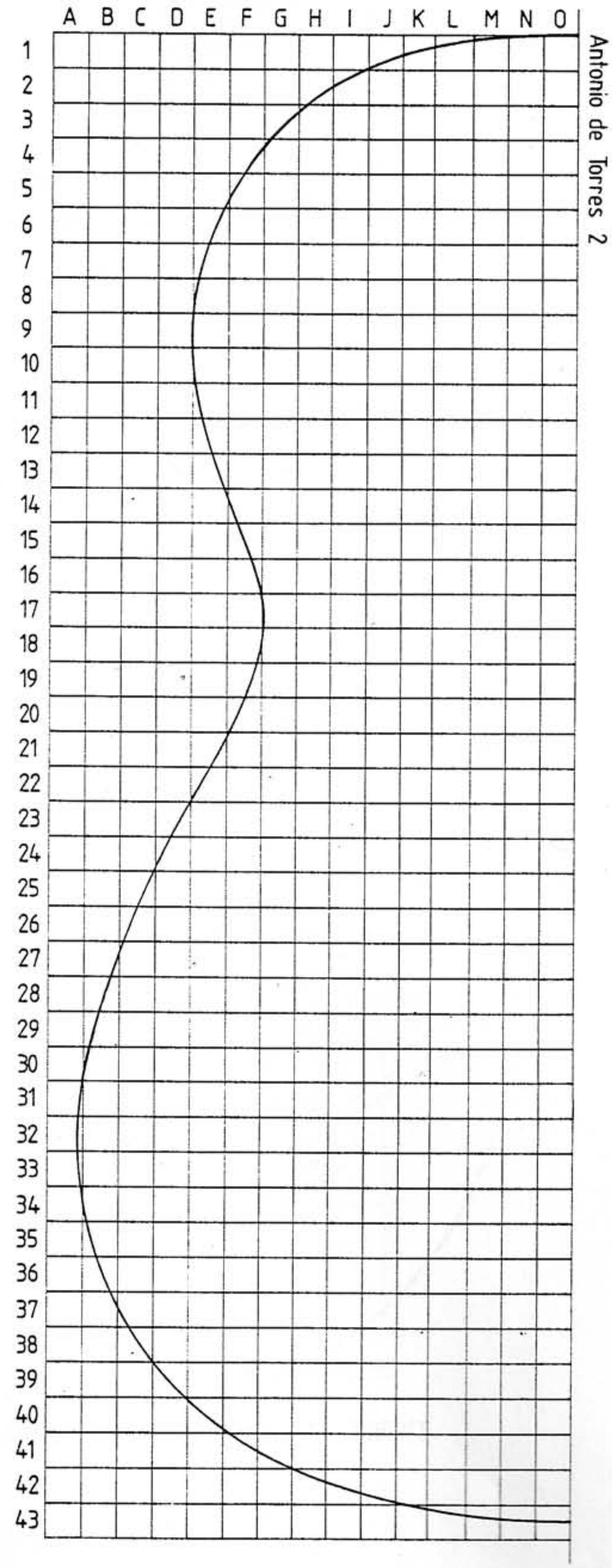
1-14 Torres 1 – bridge

Antonio de Torres 1

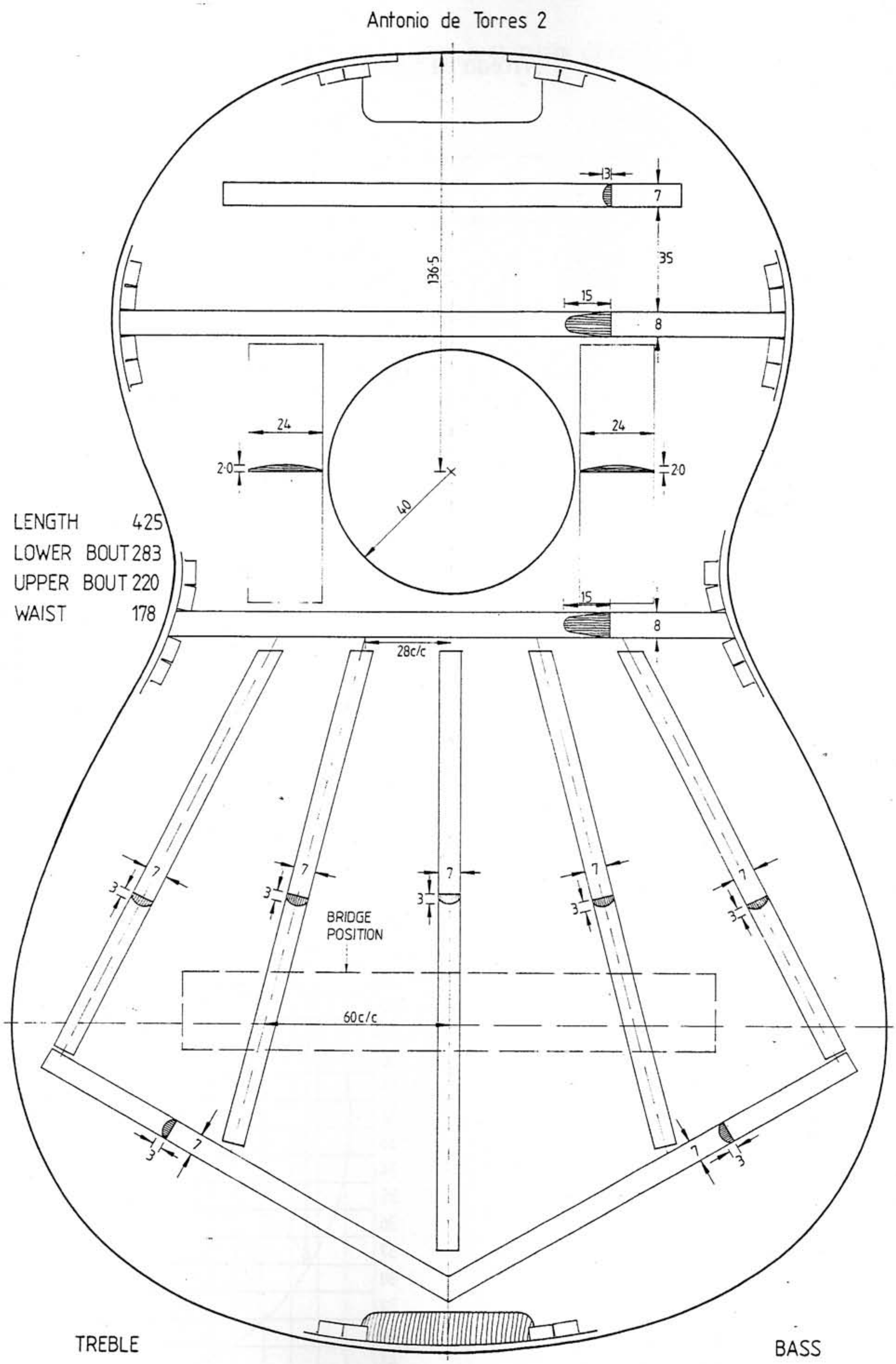




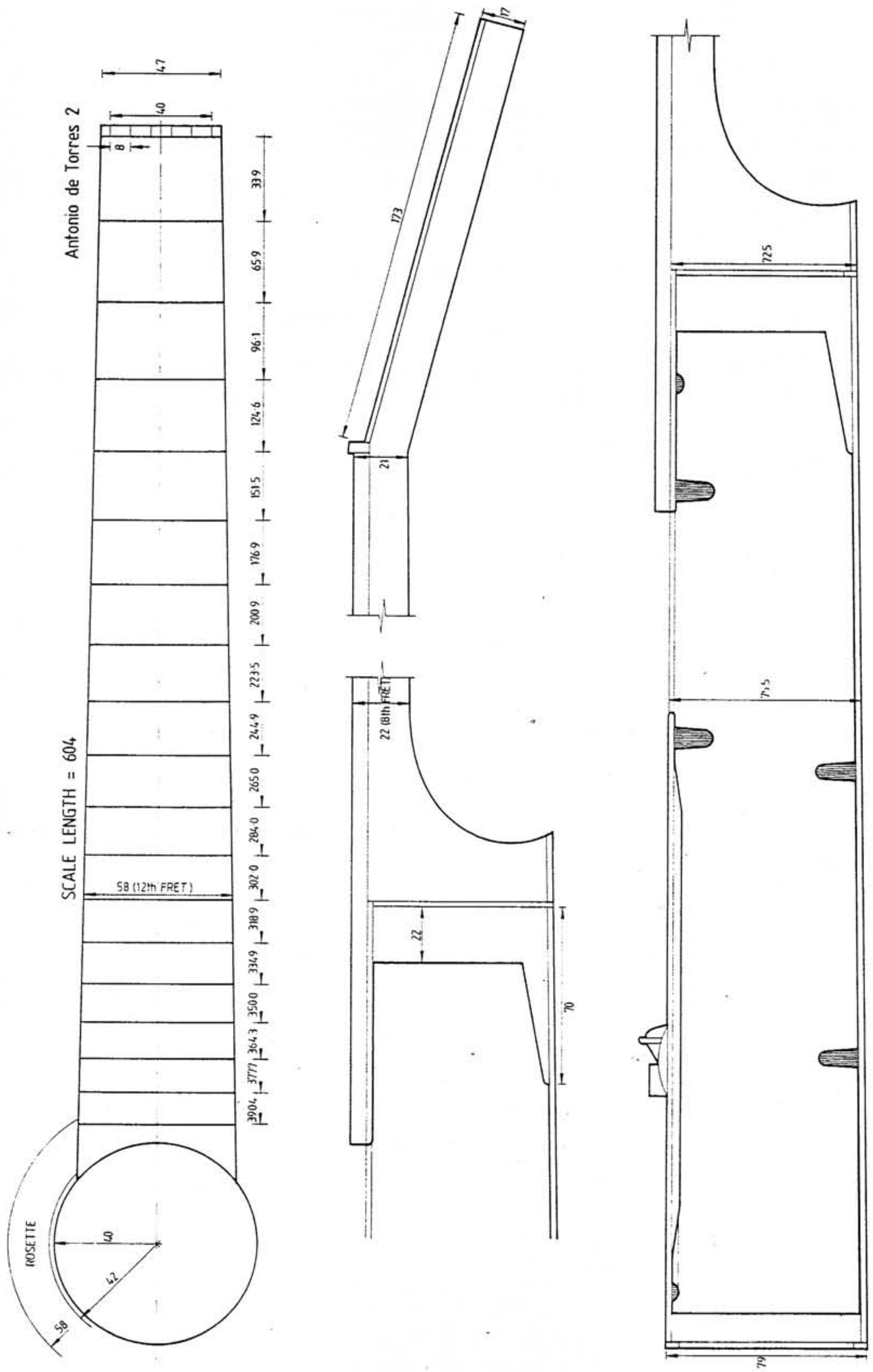
1-13 Torres 1 – neck joint



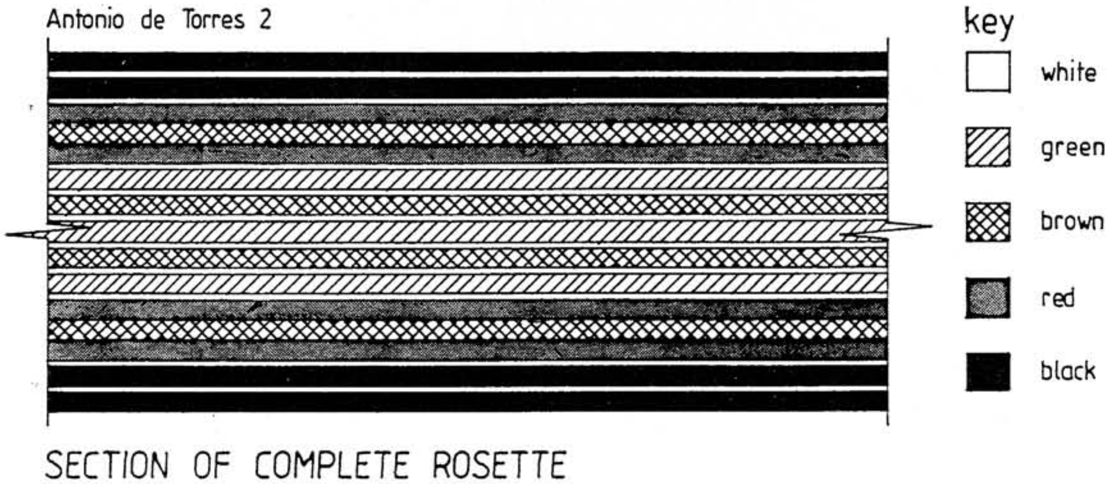
1-15 Torres 2 – plantilla (each square represents one square centimetre)



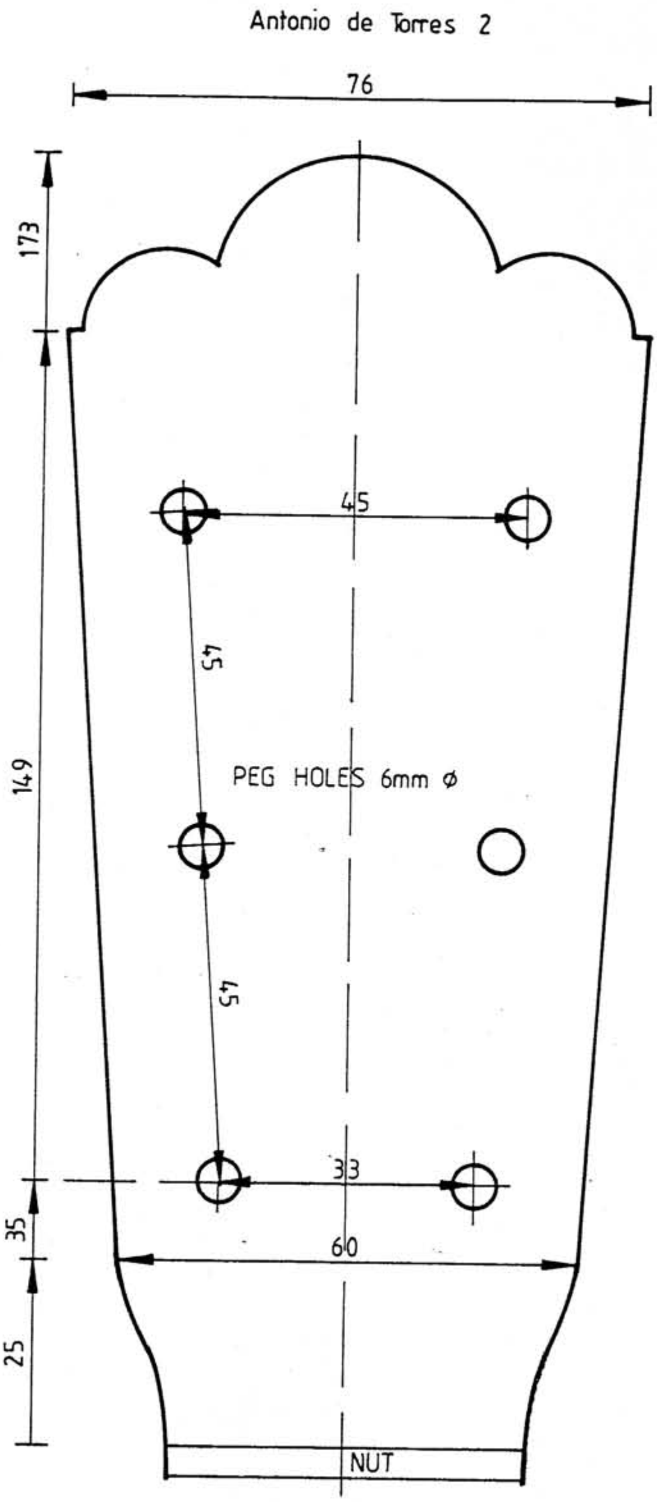
1-16 Torres 2 – soundboard



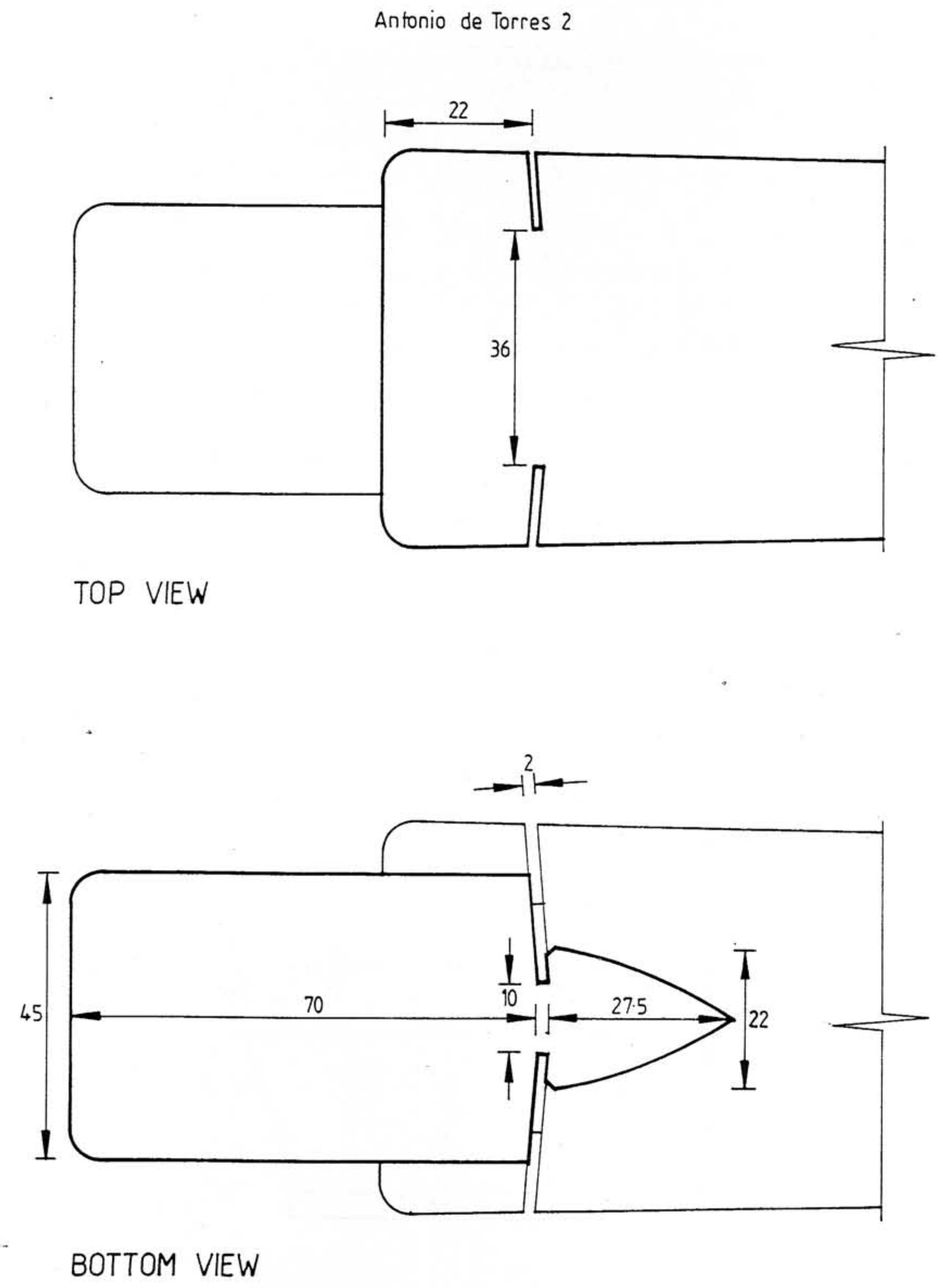
1-17 *Torres 2 – neck and body*



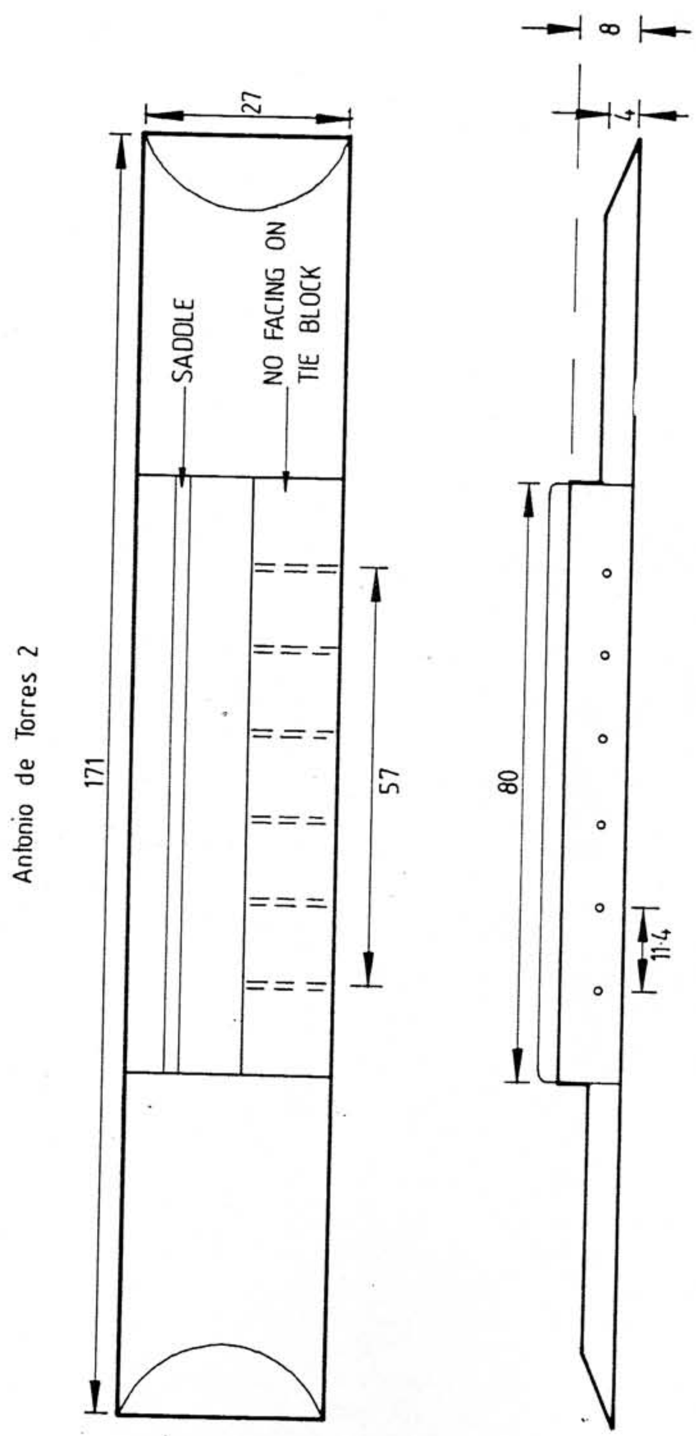
1-18 Torres 2 – rosette



1-19 Torres 2 – head



1-20 Torres 2 – neck joint



1-21 Torres 2 – bridge

2 Santos Hernández *(1874–1943)*

Background

Santos Hernández was the most famous maker of flamenco guitars this century, and he also produced concert instruments of great quality. Together with Torres, Ramírez, Esteso and Barbero, he was largely responsible for developing the true art of flamenco guitar design. Hernández was at first employed at the workshop of Manuel Ramírez, from whom he learnt the art of guitar making.

It was in 1916 that Andrés Segovia called at the workshop, hoping to borrow or hire an instrument for a forthcoming concert – he was as yet an unknown musician – and was given a guitar to try. Ramírez was so impressed with Segovia's playing that he presented the instrument to him. This particular guitar had been made by Santos Hernández. In his autobiography Segovia confirms, 'His [Ramírez] best workers were in the shop headed by the expert Santos Hernández. Ramírez asked him to bring one of his best guitars. He handed it to me and I looked it over very slowly before trying it out for sound.'

The romantic Segovia continues,

> I looked at it for a long time before awakening its resonances. The grace of its curves, the old gold of its fine-grained pine top, the delicately worked ornamentation around the exactly placed soundhole; the neck stemming straight and slim from the austere bust with its back and ribs of palosanto (rosewood), and ending in a small and dainty head; in short, all of its features, all the lines and highlights of its graceful body, penetrated my heart as deeply as the features of a woman who, predestined by heaven, suddenly appears before a man to become his beloved companion. My whole being was seized by an indescribable happiness as I began to play the guitar. Its inner qualities proved no less perfect than its outward appearance. For its tone was deep and sweet in the bass notes, diaphanous and vibrant in the higher ones. And its accent, the soul of its voice, was noble and persuasive. I forgot everything but the guitar ...[1]

Some time later, after a concert at which Segovia had played this guitar, Ramírez told him; '... the morning after the concert I congratulated my technicians, particularly this quiet one, my best ... (pointing to Santos Hernández).'[2] Segovia became especially attached to the instrument, and he continued playing it for twenty-five years, often showing it to other makers as an example from which measurements could be taken for their own work.

Eventually, Santos Hernández left the Ramírez workshop and set up on his own, continuing to develop his unique personal style, and experimenting with ideas gleaned from his knowledge of Torres. In 1941 he is known to have restored an 1889 Torres guitar (No. SE133). On some instruments he included a 'tornavoz'. This was a kind of conical tube attached below the soundhole, inside the guitar, with the idea that it would improve and amplify the sound. Although popular with a number of makers at one time, its use died out completely by 1945.

The Flamenco Guitar

The 1850s had seen the emergence of flamenco as a popular music form, with the corresponding need for suitable guitars to accompany it. Torres undoubtedly contributed much to this new development, and flamenco guitars were established with their larger shape (the earlier guitars having been much smaller), and the use of cypress for the back and ribs. The strings were usually attached by wooden pegs, rather than machine heads, and the overall instrument tended to be lighter than the concert guitar. (Cypress weighs much less than rosewood.) Sometimes a rosewood fingerboard was used instead of ebony, perhaps to reduce weight, or simply because it was cheaper and more readily available. Santos Hernández's guitars were greatly prized by the leading flamenco players of his day, including Ramón Montoya and Niño Ricardo. Today, a flamenco guitar by Santos Hernández is both rare and extremely valuable.

Soundboard and Strutting System

One of the main problems that confronts all makers is how to increase the volume, strength and sustain of the treble notes, so that they hold up well against the bass. It is relatively easy to obtain strong basses, but far more difficult to create an equivalent strength with the trebles. The 'balance' is also more difficult to achieve; often there is a clear difference in the character and quality of notes on the first string, compared with notes on the second or third strings. Santos Hernández' solution was to alter the angle of the lower harmonic bar so that, instead of placing it in the conventional way at 90 degrees to the centre join of the soundboard, he sloped it down towards the bridge, thus shortening the vibrating length of the soundboard in the region of the treble strings.

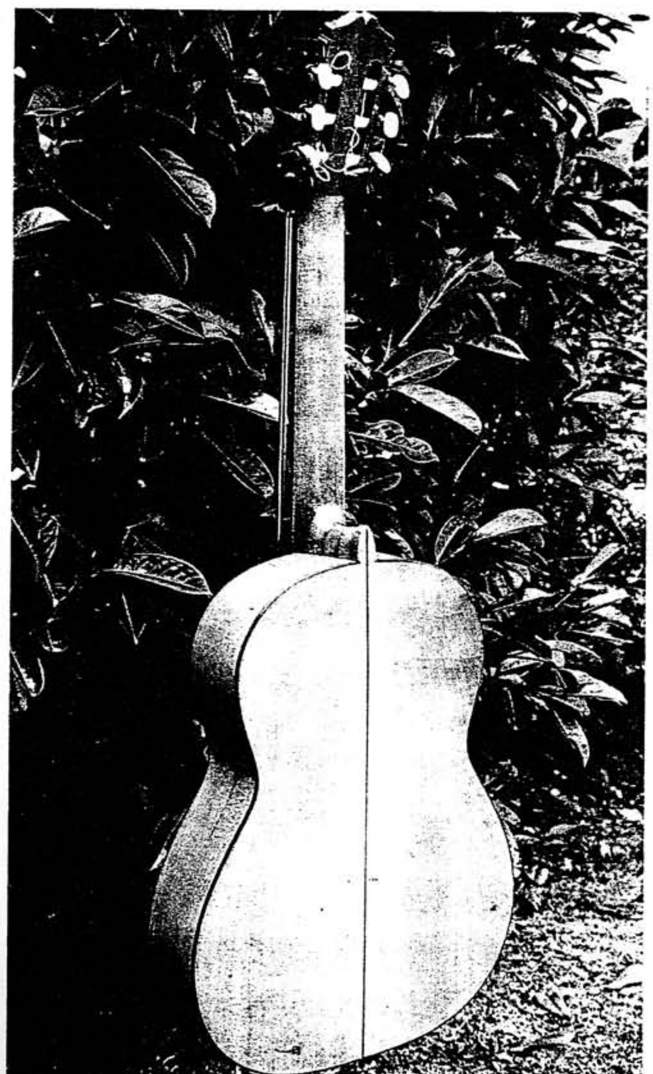
Other makers were influenced by this idea; a comparison with the Fleta strutting system shows that he felt even more rigidity was needed, including both the conventional transverse harmonic bars, and an additional sloping bar similar to that on Hernández' instruments. Some guitars by Hernández y Aguado also demonstrate a version of this idea, but they preferred to start the sloping bar about 30 mm past the centre-line (on the bass side), and slope it at a steep angle so that it cuts right across the treble fan struts and consequently reduces their length substantially. Not all makers would agree that this type of sloping bar helps the clarity of the trebles, but, as with most aspects of guitar design, it works better for some makers than others.

The remainder of the Santos Hernández strutting usually consists of seven long fan struts which are symmetrically placed, and run down close to the end of the soundboard. On at least one instrument, made in 1924, he also included an open lower harmonic bar. (The lower harmonic bar in the flamenco instruments was placed straight across, in the conventional way, and the fan struts were somewhat wider and flatter than usual.)

Plantilla

The shape is attractive, with a flowing and elegant series of curves which define the upper and lower bouts. The width across the upper bout is quite narrow.

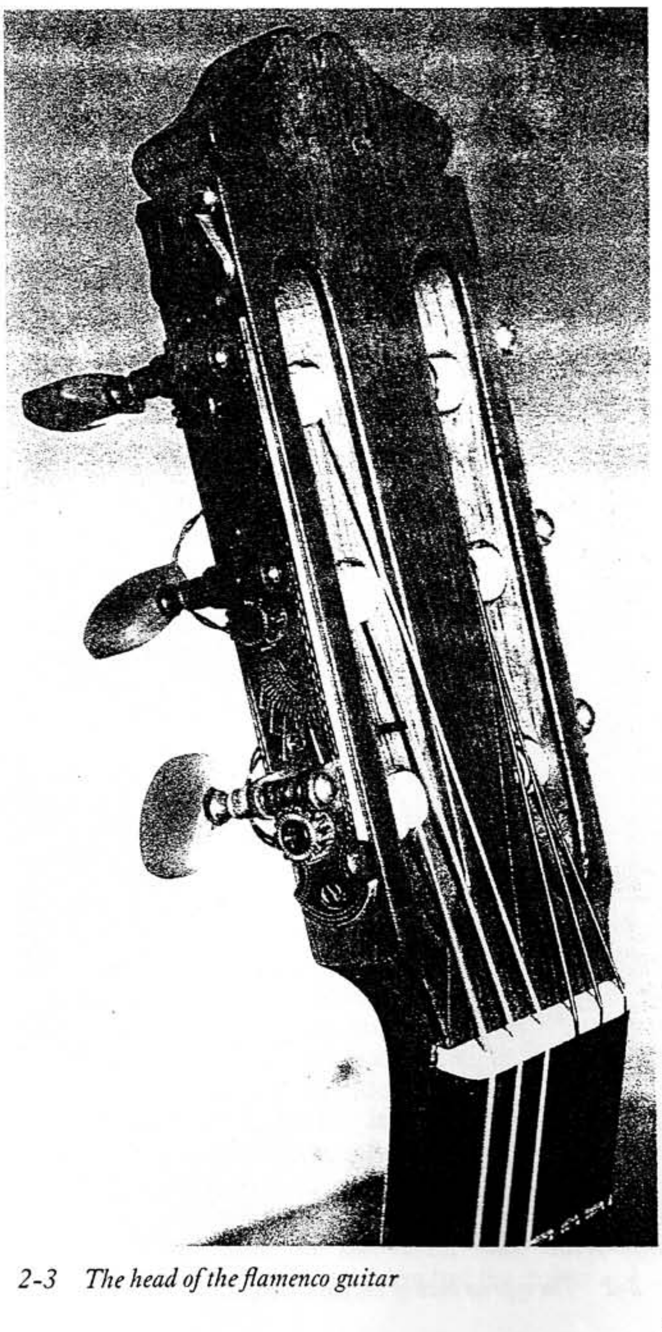
2-1 A flamenco guitar by Santos Hernández, made in 1933



2-2 The cypress back of the flamenco guitar

Neck and Head

The neck is of average thickness; 23.5 mm at the nut, tapering to 25.5 mm at the 9th fret. Its width, however, is rather narrow; 50 mm at the nut, and 61 mm at the 12th fret. What is unusual, is that the neck extension that is positioned inside the body, and supports the soundboard, is longer than normal, providing 50 mm of gluing area for the soundboard. As a result, there is not much unsupported soundboard between the end of this extension and the upper harmonic bar. For this reason, no other strengthening bars are needed at the upper region of the soundboard. The flamenco guitars were usually fitted with tuning pegs, rather than machines, although the instrument examined now has tuning machines which were probably fitted at a later date.

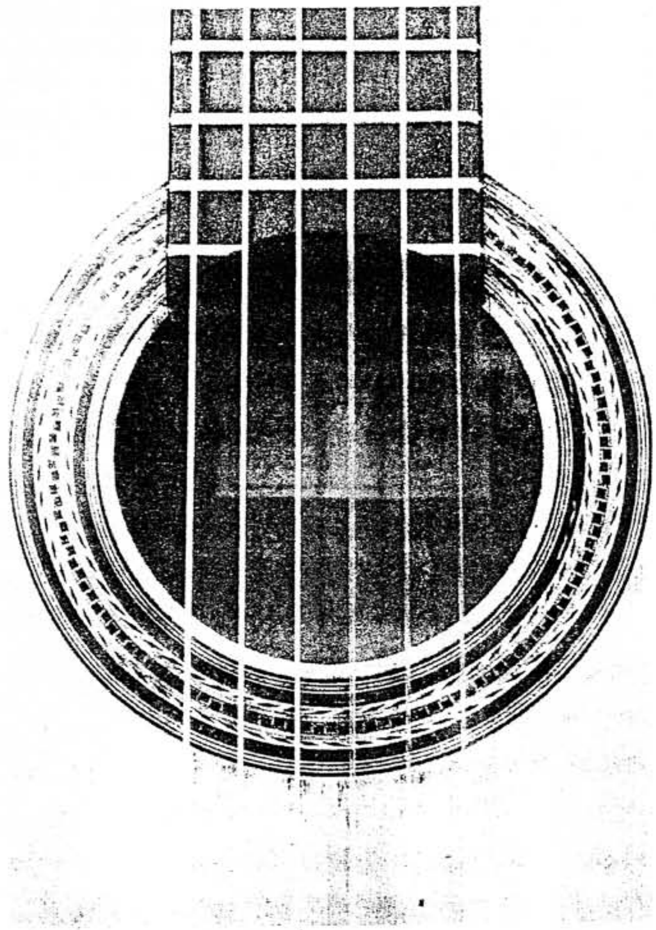


2-3 The head of the flamenco guitar

Rosette

The rosette is beautifully vibrant, consisting of outer borders of thin lines and a central motif of orange and black squares, which is itself surrounded by a half-herringbone pattern. It is made from both natural and stained woods.

The rosette is 19 mm wide.



2-4 The rosette on the flamenco guitar. This is the pattern described in the text and at (2-8)

From outer circumference:

Outer border:

1.0	black
0.2	white
0.2	black
1.0	orange
0.2	black
0.2	white
2.5	black
0.75	white
0.75	black and white herringbone
0.75	orange
0.75	green

Central section:

2.5 central motif – black background, with orange lines which form a squared, repeating pattern

Inner border:

0.75	green
0.75	orange
0.75	black and white herringbone
0.75	white
2.5	black
0.2	white
0.2	black
1.0	orange
0.2	black
0.2	white
1.0	black

Materials

soundboard:	European spruce
back and ribs:	Classical – Brazilian rosewood Flamenco – cypress
neck:	cedar
fingerboard:	ebony
bridge:	Brazilian rosewood
internal struts:	European spruce

Soundboard Thickness

2.1 mm

Back Thickness

2.0 mm

Weight

400 grams

Scale Length

650 mm

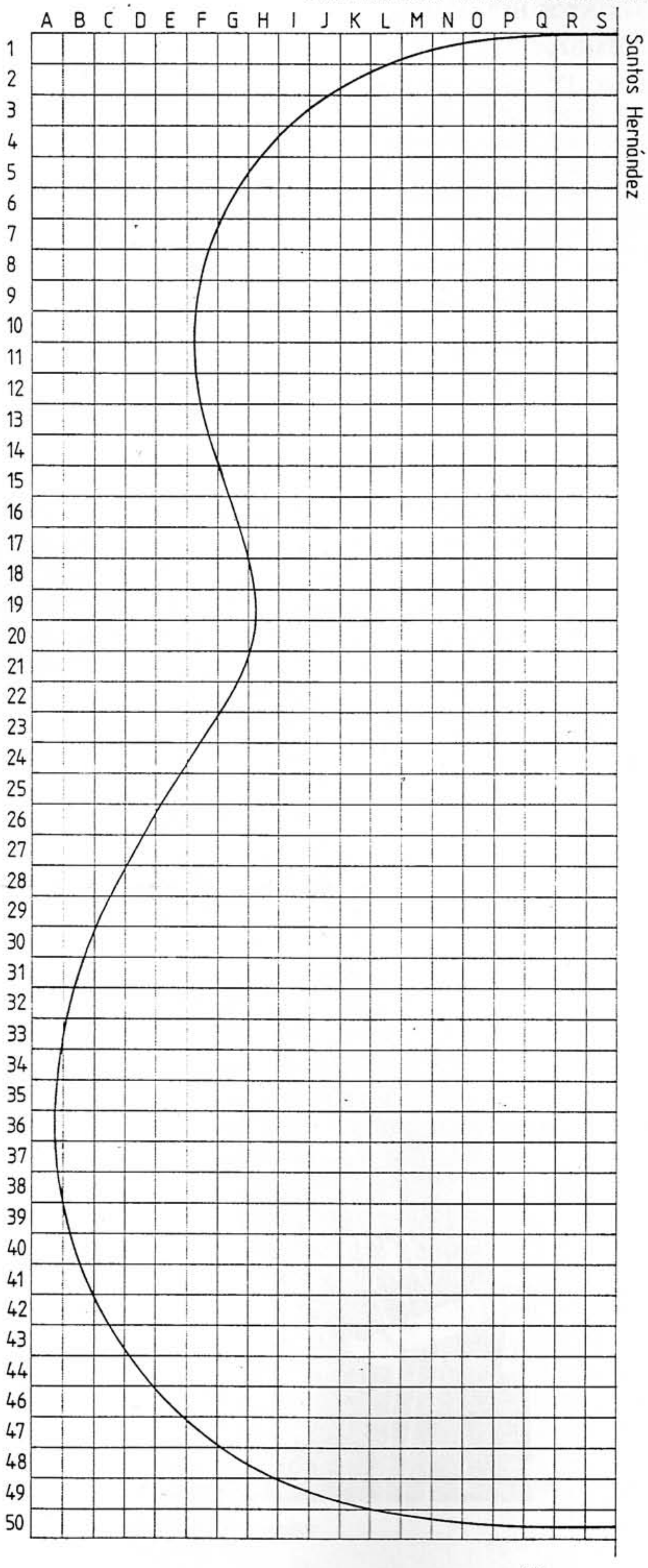
Comparison of Dimensions of Two Santos Hernández Guitars

(measurements in millimetres)

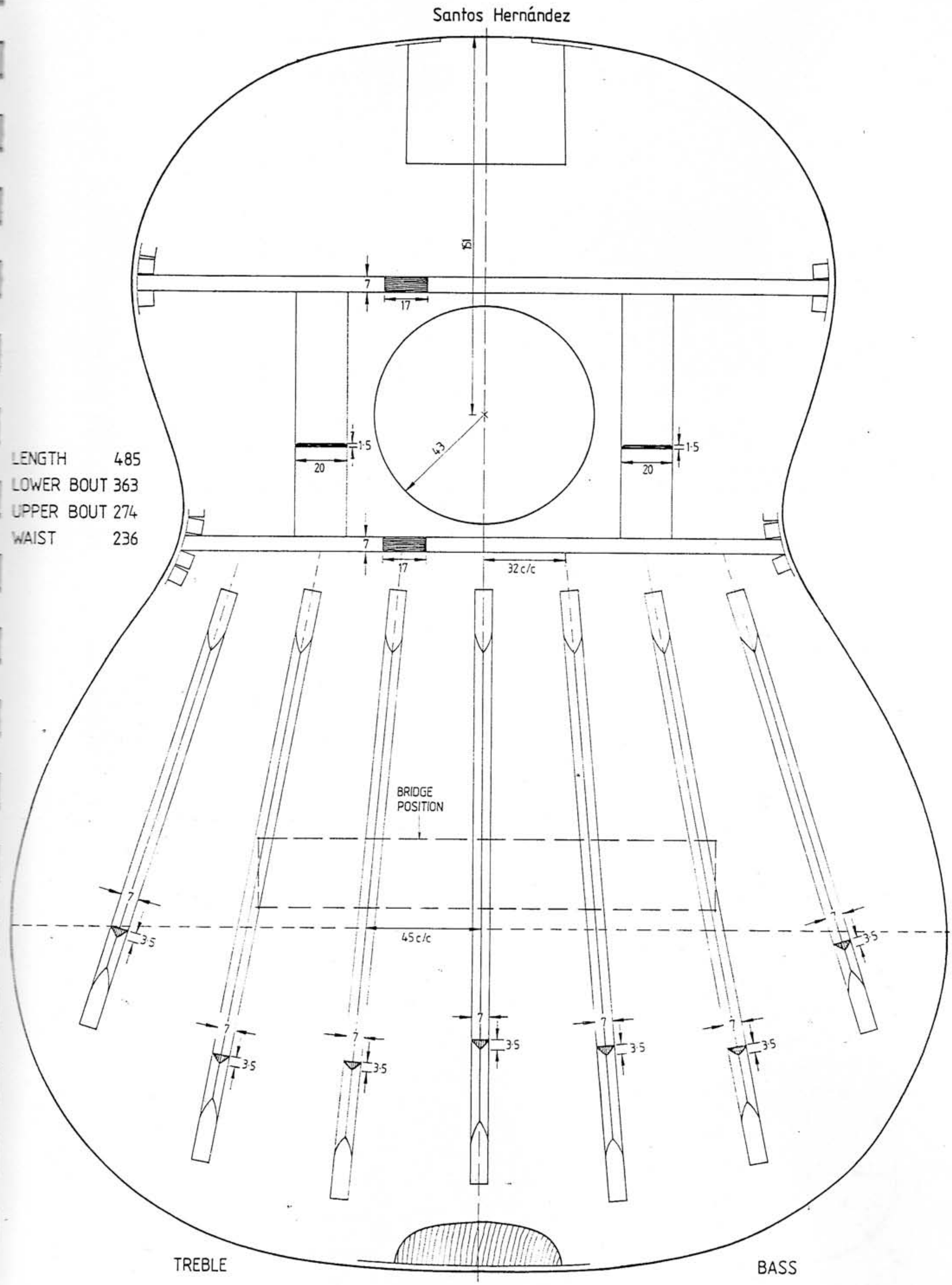
year	body length	width at upper bout	width at waist	width at lower bout	body depth at end-block	body depth at heel
1924 (classical)	484	276	235	365	100	90
1833 (flamenco)	485	274	236	363	95	87

Notes

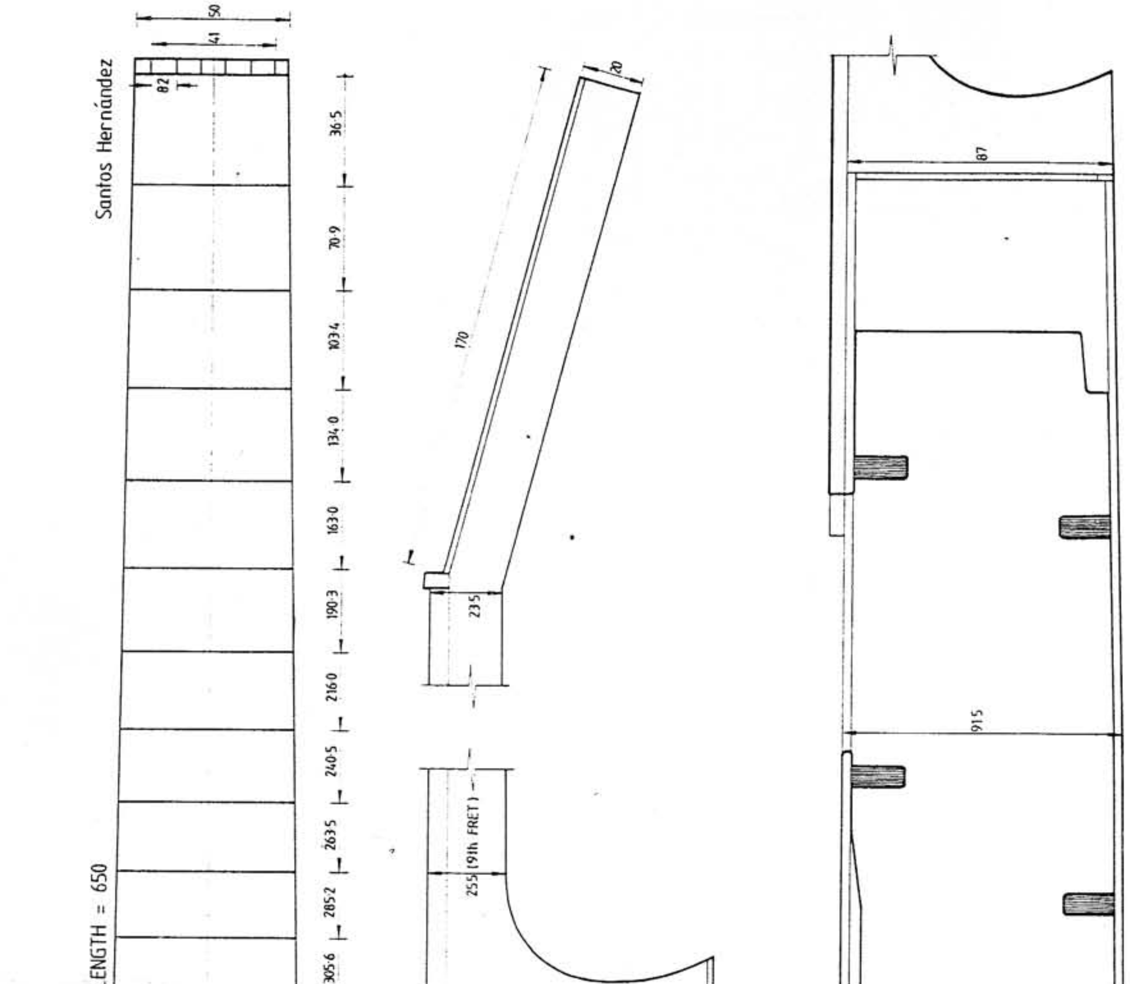
1 Segovia, Andrés, *An Autobiography of the years 1893–1920*, p. 51.
2 ibid., p. 69.



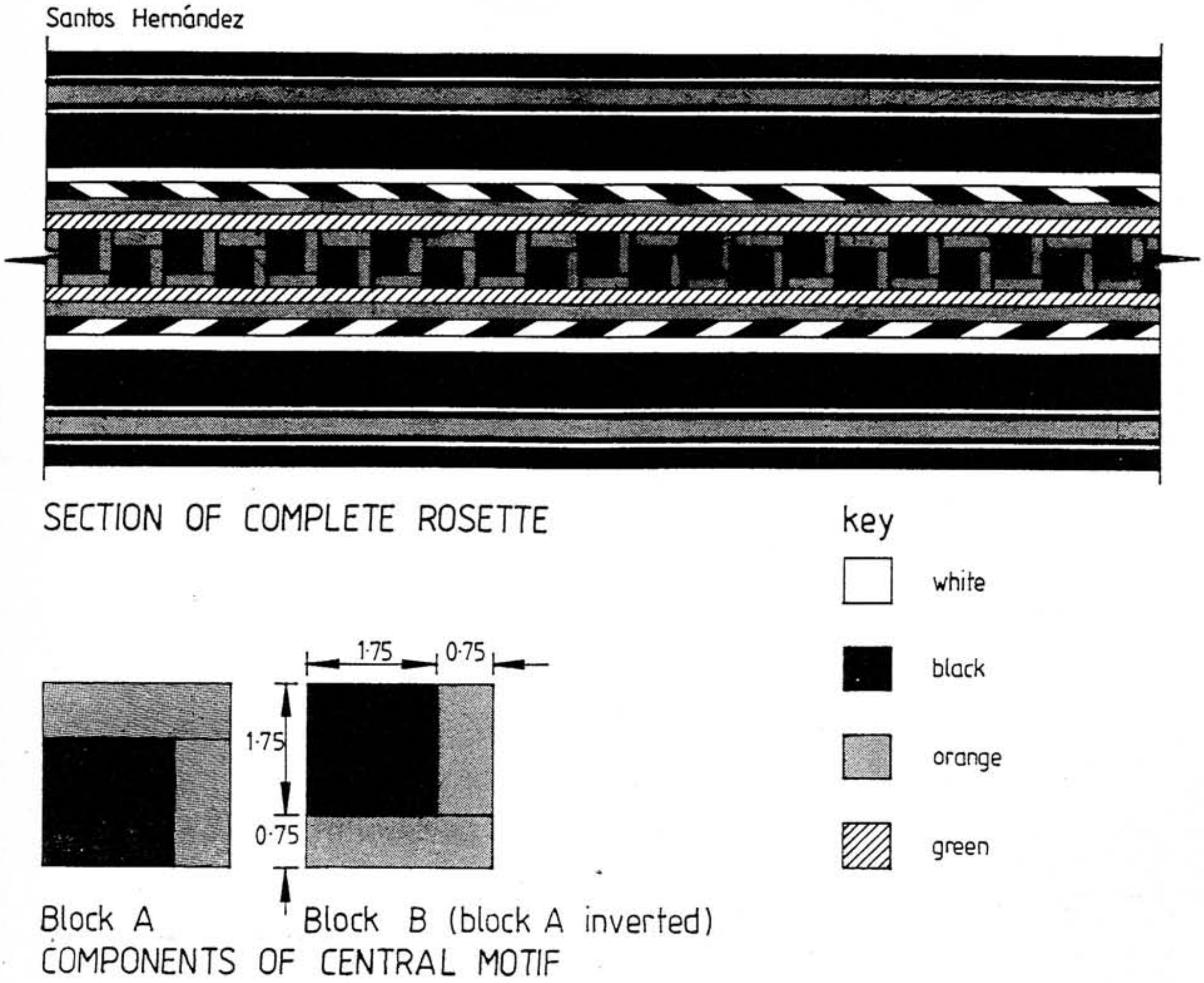
2-5 Santos Hernández – plantilla (each square represents one square centimetre)



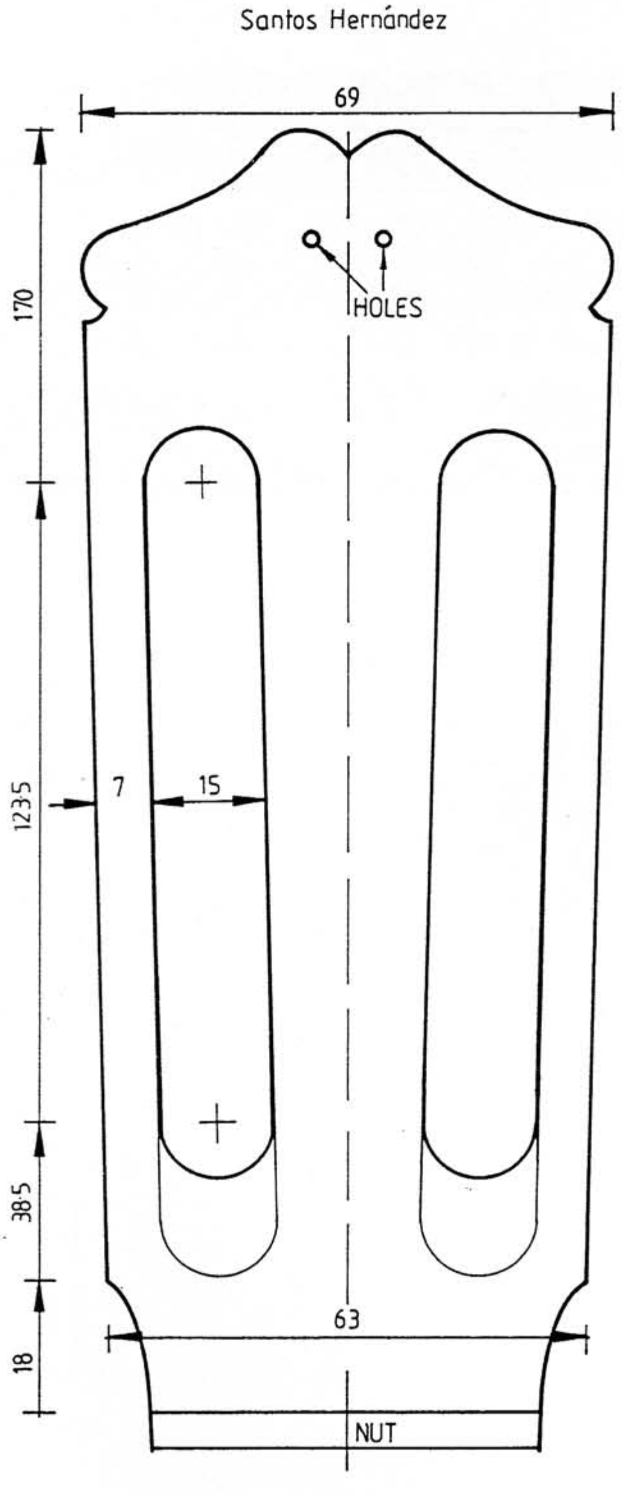
2-6 *Santos Hernández – soundboard*



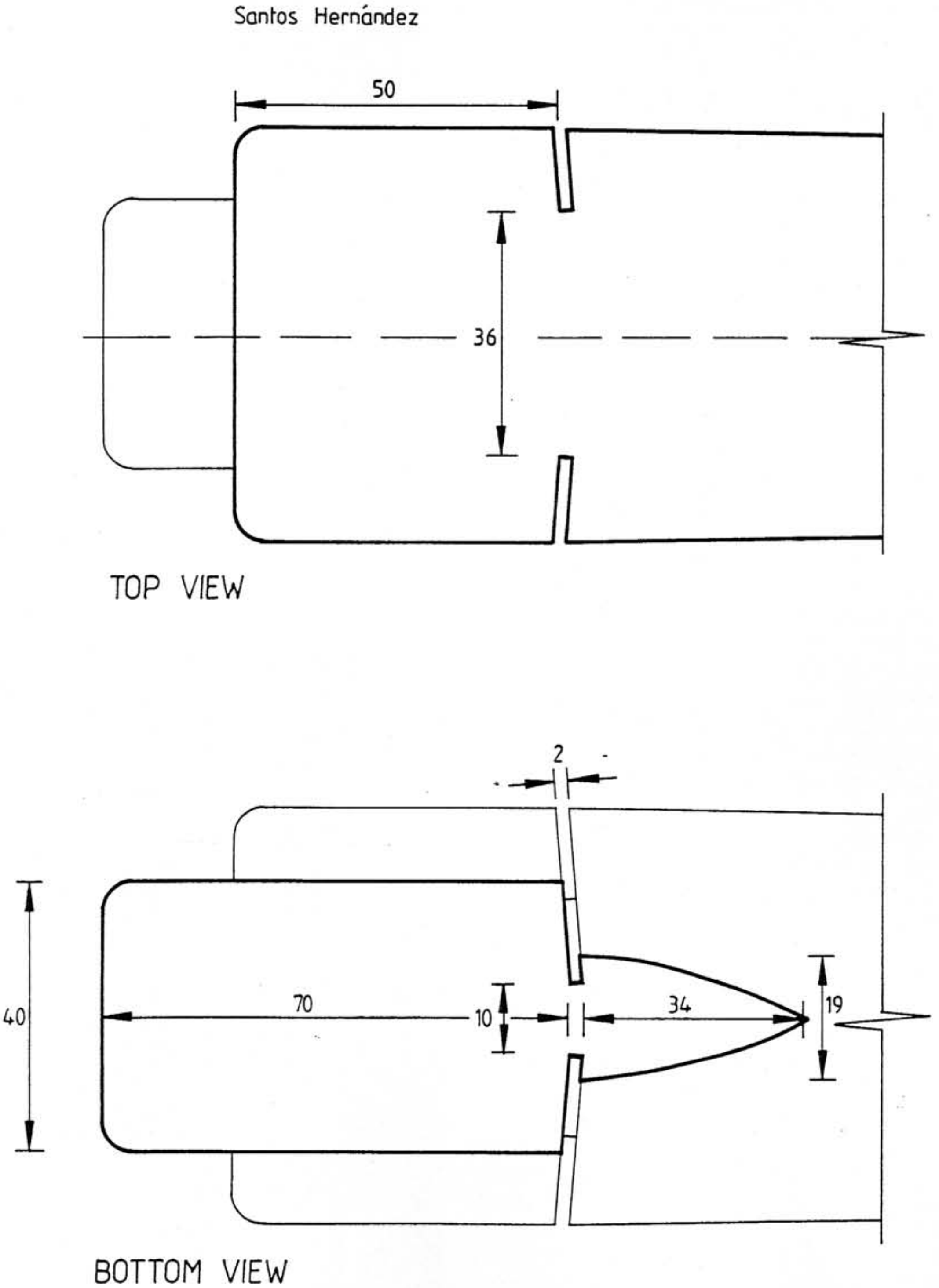
2-7 *Santos Hernández – neck and body*



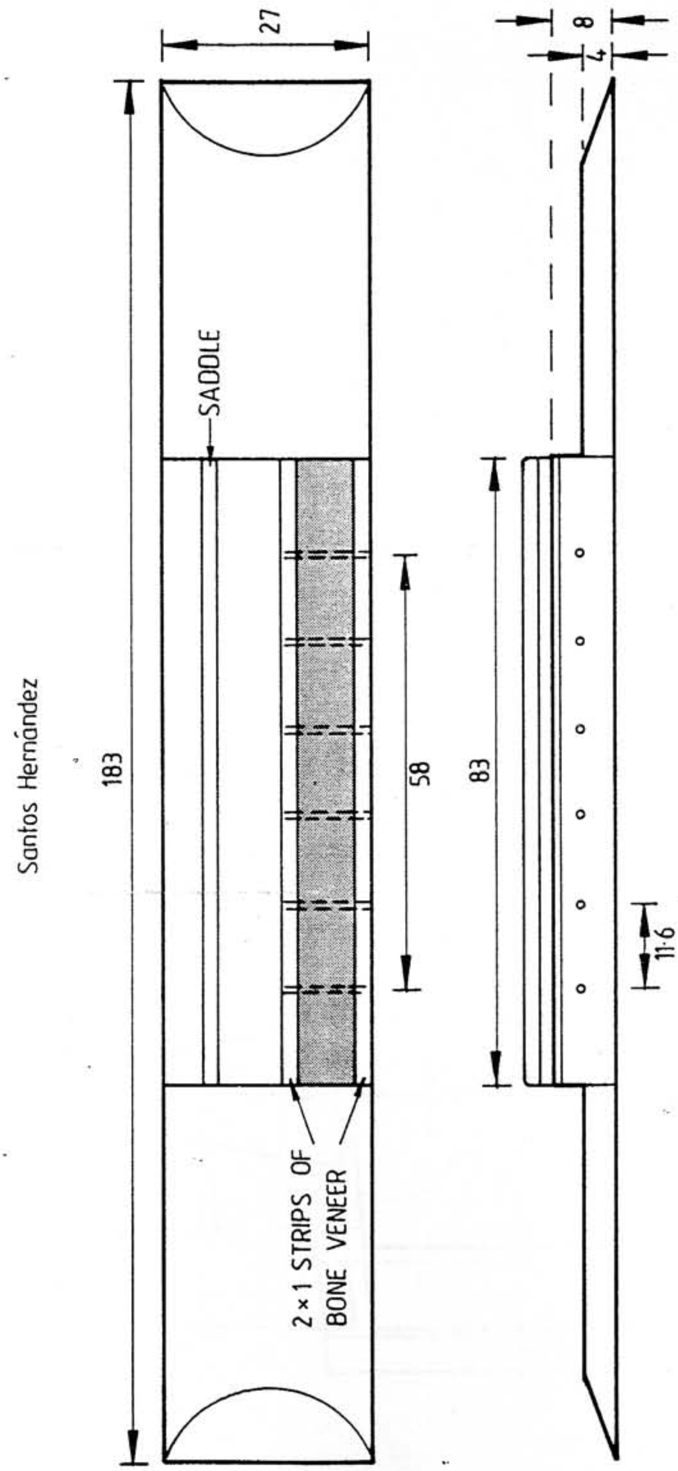
2-8 Santos Hernández – rosette



2-9 *Santos Hernández – head*



2-10 Santos Hernández – neck joint



2-11 Santos Hernández – bridge

3 Hermann Hauser *(1882–1952)*

Background

Hermann Hauser is regarded as the finest German guitar maker, and he is classed along with Torres as having influenced many twentieth-century luthiers. Some consider that he did not capture 'the true Spanish sound', but many players regard his instruments as being superior to those of Torres. Julian Bream and Andrés Segovia are but two guitarists who have owned Hausers, and have played them consistently for many years.

3-1 Hermann Hauser in his workshop

The work of Hauser and Torres support the view of many makers and players, that a reasonably small-bodied guitar can produce a more focused sound than a larger instrument; a smaller soundbox can indeed be capable of great sound projection. Some makers believe it is largely a psychological factor that leads the guitarist to feel safer with a large-bodied instrument – somehow there is an assumption that a big instrument will project more than a smaller one. Yet objective experiments, where the listener cannot see which instrument is producing the sound, often conclude that this is not necessarily so.

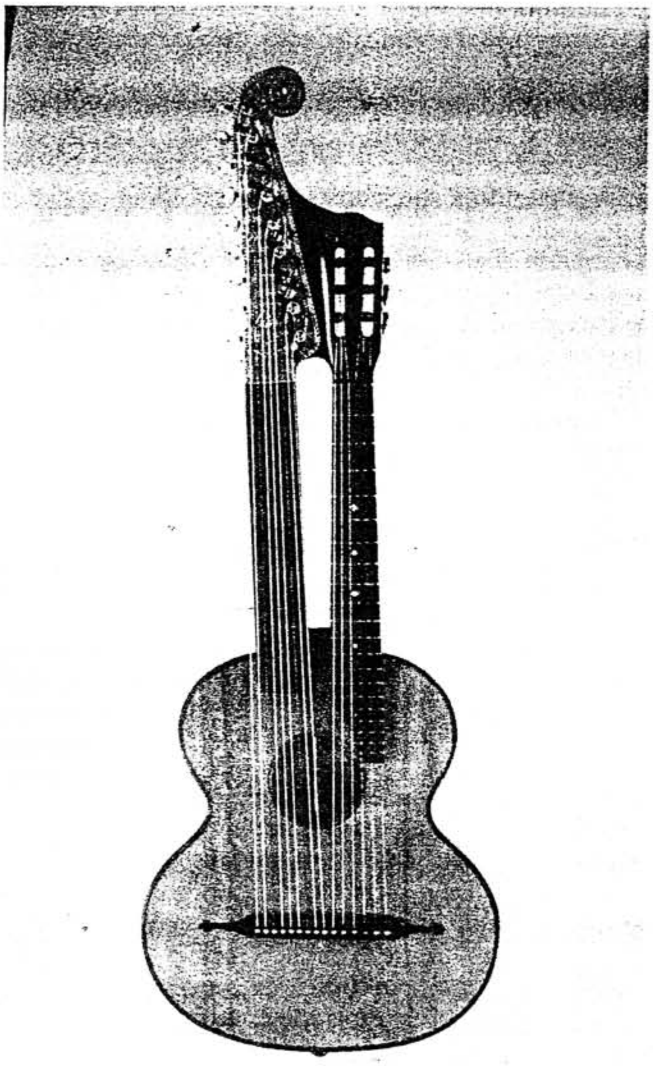
Hauser was working in Germany at a time when guitar making in Spain was in decline – by 1930, Santos Hernández was virtually the only great maker still active. Both José and Manuel Ramírez, as well as Enrique Garcia, had died by 1925. Francisco Simplicio died in 1933. So Hauser was meeting a real need for high quality instruments.

In 1924 Segovia visited Germany and Hauser was introduced to him. Their conversations were really the turning-point in the maker's career. He was now able to perceive exactly what kind of instrument Segovia was looking for, and he then embarked on a long journey to design and perfect this vision.

Segovia had attended a concert in Munich where a group of musicians had all played Hauser guitars. But these were not the typical Spanish design that he was later to perfect; rather, they were smaller instruments, drawing on the baroque German tradition – the guitar had the fingerboard on the same plane as the soundboard; the plantilla was narrow and elongated, and the soundhole followed the lute tradition of including an elaborately carved rose. Hauser had in fact made a variety of instruments including some with two necks; one for the fretted notes, and one carrying additional bass strings which were not stopped with frets, rather like theorbos and chitarrones.

Segovia wrote down his impressions of this concert at which the Hauser instruments had been played, 'The guitars had been constructed by Hauser: I examined them all, and immediately foresaw the potential of this superb artisan if only his mastery might be applied to the construction of the guitar in the Spanish pattern as immutably fixed by Torres and Ramírez, as the violin had been fixed by Stradivarius and Guarnerius.'[1]

Segovia had with him a guitar made by Santos Hernández. (This had been constructed, while Hernández was employed in the Ramírez workshop, and therefore carried the Ramírez label.) Segovia's enthusiasm prompted him to invite Hauser to examine the guitar, and the measurements that he made, together with an assessment of the character of the instrument, meant that Hauser could now pursue a more specific goal. It was over twelve years later, in 1937, that he finally produced a guitar meeting



3-2 A double-necked contra-guitar by Hauser, made in Munich in 1924. This instrument is typical of Hauser's work prior to the influence of Segovia, who encouraged him to start working the Spanish style

3-3 A later guitar by Hauser. The influence of Segovia had by now resulted in guitars based closely on the work of Torres

Segovia's criteria – the maestro described it as 'the greatest guitar of our epoch.'

Thus the influence on Hauser came very largely from his understanding of the Ramírez/Hernández design. Nevertheless, he had also had access over a long period of time to Torres' guitars. The guitarist, Miguel Llobet, had been a friend of Hauser and his 1859 Torres was therefore available for Hauser to use as a model.[2] This dual influence of Torres and Ramírez is what characterizes Hauser's work. From 1940 his guitars resemble Torres quite closely, often copying the Torres head shape, and with a rosette almost identical to one used by Torres. Hauser himself eventually owned a Torres guitar made in 1860.

Soundboard and Strutting System

Hauser developed his ideas about the ideal method of strutting over a long period, and it is therefore difficult to select one design as being typical. Some instruments were closely based on the seven, radiating-strut pattern of Torres. Hauser did not always include the two short diagonal struts at the base of the soundboard. From 1930 he experimented with open harmonic bars – arches were cut from either side of the bars, and the outer fan struts were then able to pass through without making contact. His later instruments became very close to the Torres pattern, where the struts are laid out in relation to a theoretical apex on the fingerboard. He shaped the fan struts like gable-ends, with a definite ridge on the top. An important feature in soundboard construction is the choice between a flat, arched, or domed soundboard. Whereas many makers incorporated an arch across the width of the soundboard, Hauser began to dome his wood – something in common with many of Torres' instruments. This dome results in the soundboard being arched both across its width and along its length, which creates a much stronger structure. This inherent strength means that the soundboard can be worked quite thin, without any danger of it collapsing in front of the bridge. (Many thin soundboards eventually give way in this area, due to the constant tension exerted by the strings.)

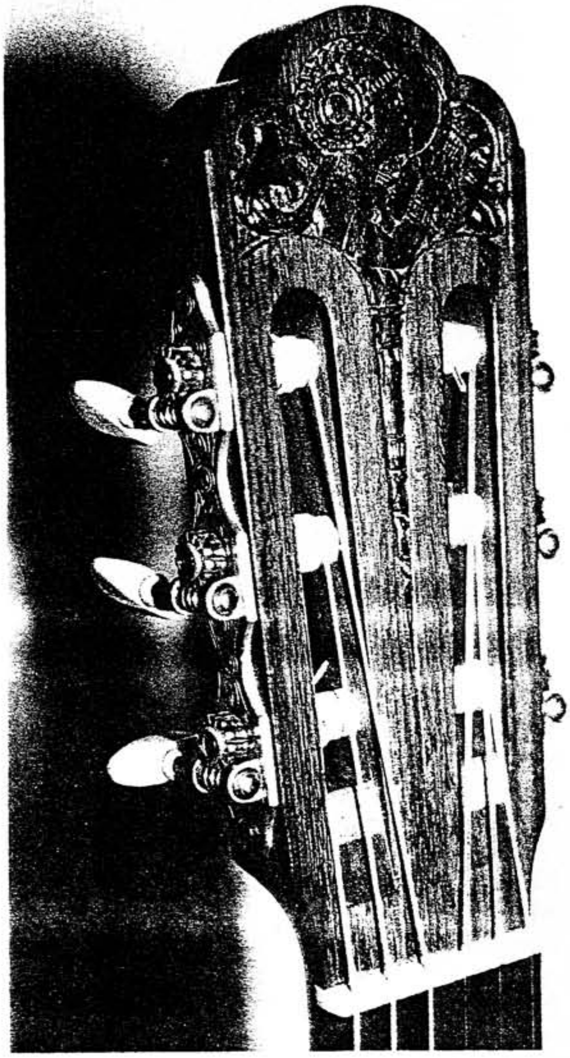
Another feature of Hauser's strutting in his preference for the struts in the central area (below the bridge) to be quite tall, whereas the outer struts become more squat. He also included a shallow flat plate of spruce on the inside of the soundboard, directly below the bridge. This has since been widely used by many makers, as a means of balancing the bridge, and encouraging a more even quality of sound across all the strings.

Plantilla

Hauser basically worked within the range of shapes developed by Torres and Ramírez.

Neck

Hauser used the traditional Spanish method of joining the ribs into slots cut in the neck. The head section is attached by a 'V' joint. This was the standard method in use on all pre-modern European instruments, but lost popularity this century, when the simpler splice joint became almost universally adopted.



3-4 The elaborately carved head of a 1936 Hauser

Head

As with the plantilla, Hauser based many of his head designs closely on those of Torres, consisting of a large, central arch, and one smaller arch either side. Some instruments had elaborate relief carving in the head veneer.

Rosette

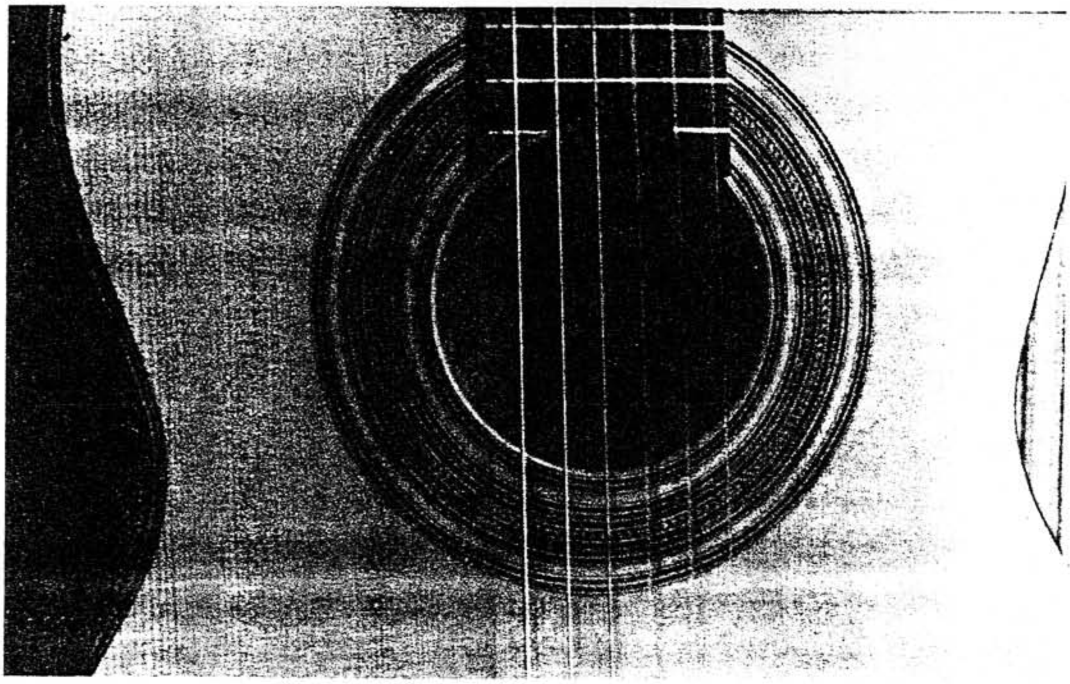
The rosette designs vary, but most are quite simple patterns, made with muted, natural colours. There is usually a narrow central motif, based on the shape of a cross, which is surrounded by wide bands of lines and half-herringbone. The majority of motifs were based on patterns used by Torres.

The rosette shown is 19 mm wide.

From outer circumference:

Outer border:

1.4	black
0.25	white
0.25	black
1.5	half-herringbone
0.25	black
0.25	white
1.0	black
0.25	white
0.25	black
0.25	white
1.0	black
1.0	white



3-5 The rosette on a 1931 Hauser, showing the close resemblance to Torres' designs

Central section:
3.75 end-grain mosaic pattern

Inner border:

1.0	white
1.0	black
0.25	white
0.25	black
0.25	white
1.0	black
0.25	white
0.25	black
1.5	half-herringbone
0.25	black
0.25	white
1.4	black

Materials

soundboard:	European spruce
back and ribs:	Brazilian rosewood
neck:	cedar
fingerboard:	ebony
bridge:	Brazilian rosewood
internal struts:	European spruce

Scale Length

650 mm (some instruments were 640 mm)

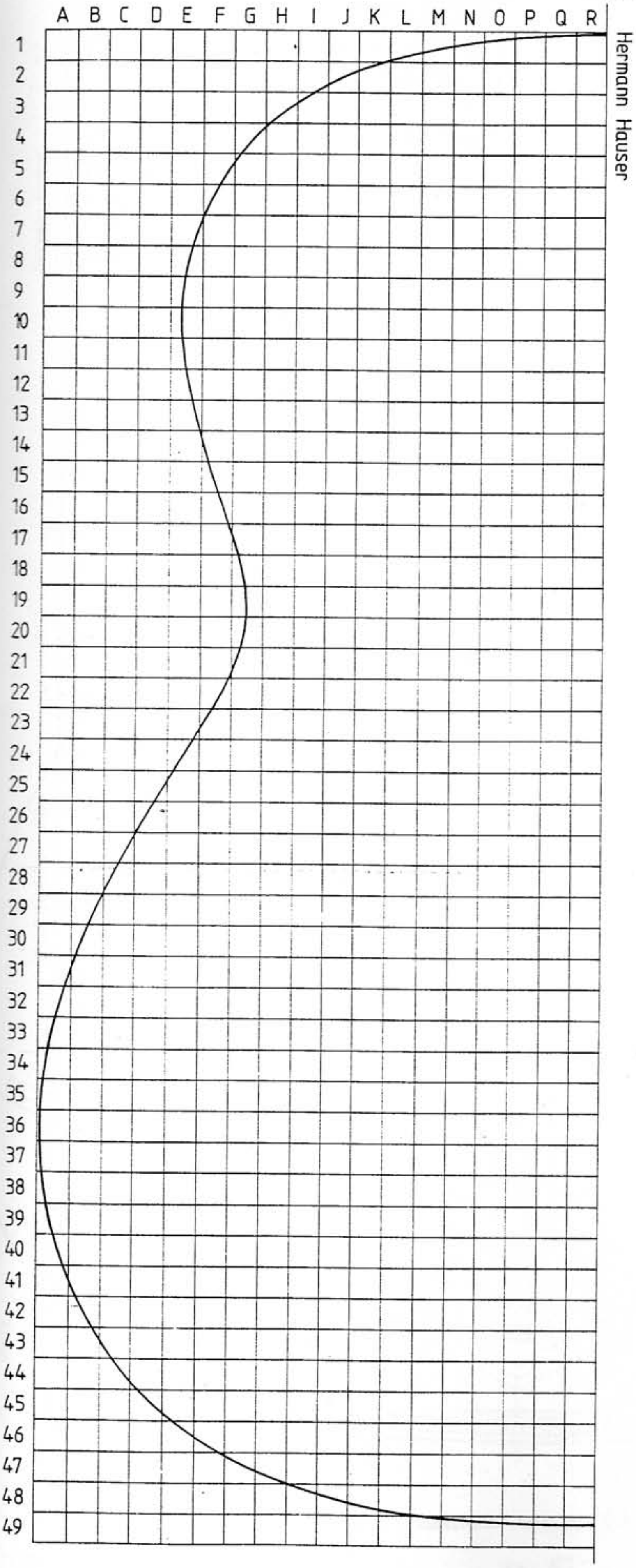
Comparison of Dimensions of Two Hauser Guitars

(measurements in millimetres)

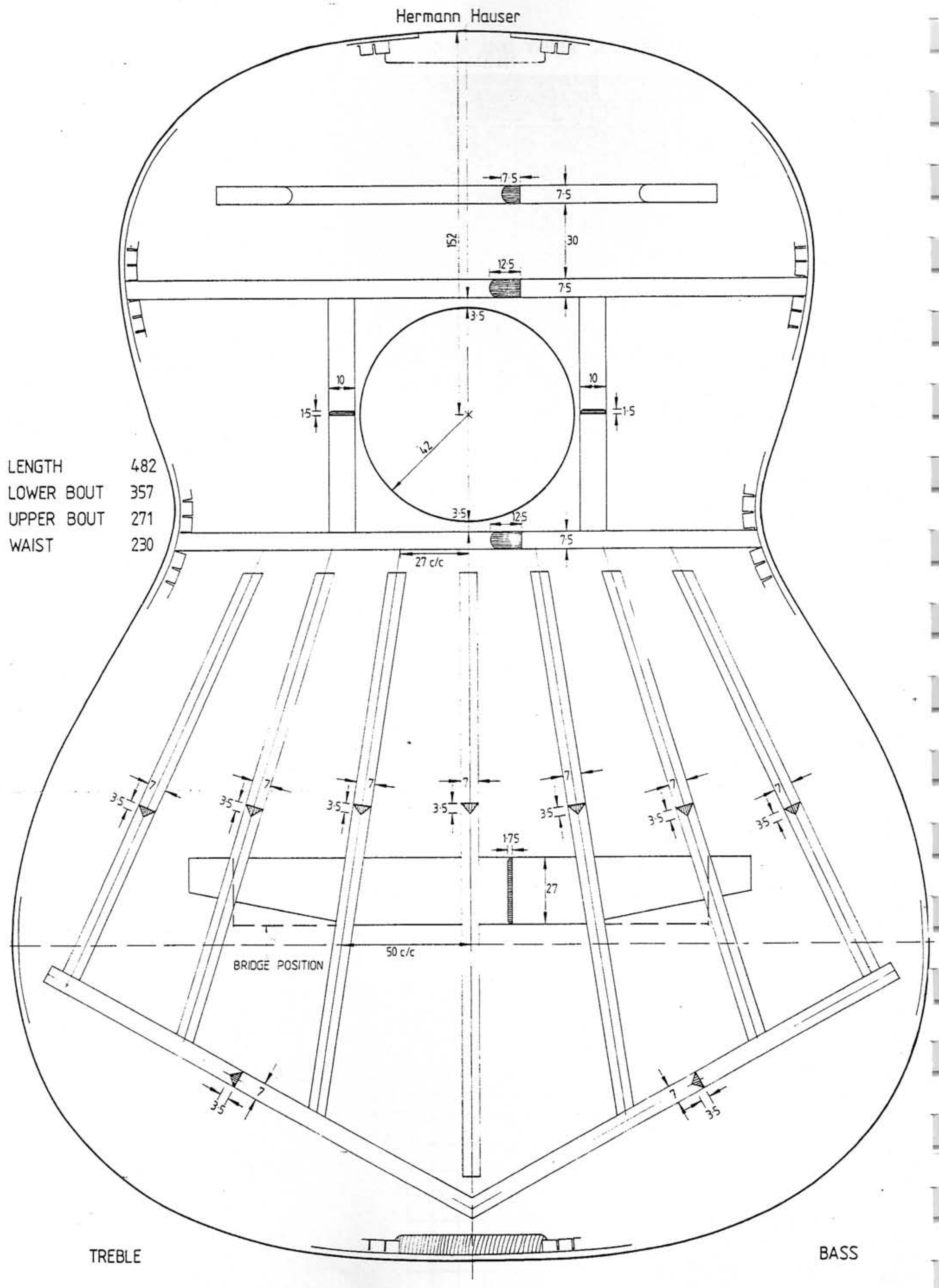
year	body length	width at upper bout	width at waist	width at lower bout	body depth at end-block	body depth at heel
1935	474	267	227	354	100	90
1949	473	266	225	352	91	86

Notes

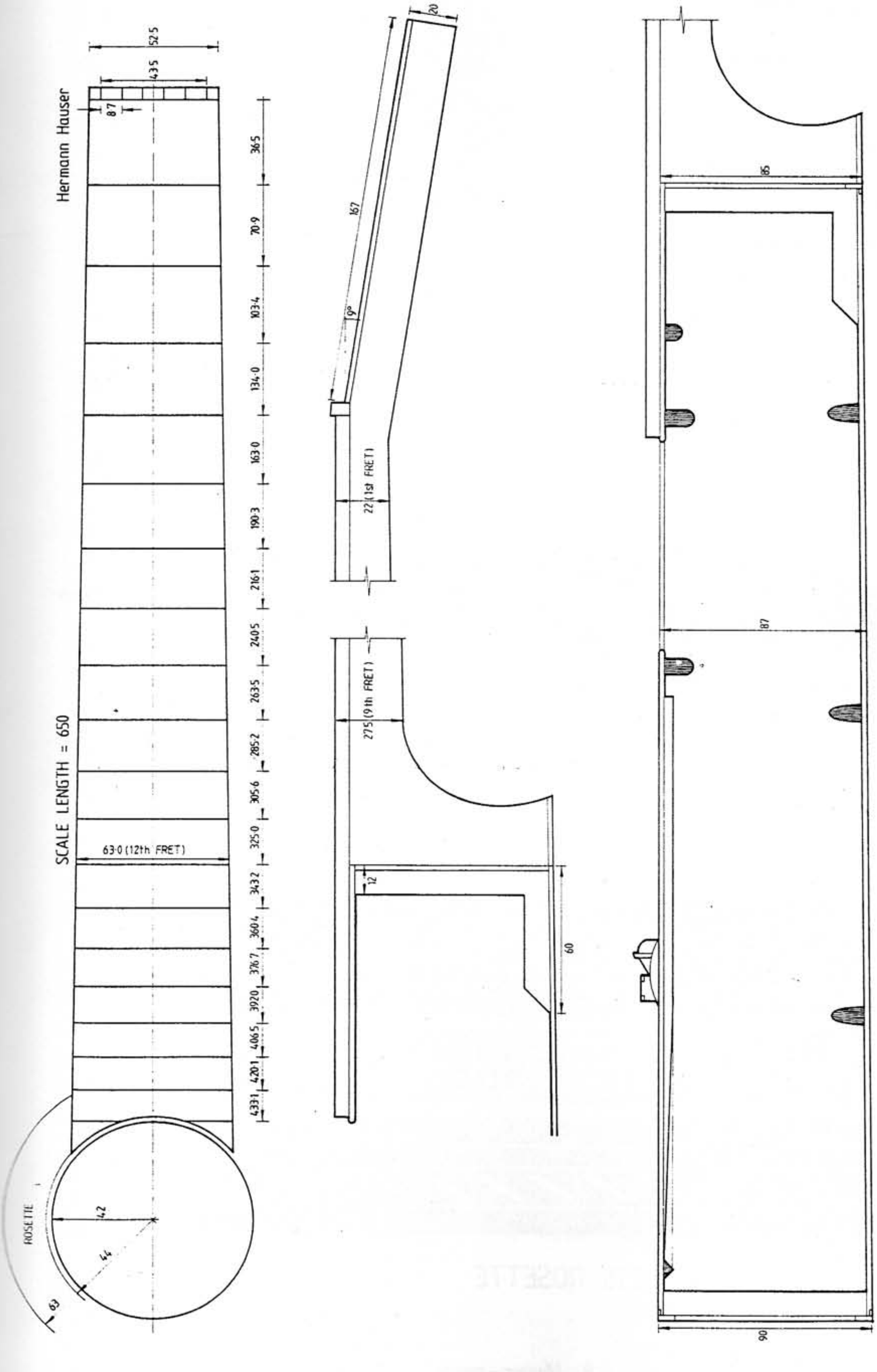
1 'In Memoriam, Hermann Hauser' by Andrés Segovia, *Guitar Review.*
2 See *Antonio de Torres – Guitar Maker – His Life and Work* by José Romanillos, for a detailed description of these events.



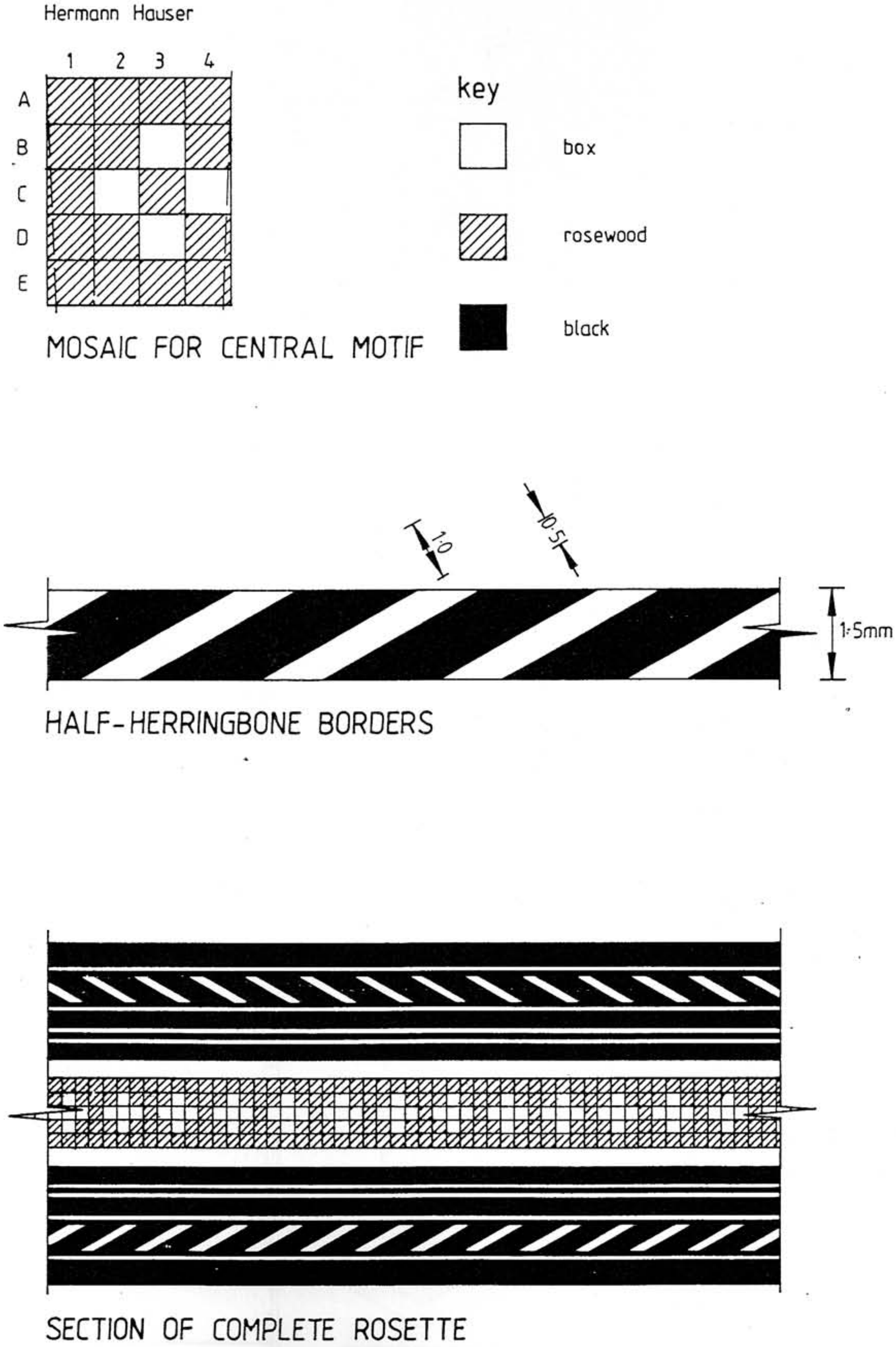
3-6 Hauser – plantilla (each square represents one square centimetre)



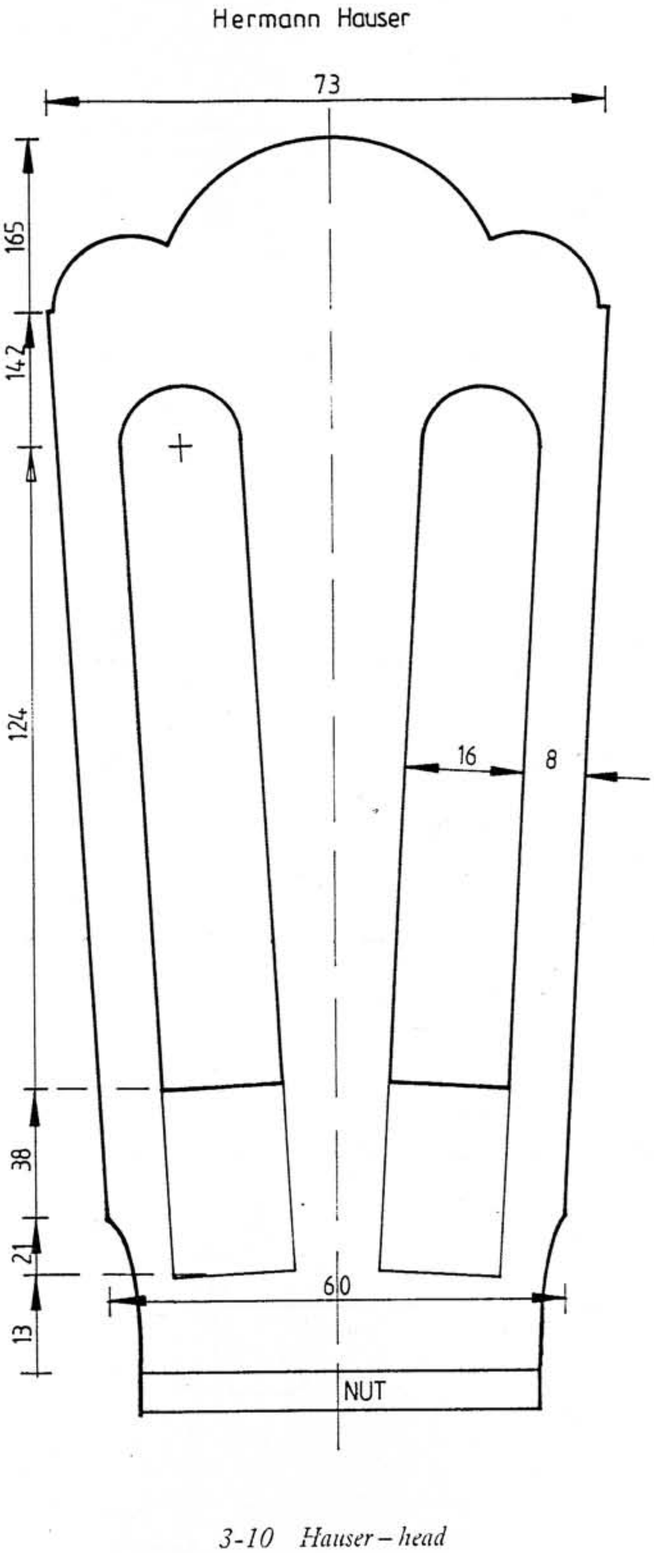
3-7 Hauser – soundboard



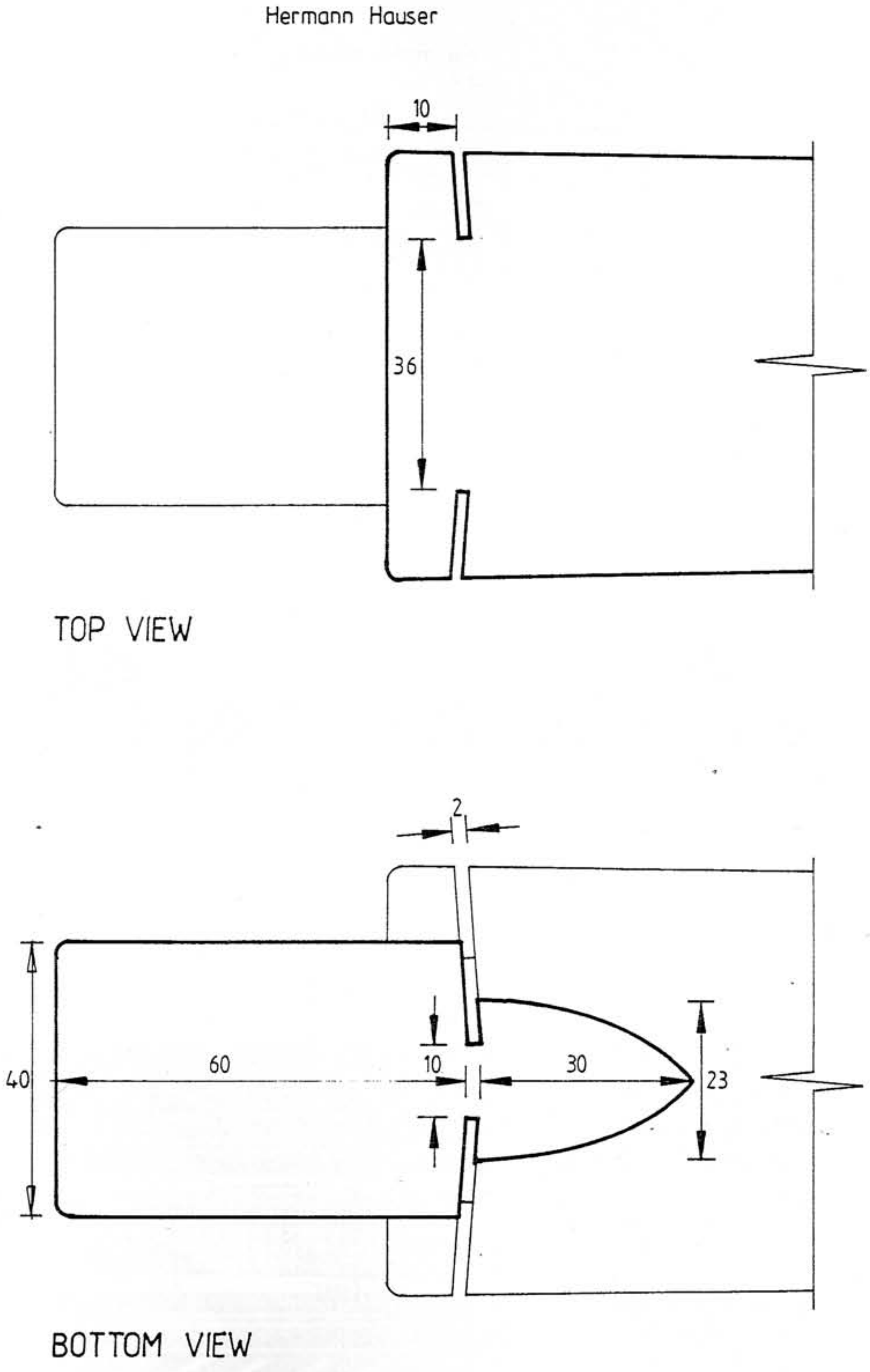
3-8 Hauser – neck and body



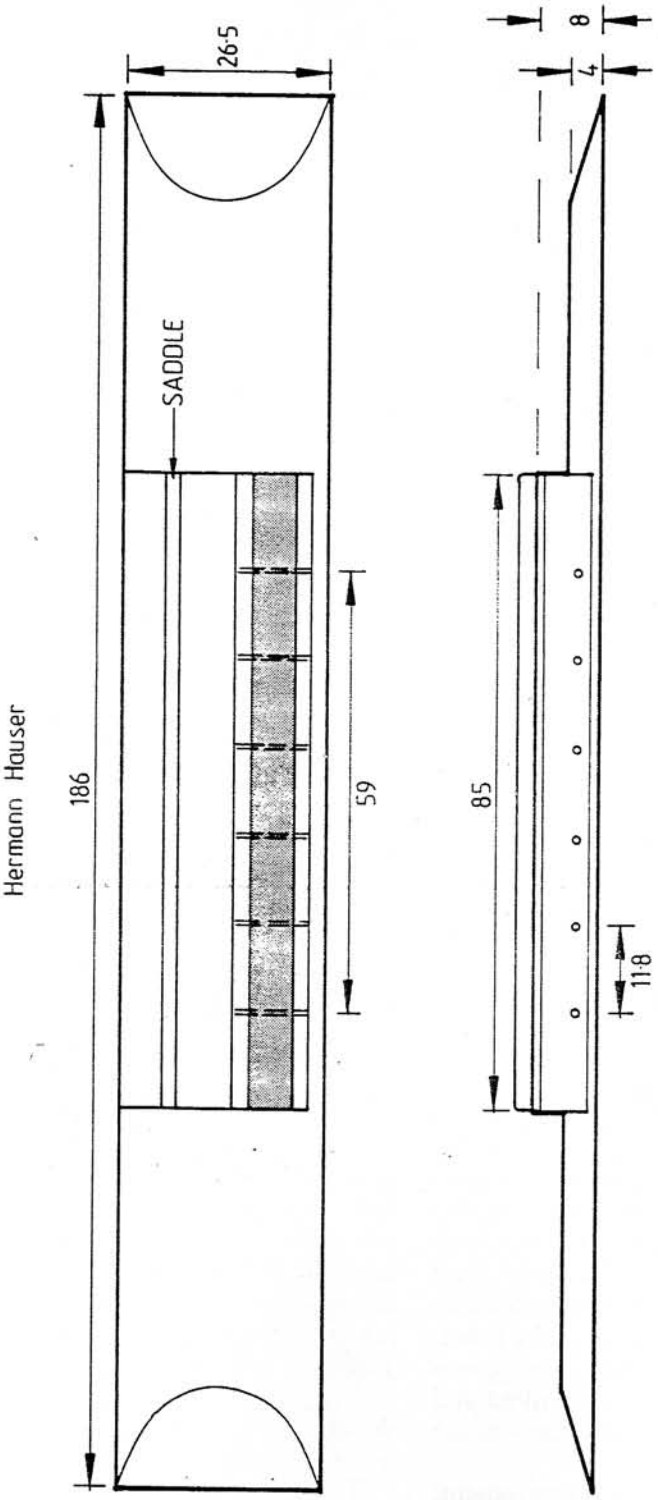
3-9 Hauser – rosette



3-10 *Hauser – head*



3-11 Hauser – neck joint



3-12 *Hauser – bridge*

4 Hernández y Aguado

(Manuel Hernández 1895–1975)
(Victoriano Aguado 1897–1982)

Background

The partnership of Manuel Hernández and Victoriano Aguado was one of the most successful in guitar making history. Hernández was born in 1895 in a village near Toledo, but his family moved to Madrid when he was eight years old. He was to remain in the Spanish capital for the rest of his life, and he became steeped in the musical tradition of the region. He began work at the age of fourteen as an apprentice at a piano workshop. His love of music, combined with his skilled craftsmanship, soon prompted his employer to allow him to work in the most creative area of the workshop – it was here that the main piano bodies were constructed, and the attendant acoustic problems solved.

Aguado was born in 1897 in Madrid. He grew up there and eventually he went to work at the same piano workshop as a french polisher. The two became close friends, and when their employer's business closed down in 1941 they decided to set up their own workshop which would specialize in the restoration of pianos and antique furniture. Aguado was an enthusiastic guitarist, and eventually the two men decided to make a couple of guitars. They were encouraged when the professor for guitar at the Real Conservatorio de Madrid responded very favourably to the instruments, and they went on to make more. They learnt much by watching Modesto Borreguero at work – he had studied with Manuel Ramírez and was able to show the two aspiring makers many of the traditional skills.

Their following guitars were a great improvement; well balanced, and with a stronger sound. They then decided to turn their entire workshop over to guitar production, and went off to Paris to buy cedar and rosewood. From Germany they bought ebony for fingerboards, and spruce for soundboards. Madrid was already well supplied with established guitar makers, yet, by the end of their first year of full-time making, they had a waiting list of seventy customers. By 1975, over four hundred guitars had been produced, although Aguado retired from the business in about 1970, when he wrote a detailed account of his friendship and working partnership with Hernández; 'Notas Biograficas de la Firma, Hernández y Aguado'.[1] Hernández worked for his last few years with his son-in-law, Jesus Belezar.

Part of the appeal of their instruments is that they do not impose a strong character on the player. Beautifully made, and elegantly proportioned, the guitar awaits the player's skill and interpretation, to bring it to life. It therefore suits the guitarist who has clear ideas about musical expression. This is in strong contrast to a maker like Fleta, whose instruments seem to exude the 'Fleta' sound before anything else. It has been said that Hernández y Aguado's instruments are 'neither very loud nor very soft, very harsh nor very mellow. It is the sort of guitar which would be boring if it were not very good of its kind. Its qualities represent a kind of mean of many of the desirable features on a guitar, resulting in an attractive instrument which has a less clearly marked 'personality' than many others.'[2]

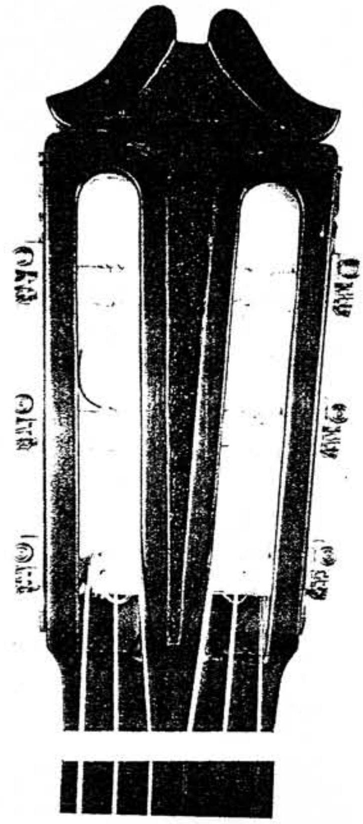
Soundboard and Strutting System

The spruce soundboard is fairly thin; indeed, the entire guitar is lightly built, although quite large in size. Hernández y Aguado varied their strutting methods – some instruments have five fan struts, some seven, and some incorporate an additional diagonal bar below the soundhole, angled down towards the treble side. They usually glued a long bridge plate on the inside of the soundboard, directly below the bridge, and the fan struts are notched to pass over it. Of three instruments examined, one was constructed in 1963 and had five fan struts; one in 1966, with seven fan struts; and one in 1968, with six fan struts as well as a diagonal bar. The dimensions of the struts are small, usually not being more than 3 mm high, and 5 mm wide. The back is joined to the ribs with a continuous kerfed lining, while the soundboard is attached with individual blocks glued together to form a continuous lining. Tiny pin holes are visible on these blocks, which result from a pointed tool being held against the blocks while the glue dried. The harmonic bars are rectangular in section, although the ends are very slightly tapered down. The bars are let into the lining, and supported by small rib-blocks glued to the ribs.

Two different strutting patterns are provided – the first is taken from the 1963 guitar (five fan struts), and the second is taken from the 1968 guitar (six fan struts with an additional diagonal bar). These two patterns are representative of the majority of their work, and provide the scope for two quite different instruments to be made.

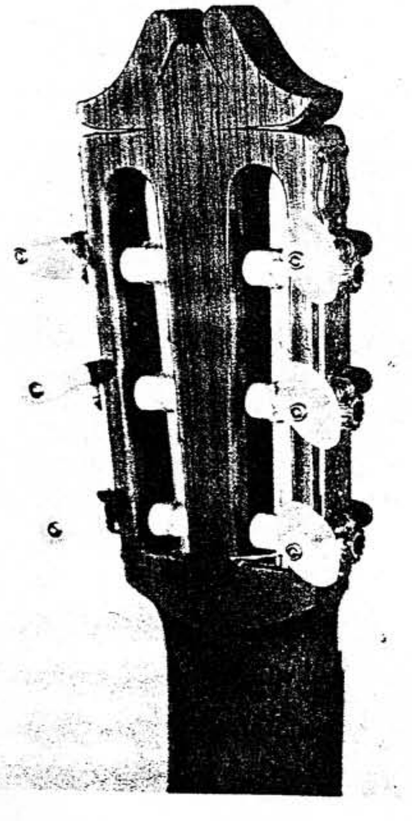
Plantilla

The body is elegantly shaped, with gently curving bouts. It is well-proportioned, and comfortable to hold. As with many makers, the dimensions vary slightly from one instrument to another, either as the result of deliberate experimentation, or simply because the ribs were not always bent to exactly the same profile.



4-2 Front view of the Hernández y Aguado head

4-1 A guitar made by Hernández y Aguado in 1967 (No. 341)



4-3 Back view of the Hernández y Aguado head

Neck

The traditional Spanish method is used, with the ribs housed into slots cut into the heel/foot unit. The neck is quite shallow, ranging from 21.7 mm at the nut, to 23.0 mm at the 9th fret. The width across the fingerboard is 52.5 mm at the nut, widening to 62.5 mm at the 12th fret.

Head

The head design is bold, and includes two central areas which are carved out, and finished with a textured effect.

Rosette

The rosette design illustrated (4-10) is one of several that Hernández y Aguado used. Made from both natural and stained woods, it consists of a central, repeating zig-zag motif, which is bordered on both sides by a multi-coloured half-herringbone design. The photograph (4-4) shows another rosette by these makers.

The rosette shown at (4-10) is 16 mm wide.

4-4 The rosette on the 1967 guitar. The zig-zag border motif was also used as the central motif on some instruments; see (4-10)

From outer circumference:

Outer border:

1.0	black
1.0	half-herringbone (multi-coloured)
0.5	box
0.5	black
0.5	green
0.5	red
0.5	box
1.0	black
0.25	green

Central section:

4.5	end-grain mosaic pattern

Inner border:

0.25	green
1.0	black
0.5	box
0.5	red
0.5	green
0.5	black
0.5	box
1.0	half-herringbone (multi-coloured)
1.0	black

Materials

soundboard:	European spruce
back and ribs:	Brazilian rosewood
neck:	cedar
fingerboard:	ebony
bridge:	Brazilian rosewood
internal struts:	European spruce

Soundboard Thickness

2.0 mm

Back Thickness

2.0 mm

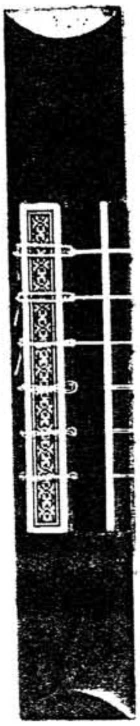
Bridge

In some examples the bridge tie-blocks are covered with a mother-of-pearl veneer, and bordered with rosewood; in others a section of the rosette motif is applied like a veneer.

Notes

1 Hogenmüller, Siegfried, 'Hernández y Aguado – The End of a Great Guitar Era' (*Guitar Magazine*). The 'Notas' were never published commercially – the original handwritten version is now in the possession of Siegfried Hogenmüller.

2 Evans, T. and M., *Guitars – From the Renaissance to Rock*, p. 68.



4-5 The Hernández y Aguado bridge – the tie-block is veneered with the central motif of the rosette

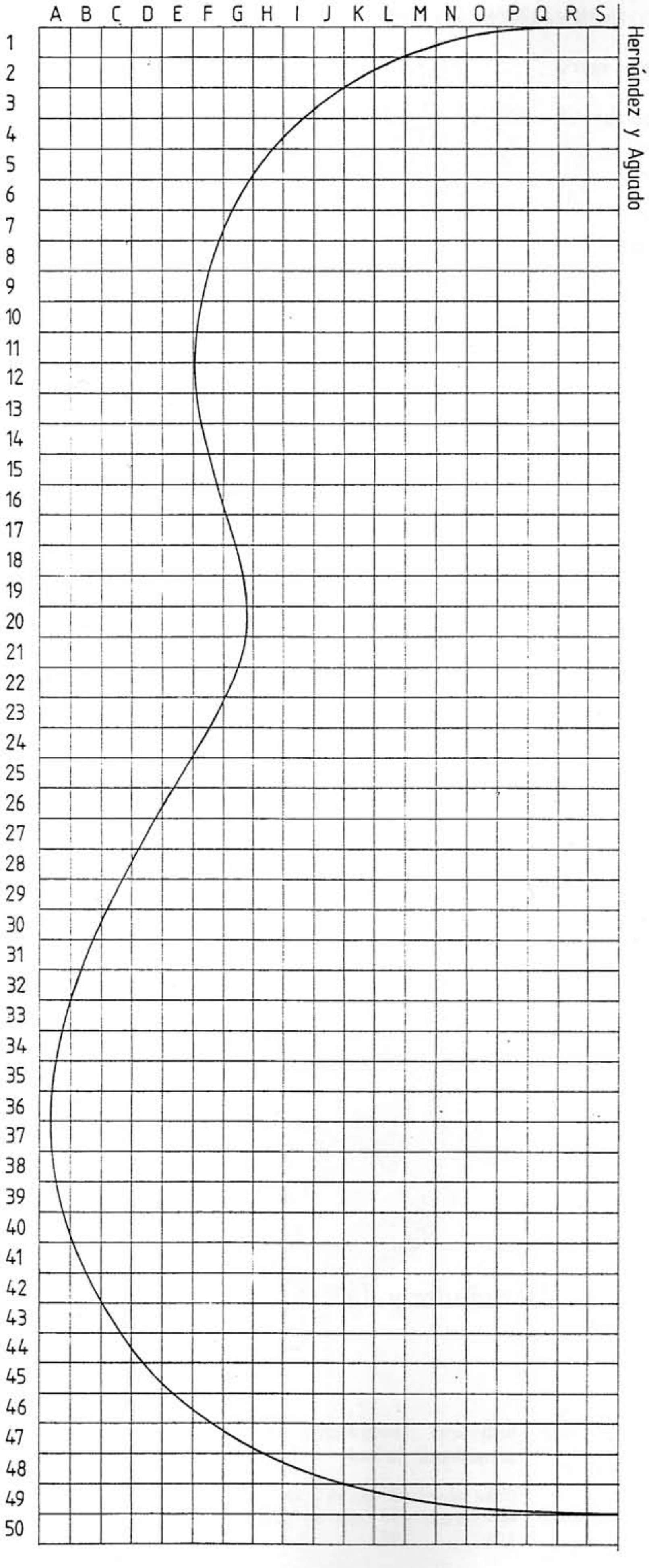
Scale Length

650 mm

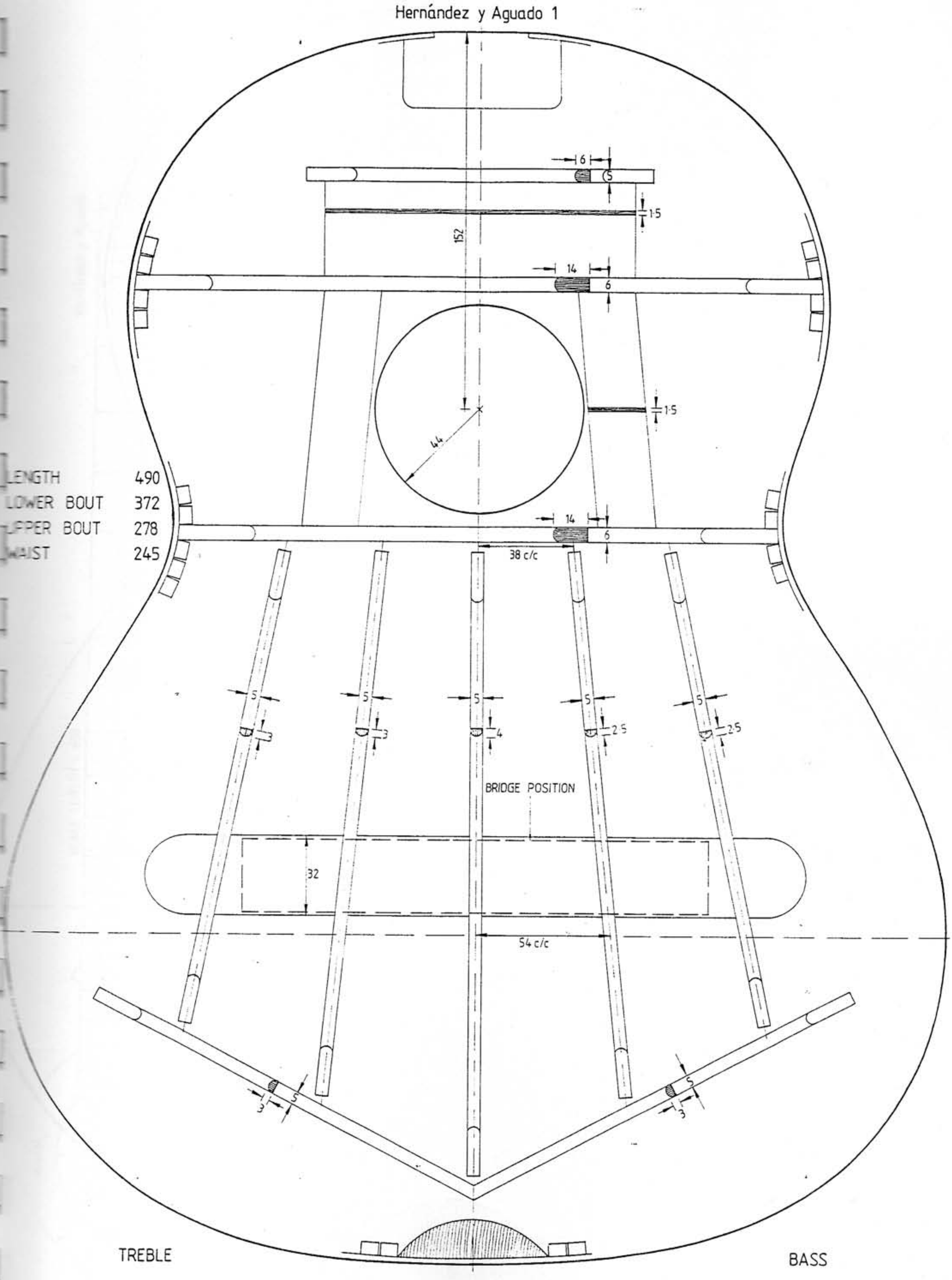
Comparison of Dimensions of Three Hernández y Aguado Guitars

(measurements in millimetres)

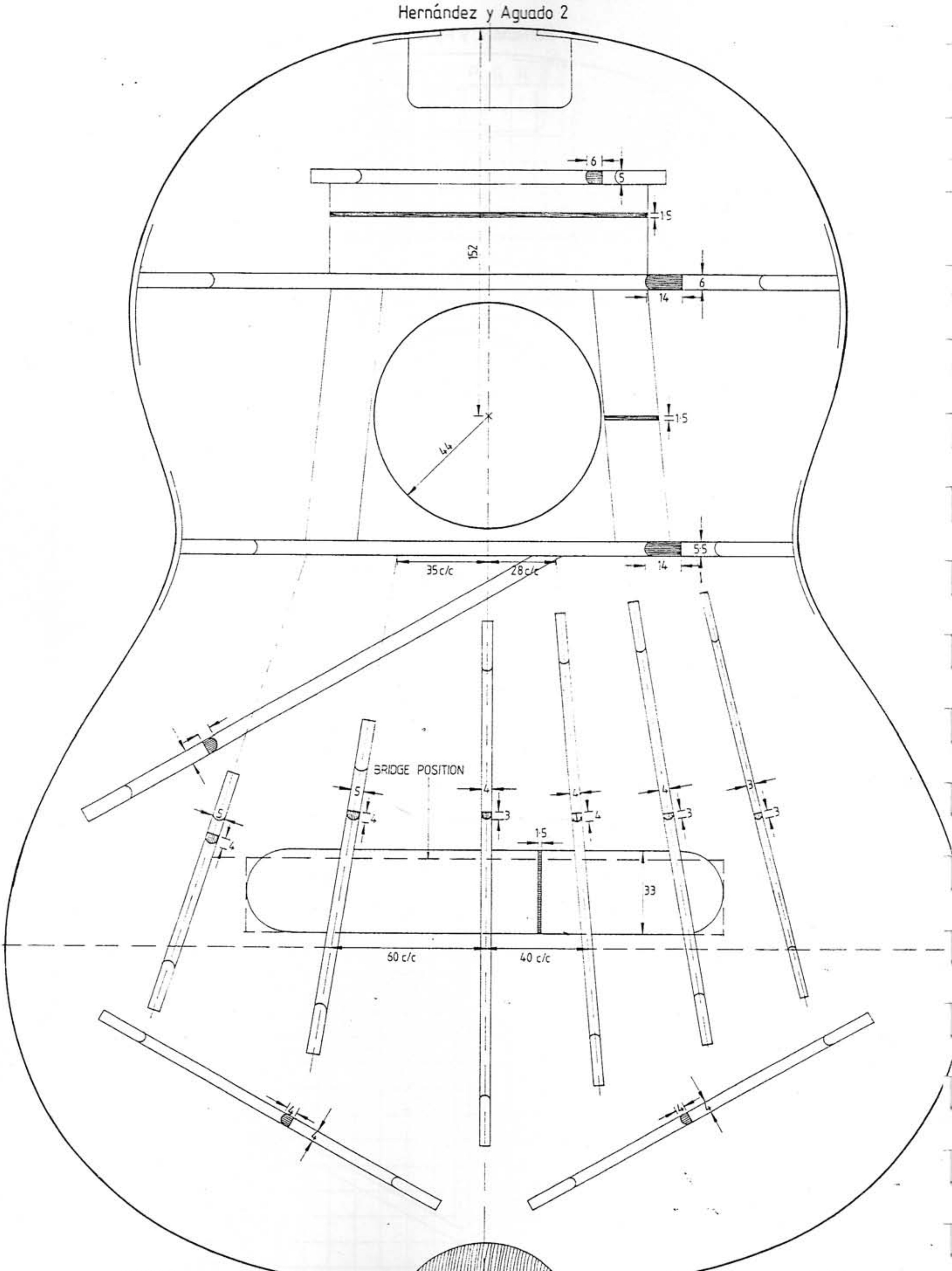
year	body length	width at upper bout	width at waist	width at lower bout	body depth at end-block	body depth at heel
1963	490	278	245	372	98	94
1966	486	282	248	372	102	96
1968	487	282	246	372	104	95



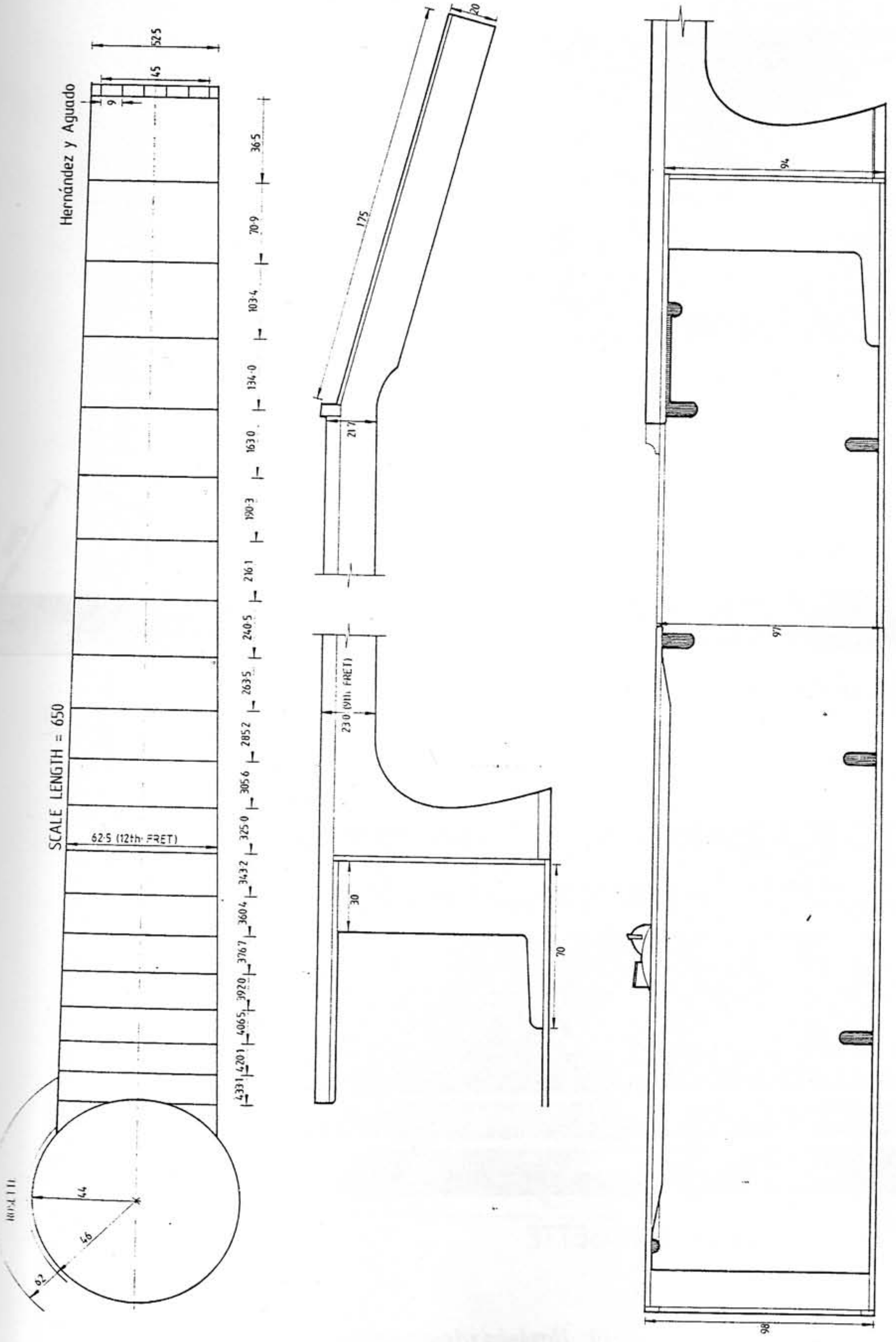
4-6 Hernández y Aguado – plantilla (each square represents one square centimetre)



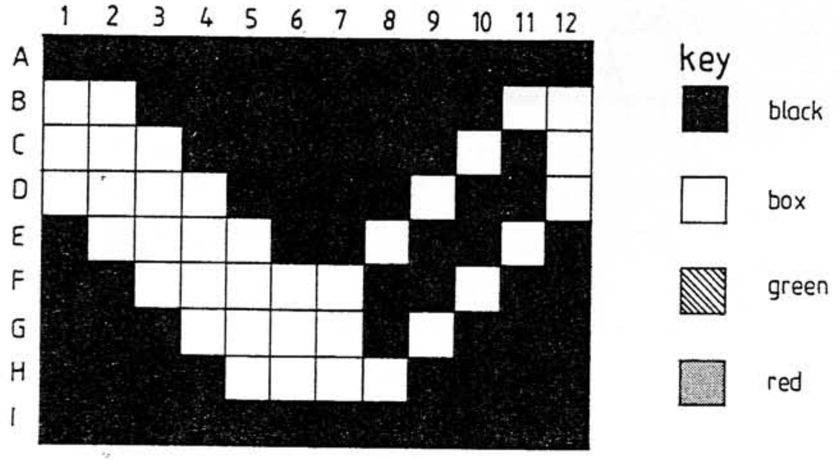
4-7 Hernández y Aguado – soundboard 1



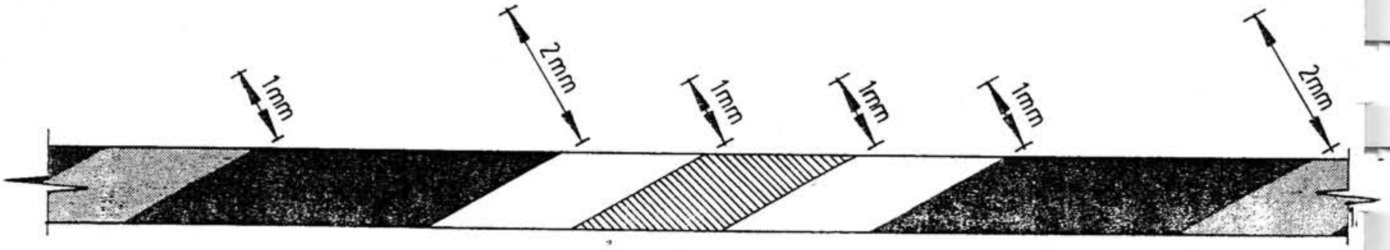
4-8 Hernández y Aguado – soundboard 2


Hernández y Aguado
SCALE LENGTH = 650
62·5 (12th FRET)
52·5
45
9
36·5
70·9
103·4
134·0
163·0
190·3
216·1
240·5
263·5
285·2
305·6
325·0
343·2
360·4
376·7
392·0
406·5
420·1
433·1
44
46
20
175
21·7
23·0 (VIII. FRET)
30
70
94
97
98

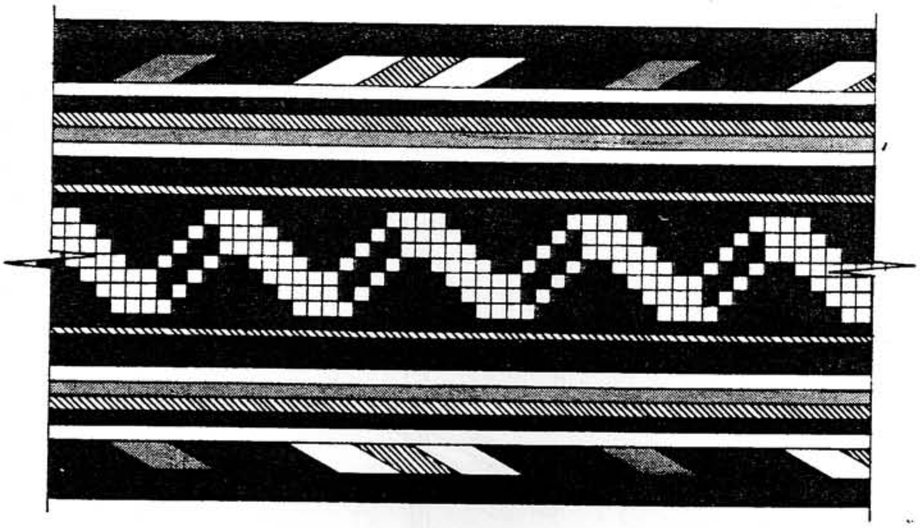
Hernández y Aguado



MOSAIC FOR CENTRAL MOTIF

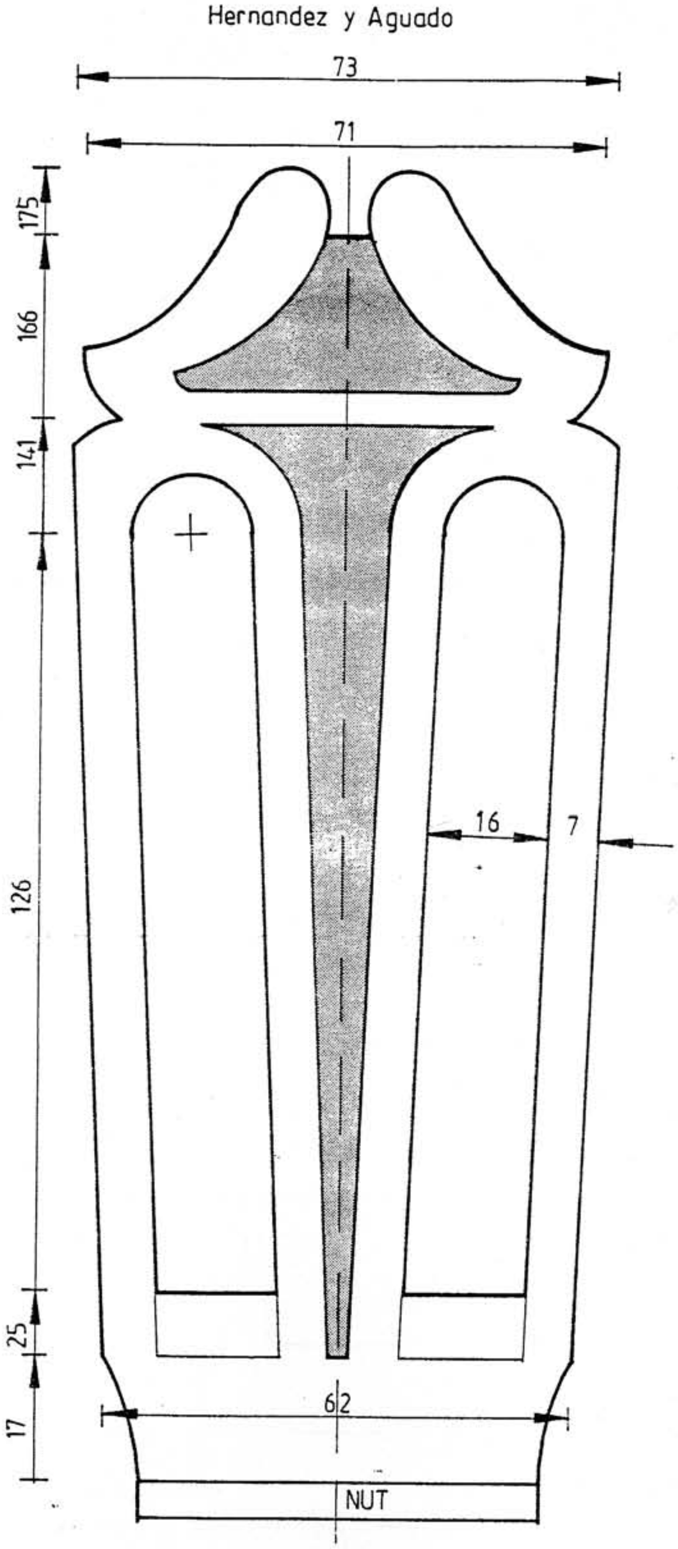


HALF HERRINGBONE BORDERS

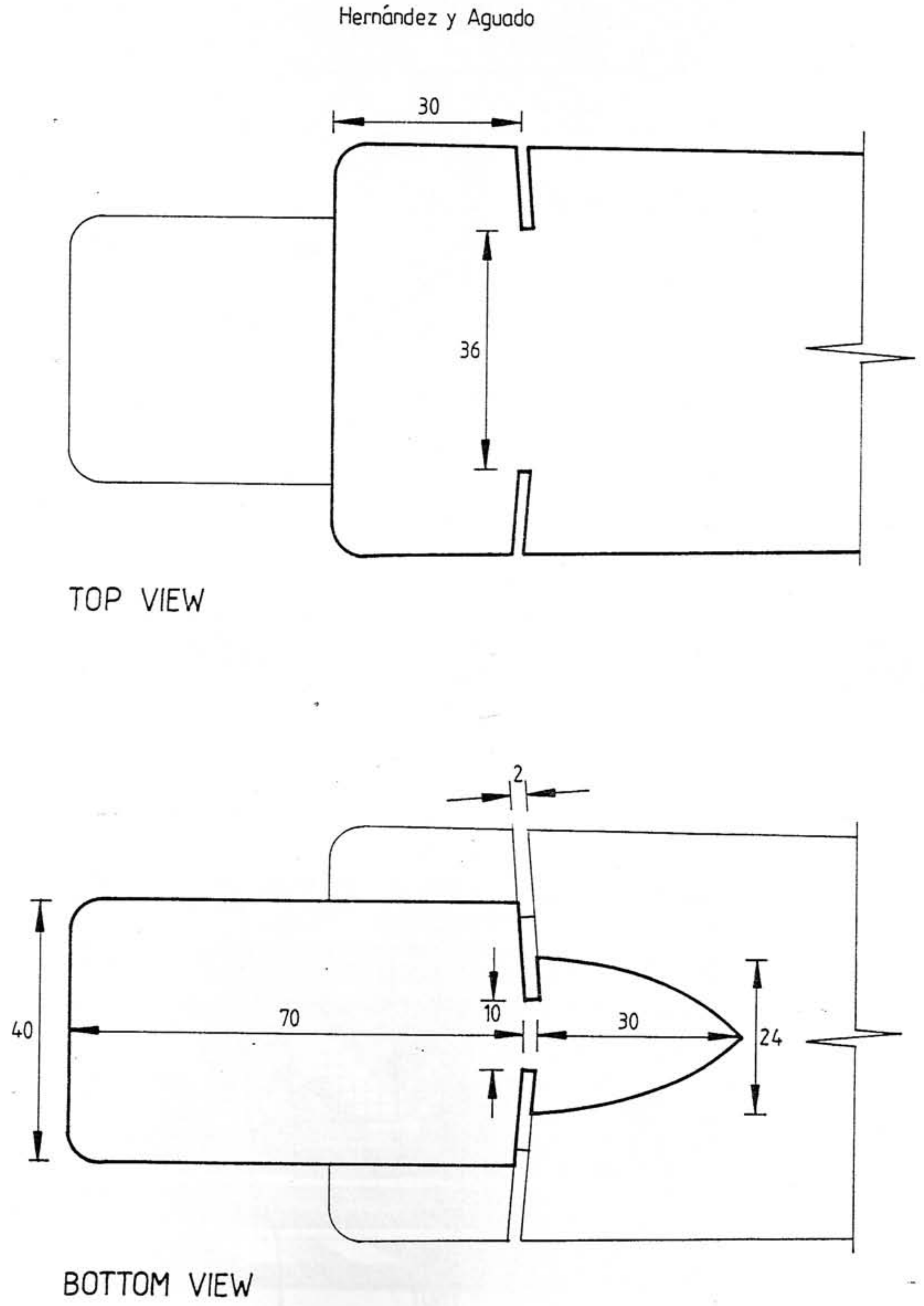


SECTION OF COMPLETE ROSETTE

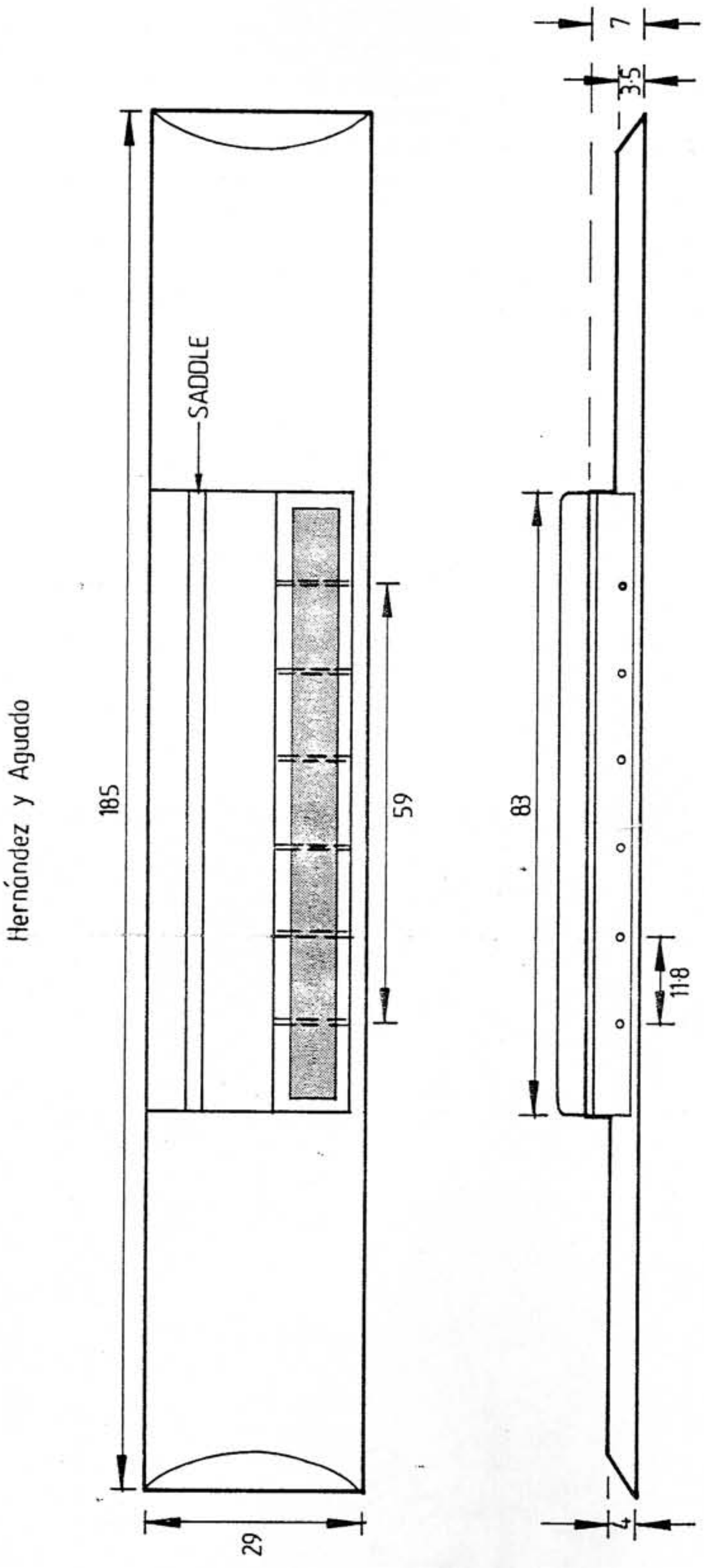
4-10 Hernández y Aguado – rosette



4-11 *Hernández y Aguado – head*



4-12 Hernández y Aguado – neck joint



4-13 Hernández y Aguado – bridge

5 Ignacio Fleta *(1897–1977)*

Background

The guitars made by Ignacio Fleta are renowned for their tremendous power, making them ideal for the concert hall. Working in two rather small interconnecting workshops in old Barcelona, he began his career as a musical instrument maker with a whole range of bowed instruments, including violins, violas, and cellos. Gabriel and Francisco, his two sons, later joined the workshop, and they carried on the Fleta name after the death of their father on 11 August 1977.

Fleta's father was a joiner, and the young Ignacio developed a love of working with wood early on in life, when he helped in his father's workshop. By the time he was eight years old, he could play the guitar, and at thirteen, he was sent to Barcelona with his two brothers, Bienvenido and Manuel. They were employed in the workshop of a French luthier, where they worked on a variety of stringed instruments. This was Fleta's introduction to the world of musical instrument making, and he later set up a workshop with his two brothers. In 1927, they parted company and Ignacio established his own business at Calle de Calazbria 90 in Barcelona. Eventually he moved to a new workshop at Calle de los Angelos 4, and from here he worked for the rest of his life.

In 1920 Fleta made his first instrument – a cello. He also carried out restoration work on lutes, guitars and bowed instruments. The first guitar was made around 1930, and he continued working, despite the subsequent difficulties with supplies, caused by the onset of the Civil War. He gained a wide experience of instrument making, and during the Second World War he was commissioned to make a number of instruments for the music society 'Ars Musica'. These included a gothic harp, a violin, a lute, a vihuela and a modern guitar. The collection was extremely successful, and the name of Fleta began to spread.

5-1 The Fleta brothers in their Barcelona workshop

It was in 1955 that Fleta was able to hear the great guitarist, Andrés Segovia, for the first time. He was then determined to make guitars; 'I've heard Segovia playing. There I decided to build guitars, and only good guitars.'[1] In 1957 he made the first of three guitars which Segovia was to play all over the world. The fame of Fleta spread rapidly, and many of the greatest guitarists of the last few decades have owned his instruments; Alexandre Lagoya, Eduardo Falu, Alberto Ponce, and John Williams are but a few.

In 1975 Fleta told a visitor,

> ... only about twenty guitars are built every year. My only interest is to excel myself in my working. Each guitar we construct differs a little from the others because we always have different raw material to work with. In order to give the instruments the character I want, details in construction have to be changed from guitar to guitar. Then, at last, I am very happy when I listen to the guitar's voice for the first time and hear my ideas of sound coming out of her. I could have had the opportunity of earning millions, but this would have meant a lack of quality in my instruments – that's what I never wanted.[2]

The long waiting list made it virtually impossible to obtain a new Fleta. From time to time, second-hand Fletas come on the market, and they now fetch the very highest prices.

Fleta's early instruments were greatly influenced by Torres – a 1938 guitar (No. 83) was made with both a Torres plantilla, and an elaborate piece of maple for the back and ribs, a wood often used by Torres. The strutting and head design were also very similar. The central motif of the Fleta rosette has similarities to some Torres patterns, and he is known to have carried out repairs to Torres' guitars on a number of occasions. However, his work developed quite radically away from the Torres influence, and the character of his later guitars bears little relation to that earlier period.

Soundboard and Strutting System

Although European spruce is the traditional wood used for the soundboards of stringed instruments, many makers have also used a wood from Canada – Western red cedar – as an alternative. Fleta has used both, and it is his cedar instruments which tend to produce the unmistakable 'Fleta' sound. Cedar has very different tonal characteristics to spruce. It tends to produce a strong sound immediately when the instrument is strung up for the first time. Spruce takes quite a while to mature to its full potential. Cedar is a difficult wood to use, because the quality varies a great deal from one tree to another. It is very brittle, and splits easily along the grain. Certain visual checks can be carried out on a piece of cedar to decide how good it is. But often, the character of sound produced can be disappointing – the treble notes in particular can lack clarity. However, a good cedar soundboard can produce a remarkably powerful sound, and Fleta had a talent for using this wood to its optimum. His best cedar guitars are clear and powerful, with no hint of haziness. The Fleta strutting system is one of the unique features of his guitars.

5-2 A guitar made by Ignacio Fleta & Sons in 1968

Moving on from his earlier dependence on Torres, he modified many aspects of his strutting design. The main 'fan' section now includes nine struts, placed symmetrically. Most makers use only seven. Almost all strutting systems include two large, harmonic bars – one is above the soundhole, and the other below it. In addition to these two bars, Fleta includes an extra bar which is placed diagonally, so that, on the bass side, it is quite close to the lower harmonic bar, but on the treble side it ends near the bridge. This has the effect of containing the free vibrating area of soundboard around the treble side, which is thought to increase clarity of sound. A spruce bridge plate is glued directly below the bridge, and is 1.6 mm thick. Fleta experimented with a number of other variations – in some cases, the lower harmonic bar has wide apertures cut out, so that the area of its contact with the soundboard is limited to three points. The shape of the fan struts also varies; in some instruments they are carved like gables, while in others they are fairly wide and flat topped.

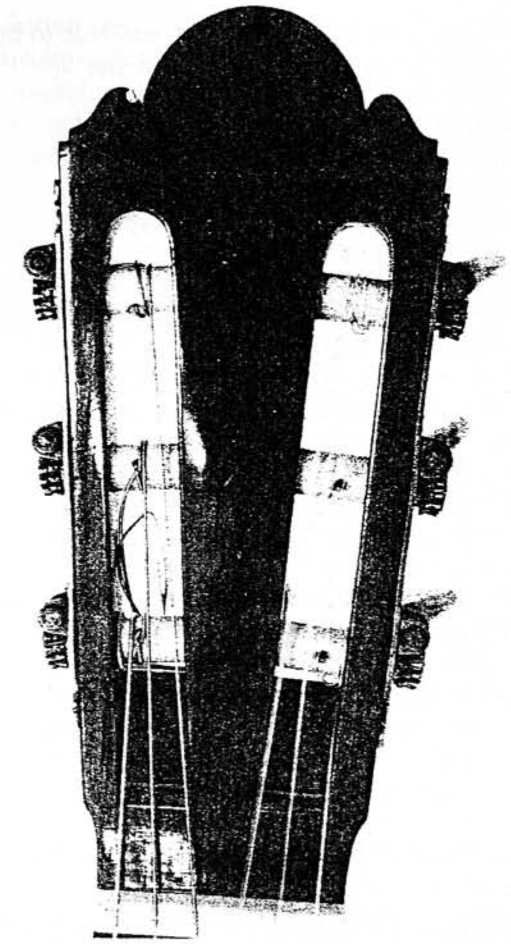
An unusual feature on some Fleta guitars is the way in which he housed the ends of the two diagonal closing struts into the end-block, perhaps to give more rigidity to the entire structure.

Plantilla

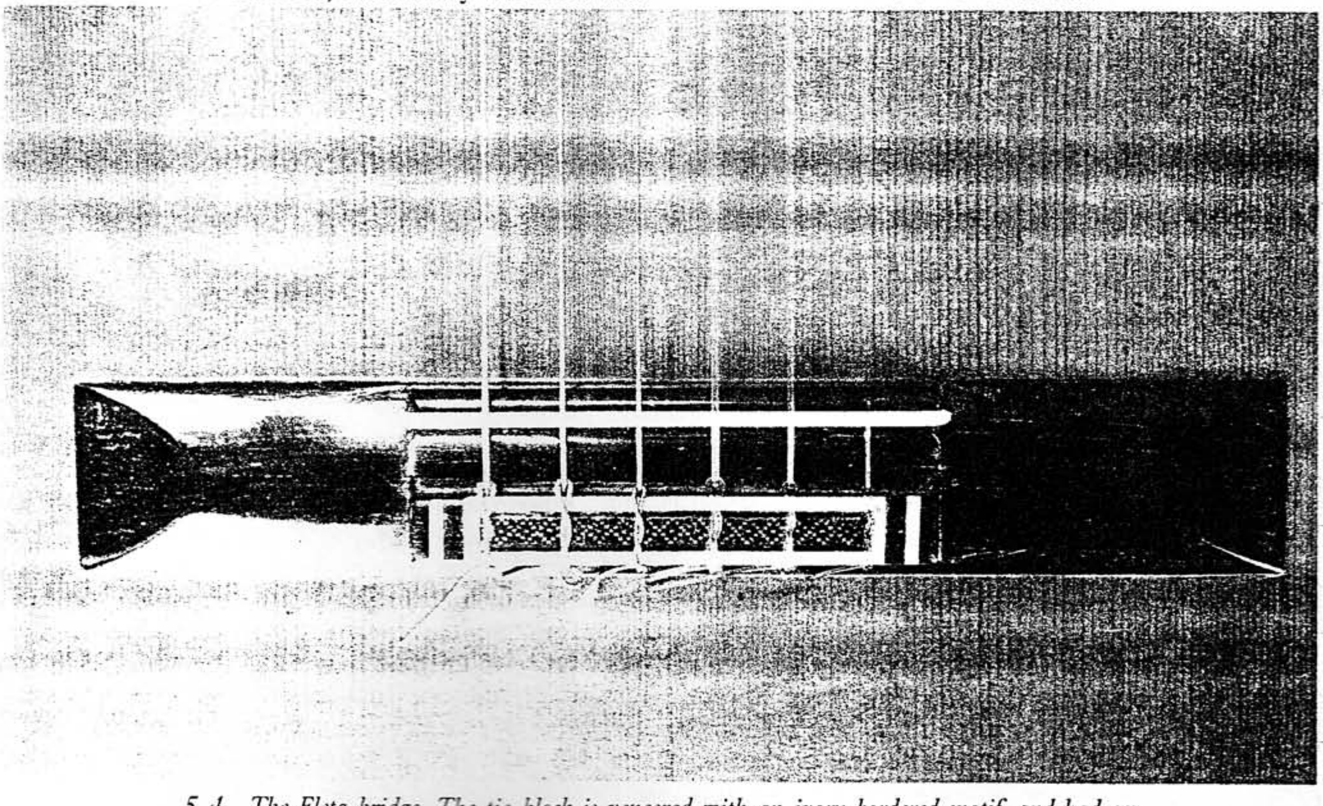
The Fleta plantilla is quite large, and both the upper and lower bouts are rather bulbous. There are no flat areas around the periphery. The width across the upper bout (roughly opposite the 18th fret position) is much greater than normal. Although not the most elegant plantilla, it seems likely that it is partly this aspect of the design that contributes to the fullness of sound produced by the instruments.

Neck

Perhaps because of his experience as a violin maker, Fleta constructed his guitars in a similar way. The body of the instrument was completed first; the ribs were bent and cramped against a mould, then the back and soundboard were attached, and finally the neck was



5-3 The Fleta head



5-4 The Fleta bridge. The tie-block is veneered with an ivory-bordered motif, and had an additional ivory strip at each end joined into a large neck block positioned inside the instrument. He constructed both the neck block and end block by laminating them from three separate pieces of wood – the main section has the grain running vertically, but the top and bottom parts are joined in with their grain running horizontally. This provides a better gluing surface for the back and soundboard, as glue does not adhere well to end-grain wood. An examination of a number of Fletas reveals that he varied the width across the fingerboard at the nut. On some instruments, this measures as little as 50 mm; on others, as much as 54 mm. As with most makers, this was probably to suit the hand size and span of the customer for whom he made the guitar. Some Fletas have an undivided 19th fret, but others follow the more conventional pattern of dividing this last fret into two.

Head

Fleta consistently used the same design for the head, which bears a resemblance to the Torres shape, except that the two small, outer curves are more elaborately shaped. The neck and head are made from one piece of wood, but the heel/foot section is laminated.

Rosette

A Fleta guitar is instantly recognizable by its rosette. Based on traditional motifs, it contains a central end-grain pattern, which repeats itself around the circle. This is sandwiched between borders of herring-bone pattern inlays.

Fleta established his personal design early on, and the same rosette is used by his sons.

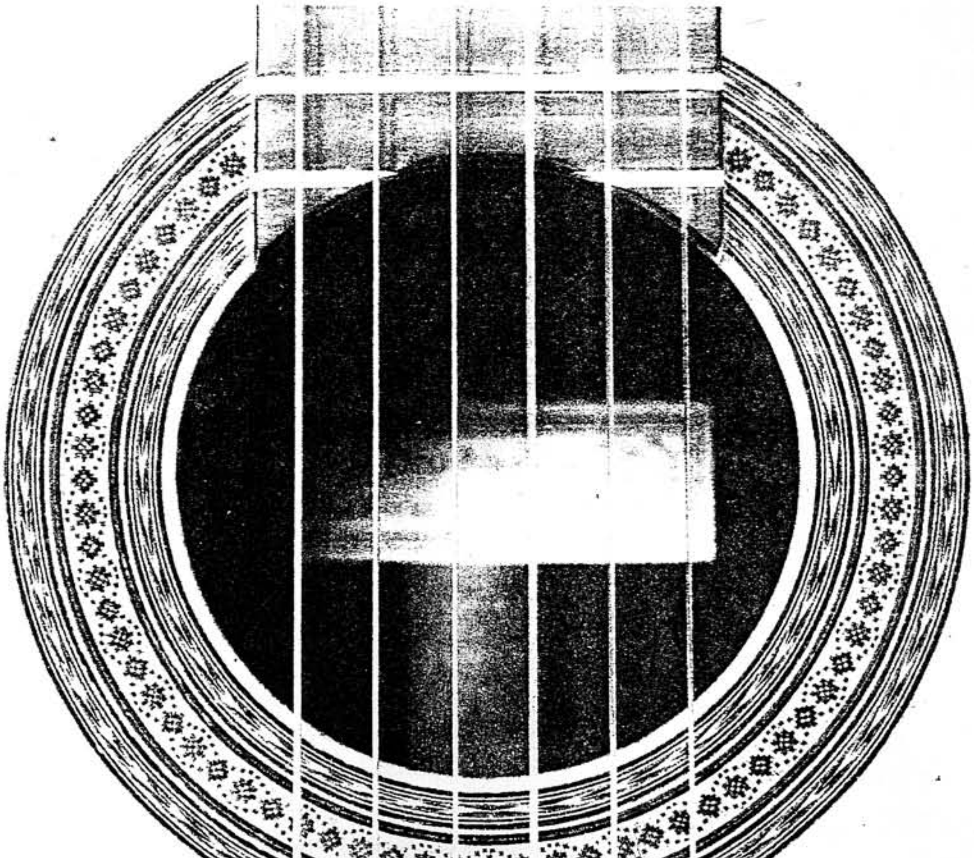
The central end-grain motif is itself the sum of two different patterns, and the simplest method of making them is to produce two separate logs, one for each pattern, and then glue them together. The various inlay lines which run between the herringbone and the central motif are cut from sheets of veneer.

The rosette is 21 mm wide.

From outer circumference:

Outer border:

0.5	black
0.25	box
0.25	black
0.25	box
2.0	black and white herringbone
0.25	box



5-5 The Fleta rosette

0.25	black
0.25	box
0.5	black
1.0	box
0.25	black
0.25	green
0.25	black
1.0	box
0.5	orange

Central section:

6.5 end-grain motif

Inner border:

0.5	orange
1.0	box
0.25	black
0.25	green
0.25	black
1.0	box
0.5	black
0.25	box
0.25	black
0.25	box
2.0	black and white herringbone
0.25	box
0.25	black
0.25	box
0.5	black

Materials

soundboard:	Western Red Cedar
back and ribs:	Brazilian rosewood
neck:	cedar
fingerboard:	ebony
bridge:	Brazilian rosewood
internal struts:	European spruce

Soundboard Thickness

2.6 in central and bridge areas
2.1 around the periphery

Back Thickness

2.3 to 2.1 (thickest in the central area)

Weight

The complete instrument weighs 550 grams

Scale Length

650 mm

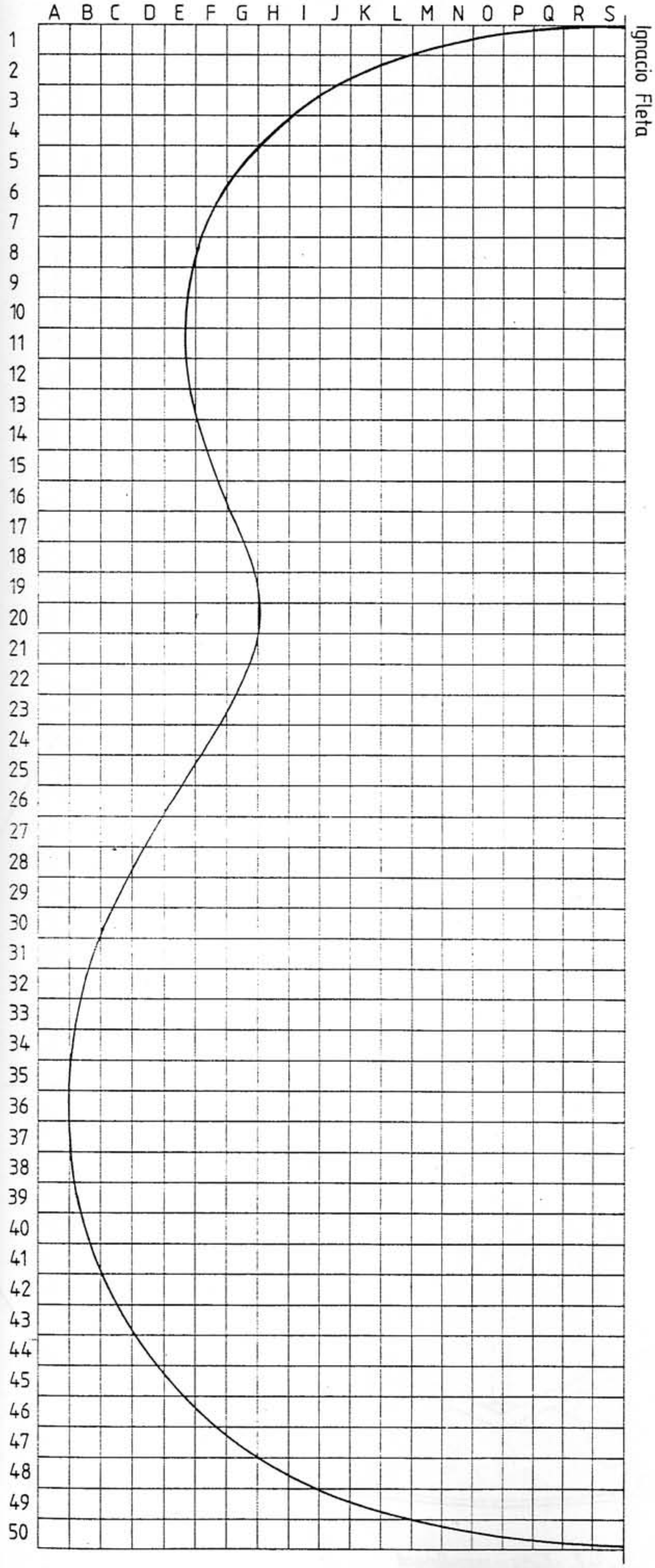
Comparison of Dimensions of Three Fleta Guitars

(measurements in millimetres)

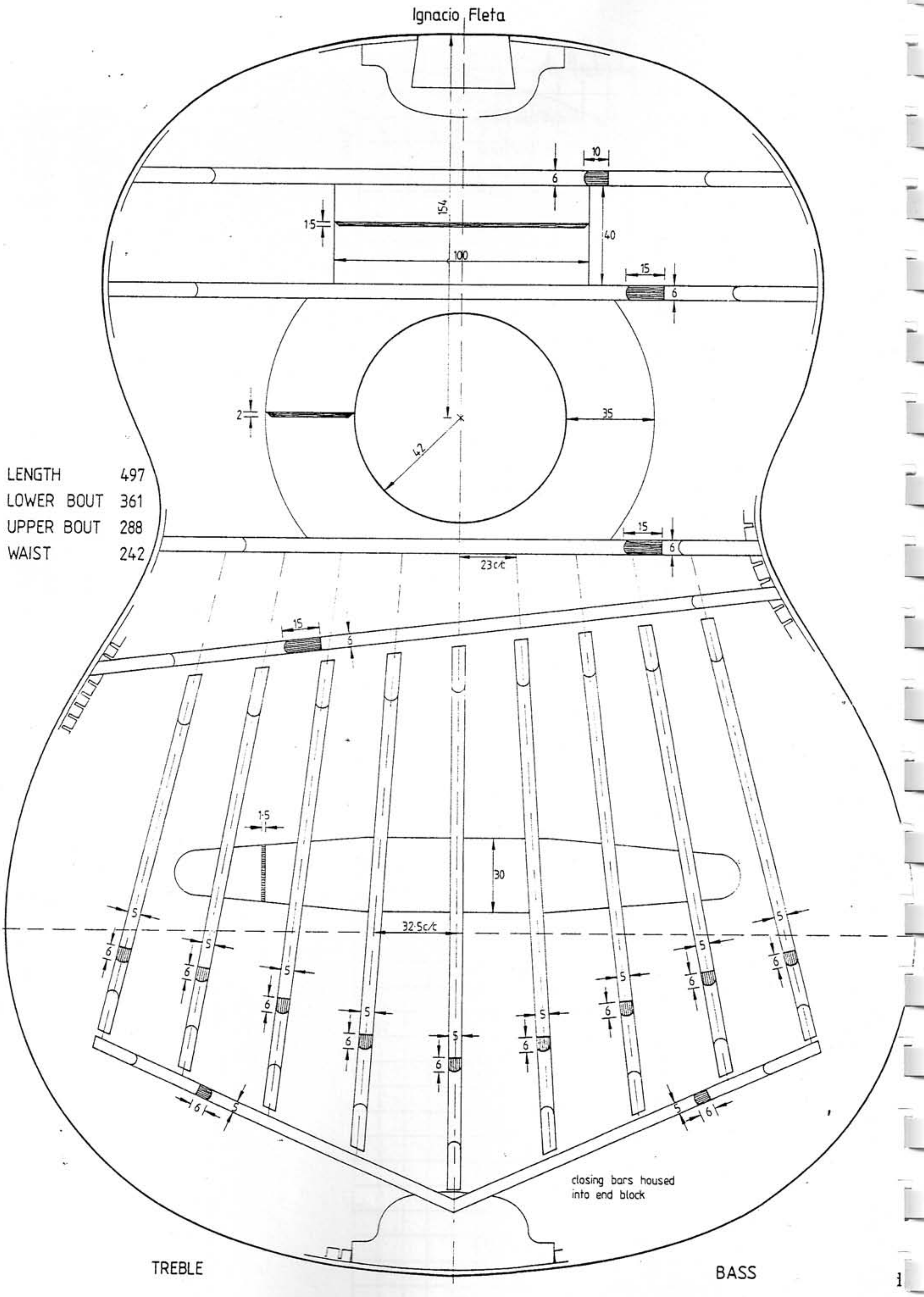
year	body length	width at upper bout	width at waist	width at lower bout	body depth at end-block	body depth at heel
1961	495	290	242	363	98	96
1968	497	288	242	361	100	96
1969	495	293	246	367	99	96

Notes

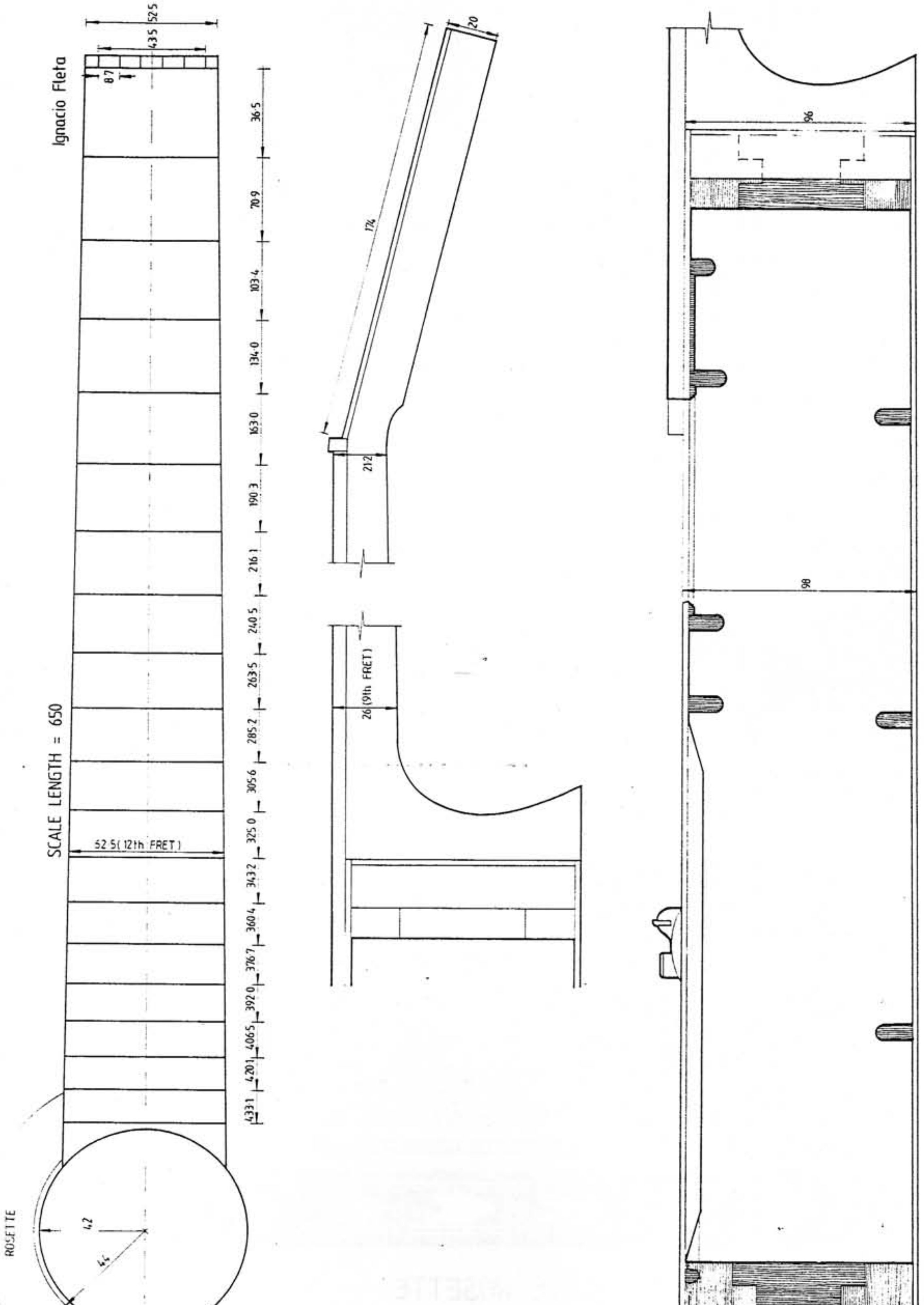
1 'In Memoriam – Ignacio Fleta' by Siegfried Hogenmüller (*Guitar Magazine*).
2 ibid.



5-6 Fleta – plantilla (each square represents one square centimetre)

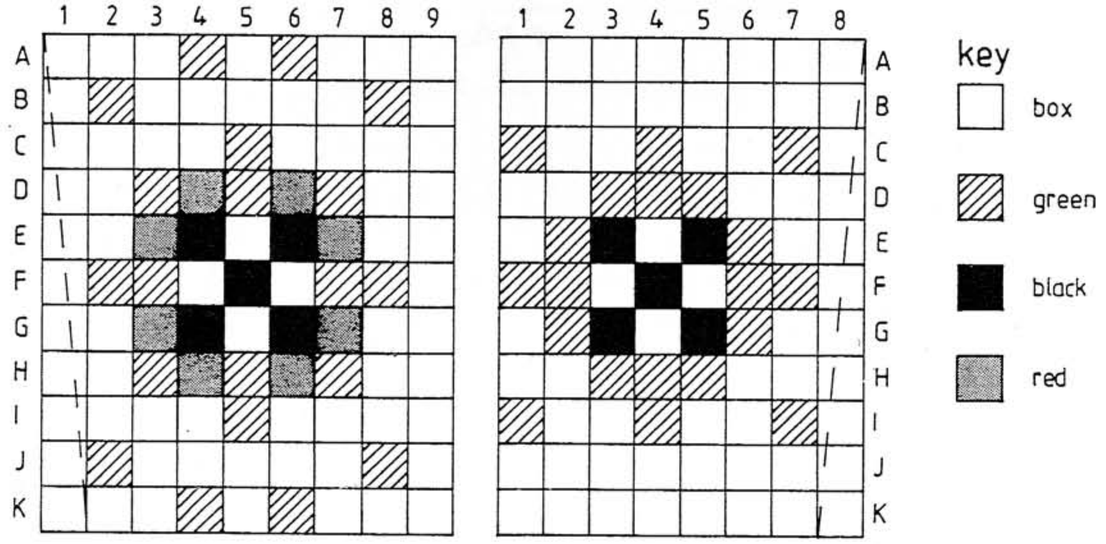


5-7 Fleta – soundboard



5-8 *Fleta – neck and body*

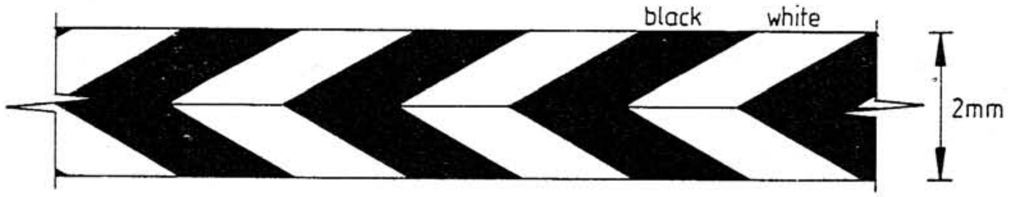
Ignacio Fleta



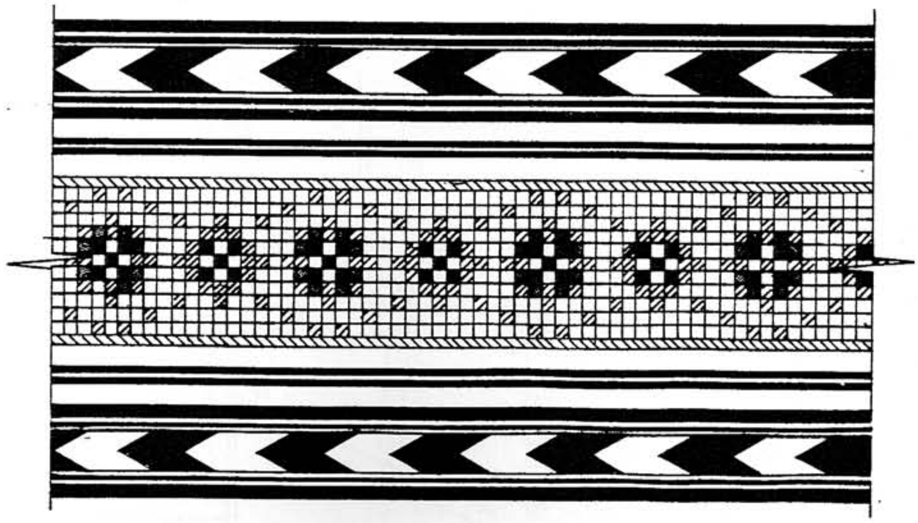
Block A

Block B

MOSAIC FOR CENTRAL MOTIF

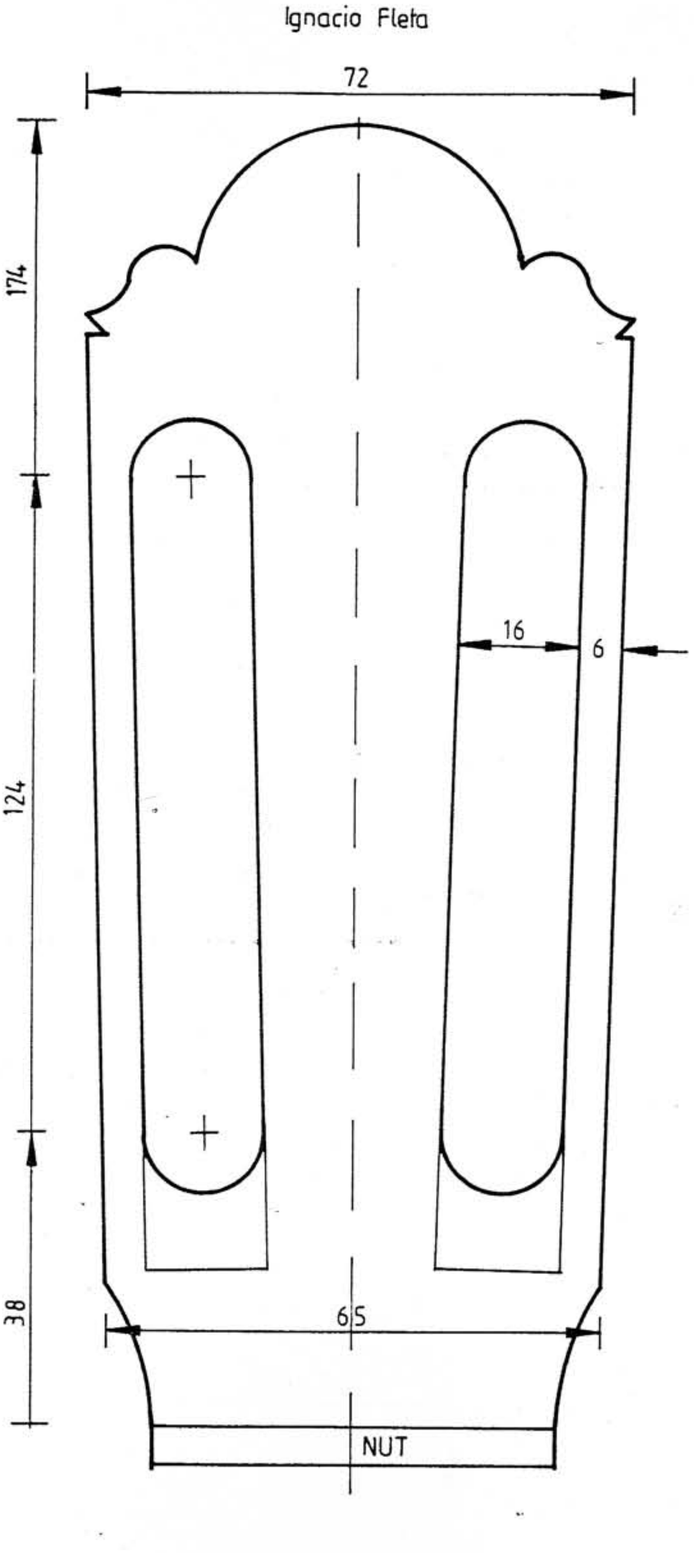


HERRINGBONE BORDERS

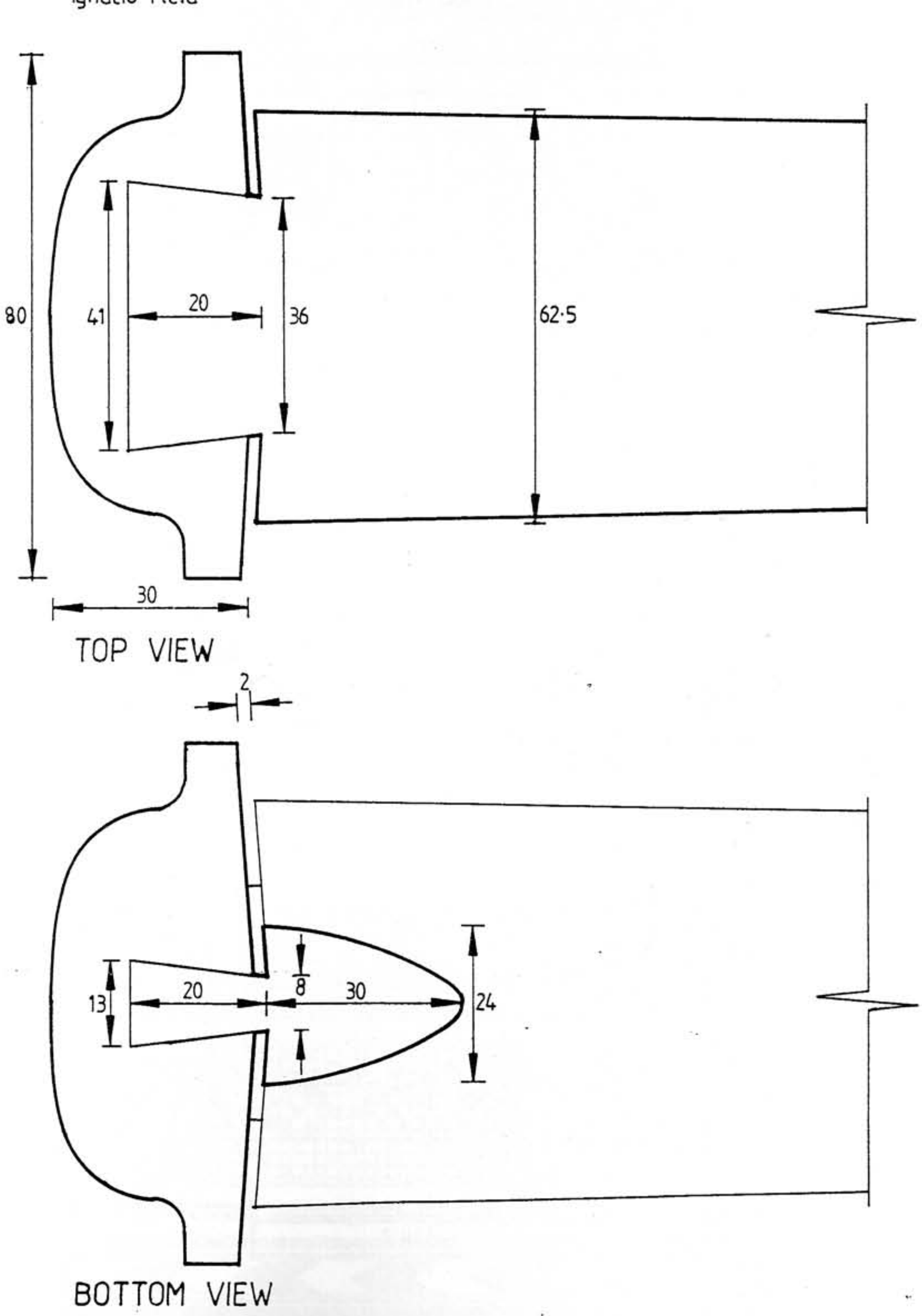


SECTION OF COMPLETE ROSETTE

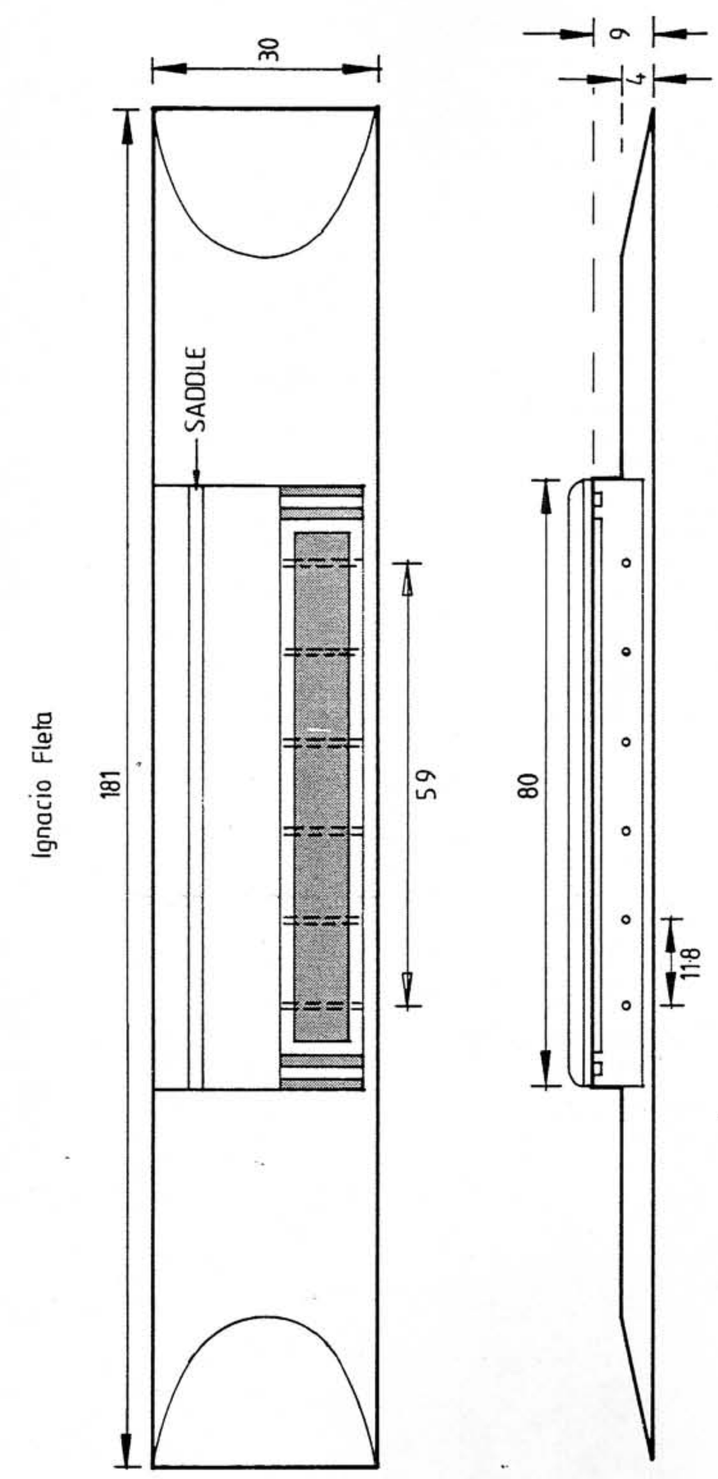
5-9 Fleta – rosette



5-10 Fleta – head



5-11 Fleta – neck joint



5-12 Fleta – bridge

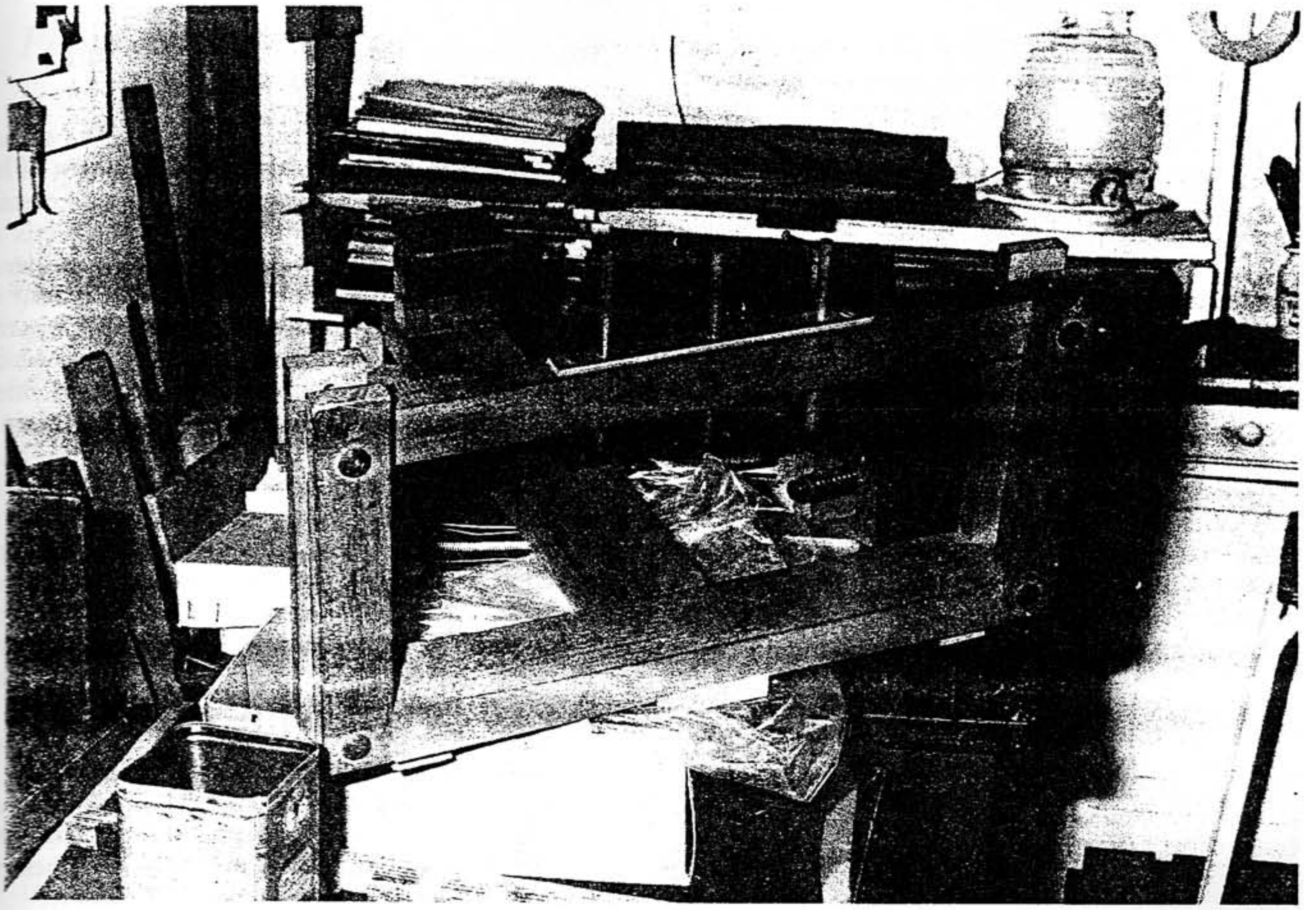
6 Robert Bouchet *(1898–1986)*

Background

Robert Bouchet was a multi-skilled craftsman – in fact, guitar making was a pursuit he took up relatively late in life. He was primarily an artist, painting in a neo-Impressionist style, and for many years he taught painting at the School of Decorative Art in Paris. Being a keen guitarist, he made his first instrument for his own use in 1946, and he kept it for the rest of his life. He belonged to 'Les Amis de la Guitare', a classical guitar society in Paris, and it was here that his instruments were first exposed to public scrutiny. He had the opportunity of observing the Paris-based maker, Julian Gomez Ramírez, with whom he had a close friendship, and this provided his introduction to the art of guitar making.

Bouchet did not have any formal training, and he developed his own style, influenced by his admiration for Torres. He lived in a small flat in Montmartre, and it was here that he painted and made his guitars. The tiny workship was impeccably tidy, being well-stocked with his own home-made tools and jigs. His guitars became widely appreciated, and have been sought after by many great guitarists, including Alexandre Lagoya, Emilio Pujol and Julian Bream. Bream owned three Bouchets, the first was made in 1957, the second in 1962 and the third in 1964. Bouchet only made about 150 instruments over a period of thirty-five years. He worked slowly, and did not regard himself as being under commercial pressure. With international recognition came the never-ending visits of admirers from all over the world. Bouchet told of visits by parties of Japanese enthusiasts, who alternatively bowed with respect, and then proceeded to photograph everything in sight. He enjoyed building elaborate jigs and devices to assist the construction process. These included cauls for gluing all the fan struts simultanoeusly, jigs for gluing on the bridge, and pull-through thicknessers for preparing strips of veneer to be used in purfling and rosettes.

6-1 Robert Bouchet in his Paris workshop



6-2 Robert Bouchet's jig for gluing the bridge to the guitar

Bouchet worked in the traditional Spanish method; the neck was attached to the strutted soundboard, and the ribs then let in the pre-cut slots in the neck. He then glued small blocks of wood to secure the soundboard to the ribs, these being in a continuous line, without any gaps. A long kerfed lining was glued to the other edge of the ribs, ready to receive the back. He used animal glue throughout, and made his own french polish with which to finish the instruments.

Late in life, Robert Bouchet undertook a kind of 'joint project' with the well-known Granadan maker, Marin Montero, who had seen one of Bouchet's instruments and greatly admired it. Montero visited Bouchet in Paris, and found the French maker to be both friendly, as well as interested in discussing ideas about guitar making. Some time later, in 1977, Bouchet visited Montero in Granada, and suggested that they construct a guitar together. Bouchet determined most of the design details; plantilla, strutting, and the selection of a spruce soundboard. (Bouchet had in the past made several instruments with cedar soundboards, but was not pleased with the result.) This joint effort essentially involved the elderly Bouchet acting as instructor, while Montero carried out the actual work of making the guitar. According to Montero, Bouchet had a fastidious approach to the method of construction, and the Spaniard found this rather different to his own, more simple way of working. The guitar was completed, sounded good, and cemented the friendship between the two makers.

Two years later they arranged to meet up again, in France this time, where they would work together for a couple of months. They produced four guitars, and this time Montero contributed more to the design – the bridge, the decorative inlays of the rosette and purfling, the head design and the label being his contribution. Most makers are constantly introducing subtle changes into their work, in order to improve the instrument and search for that ever elusive goal of perfection, and Montero observed, 'I remember seeing in Bouchet's house a guitar he was making; it had seven struts instead of five, as was usual for him.'[1]

Bouchet was a close friend of José Ramanillos, who recalls,

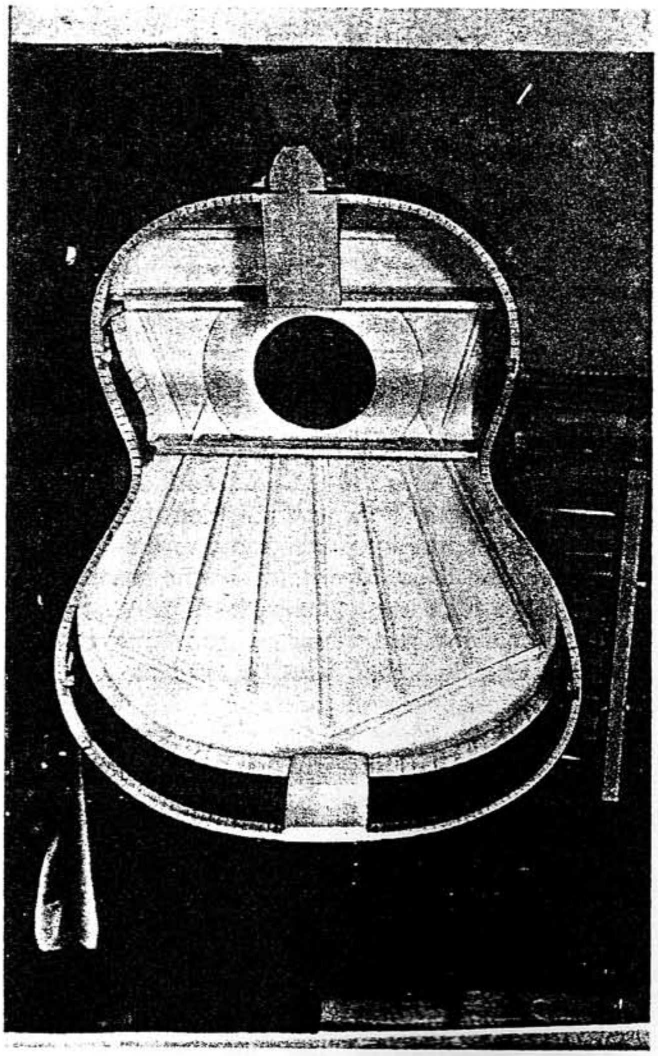
> Bouchet was a very clever man – he made some beautiful instruments ... he was inspired by Torres. If you want to know about Bouchet, the Paris Conservatoire has his book, it's all

hand-written, a fascinating document. He recorded everything about his guitars in it. For the best ones he went to the Spanish prototype. But his soundboards were very thin – he had to put the large transverse bar beneath the bridge, or the soundboard would sag. He had a flamenco guitar, the fourth or fifth that he made, which he never sold, and it was an exact copy of a Torres. He did not scallop the transverse bars, something else he took from Torres.[2]

In fact, Bouchet experimented a great deal over his thirty-five years of guitar making, introducing changes to both the plantilla and the strutting on many occasions.

Bouchet's guitars are noted for both their considerable volume and their superb sustain, as well as their aesthetic beauty.

These rare instruments are now extremely valuable, and are virtually impossible to obtain.



6-3 A Bouchet guitar during construction in 1948

Soundboard and Strutting System

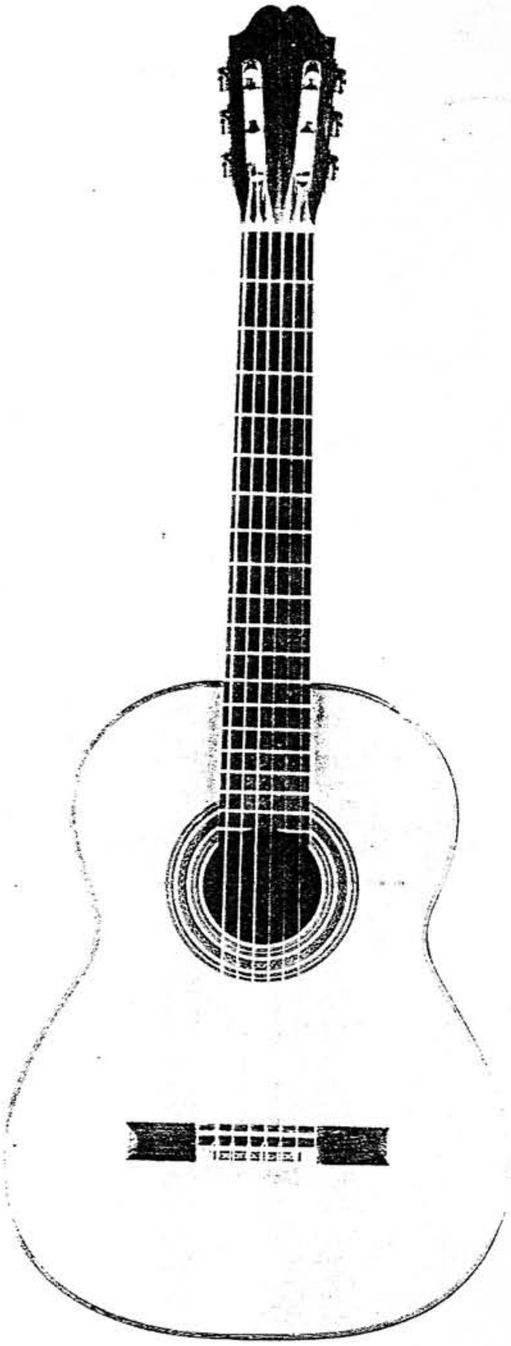
Bouchet achieved his best results with spruce soundboards, and he used this wood for most of his instruments. He has become associated with certain innovations in the design of strutting, but it is of interest to note that recent research makes it clear that Torres himself had experimented with many of the innovations later attributed to other makers; the lower harmonic bar with its two cut-out arches which allow the outer fan struts to pass through is often attributed to Bouchet, but he in fact took this from a Torres guitar which had been made as early as 1883. This guitar came to Bouchet for repair, and, in removing the back of the instrument, he was able to study the strutting closely. This guitar incorporated an open lower harmonic bar through which the outer fan struts were extended. Another feature he borrowed from Torres was the use of two short struts in the upper bout area which splay out, following the angle of the plantilla at this point.

In correspondence with Romanillos, Bouchet confirmed, 'When I constructed my first guitar, I adopted the strutting of Torres for whose instruments I had the greatest admiration – then from my third or forth instruments on, I adopted the opening of the lower harmonic bar, inspired by Torres ...'[3]

Until 1956, Bouchet usually employed a system of seven fan struts, symmetrically spaced in the lower bout area. The harmonic bar is open, as described above. About 1956, Bouchet reduced the number of fan struts to five, which were still spaced symmetrically, but leaving larger areas of soundboard unsupported. (These dates are generalizations, as some later instruments returned to the original seven fan struts.) Sometimes he carried one outer fan strut on either side through an open lower harmonic bar, but on other instruments they stopped just before the lower harmonic bar, which was solid, in the conventional manner. The more important development was that he now added a substantial transverse bridge bar directly beneath the bridge saddle. It spanned virtually the total width of the guitar at this point, but stopped just before making contact with the linings. At those points which make contact with the five fan struts, this bridge bar had notches cut out, so that the fan struts are housed into it; the bar itself is not equally wide along its length, but is slightly thicker and heavier on the treble side.

Bouchet worked on the principle of adjusting the dimensions of the various bars and struts in order to obtain the optimum response for a particular soundboard, rather than varying the thickness of the soundboard itself. He usually left this at a constant thickness throughout. He also believed that the grain direction in the strutting was important for sound quality. The soundboard is domed, that is, it is arched both across its width and along its centre.

Plantilla



6-4 *Julian Bream's Bouchet guitar which was made in 1964*

Early on, Bouchet's plantilla was copied from Torres, but he changed it over the years, and it became unique to him, being based more on his own aesthetic judgements than on any historic instruments or construction theory.

Neck

Bouchet constructed the neck in the traditional Spanish method, cutting two slots, and letting the ribs into them. The thickness tapers from 22.8 mm at the nut, to 23.5 mm at the 9th fret.

Fingerboard

The simplicity of design is reflected in the fingerboard, which is absolutely flat across its width and quite narrow, being 50.5 mm at the nut and 61.0 mm at the 12th fret.

Rosette

The decorative parts of the guitar are subtle. Although Bouchet preferred fairly wide rosettes, they consist largely of a great number of extremely thin lines, which provide the borders to a central, repeating end-grain motif. This motif is itself made from two alternating blocks. Although all Bouchet rosettes have the same overall layout, the precise pattern of the central motif varies.

The rosette is 24 mm wide.

From the outer circumference:

Outer border:

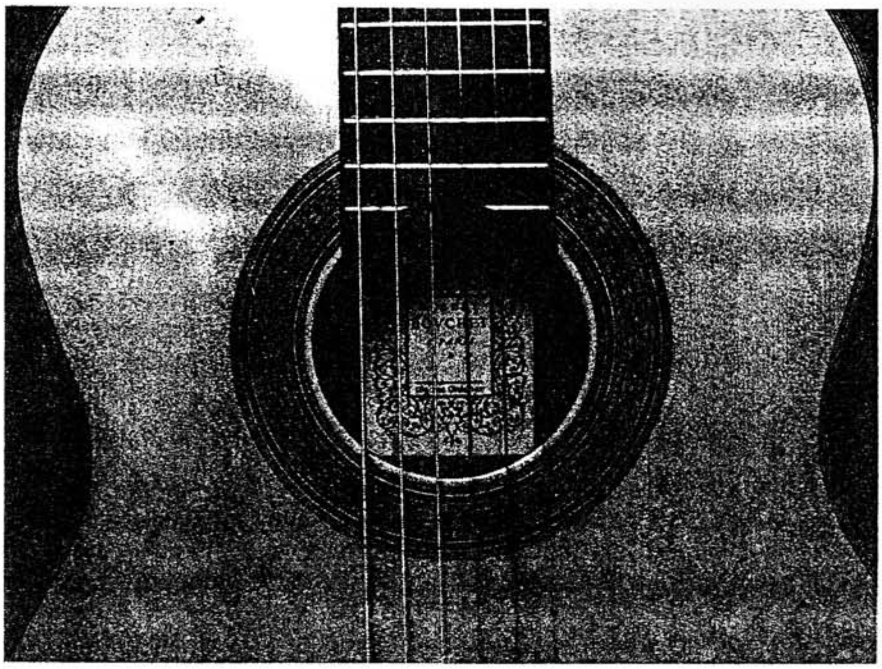
0.6	black
0.6	box
0.2	black
0.6	box
0.2	black
0.6	box
0.6	black
0.6	box
0.2	black
0.6	box
0.2	black
0.6	box
0.6	black
0.6	red
1.2	black
0.6	red
0.6	black

Central section:

5.6	end-grain motif

Inner border:

0.6	black
0.6	red
1.2	black
0.6	red
0.6	black
0.6	box



6-5
The rosette on a Bouchet guitar made in 1972 (No. 139)

0.2	black
0.6	box
0.2	black
0.6	box
0.6	black
0.6	box
0.2	black
0.6	box
0.2	black
0.6	box
0.6	black

Materials

soundboard:	European spruce
back and ribs:	Brazilian rosewood
neck:	cedar
fingerboard:	ebony
bridge:	Brazilian rosewood
internal struts:	European spruce

Soundboard Thickness

2.0 mm-2.1 mm

Back Thickness

2.1 mm

Scale Length

650 mm

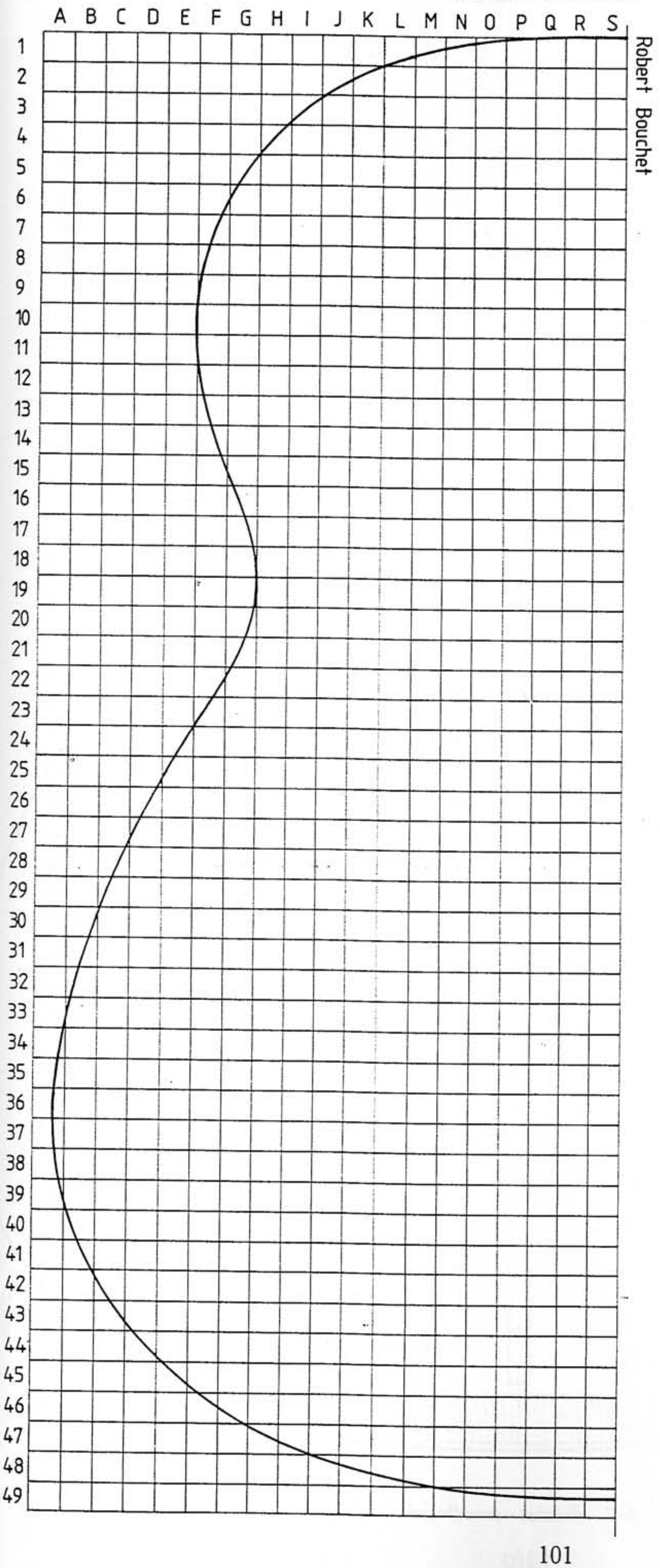
Comparison of Dimensions of Two Bouchet Guitars

(measurements in millimetres)

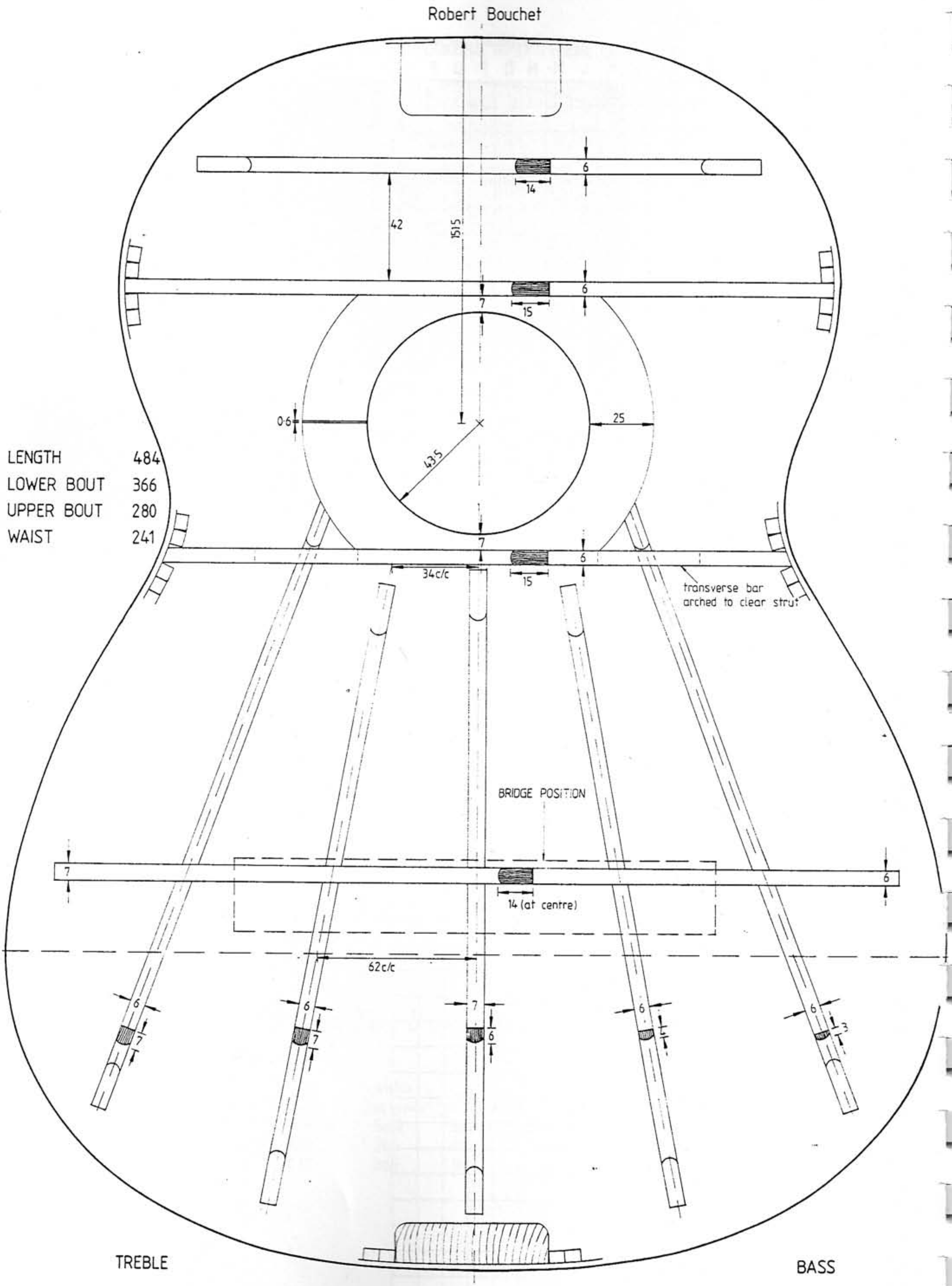
year	body length	width at upper bout	width at waist	width at lower bout	body depth at end-block	body depth at heel
1954	485	280	238	366	92	88
1963	484	280	241	366	94	89

Notes

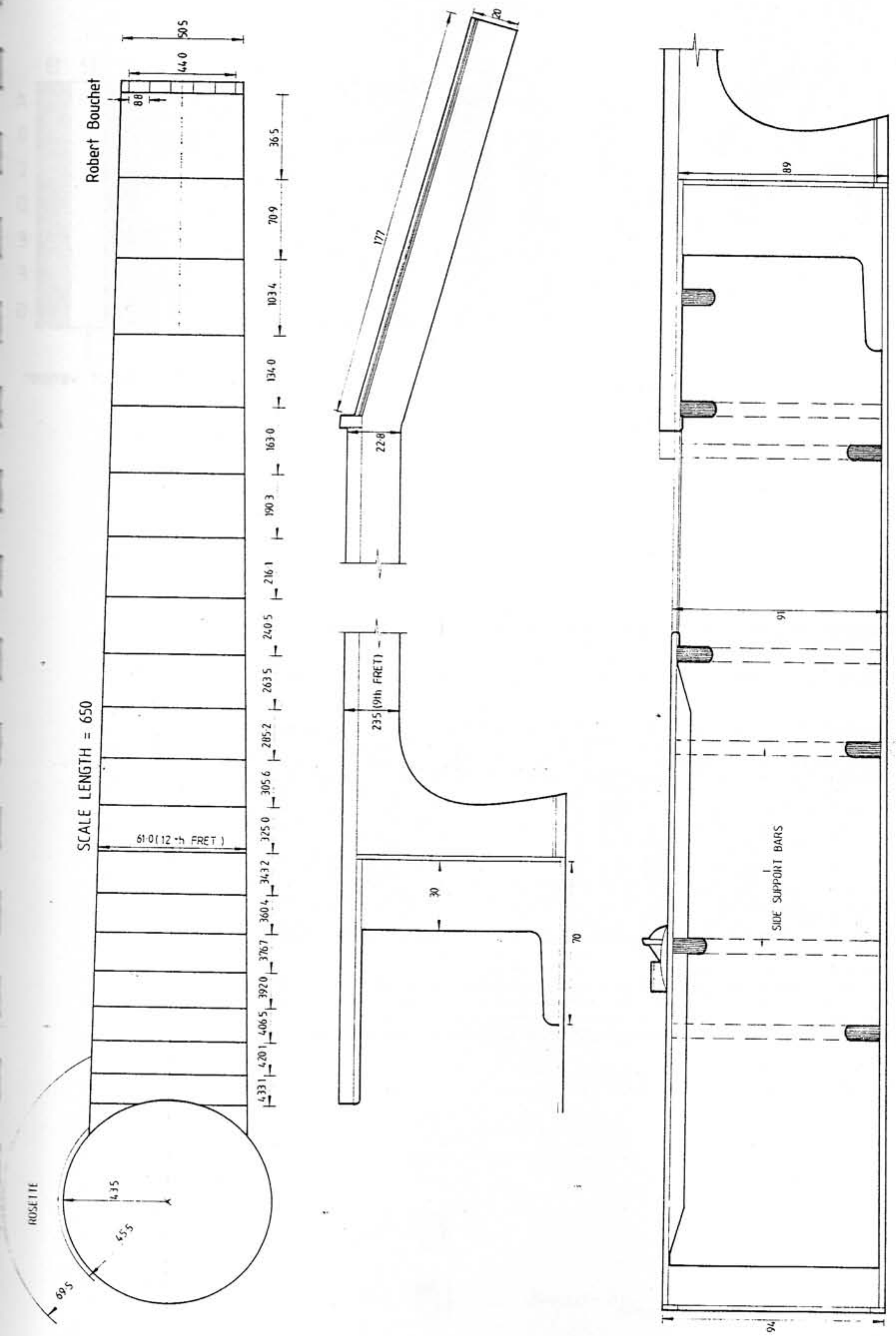
1 *Guitar International* (January 1989).
2 J. Romanillos in conversation with the author (1991).
3 J. Romanillos in conversation with the author (1991).



6-6 Bouchet – plantilla (each square represents one square centimetre)

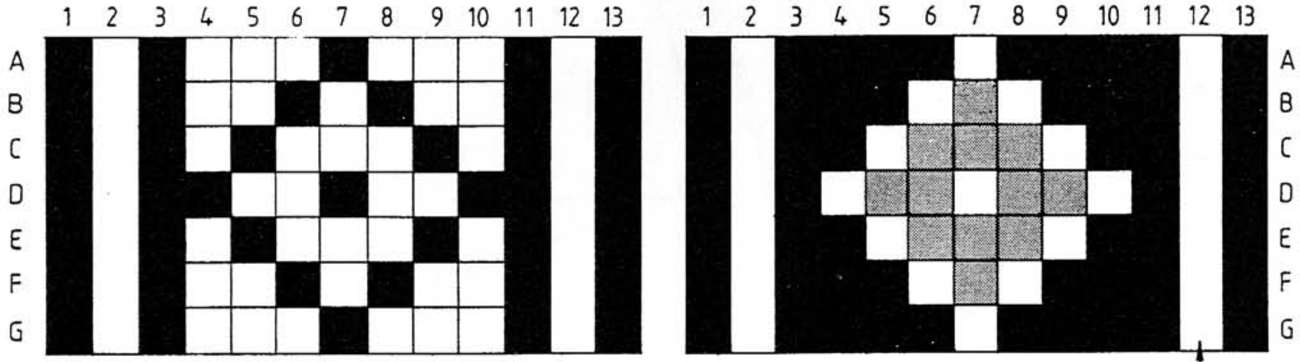


6-7 Bouchet – soundboard



6-8 *Bouchet – neck and body*

Robert Bouchet

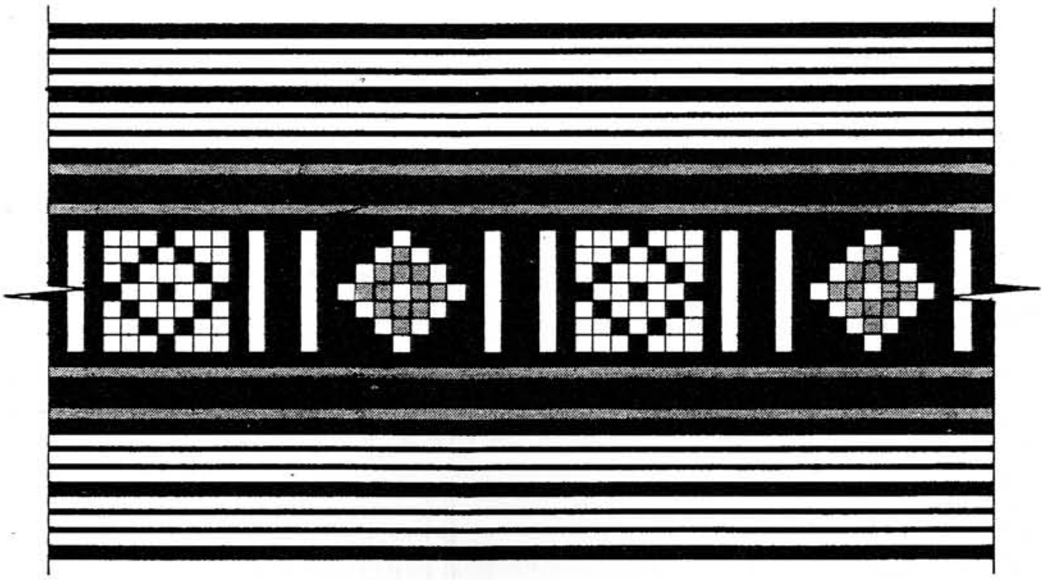


Block A

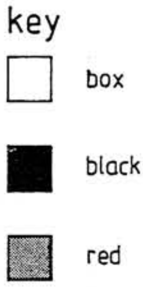
Block B

strip of veneer

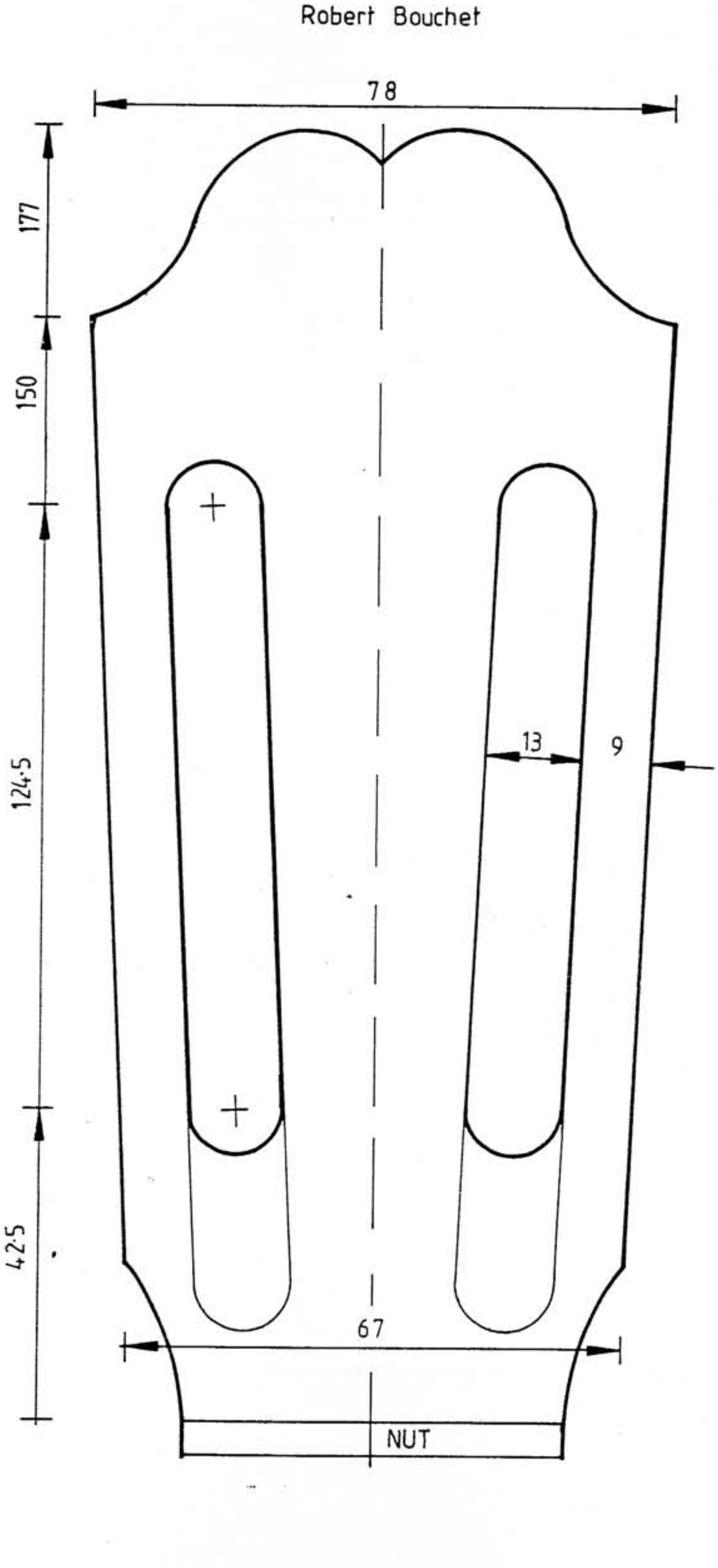
MOSAIC FOR CENTRAL MOTIF



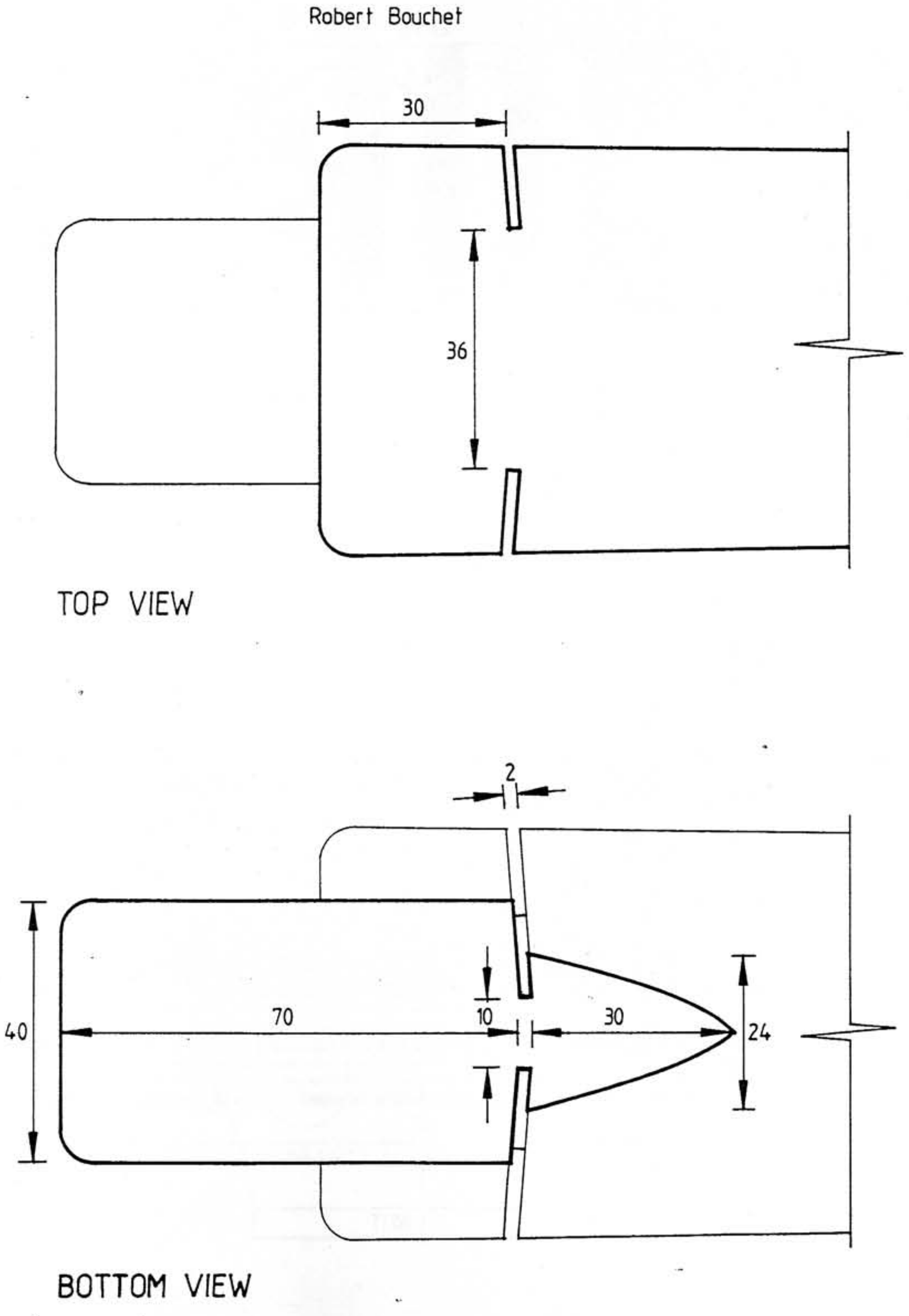
SECTION OF COMPLETE ROSETTE



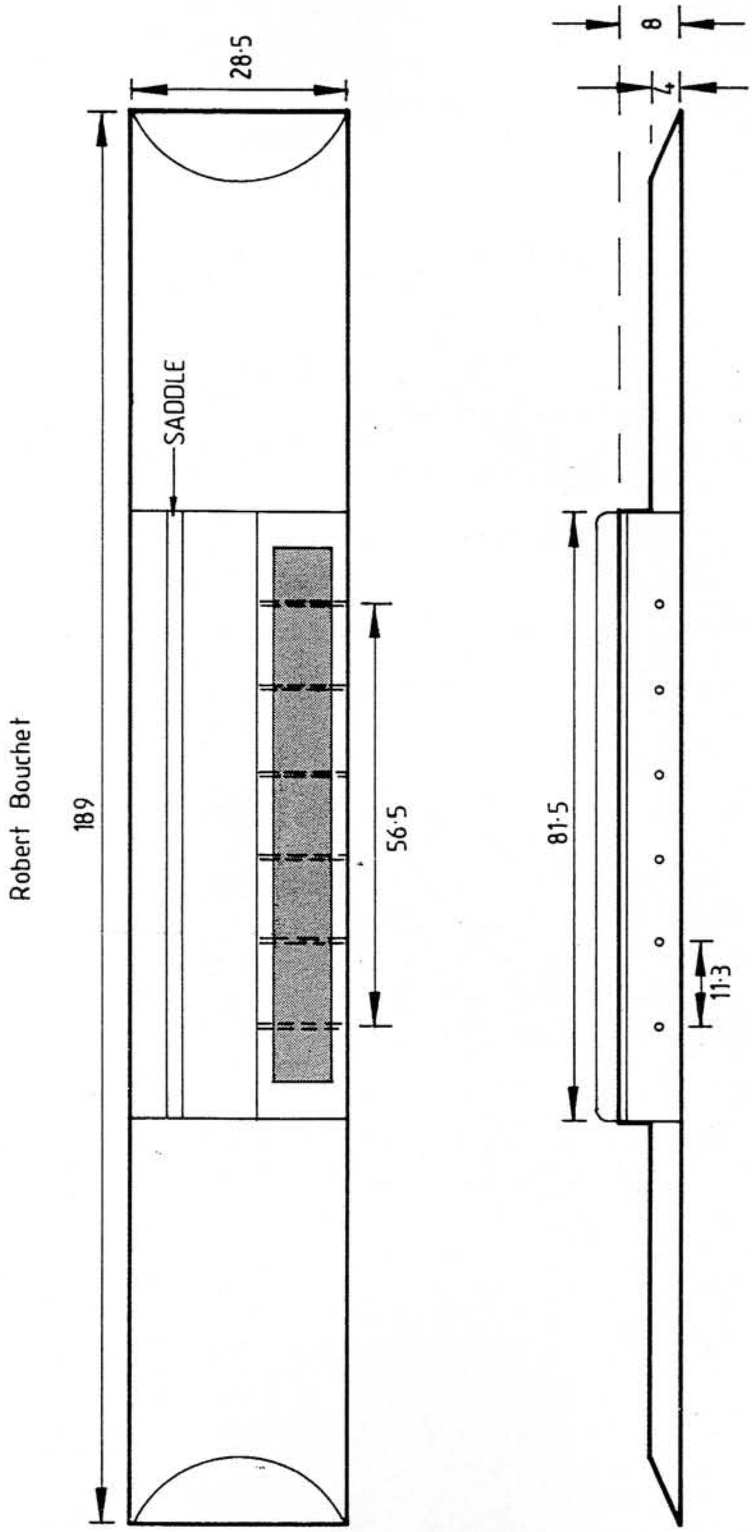
6-9 Bouchet – rosette



6-10 Bouchet – head



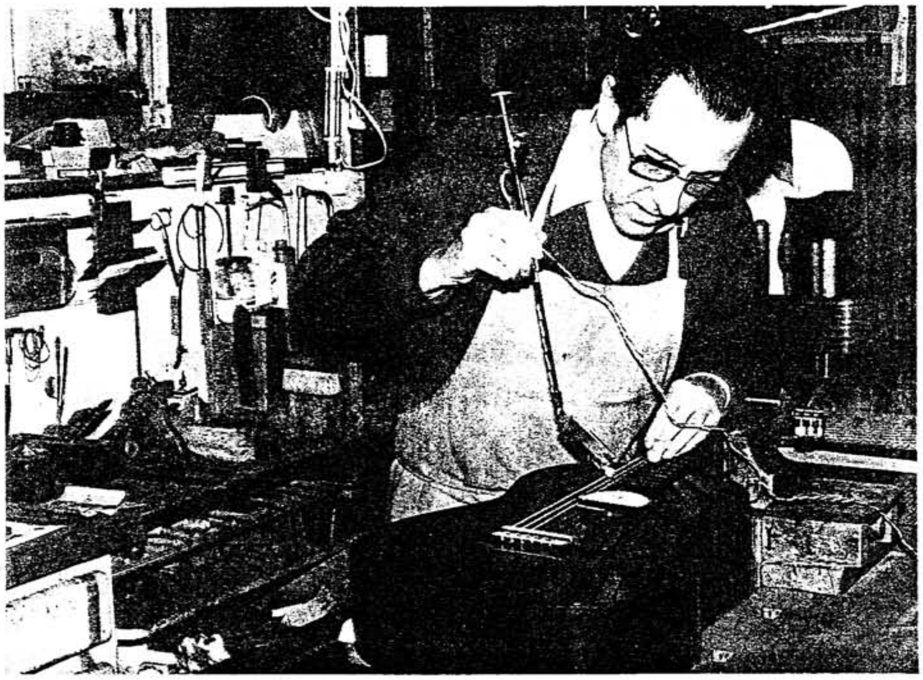
6-11 Bouchet – neck joint



6-12 Bouchet – bridge

7 Daniel Friederich
(1932–)

Background



7-1 Daniel Friederich in his Paris workshop

Daniel Friederich is the most respected French maker of recent times, and he has made instruments for a great number of European, Japanese, and Latin American guitarists. At the beginning of his career he was influenced by his fellow countryman, Robert Bouchet, who also lived in Paris. Bouchet gave Friederich general instruction in guitar making procedures, but Friederich went on to perfect his own unique tools and techniques. He has been particularly interested in experimentation concerned with musical acoustics, and how this relates to the technical aspects of guitar construction. He has been a member of an informal group of musicians, musical instrument makers and physicists, based in Paris, who pool their ideas and theories in order to develop new directions in this field.

A meticulous and logical craftsman, he has always maintained a detailed account of his instruments, with accurate notes of dimensions, strutting and every other specification. His guitars are aesthetically very pleasing; a fresh, clean-cut approach to design is reflected in the crisp formality of the head shape and the fine and subtle use of colour in the inlay work. Friederich's guitars are popular because they possess great power and richness, and are always well-balanced.

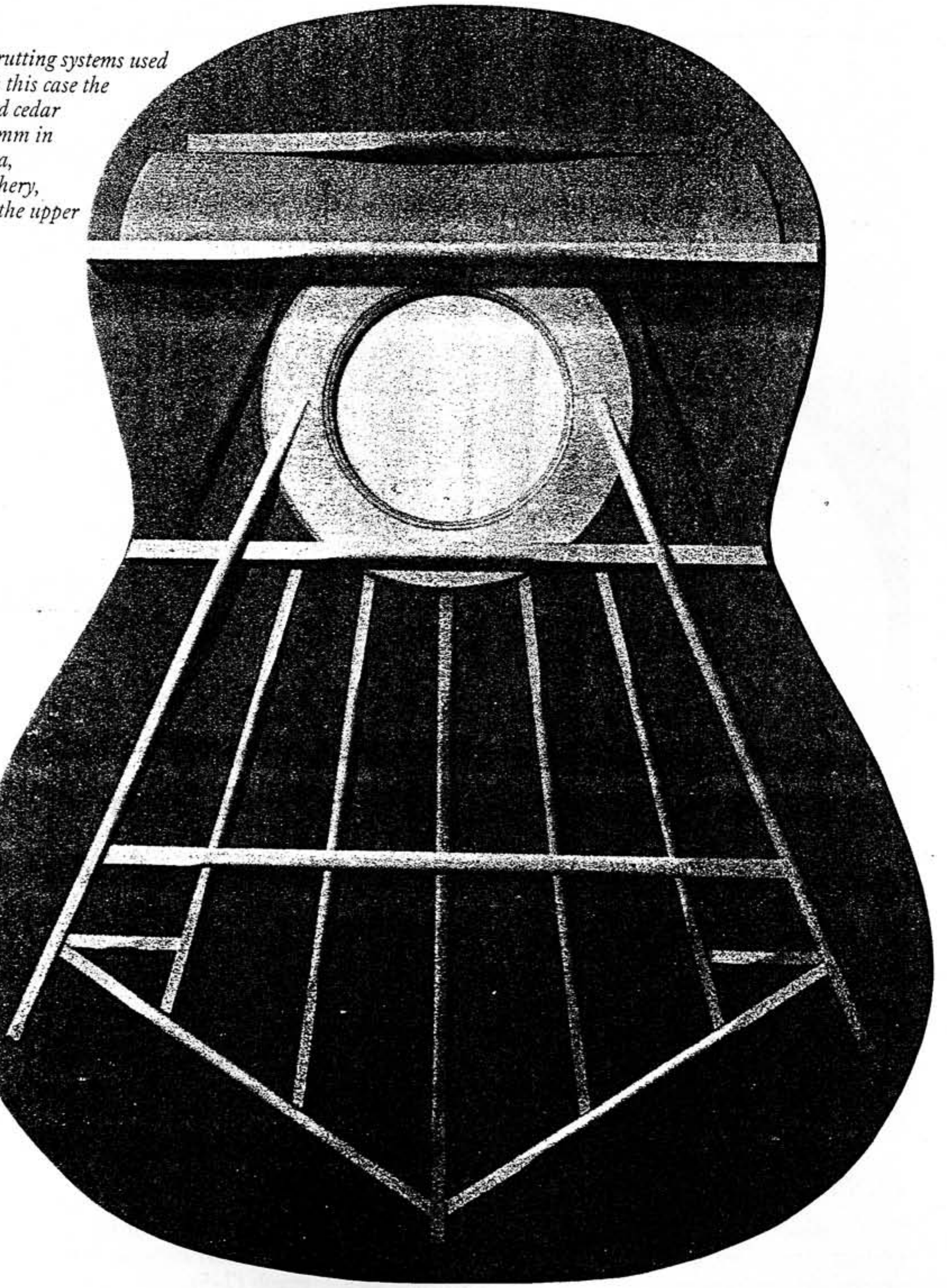
Following a family tradition of working as cabinet makers, Friederich started training for this craft in 1945, and continued working until 1955. This coincided with a developing interest in studying music and playing the guitar. After 1955 he made a number of guitars, finally showing one to Robert Bouchet who encouraged him to continue, and from whom Friederich learnt much about the great maker's ideas and construction methods.

By the early 1960s Friederich was establishing himself as a full-time guitar maker based at his Paris workshop. While on a visit to Canada, he met the famous guitar duo, Presti-Lagoya, who were interested in his work. Through Lagoya, Friederich became involved with the Musical Acoustic Laboratory in Paris, and this helped in his research. In 1967 he exhibited a guitar at the International Concourse of Lutherie in Belgium, and he was awarded medals for craftsmanship and sound quality – the president of the jury was Ignacio Fleta. His research into acoustics related to the guitar continued, and in 1977 he read a paper at the Paris University entitled 'History and Function of the Guitar'. Since 1982 he has been a judge on the stringed instrument section of 'The Best Craftsmen in France' competition.

Soundboard and Strutting System

Friederich's technical experiments, combined with his experience after having made many hundreds of guitars, have resulted in three different strutting designs. The strutting system is chosen to suit both the physical qualities of the timber being used, and the character of sound that the customer requires. He has worked with cedar soundboards as well as spruce, and has achieved good results with both.

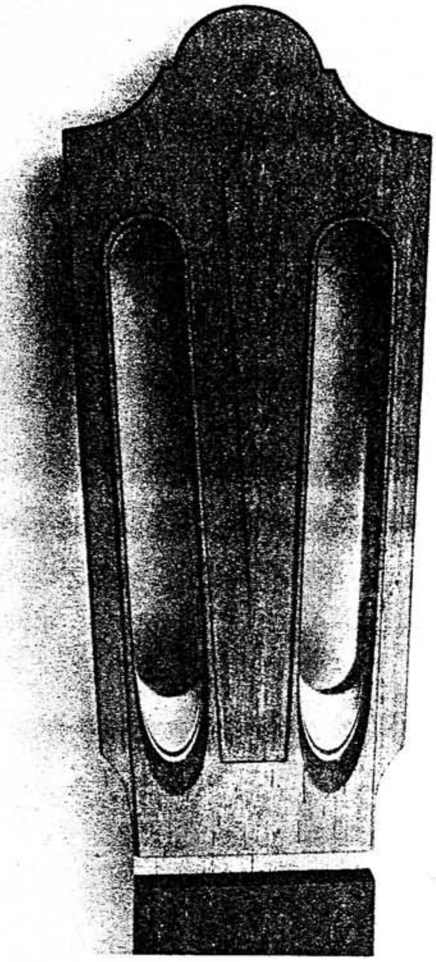
7-2 One of the three strutting systems used by Daniel Friederich – in this case the soundboard is Western red cedar and is thicknessed to 2.1 mm in the central lower bout area, 2.2 mm around the periphery, and 2.4 mm–2.5 mm in the upper bout



Plantilla

The body shape is extremely elegant, and quite similar to that of Hernández y Aguado, but slightly fuller in the region of the upper bout, which falls away gracefully from its junction with the neck.

7-3 Guitar by Daniel Friederich



7-4 Head by Daniel Friederich, including a raised central design (not all his instruments have this feature)

Neck

The neck to rib join is done in the Spanish method of cutting slots into the heel/foot section, and inserting the ribs into these slots. The fingerboard is of average dimensions, but the thickness of the neck is virtually the same from the nut to the 10th fret. (Most makers taper the neck so that it is slightly thicker at the heel end than at the nut end.)

Head

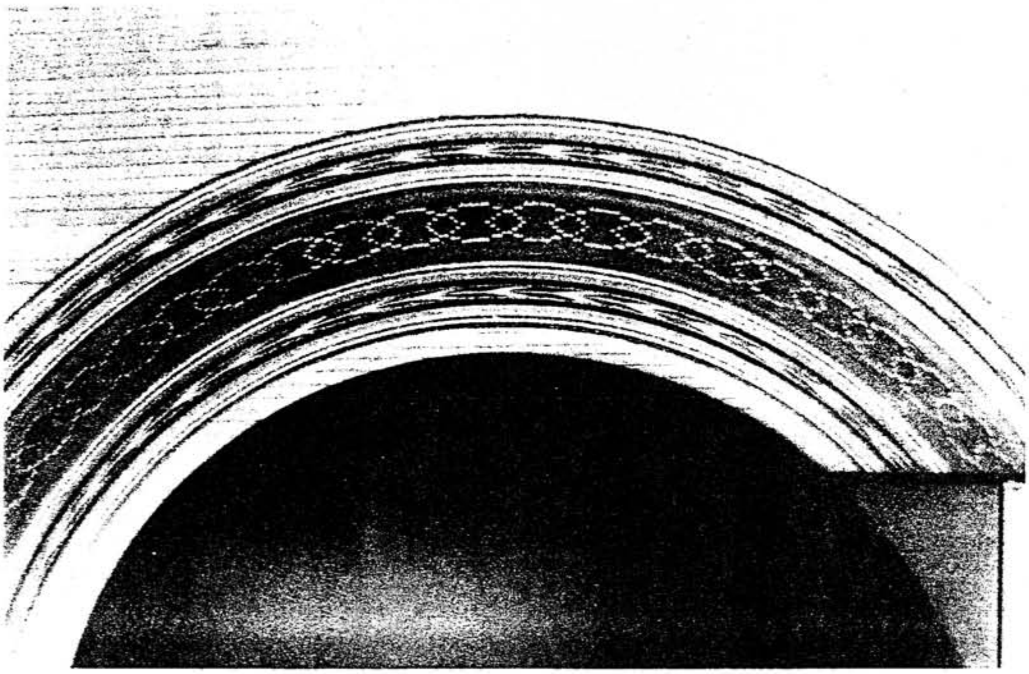
The distinctive shape of the head makes Friederich's guitars easily recognizable. The design is rather geometric, perhaps reflecting his overall attitude as a guitar maker.

Ribs

Since 1970 (guitar No. 286) Friederich has constructed the ribs in an unusual way – they have been laminated from two layers of wood glued together; either rosewood and mahogany, or rosewood and rosewood. In both cases the layers are each 2 mm thick, giving a total rib thickness of 4 mm.

Rosette

A number of rosette designs have been used, and they are all intricately constructed from thin veneers. The example illustrated consists of a central, repeating motif, which is surrounded on both sides by a symmetrical border. Some instruments have a finely made herringbone border as shown in the photograph (7-5).
The rosette is 20.5 mm wide.



7-5 Friederich – rosette

From the outer circumference:

Outer border:

0.25	black
0.25	box
0.25	black
2.0	red
0.25	box
1.0	black squares with box divisions
0.25	box
2.0	red
0.25	black
0.25	box
0.25	black
1.0	box

Central motif:

5.5 end-grain pattern representing an interlocking chain

Inner border:

1.0	box
0.25	black
0.25	box
0.25	black
2.0	red
0.25	box
1.0	black squares with box divisions
0.25	box
2.0	red
0.25	black
0.25	box
0.25	black

Bridge

The tie-block of the bridge is covered with a section of the central motif of the rosette and bordered with ivory.

Materials

soundboard:	European spruce or Western red cedar
back and ribs:	Indian rosewood
neck:	Honduras cedar
fingerboard:	ebony
bridge:	Indian rosewood
internal struts:	European spruce and cedar

Soundboard Thickness

2.1 mm	in the central and bridge areas
2.2 mm	around the outer periphery of the lower bout
2.5 mm	in the upper bout region

Back Thickness

2.5 mm	for medium density rosewood
2.2 mm	for heavy density rosewood

Scale Length

650 mm

Comparison of Dimensions of Three Friederich Guitars

(measurements in millimetres)

year	body length	width at upper bout	width at waist	width at lower bout	body depth at end-block	body depth at heel
1966	487	279	237	367	96	92
1972	487	278	240	368	103	97
1992	489	279	240	369	103	98

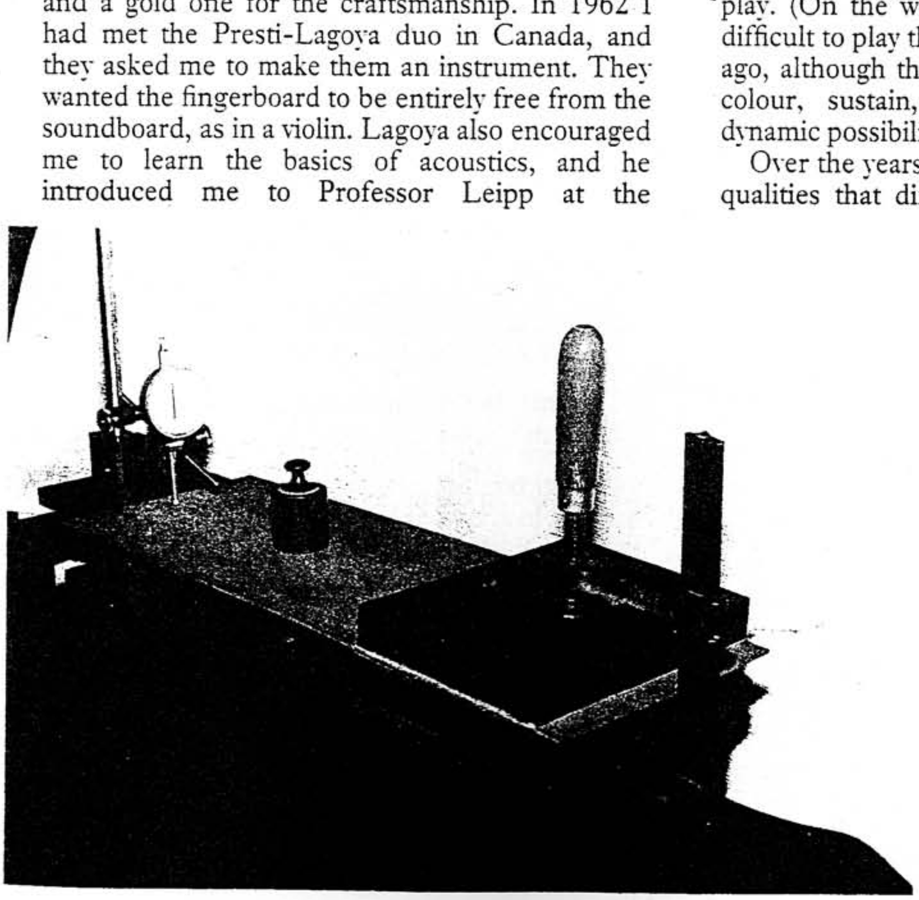
Daniel Friederich supplied the following information about his life and career:

I was born on 16 January 1932 in Paris. I began to build my first classical guitar in 1955 – it was for my own personal use. I was learning to play the guitar and my teacher, Cristian Aubin, said that I needed a better instrument. I realized that I could not possibly afford to buy a good guitar so I decided to make one for myself. It was a very simple copy of a guitar by Francisco Simplicio. Aubin helped me – he had already made a copy of his own Torres, and had spoken to Robert Bouchet about the construction method. I completed fifteen guitars before showing one to Bouchet in 1960. I was encouraged when he said that it was a good beginning. Some time later, in 1967, I entered a competition anonymously. The jury included both Fleta and Bouchet. I was awarded a silver medal for the sound of my guitar and a gold one for the craftsmanship. In 1962 I had met the Presti-Lagoya duo in Canada, and they asked me to make them an instrument. They wanted the fingerboard to be entirely free from the soundboard, as in a violin. Lagoya also encouraged me to learn the basics of acoustics, and he introduced me to Professor Leipp at the Laboratoire d'Acoustique in Paris. Leipp pointed out the importance of measuring the various qualities of the wood so that you could then predict what the instrument would sound like. We carried out many experiments.

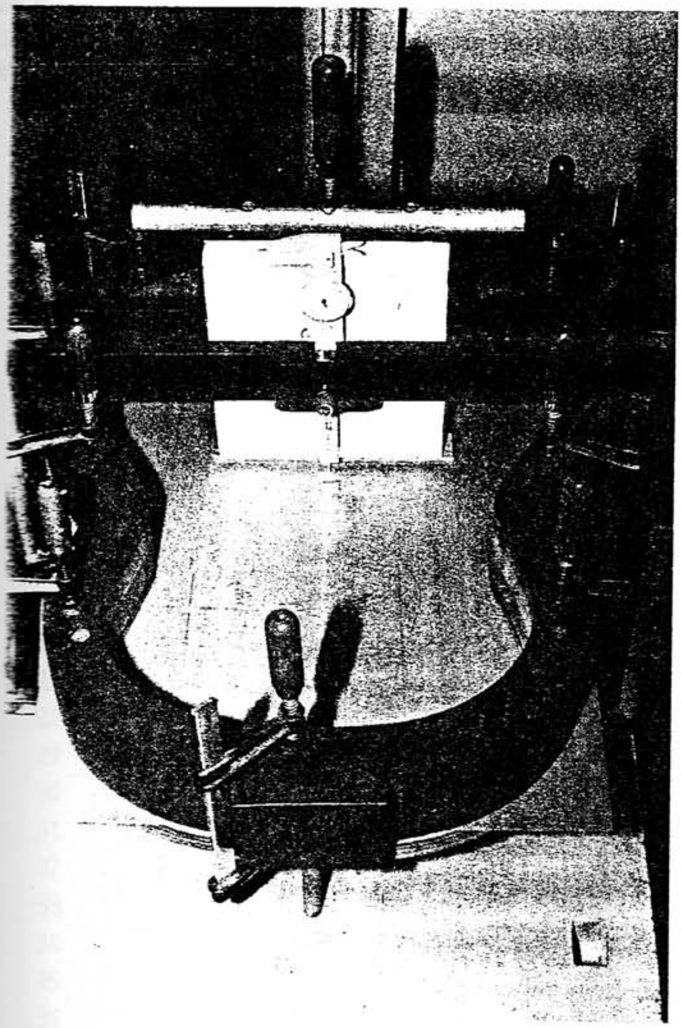
I test the flexibility of all the wood I use. For the struts, I place them across two supports and hang a weight in the middle. For the soundboards, I plane them to a uniform thickness and then clamp one end to a support. I place a weight on the free end and measure the amount of movement. When the table is glued together I measure the combined flexibility at the point where the bridge is to be placed. I also measure the compressibility of the wood and its weight.

My earlier guitars were relatively simple; pleasant to play, and the sound was quite 'explosive'. Since about 1973 I have increased the weight and the guitars have more sustain, and a richer, sweeter sound, but they are still easy to play. (On the whole, modern guitars seem more difficult to play than those made thirty to fifty years ago, although they do give more vigour, contrast, colour, sustain, and have more timbral and dynamic possibilities.)

Over the years I have tried to master the various qualities that different guitarists look for. Some



7-6 The initial set-up used by Daniel Friederich to measure the longitudinal flexibility of each half of the soundboard players attack the strings heavily and they want a long sustain. This contrasts with the Latin-Americans like Alvaro Pierri, Roberto Aussel and Eduardo Fernandez, who want a sound that is more explosive, full-bodied, higher in contrast and very coloured, because they play with a lighter style. The pupils of Lagoya are looking for a sound that is powerful and sustained with a very even response. My personal taste, along with my style of



7-7 *Once the soundboard has been glued together, it is cramped to a guitar-shaped former so that the flexibility in the bridge area can be measured. The results will suggest what the final thickness should be, and also which strutting system is most appropriate*

playing tends towards a sound that is full-bodied, full of charm and depth, more like a piano than a harpsichord.

I have developed several different strutting systems and also two designs of plantilla in the last thirty-five years. I now use three strutting systems; one is completely symmetrical, the second is asymmetrical and complex – I use this for most of my standard guitars, and the third layout is for soundboards that are exceptionally flexible longitudinally. My spruce soundboards come from trees in the French and Swiss Jura. The Western red cedar I obtain at the port of Le Havre. The cedar is often lighter than spruce and this interests me. The disadvantage with cedar is that it is very fragile. It is vital for me to work as long as possible with soundboards from the same tree – each tree possesses very different mechanical and physical properties. I do not use soundboards for aesthetic reasons or because the wood is extremely regular and has close annual rings – this has nothing to do with sonority. I begin by measuring the longitudinal flexibility, then the combined flexibility (transverse and longitudinal). I note the weight. I look at the general appearance and decide on the thickness, strutting system, neck and other parts by comparing it with a model already built from similar wood. If I do not have good results after four or five guitars, I abandon that tree. If the results are good I modify and improve as much as possible the points which characterize the sonority of a guitar:

1 power
2 sustain
3 uniformity of sound level of each note
4 timbre (quality of the voice)
5 balance between bass and treble
6 ease or difficulty of playing the instrument
7 evenness of sound
8 response and sensitivity
9 attack of the sound; biting, audible, or slight
10 contrast of tones
11 dynamic range
12 sympathetic resonances (present or not)
13 degree of clarity in polyphony

When one wishes to copy as faithfully as possible a guitar which has seduced a demanding musician it is necessary to use a soundboard from the same tree, possessing the same flexibility, and to make a neck from the same wood and the same weight. The back and ribs should be of similar density. On this basis one has a much better chance of building a truly identical guitar by equally controlling the thickness, strutting, and flexibility of soundboard and bridge. This demands a little extra work and poses some problems in bringing together the most suitable woods. I try not to give too important a place to chance.

When the guitar is finished my ear quickly tells me if the result is better and if it has succeeded in less than thirty minutes. The guitar works as a complete harmonic unit and all its elements must be combined like in a painting. There are no great secrets, but there are a hundred components and a hundred parameters to master, to respect and to control. It will still be an art for a long time, in spite of laboratory experiments that are improving our acoustic theories. I will make my seven hundredth guitar in 1992 and it takes me more than two hundred hours to build one guitar.

We worked a great deal on soundboard wood in the musical acoustic laboratory in Paris around 1984 to 1986. We established that it is difficult to find one tree similar to another within the same species. There are always differences in the flexibility, variations in density, variations in the size and thickness of the hard growth rings of autumn and the soft growth rings of spring. The laboratory has thought up an ideal synthetic wood based on carbon fibre sandwiched between thin layers of wood for the soundboard. I made a guitar with this wood in 1986 but it is difficult to work and the sound had little attack and was not very clear. It gave better results with double bass, lute and harpsichord.

Since 1975 I have used only Western red cedar for soundboards. The French spruce always has wider annual rings than the Swiss, but this often makes the soundboards more supple because the spring wood is wider. The Swiss spruce is very fine to look at, but it often makes the soundboards too stiff and heavy.

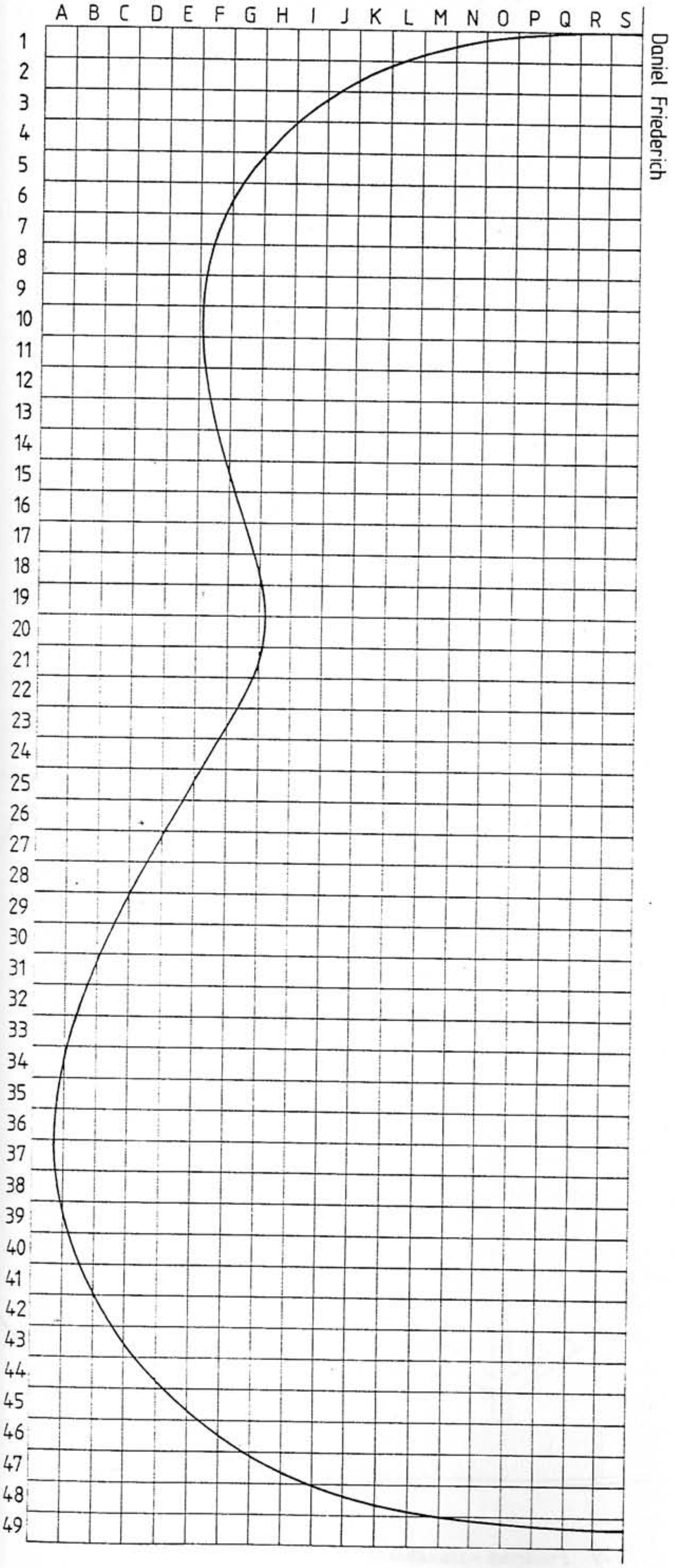
At the beginning of my career I worked with old Brazilian rosewood. Then I used Indian rosewood which is often lighter in weight than Brazilian. This allowed me to make lighter instruments which are more sensitive to vibrato and tonal contrasts. In the last few years I have used slightly heavier rosewoods, marrying them with supple, elastic soundboards.

For necks I have used mahogany from Tabasco (south of Mexico) which is very stable and is not too heavy. Unfortunately it is no longer available. I now use Honduras cedar. It has very great weight variations within the same board and one has to take account of this, as well as its greater flexibility. One must also allow more wood for attaching it to the body – it requires a thicker foot inside the guitar, otherwise the neck would be too flexible. Guatemalan mahogany, which is heavier, makes a guitar with great sustain. Robert Bouchet used it a lot, but now it is very rare. I have not had good results with Cuban mahogany – the best of all mahoganies. It is very heavy and has a fine close texture, but its weight results in the instrument not being properly balanced.

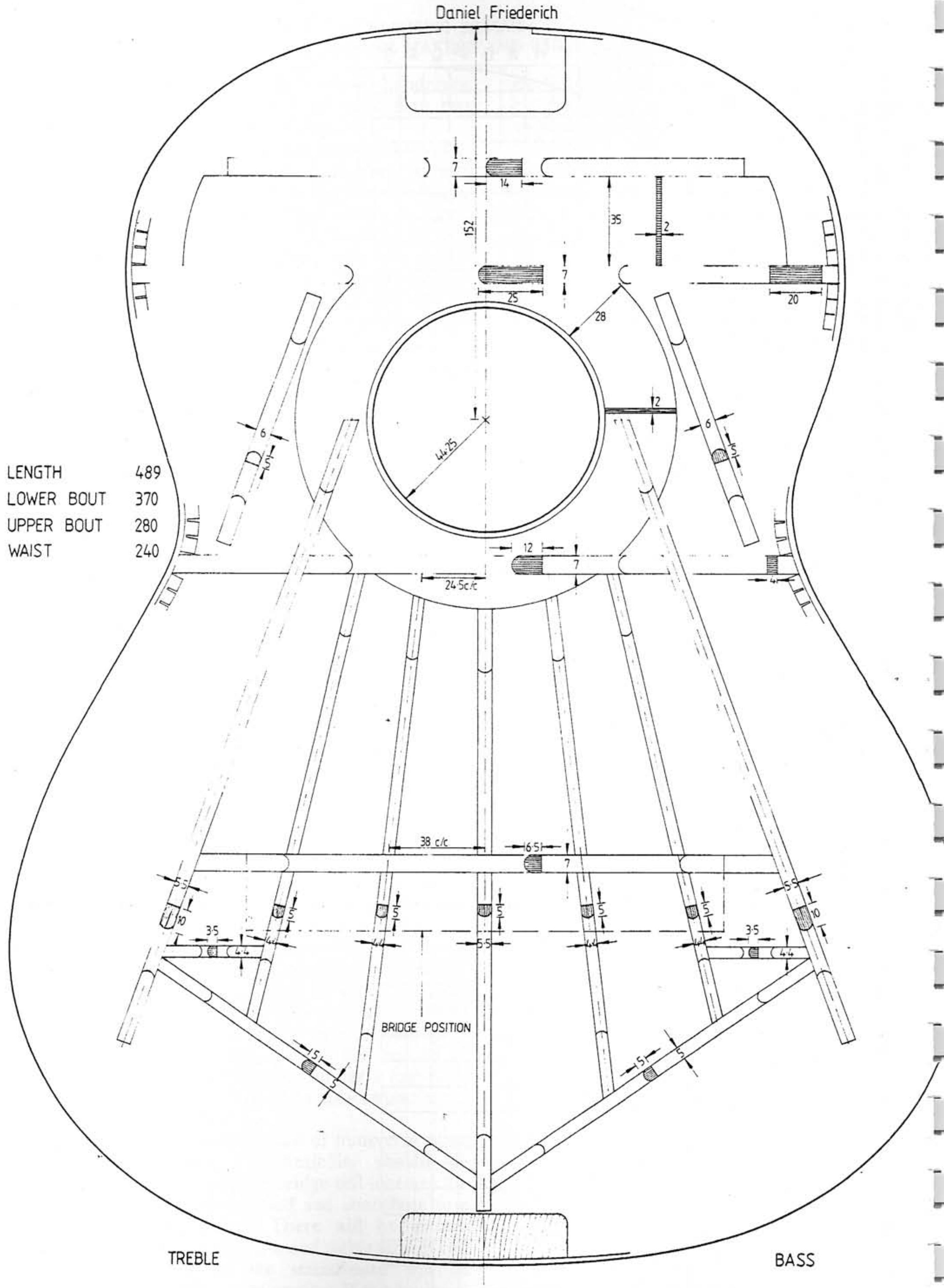
The bridge is really a kind of transverse strut, and its thickness and flexibility should be considered. A fine, supple bridge will increase the flexibility of the soundboard and contribute to a more explosive sound. There will be greater independence between bass and treble strings and the central part of the soundboard will be subjected to considerable torsion. If the bridge is thick and inflexible then when a string is plucked the entire bridge will move and vibrate. I use medium weight and medium thickness for my bridges (4 mm thick at the wings and weighing about 22 grams when the bridge is complete).

I polish the bridge separately and glue it to the soundboard just after french polishing the instrument. I make my own french polish.

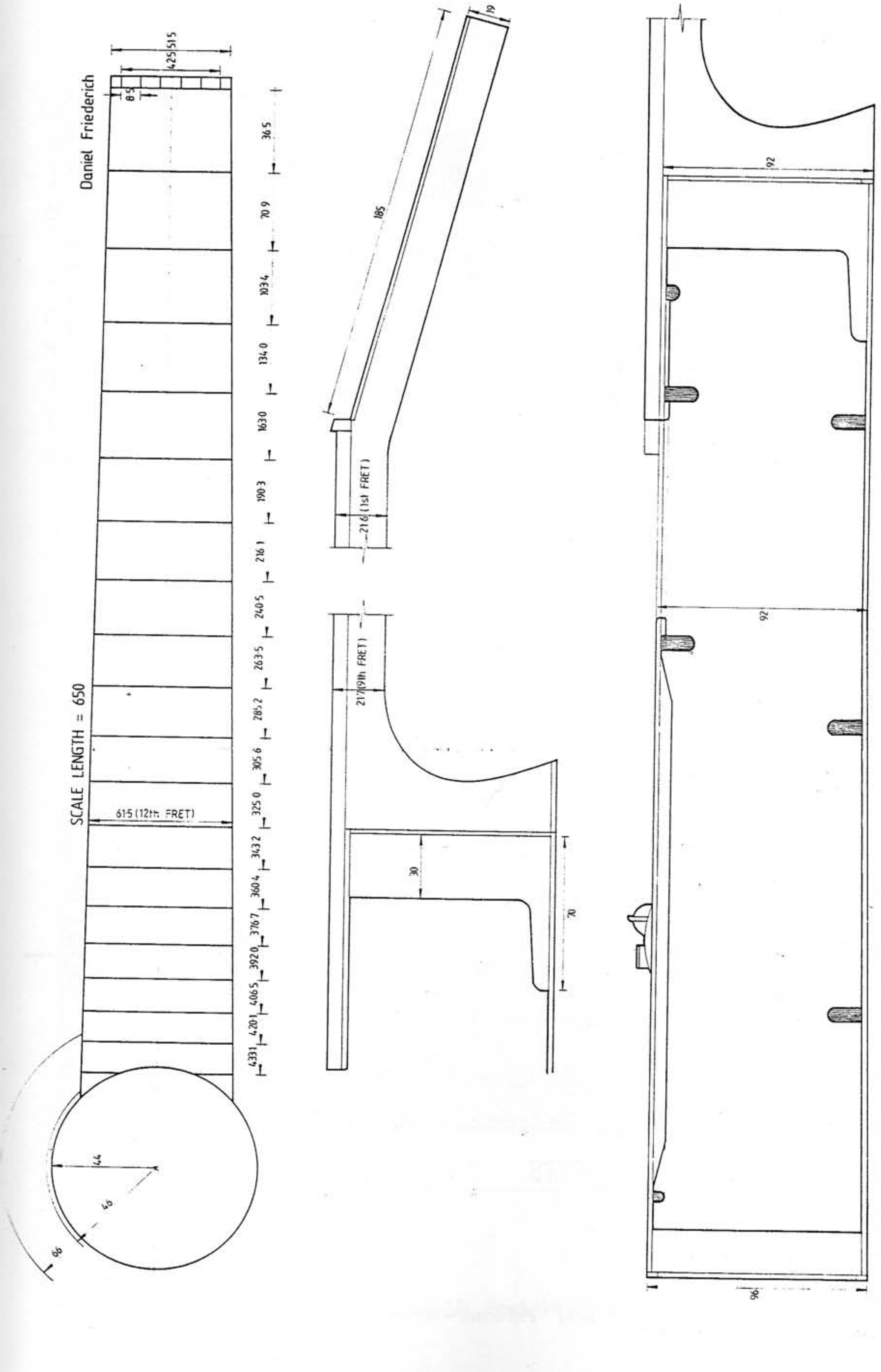
To make a career as a luthier one must be fired by a total and enduring passion for it. One needs to study the various aspects of acoustics and musical theory. Above all, one must educate the inner ear and develop an acute ability to listen, as each note of the guitar is a great chord with the superimposed harmonics forming each sound.



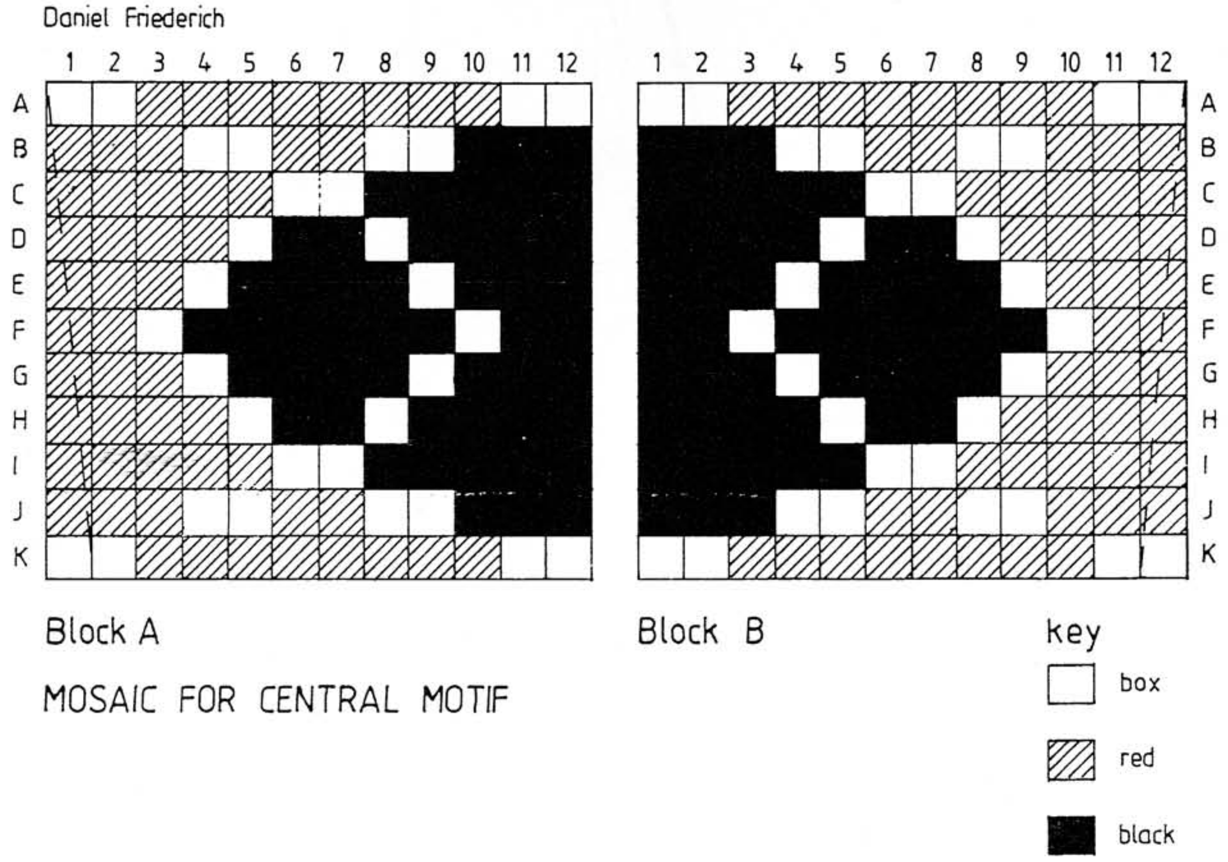
7-8 Friederich – plantilla (each square represents one square centimetre)

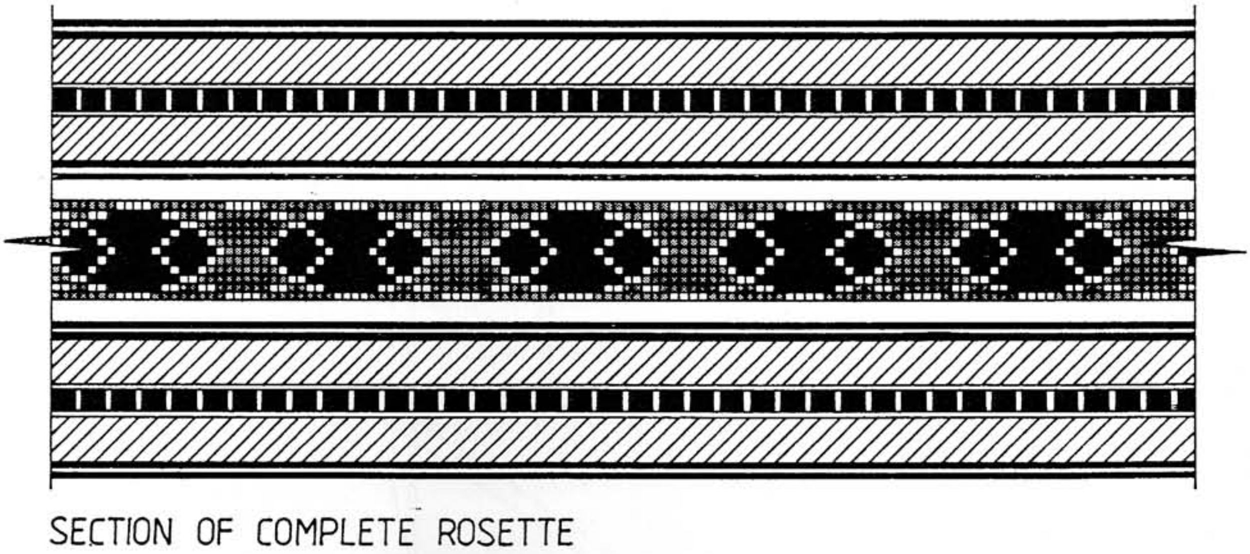


7-9 Friederich – soundboard

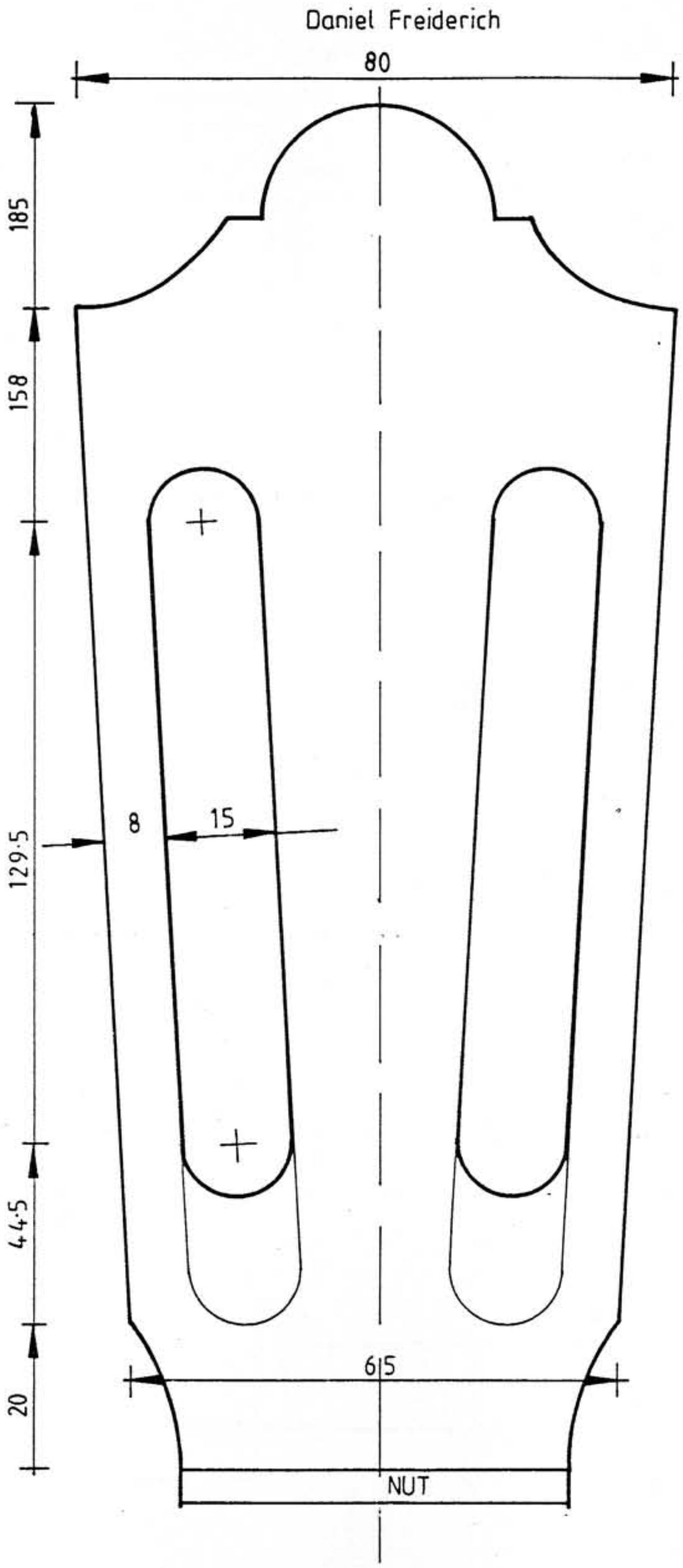


7-10 Friederich – neck and body

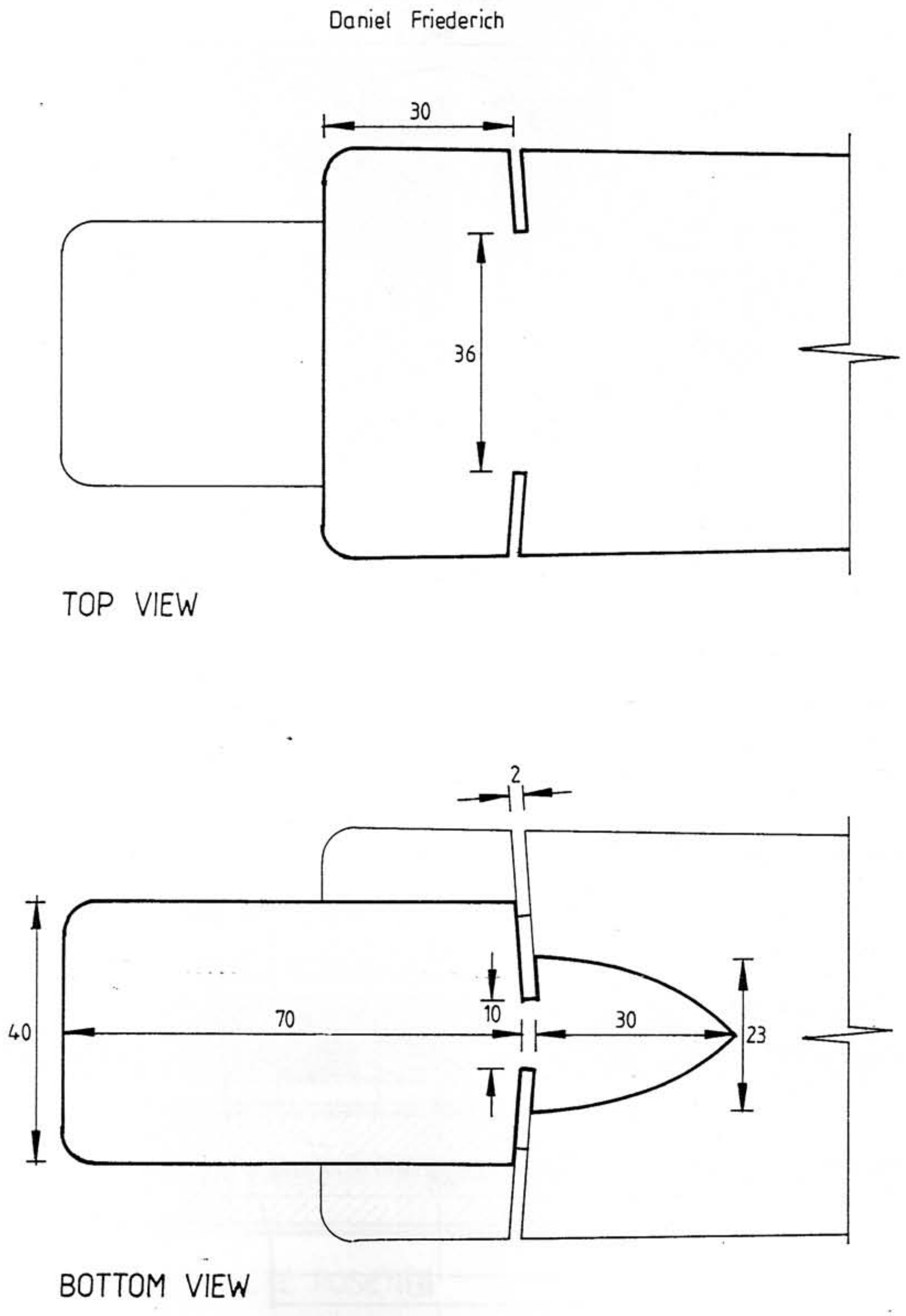




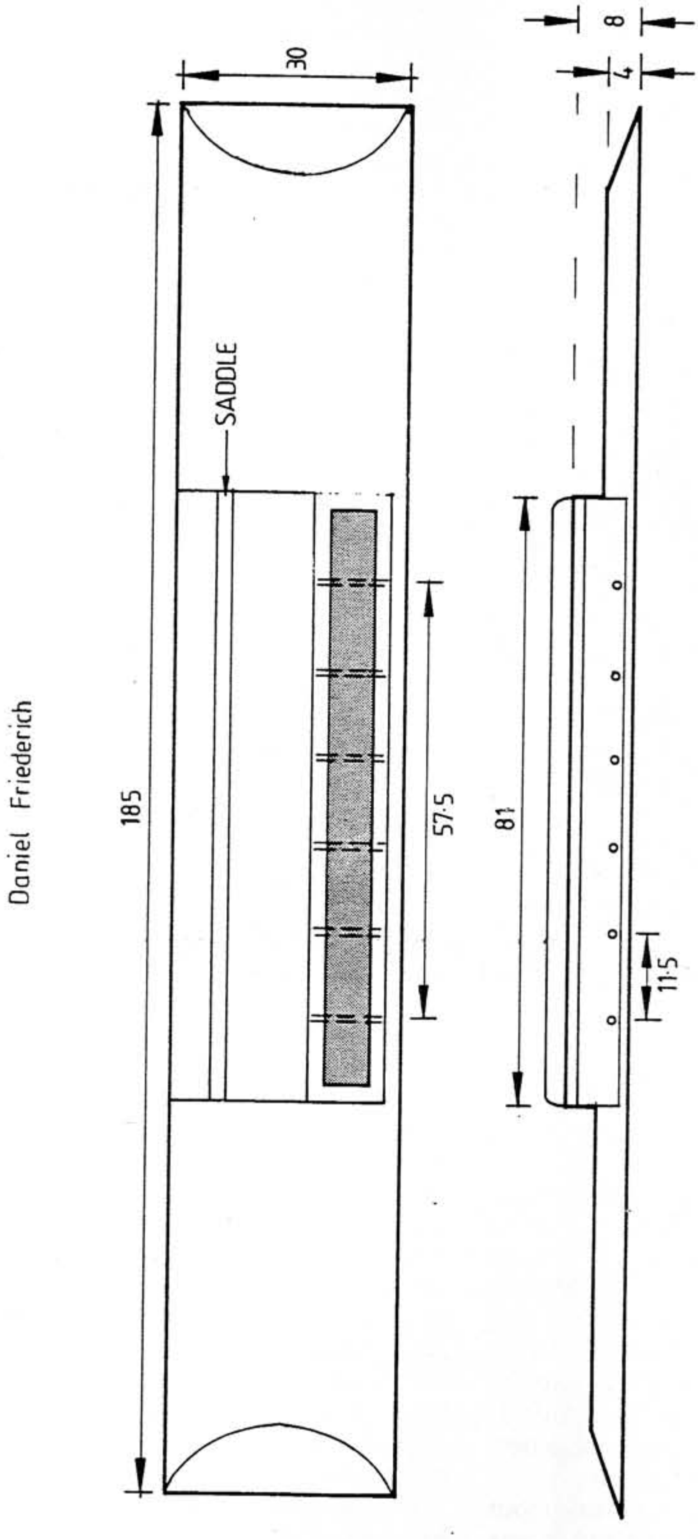
7-11 Friederich – rosette



7-12 Friederich – head



7-13 Friederich – neck joint



7-14 Friederich – bridge

8 José Romanillos (1932–)

Background

8-1 José Romanillos in his workshop

José Luis Romanillos is the foremost guitar maker currently working in England. He lives and works in the small village of Semley, near Shaftesbury in Dorset. He was born on 17 June 1932 in Madrid, and when thirteen years old, he was apprenticed to a cabinet maker, gaining some experience of working with timber and hand tools. In 1956 he came to England, with a work permit to work as an assistant nurse in a mental hospital. He married his English wife, Marian Harris Winspear in 1959, and they had three sons, one of whom, Liam, has assisted in his father's workshop since 1982, gradually learning the Romanillos technique of guitar making. In late 1991, Liam became a full partner with his father, and a new Romanillos label was made to mark this occasion.

Romanillos came to guitar making in a roundabout way. Entirely self-taught, his original motivation was to make a guitar for his own use, and to remind him of home – he had become rather homesick for Spain. He could not afford to buy a guitar, and happened to come across an elementary book on guitar making, which served as a guide for his first instrument.

He did return to Spain in 1964, where he made several more guitars. Four years later he travelled back to England, where he settled permanently. During the 1960s he worked as a carpenter, but carried on making guitars whenever he had the time. In 1969 he was introduced to Julian Bream, and he showed the guitarist one of his instruments. In time, Bream saw more of Romanillos' work, and finally they came to a mutual agreement that provided the guitar maker with workshop space on Bream's land, which happened to be close to where the Romanillos family lived. So, early in 1970, Romanillos moved in to his new workshop, and began making his first batch of four guitars. One of these four, No. 101, was acquired by Bream for his own use, and featured in many concerts and recordings.

Bream already owned a 1936 Hauser, and a crack had appeared on its back. It fell to Romanillos to carry out the repair and, as this entailed removing the back completely, he was able to examine the Hauser interior in great detail. This was an important stage in Romanillos' development as a great maker, because he had not really had much access to fine instruments before this. Hauser was to become one of the greatest influences in Romanillos' career. In 1973 he made what was to become Bream's famous guitar. It was closely based on his examination of Sergio Abreu's 1930 Hauser. Over the years it had numerous repairs, including a new back which was put on in 1978. More recently, the back has once again been replaced. This was done by Hermann Hauser III, who is the grandson of Hermann Hauser I.

Romanillos makes an average of fifteen guitars every year. He also devotes some of his time to carrying out research into his favourite area of interest – the history of the Spanish guitar. In 1987 he published a summary of his research into the guitar maker, Antonio de Torres (*Antonio de Torres – Guitar Maker – His Life and Work*).

In 1991 he made a guitar based closely on one of Torres' finest instruments. (FE08, made in 1858.) In the original, the back and ribs are of bird's-eye maple. The soundboard, back and ribs are all embellished with an elaborate double herringbone pattern of dark and light woods. The dramatic rosette design includes a central motif consisting of mother-of-pearl shapes, which alternate with squares of a chequerboard pattern. With this instrument Torres demonstrated his tremendous skill in making and setting in the herringbone and other inlays. The neck is cedar and the fingerboard is ebony. Machine heads, nut and frets are all made from silver. The guitar was exhibited in 1858 at the Seville Exhibition.

Romanillos made some slight changes to his 'copy' of the guitar – the shape of the body is slightly larger, and the back and ribs are of cypress. The interior strutting is virtually identical to the original – seven radial fan struts, and a lower harmonic bar with openings either side.

Romanillos has a very clear vision of the kind of guitar he strives to make, and of the character of sound that he wishes to produce – he is interested in capturing the 'true Spanish sound'; hence his thorough research into Torres, who worked very differently to other nineteenth-century European makers. Guitars by José Romanillos are now in such demand that the waiting time is virtually indefinite – perhaps ten to fifteen years.

(The following notes are elaborated on in the transcription of a conversation with Romanillos that appears further on in the book.)

Soundboard and Strutting System

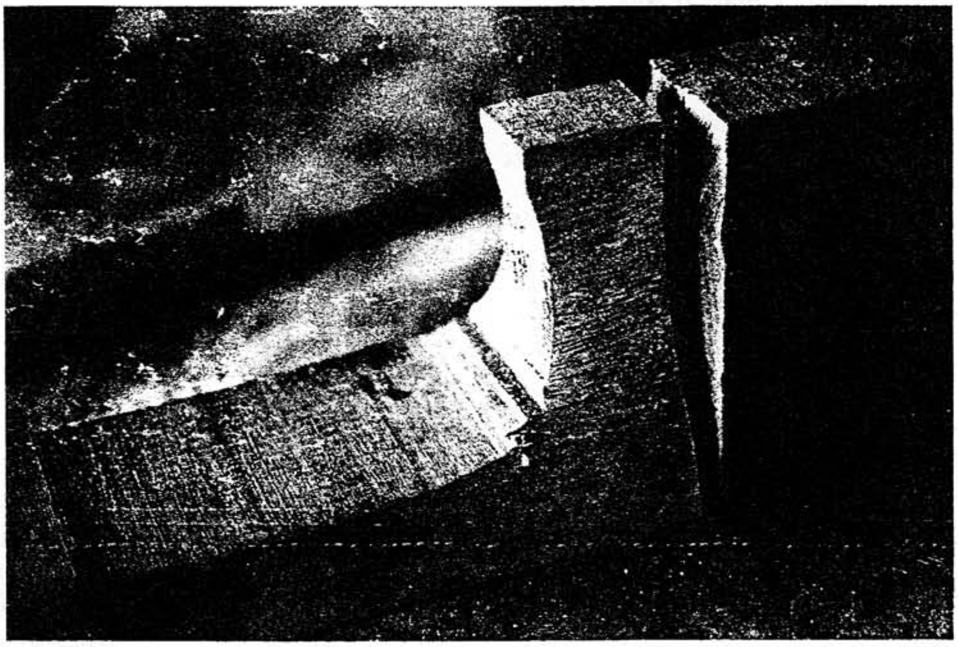
Romanillos uses only the finest spruce for his soundboards, as he believes that this is the first essential element for a good guitar. The second important factor is to thickness a given soundboard to the correct dimensions so that it will respond to the vibrations set up by the strings as fully as possible. His strutting system is essentially based on Torres, but he prefers to spread out the fan struts more than on most of Torres' guitars. The seven fan struts are much closer to being parallel to one another than would be the case with Torres. Two thin closing struts are placed diagonally, very close to the end-block area. Additional bracing is sometimes included either side of the soundhole – two thin bars on each side. This he observed in a Hauser guitar. Another distinguishing feature is the use of open harmonic bars – all three harmonic bars have apertures formed so that the soundboard is not so rigidly held, and can move more freely. (Two different soundboard plans are provided, in order to give as comprehensive a view as possible of this maker's work.)

Plantilla

Drawing from his research into Torres and Hauser, Romanillos has made instruments following both these patterns. His own design has evolved somewhat, and is recognizable by the shape of the upper bout/waist area, the upper bout being rather flat as it leaves the waist. The soundhole diameter is 87 mm (somewhat larger than many other makers).

8-2 A Romanillos guitar made in 1991

Neck



8-3 A Romanillos neck ready to receive the ribs – the tapered slot has been prepared so that a wedge can be driven down behind the rib

Romanillos always uses a 'V' join to connect the neck to the head. The shape of the heel is based on that found on many of Torres' guitars – small and round, rather than the more angular shape often used. The ribs are secured into the neck with a variation on the usual Spanish method – slots are cut for the ribs, but they are much wider than usual, and are tapered so as to be wider at the heel than the fingerboard side. The rib is then placed into the slot. A wedge that has been prepared to exactly the same taper, is tapped down into the slot, behind the rib. This forces the rib against the outer edge of the slot. A perfect join is formed, and any of the usual problems associated with adjusting the rib width by trial and error, until it fits a narrow slot, are avoided.

Rosette

The Romanillos rosette is definitely a feature that makes his guitars instantly recognizable. He is a master of the techniques involved in making wood inlays, and he uses a variety of methods to produce his famous 'arch' design. He took the original idea from the architecture of the mosque at Cordoba in southern Spain. Only natural woods are used, including cedar, satinwood, sycamore and yew. The main design consists of two blocks which are prepared separately; the first represents the column, and the second represents the arch which is placed above the column. The arch is made by cutting wedge-shaped sections from a veneer sandwich, and then gluing them together, like slices of a cake. The wood for the column is rebated to shape, and joined to a mirror-image shaped background. The inner and outer borders consist of a lozenge design, which is made from varying types of wood.

The rosette is 24 mm wide.

From outer circumference:

Outer border:
1.5 rosewood
0.2 sycamore
2.5 lozenge pattern in various woods
0.2 sycamore
1.5 rosewood
0.2 sycamore

Central section:
5.5 arch motif
7.0 column motif

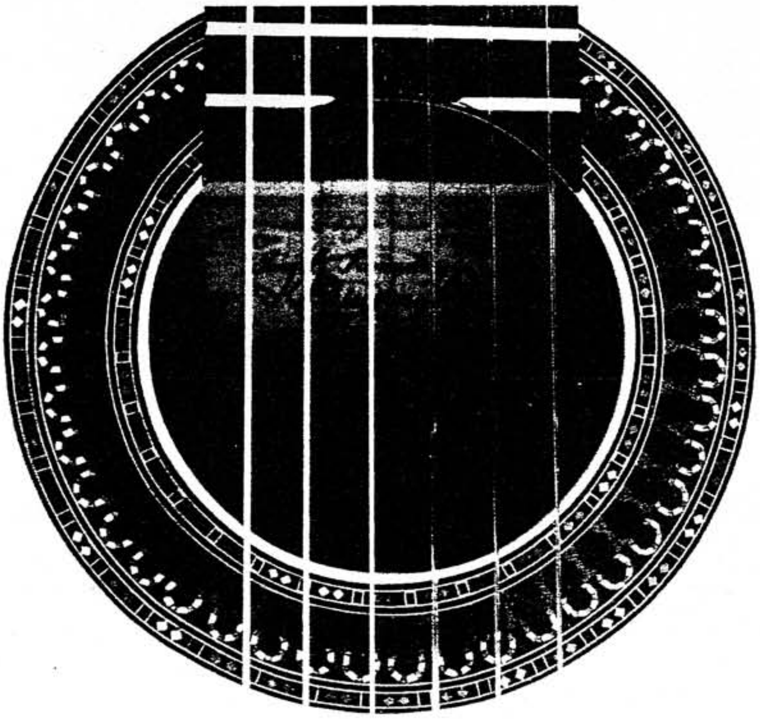
Inner border:
0.2 sycamore
1.5 rosewood
0.2 sycamore
2.5 lozenge pattern in various woods
0.2 sycamore
1.5 rosewood

Materials

soundboard:	European spruce
back and ribs:	Indian rosewood
neck:	Honduras cedar
fingerboard:	ebony
bridge:	Brazilian rosewood
internal struts:	European spruce

Soundboard Thickness

2.5 mm-2.75 mm in the bridge area and up to the soundhole
1.9 mm-2.2 mm around the periphery



8-4 The Romanillos rosette

Comparison of Dimensions of Two Romanillos Guitars

(measurements in millimetres)

year	body length	width at upper bout	width at waist	width at lower bout	body depth at end-block	body depth at heel
1973	480	268	225	354	97	84
1974	480	267	224	353	98	87

(The 1973 guitar is Julian Bream's famous instrument.)

Back Thickness

2.0 mm-2.3 mm; thickest in the centre

Bridge

The bridge is inlaid with a section of the rosette motif, and is bordered with two strips of ivory.

Scale Length

650 mm

The following section includes extracts from conversations with Romanillos, recorded at his workshop in Dorset, England, on 29 September 1991.)

> I started making guitars because I wanted to play, but at that time I did not have enough money to buy one. But I've always been very inquisitive. I started in 1961, and there weren't many people doing it then, so I suppose I was one of the pioneers in this country. I started with a very basic book, it was all I could find. Once I started, I became fascinated, not only with the construction, but also with the history of the Spanish guitar. I wanted to know as much as I could about everything to do with it. No one could teach it; I had to do it on my own.

(I asked José to elaborate on how the Spanish school of guitar making differed from the European school.)

> In principle, the Spanish guitar is much more lightly built. Also, the strutting is different – the European makers used several transverse bars across the soundboard, rather than fan struts. The pitch of resonance of the soundboard will be much higher if it has been 'tightened' with transverse bars. Fan struts allow a lower pitch. This is why, in my view, the Spanish prototype (of Torres) became preferred to the European. The Spanish

method is to get the soundboard, and then the air in the cavity, to vibrate at its optimum. A lot of central European guitars of the nineteenth century are 'tight'; they may have nice trebles, but the basses are restricted. They have no vibrancy. Hauser had to forget the German tradition, and revert to the Spanish prototype, in order to produce the kind of sound that Segovia was looking for. In the eighteenth century there were one or two lute makers who put a very primitive fan strutting at the bottom, but nothing came of it. It was the guitar makers who took it further.

Some makers work totally differently to me – Fleta uses cedar, and quite a heavy construction – the soundboards are heavily braced. To me, his guitars are more French than Spanish, in the sound, the construction, and the whole approach. He's a very good maker, but it is not the kind of sound that attracts me. I'm attracted to what I consider the Spanish guitar, which is very vibrant and very free and very bright. Before I started my career in 1967 I went to see a collector who had three or four Fletas, but to me they were not Spanish in character. I want to capture the essence of the Spanish character. I'm not sure if I can, but that's what I'm trying to do. I'm working on different principles. Friederich is somewhere between Bouchet and Fleta, an amalgamation of the two, but he has a scientific approach to design. His spruce guitars are, in my view, the better ones. They are well made, but he works by trial and error like the rest of us.

The essence of guitar making today, if we consider the Spanish classical guitar, is still based on this Spanish instrument developed by Torres. There are people changing things, like Smallman, but that's a different type of instrument altogether.

(Like most makers, Romanillos regards a good soundboard as being central to a guitar's success.)

If the soundboard is 'soggy' and has 'no guts', then the guitar will not be good. I've seen some pieces of spruce that bend like rubber, and that is no good at all. Perhaps the fibres of the wood are not compact enough, I don't really know. And yet, some makers will pay a lot of attention to one small detail, for example, the strutting. But the strutting isn't relevant as a detail, yet it is relevant as part of the overall unit. The art of guitar making is to get the tolerances right – working to the limit, but it's no good getting to a limit with one part only, you must look at the guitar as an overall entity. I don't think we give enough serious thought to the guitar as a whole, and particularly, to the contribution of the soundboard to this whole. Of course, it is not always easy to get hold of good spruce. The majority of the spruce these days comes from Yugoslavia, although the suppliers still call it 'German'. A lot of the wood is cured artificially – they are dealing with vast quantities, and would not risk unpredictable climatic conditions – spruce is tricky to dry properly. Also, the demand for wood means that a lot of it is quite new, perhaps only two or three years old, and some of it is not properly cut; I had all these problems when I started. I have a soundboard that I bought commercially twenty years ago, and I never used it – if you look at it now you can see that each half has bowed across to such an extent that you can imagine the stresses that would occur if it was now part of a guitar.

I am in contact with some researchers at Cardiff University, who are working on acoustics, and I am trying to steer them to give us some tangible information. They can't solve our problems, but at least they can tell us the parameters in which to work. The trouble is that they theorize everything, and come up with tables and figures, but it makes no sense to us, the makers, so I have asked them to try and present the information in a form that would have meaning, in an applied sense. We are really working in the dark. We rely on our intuition, and on our experience of what we did before. Yet the principle of the guitar is very simple – the structure has to respond to the whole set of resonances in the guitar. This is not possible to achieve, but it can be aimed at. That's the principle – the soundboard has to in fact be 'dead' – it must not show any favouritism for one particular note. The instrument has to be light and strong, and the scientists could tell us at what particular dimension the soundboard would give us a certain frequency of response. This would be related to the air cavity, and to the back. This would be interesting, because at the moment we all work by the results we had in the past.

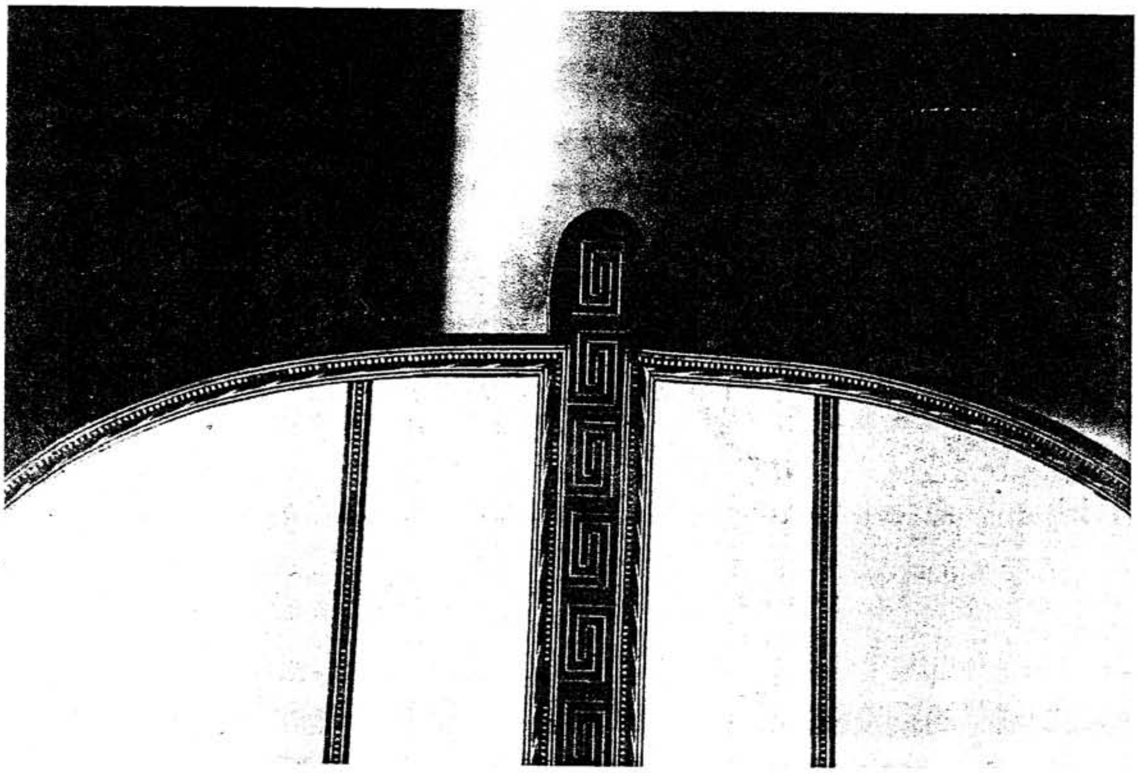
(I asked if he had any particular thicknesses in mind when he worked on his soundboards.)

In general, I thickness the soundboard to about 2.75 mm maximum, around the bridge and up to the soundhole, and less around the edges, to about 2.0 mm, or sometimes 1.9 mm. But once again, it all depends on the particular piece of spruce I am using.

When you make the guitar, you have to consider the playing technique – what happens these days is that the technique has developed in favour of a heavy and sometimes unruly style, which may work on some instruments, but if such a player picks up a Torres, or one of my guitars, they don't know what to do with it. If a guitarist is only interested in playing fast, and with bravado, he can't make it work. When you have a very responsive instrument, you have to apply certain rules in playing it, which many modern players are not prepared to do. I know this is controversial, but I know of players who may take one year to come to terms with one of my guitars, particularly if they have been used to a heavier instrument. The guitar is a limited object, and the player has to fit in to the capacity of the instrument. There is a limit to what that string can produce. I made several guitars for Julian Bream, and the 1973 is the one he has played for twenty years, because it responds to his style.

(José had recently been commissioned to make a guitar based closely on one of Torres' most beautiful and elaborately inlayed instruments (FE08, which is described above). The construction of the 'copy' was complete, and the guitar was now being polished. It had already been strung up, and had a beautiful sound.)

It's very similar to the Torres – the inside is all Torres, the inlays are similar – it's taken me three and a half months to get to this stage – I don't think I'll make another one like this! It's for a Norwegian guitarist, who already has one of my guitars and he asked me if I could make one in cypress, and for it to be an approximation of the Torres guitar. I didn't think too deeply – I said yes – but I didn't know what I was taking on. Now it's nearly finished, I'm glad. I enjoyed making it. You think you have worked everything out, but when you put it into practice, you discover that it's a different kettle of fish. If you look carefully, the inlays are not end-grain, they are all across the grain. To do this design with end-grain is no problem, but it is much harder to do it across the grain. Here is one piece that is end-grain – it is much darker than the next piece, which is across the grain. The mother of pearl inlays are bedded into a black background made from Araldite mixed with charcoal. The sides were each made from two strips of cypress, with the inlays put across the join. The back of the join was re-inforced with paper. I thought for hours how to do it. The best thing about this guitar is the clarity of the sound – it is totally Spanish. It has the best soundboard I could find, and I've got thousands to choose from.



8-5 The back inlays on the Romanillos copy of Torres' 1858 guitar (FE 08)

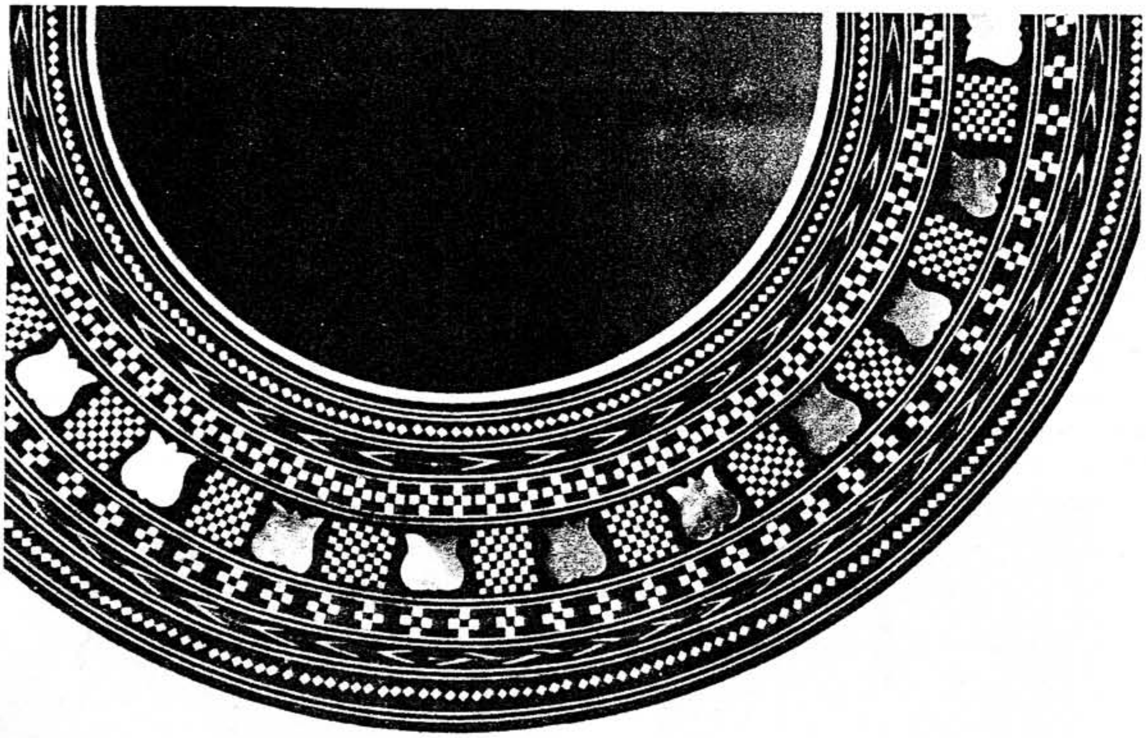
(We discussed other aspects of his construction method.)

Templates for the plantillas

José showed me the various templates that he uses for his guitars; one taken from a Torres, one from Bream's Hauser, one from a Santos Hernández, and one which is used for most of his current guitars. Each one is beautifully made in thick brass, and small holes have been cut out to define the ends of each fan strut.

The rosette

I make a sandwich of the colours for the arch, and it is cut into wedges, which are then put together. I make it about 100 mm long, enough for quite a few



8-6 The rosette on the Romanillos copy of Torres' 1858 guitar (FE 08)

rosettes. This is laburnum, it has a very close grain (the column). I've done the column in many different ways, now I use a circular saw to rebate it, then fit the other pieces into it. The basic method is to build the rosette around a metal tube, the diameter of which is slightly more than the soundhole. The various sections of sandwich, and also flat veneers, are laid round the tube, and then an aluminium strip is clamped around it all. This keeps everything in place until the glue is dry. Finally, slices are cut off, just the required thickness for one rosette at a time.

The strutting

This pattern is the one for Bream's 1973 guitar. It is a very successful design. There are two struts either side of the soundhole, which pass through arches in the harmonic bars, an idea I took from Hauser and which probably he took from Torres. The head is different to my usual design – I only ever made one like this. The strutting arrangement is not the most important aspect of the guitar. More important is the thickness and the quality of the timber. I shape the fan struts like gables up to the bridge, then they are flat. I have tried so many variations that I know that the exact arrangement is not so critical. I have used a plate under the bridge for a long time, but I have decided to do away with it now. The next guitar will not have it. I have never been quite convinced of its use. I decided to do some experiments – not acoustically, but structurally. The thing is that the plate is in conflict with the rest of the soundboard. The grain is going the other way, so if the soundboard moves – by shrinking or swelling, it causes a lot of strain. So I have recently decided that from now on I will not use it. It definitely puts a lot of stress on the soundboard when there are climatic changes. On that precept, I am doing away with it. Torres never used it. In my guitars I have used it sometimes, and many times not, and I don't think it really made any difference to the sound. At one time I thought that if I made it very thin, it would help to discipline the bridge a little. But our experiments show that if you have an extreme change in conditions, the plate causes the soundboard to buckle. But I won't make the soundboard any thicker.

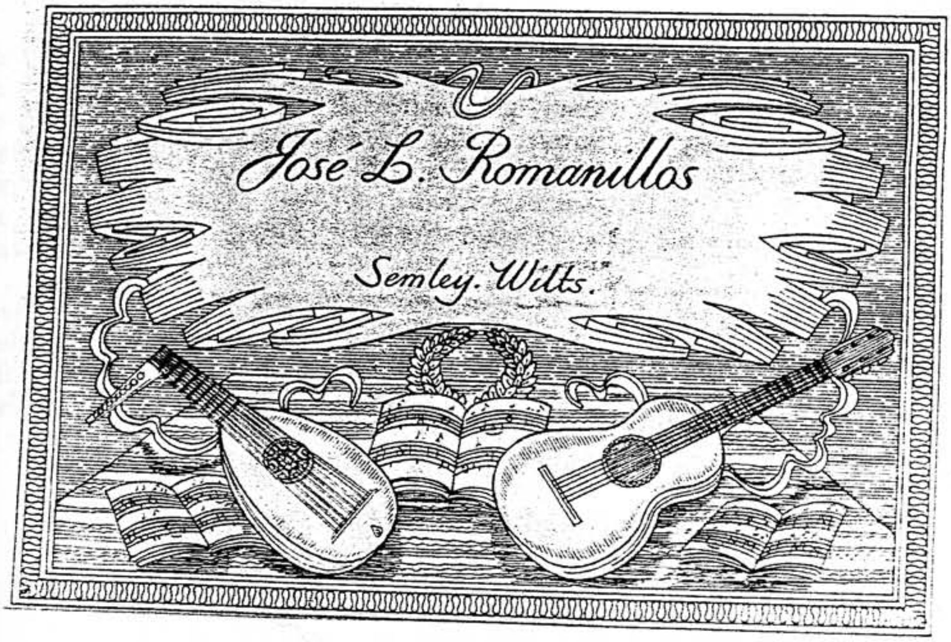
Rib to neck joint

I saw this joint in a seventeenth- or eighteenth-century French guitar, not in a modern one. You cut a wide, tapering slot, then fit the rib tight up against the front end. Then you drive a wedge down, which matches the taper exactly. It is very strong.

Back bars

I take them down in the centre, to make the guitar lighter.

(The top surfaces of the back bars are not left flat, but scooped out so that they are lower in the centre, leaving the full height only at the two ends, where



8-7 The Romanillos label that was in use until late 1991

8-8 The new Romanillos label that was introduced in late 1991

they butt against the ribs.)

New label

(José showed me the new label that will be used in the guitars from now on. His son is now a partner in the business.)

This is the label we are going to use now, to include my son. The drawing represents the house with the workshop and the hills, seen from below. It's a wood-cut, done by a friend.

Head inlays

We make them all slightly different, every two or three we change slightly. The decorations develop constantly. We get new ideas, and try them out, but they are usually variations on the same theme.

Linings

I often use individual blocks to attach the sides to the soundboard, but I have also used continuous linings. I build the guitar on a solera. The soundboard is face down, and the ribs are let on to it. In some cases, Torres, and other makers, have glued the complete lining in place after the ribs are positioned. They must have glûed the rib to the soundboard, and then fitted the lining in place. I have never done it that way, but I have glued the lining to the rib, and then the rib to the soundboard. But now I use the individual blocks, placed in one at a time, and pushed in with a prodder.

Glues

I use different glues for different parts of the guitar – Cascamite for attaching the fingerboard and the bridge; I use a type of 'Titebond' (Humbrol) to glue the bindings and the back. But all the strutting and bars inside are done with animal glue. I make many gadgets to help the construction – this one is to glue on the bindings. I don't know if it will work.

The future

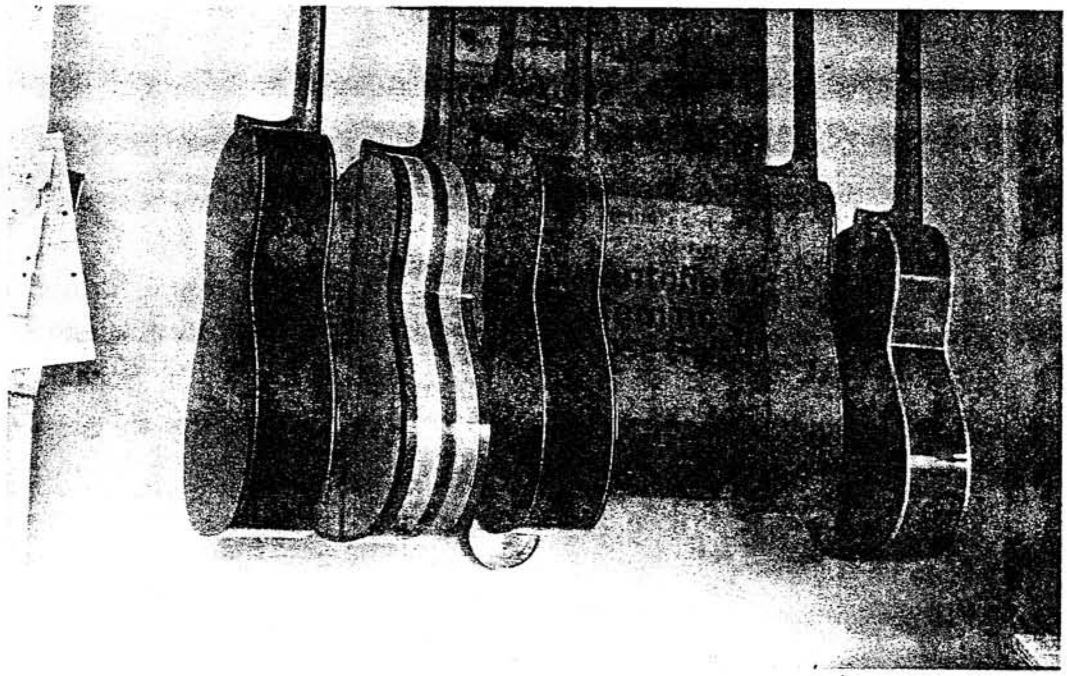
We've got nearly four hundred orders on the books, so my son and grandson will have to fulfil them! I've tried to instil the idea in to my son that he must keep the workshop on a modest scale, and try to enjoy himself. My son started to help me when he was sixteen, about ten years ago. Some established makers in Madrid have had their workshops developed into factories, once their sons took over. But guitar making is not a profession in which to make a lot of money. Now my son realizes this – he shares my view, and he has become very skilled. My grandson has already been sitting in the workshop, watching. We do it because we enjoy it. I don't want to over-price my guitars, because I want players to be able to have them, and not for them all to go to collectors abroad.

In conclusion

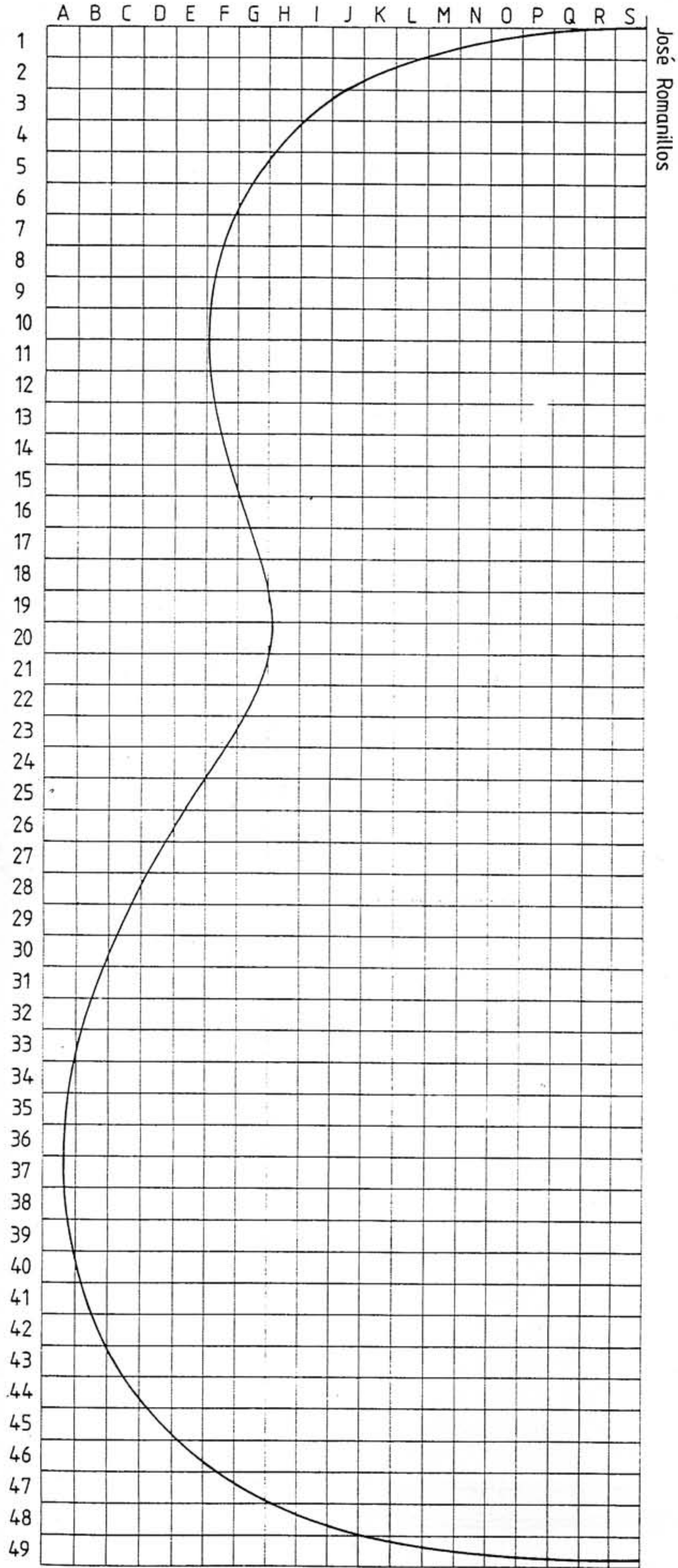
I give each guitar a Spanish name, and I record all the details of every guitar in this big book. It is a blank log book for a ship from 1774. It is beautifully bound in leather, and it was empty when I found it, so I decided to use it for keeping records of all my guitars.

Making a guitar is a great experience. At the end of it you have something to be proud of. I have many students in different countries and have given occasional guitar making courses in Canada, Belgium, Spain, Switzerland and Germany. The students seem to get very close – they keep in touch with each other. Guitar making is a great thing to do. I find it very rewarding.

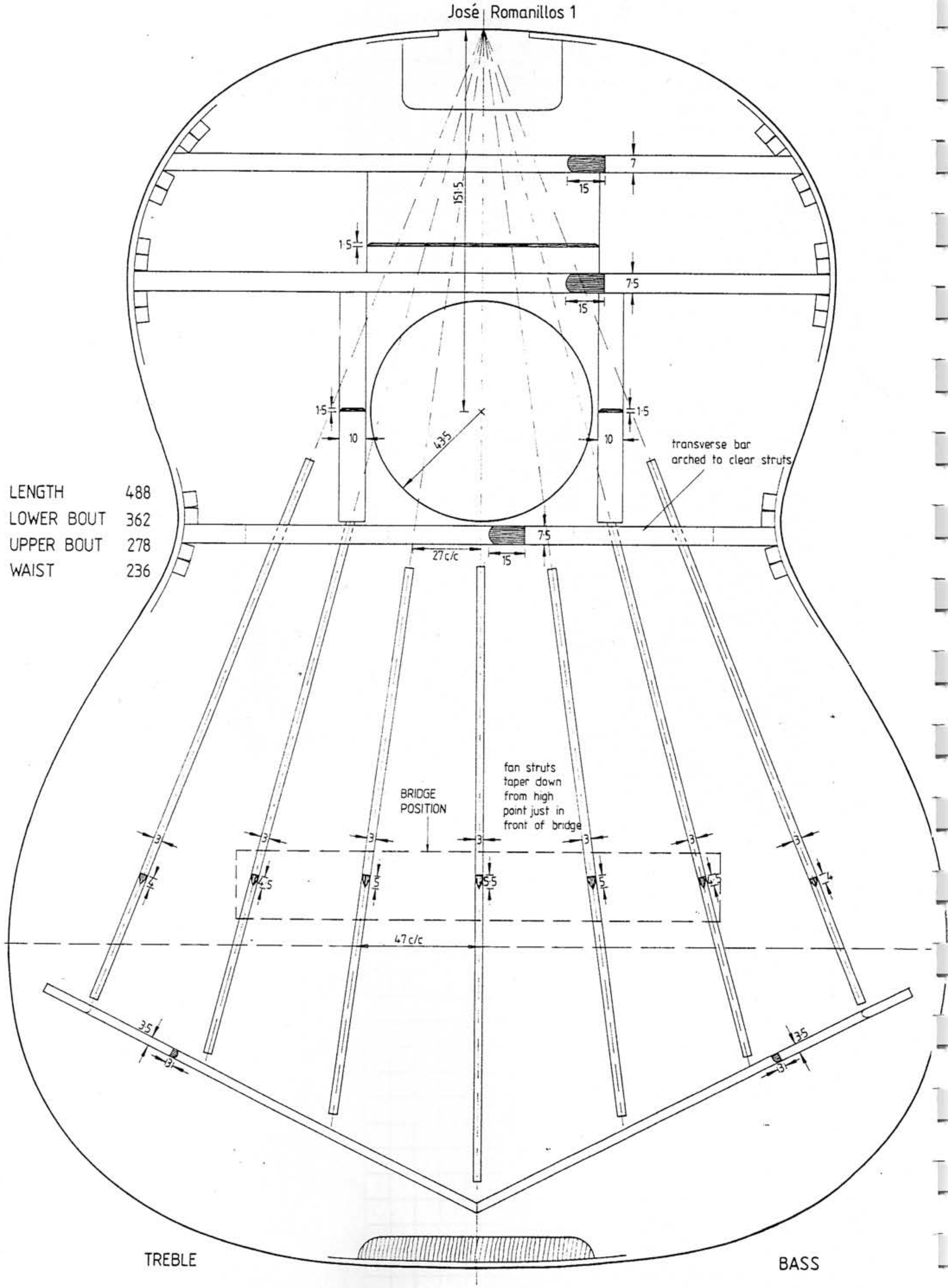
I am now completing my research for another book, which is about the development of the Spanish guitar from the sixteenth century. It will cover the organization of the craft guilds; construction techniques; makers, and so on, but I still have quite a lot more to do.



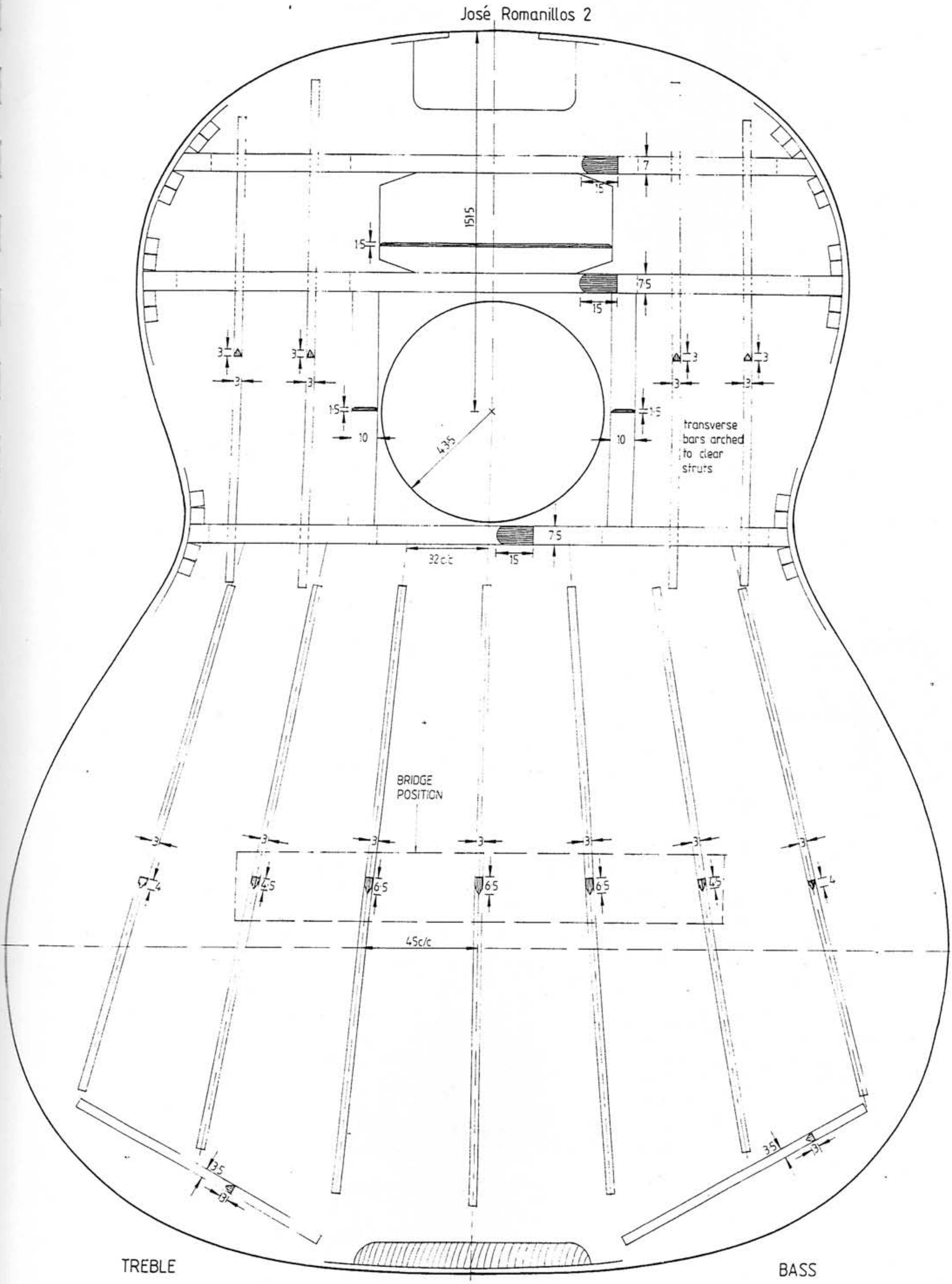
8-9 Guitars hanging up in the workshop during french polishing. Second from the left is the Torres copy



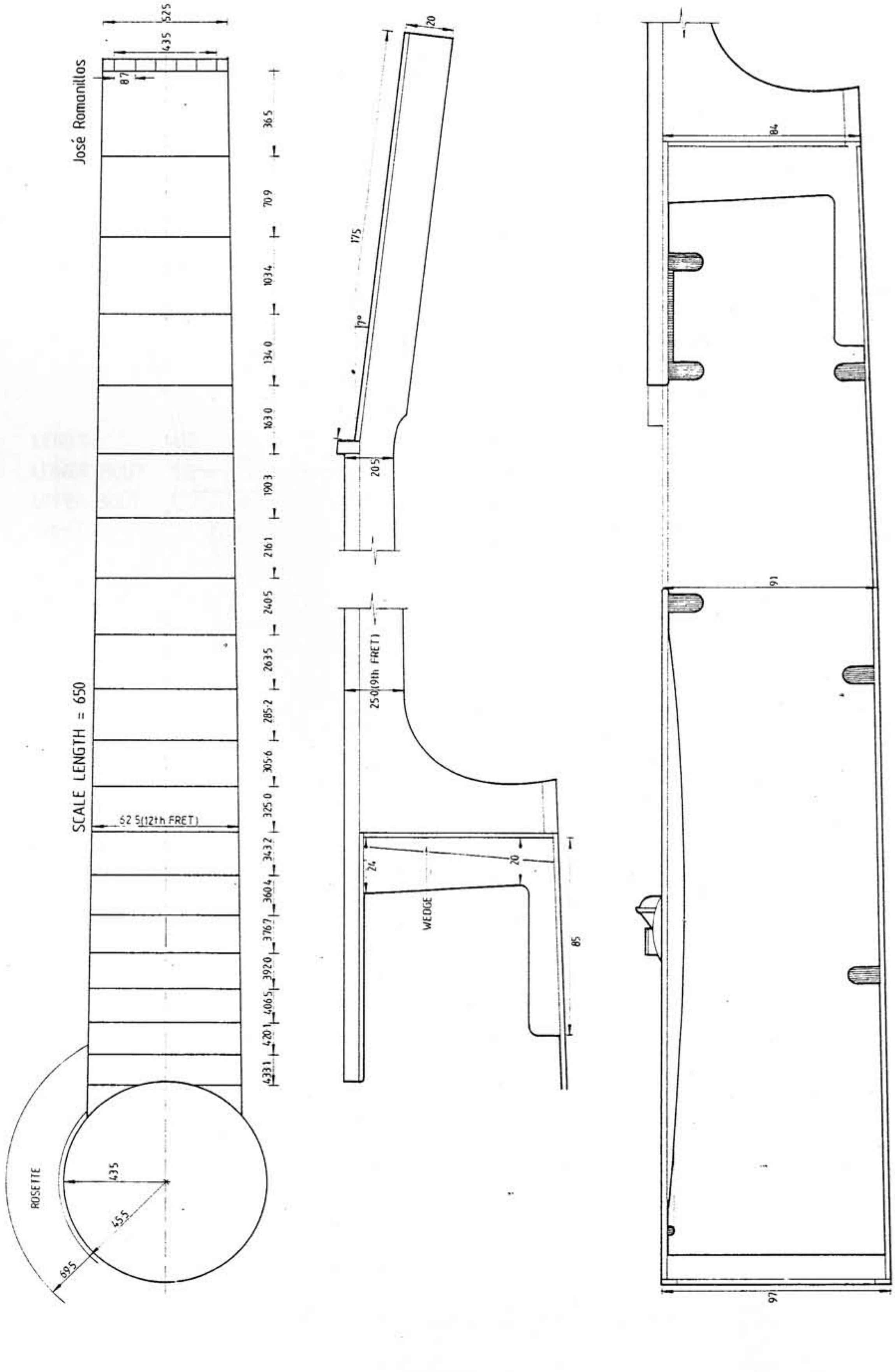
8-10 Romanillos – plantilla (each square represents one square centimetre)



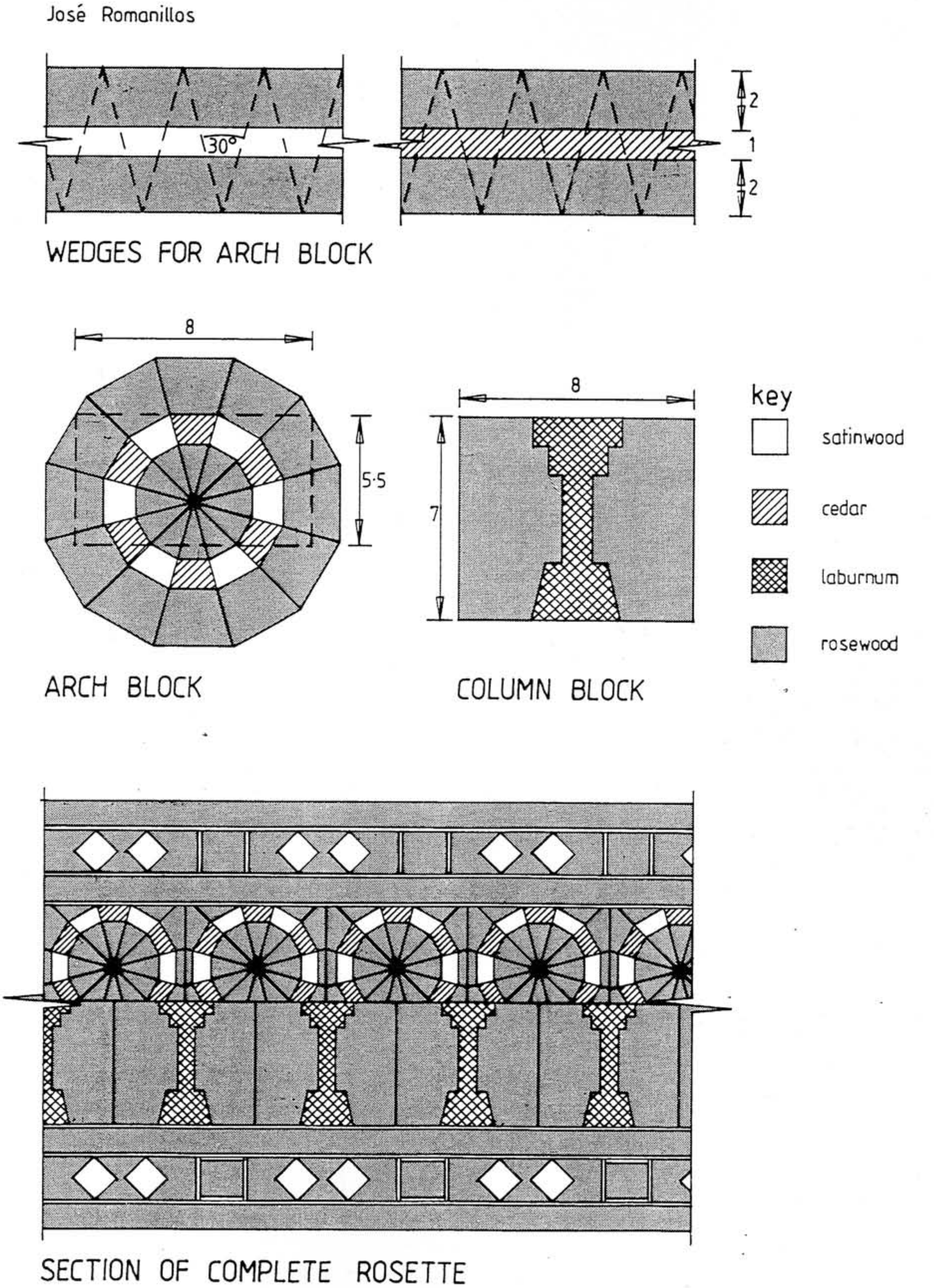
8-11 Romanillos – soundboard 1



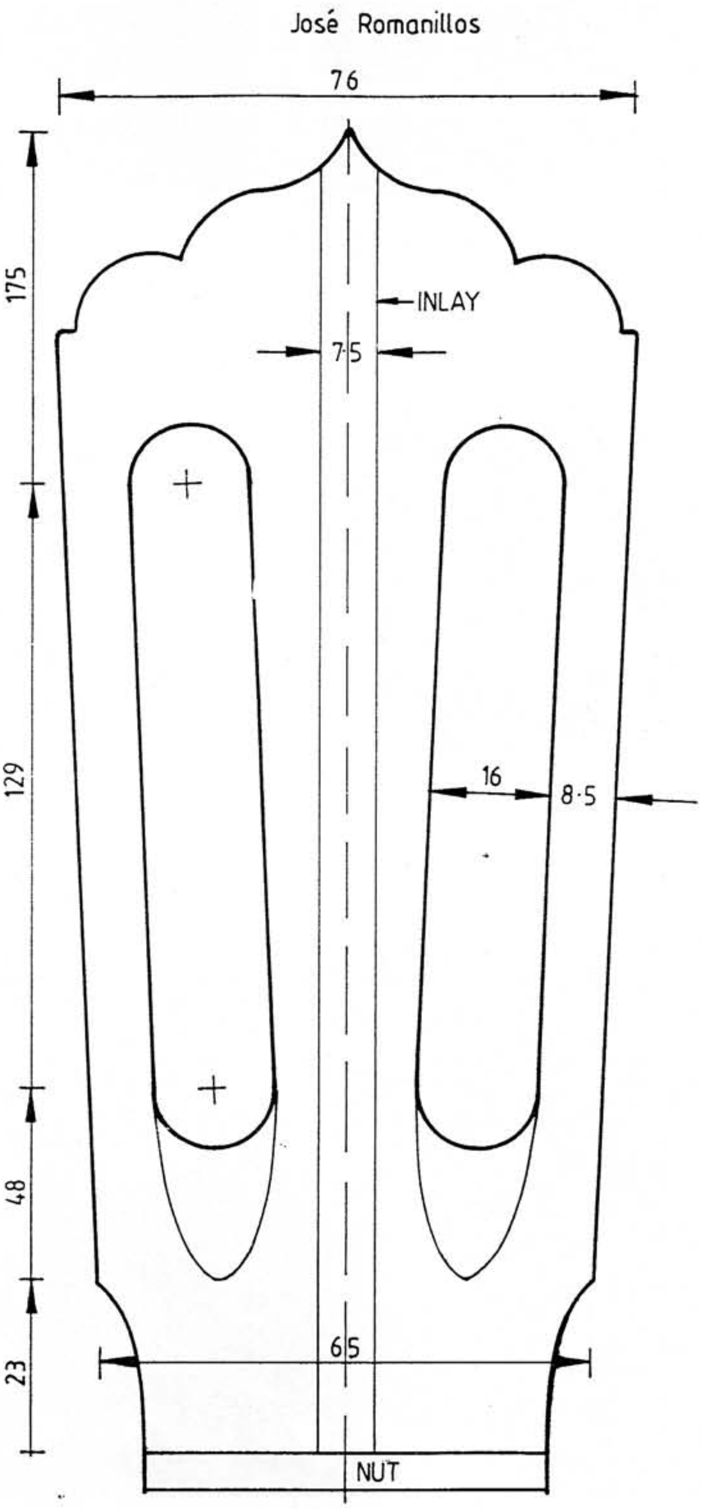
8-12 Romanillos – soundboard 2



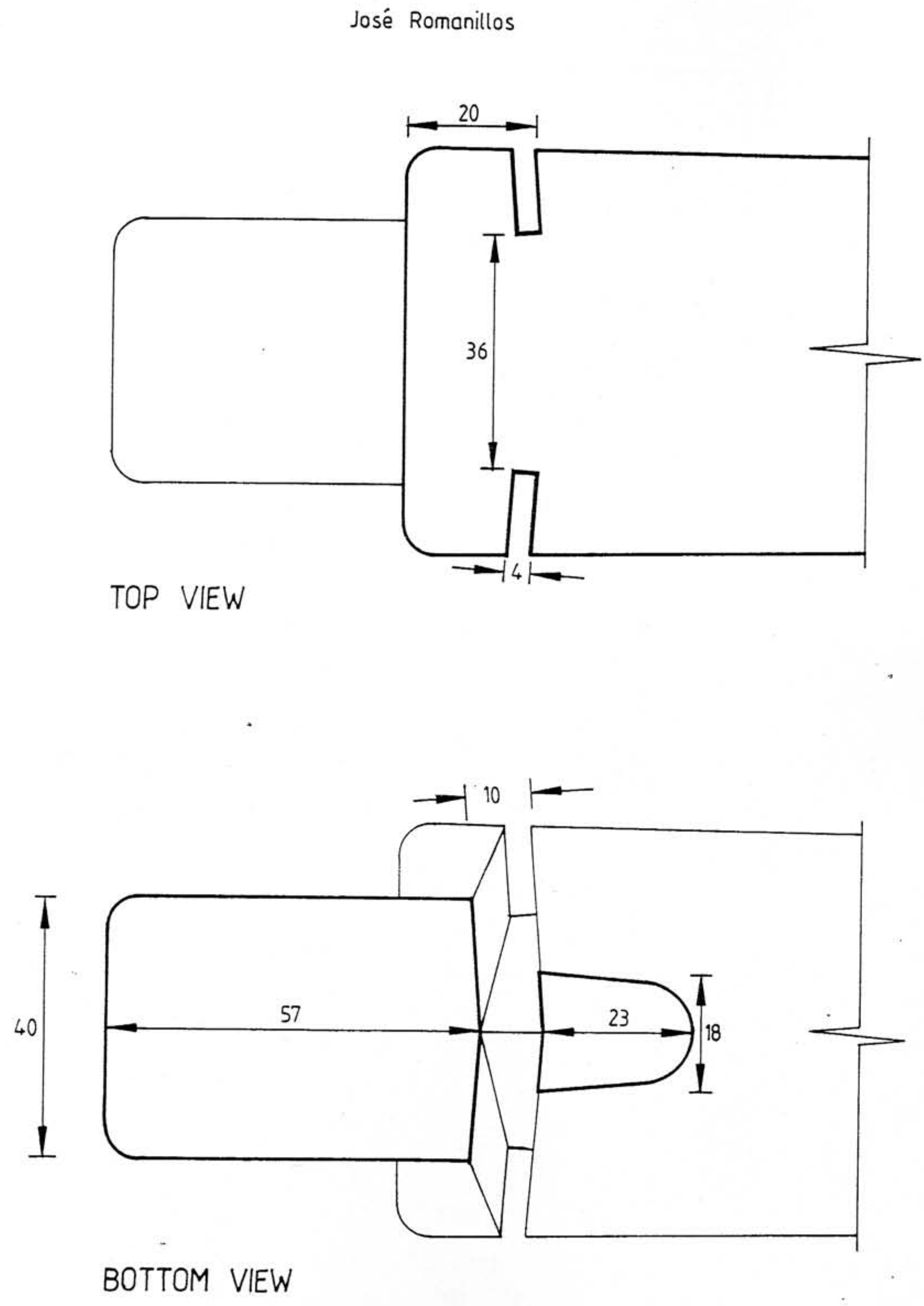
8-13 Romanillos – neck and body



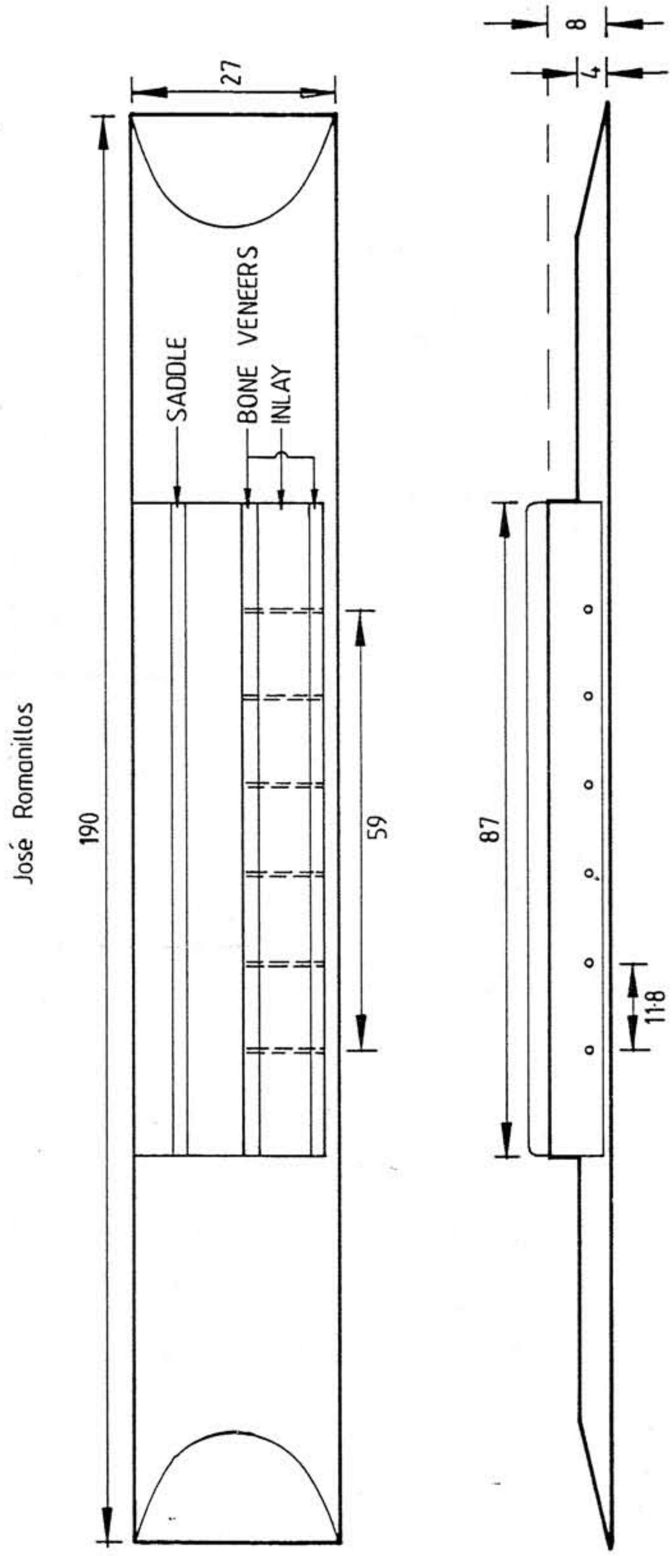
8-14 Romanillos – rosette



8-15 Romanillos – head



8-16 Romanillos – neck joint



8-17 Romanillos – bridge

9 Workshop and Tools

Working Environment

Many established guitar makers began their careers in humble surroundings; working in cramped conditions without much light, and lacking basic items like a sturdy workbench or a warm room. If your enthusiasm is great, then almost any obstacle can be overcome. It can be interesting to visit different makers' workshops, and see how great the variety of working attitudes can be. Some are well-organized, spacious, logically set out, and reminiscent of a small factory or laboratory. Others are in tiny rooms, with hundreds of shelves, boxes, tools and materials stored in an apparently random way, yet from such a workshop may emerge an exquisite instrument. The workshop reflects the character of the maker, and no two are the same. Nevertheless, it is worth considering objectively what the ideal working conditions would be, and then each maker can adjust to the available resources accordingly.

Lighting

A fundamental requirement is for a well-lit room. An abundance of natural daylight is the best light source as it makes close scrutiny of wood surfaces possible. A room with windows on several walls rather than just one is helpful, because light will fall on the workbench in a more balanced way and, as the day progresses, sunlight will be able to enter from various directions. Some components of the guitar need a lot of attention to ensure that they are flat and smooth, and that every last scratch and tiny dent has been removed. If not much daylight is available, and in winter months when the days are short, a strong artificial light source must be used. Ideally, a combination of overhead strip-lights combined with movable lamps is best. It is often necessary to move work from one end of the bench to the other in order

9-1 The Fleta workshop in Barcelona

Part 2

Workshop, Tools and Materials

to use a particular vice or cramp, and it is convenient if a portable lamp is available for these situations. Final examination of surfaces should always be done in daylight, particularly just before varnishing, or scratches are likely to go unnoticed but become all too apparent once varnishing has begun.

Humidity

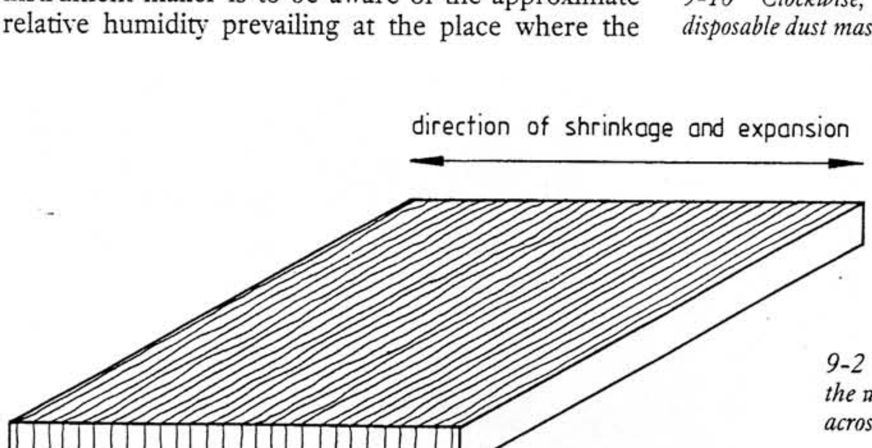
The moisture that is in the air can be the instrument maker's greatest enemy. It is not a constant amount, and the air can become drier or wetter, depending on a range of factors; the seasons, the temperature on a particular day, the wind direction, the kind of heating in use, and so on. The amount of moisture in the air is commonly measured as 'relative humidity' in the form of a percentage. The simplest way of determining the relative humidity of the room in which you will be working is to buy an inexpensive hygrometer, which measures the amount of moisture in the air. These meters are sold in hardware stores. They work by means of a simple metal coil mechanism which is sensitive to moisture – the coil is attached to a needle which in turn moves over a graduated scale. They are accurate enough for the guitar maker's purpose, provided that the calibration is checked when the meter is first purchased. The usual method of checking is to wrap the meter in a wet cloth for several hours, after which time the needle should point to a relative humidity of 95%. If it shows either less or more than this, there is a screw adjustment on the back of the meter which can be turned until the needle points to 95%. The meter should then be hung on a wall, well away from windows and sources of heat, so that it can given an 'average' reading for the room. Having calibrated the meter, it should be left for at least six hours so that it can dry out and then reflect accurately the moisture level of the air in the workshop.

The relative humidity varies not only according to the time of year, but also according to the geographical location – some countries are far more humid than others. The main consideration for the instrument maker is to be aware of the approximate relative humidity prevailing at the place where the instrument will finally be kept. In humid countries, air-conditioning may result in a large difference between the outdoor humidity level and the indoor level. It is really the indoor level that matters most, as this is the environment in which the instrument will be stored.

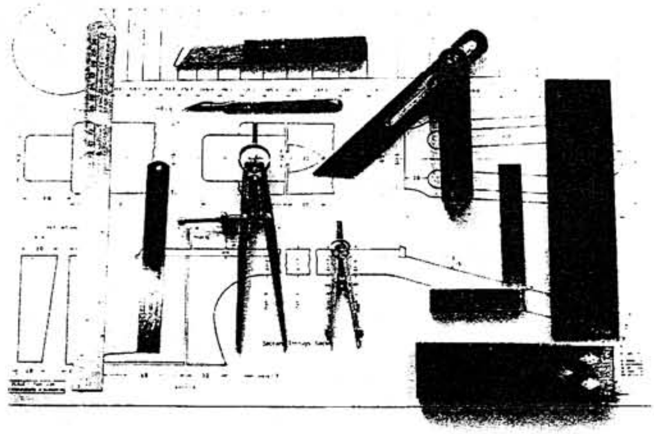
An average indoor reading of relative humidity is likely to be between 50% and 65%. If these readings can be achieved in the workshop then there are unlikely to be any problems with the instrument later on. As wood loses moisture and becomes drier, it shrinks across the grain. As wood absorbs moisture it swells and expands across the grain (9-2). The two most vulnerable parts of the guitar are the soundboard and the back because they consist of wide areas of wood which are not free to expand and contract, as they have been glued down on all sides to the ribs of the guitar. If a soundboard is fitted and glued to the ribs in an environment of high relative humidity (75%), and later the instrument is kept in a much drier location (40%), then the soundboard will shrink across its width. Because the glued edges are now prevented from moving inwards, there is bound to be some change in the condition of the wood. The

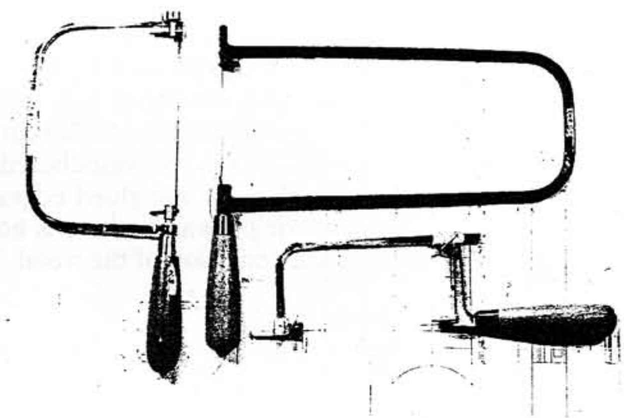
Right column:
9-3 Left to right: fret-slot saw, dovetail saw, small tenon saw, rib-slot saw set to produce a 2 mm wide cut, large tenon saw
9.4 Left to right: coping saw, fret saw, jeweller's saw
9-5 Clockwise, left to right: scraper plane, block plane, smoothing plane
9-6 Left to right: half-round file, flat file, wood rasp, 3 mm chisel, 10 mm chisel, 13 mm chisel, 19 mm chisel, 19 mm carving chisel

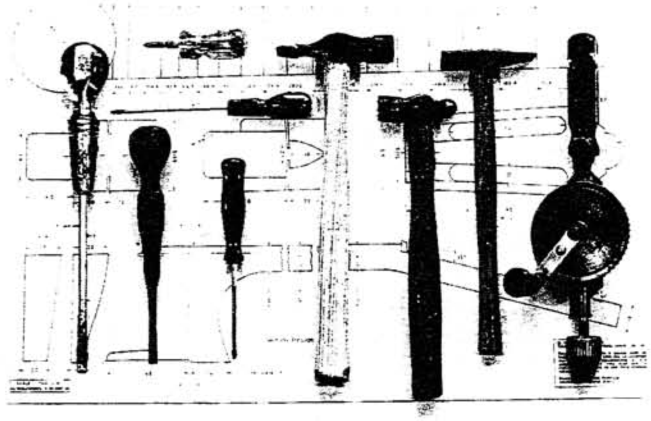
Far right column:
9-7 Clockwise, left to right: 300 mm steel rule, 150 mm steel rule, marking knife,. scalpel, adjustable bevel, try-square, engineer's square, small dividers, large dividers
9-8 Left to right: various screwdrivers, hammer (flat head), hammer (round head), fretwire hammer, hand-drill
9-9 Small and large cramps
9-10 Clockwise, left to right: vapour/dust mask, goggles, disposable dust mask

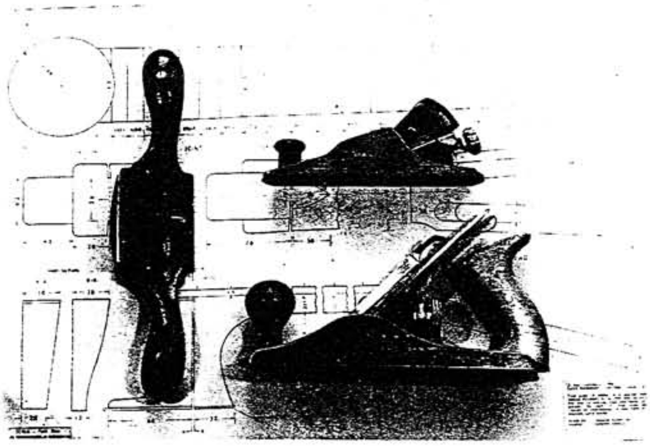


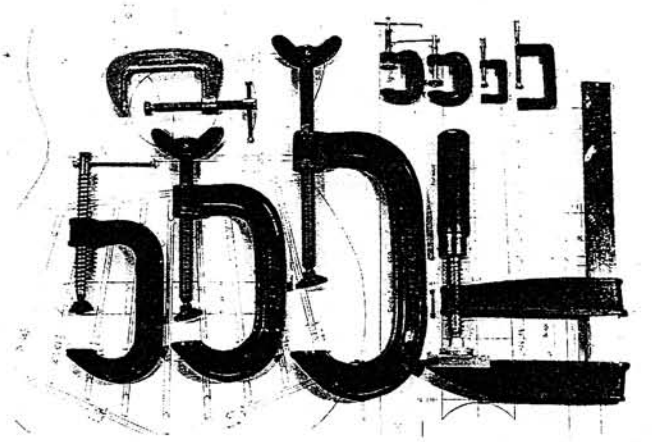
9-2 Changes in humidity cause the wood to either shrink or expand across the grain

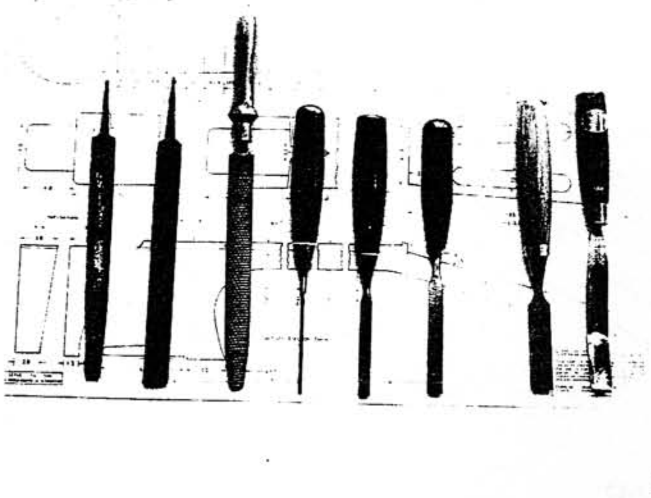


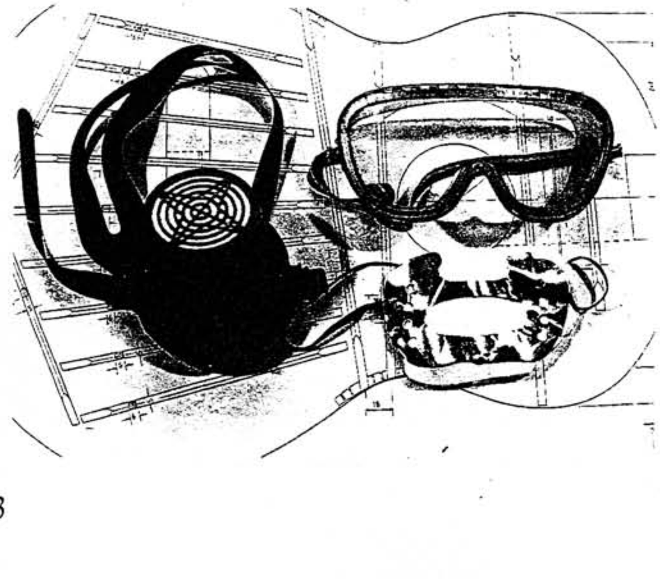


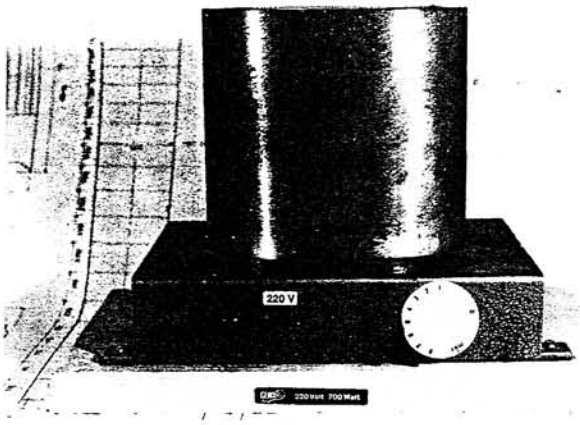








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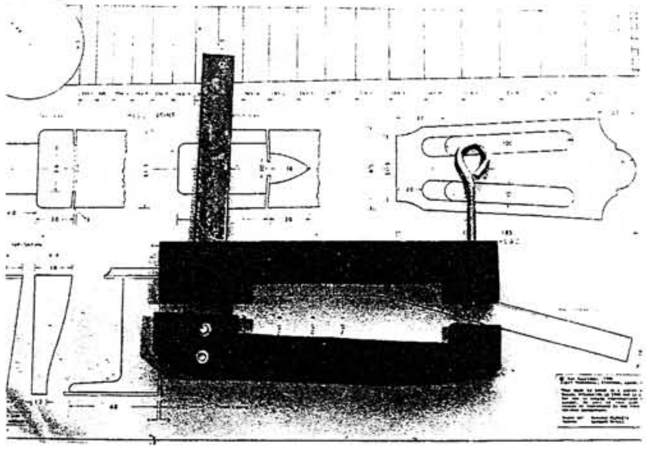

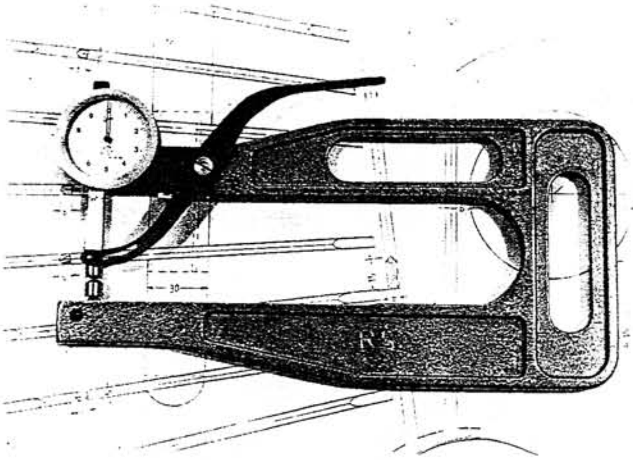

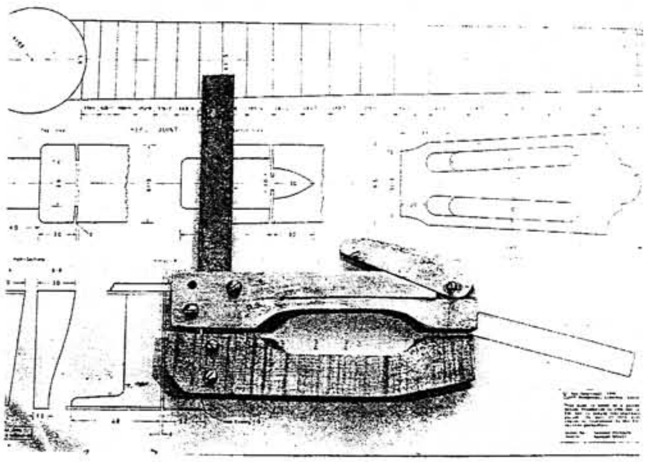

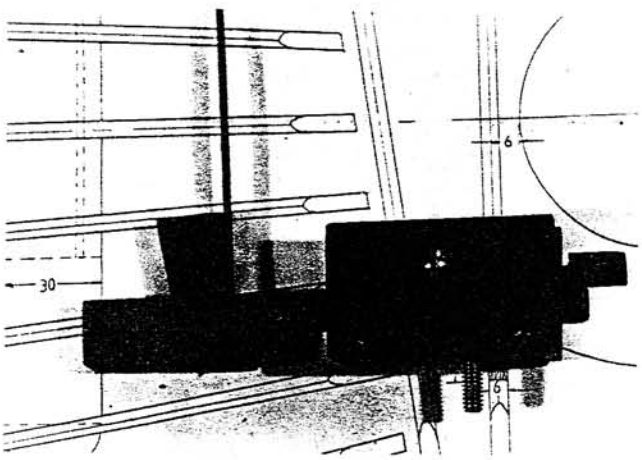
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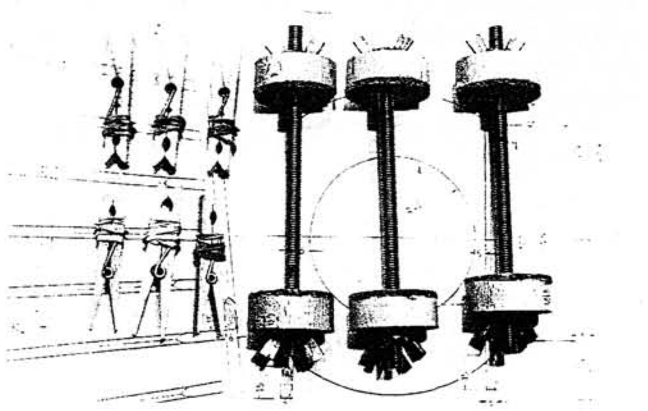
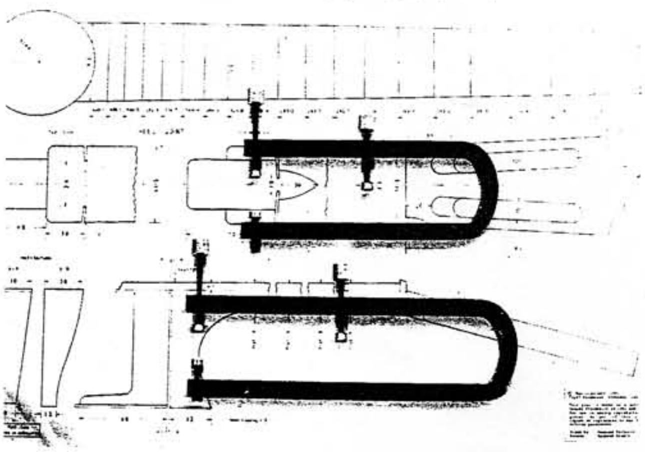
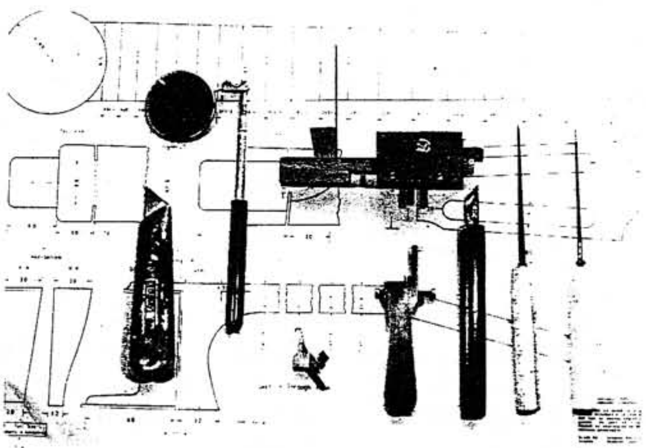


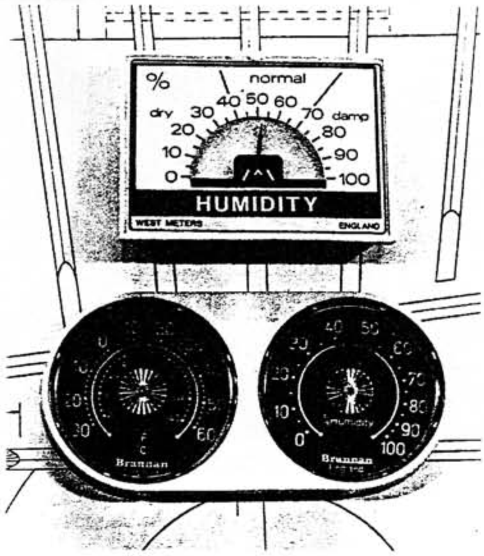


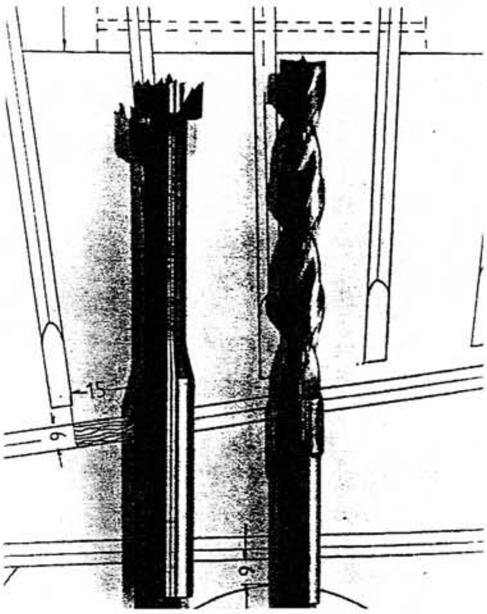


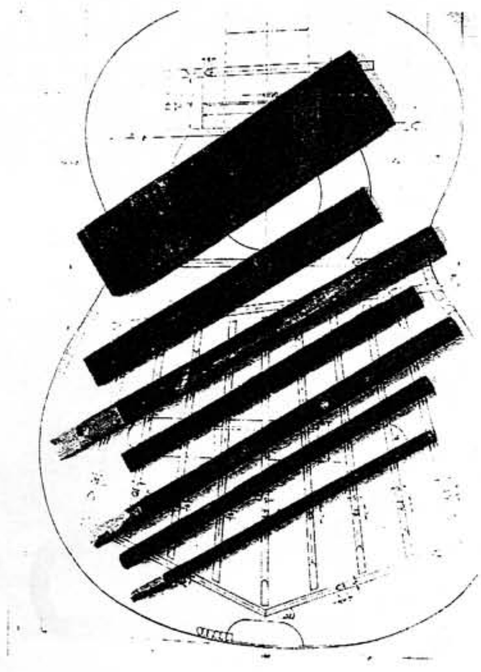
first possibility is for the arch of the soundboard to collapse as the wood shrinks. If the shrinkage is extreme, then a crack will appear, probably in the lower bout area. The fact that the soundboard has been braced with numerous struts will not prevent this movement. Conversely, if the soundboard is glued to the ribs in an exceptionally dry environment (40%) and the instrument is subsequently stored in a damp house (85%), the wood will absorb moisture and swell. This swelling will be evident as an increased arching of the soundboard, but cracking is unlikely. (Severe changes in the arching of the soundboard can result in the height of the strings above the frets altering, and may require adjustment of the saddle, either up or down, to compensate.)

From these examples, a general rule emerges; it is safer to plan for the soundboard to swell, rather than to shrink; it is better if the workshop is slightly drier than the final place in which the instrument will be kept.

If the readings on the meter show that the workshop is too damp, it may be possible to introduce a heat source to dry the air. However, in some cases, adding heat will simply attract more moisture and the room may become even more humid. The safest solution is to place a dehumidifier in the workshop. A dehumidifier works by drawing in the damp air, and passing it across a double heat exchanger. The moisture in the air condenses and drips down into a container, for disposal. The air, now having lost most of its moisture, is blown out into the room. The process is continual, but the machine has a variable setting, so that it can be programmed to switch on and off, thus maintaining the required humidity level. For the serious maker, installing a dehumidifier provides the peace of mind of knowing that the problems of split soundboards and backs are reduced to a minimum.







Far left column:
9-11 Electrically operated bending iron
9-12 Thicknessing caliper
9-13 Circle cutter
9-14 Long-reach cramps with leveller supports

Left column:
9-15 Long-reach cramps (screw operated)
9-16 Long-reach cramps (cam operated)
9-17 Left to right: lining cramps, spool cramps
9-18 Clockwise, left to right: stanley knife, inspection mirror, circle cutter, 1 mm chisel, 2 mm chisel, luthier's knife, purfling groove cutter, small violin maker's plane

Right column:
9-19 Hygrometers
9-20 Left to right: 16 mm saw-tooth drill, 11 mm brad point drill
9-21 Sanding sticks

Among Torres' descendants, there are tales of how the master maker was particularly concerned about the exact time that he assembled his instruments, when he would not allow anyone to enter his workshop. It seems that Torres had made a primitive hygrometer, which he kept by the workbench, and which helped him decide exactly when to glue the critical components together – soundboard to ribs, back to ribs, fingerboard to neck, and bridge to soundboard. It is these parts of the assembly that are likely to crack if they are fixed in position in too humid an atmosphere. Torres' great-grandson, Juan Francisco, who is also a guitar maker, has constructed a wooden hygrometer along the same lines. It consists of two thin pieces of spruce which are attached to a backing plate by means of tiny spots of glue. The end of one piece of spruce is close to the other, so that changes in humidity result in the gap between the two pieces either increasing or decreasing. The maker knows from experience how to interpret this gap, and therefore how damp or dry the air is at the time.

Tools

The tools needed for guitar making can be divided into two groups; common woodworking tools, and specialized guitar making tools. The following list is fairly comprehensive, and not every tool is essential.

Common Woodworking Tools (9-3 to 9-10)

Workbench
Woodworking vice
Metalworking vice
Tenon saw (large)
Tenon saw (small)
Tenon saw (re-cut and set to produce a 2 mm wide slot)
Dovetail saw
Coping saw
Jeweller's saw
Hack saw (small)
Smoothing plane
Jointer plane
Block plane
Bull nose plane
Scraper plane
Spokeshave (flat base)
Chisel (3 mm)
Chisel (6 mm)
Chisel (9 mm)
Cabinet scrapers
Metal files
Needle files
Oil stone
Honing guide
Hammer
Screwdrivers
Hand drill and bits
Pincers
Steel rule (300 mm)
Steel rule (1000 mm)
Straight-edge (1000 mm)
Craft knife
Dividers
Scalpel
Marking knife
Square (small engineer's)
Square (woodworker's)
Adjustable bevel
Marking gauge
G-cramps in assorted sizes

Specialist Guitar Maker's Tools (9-11 to 9-21)

Electric bending iron
Thicknessing caliper
Purfling-groove cutter
Circle cutter
Long-reach guitar makers' cramps
Spool cramps
Fret file
Chisel (1 mm)
Chisel (2 mm)
Small violin maker's plane

Machine Tools

Access to the following tools is helpful, but not essential.

Bandsaw
Drill press
Router

Making Your Own Tools

Commercial tools are manufactured to meet the most general uses. Most guitar makers find that as time goes on, they evolve their own particular preferences for certain tools, and they make them themselves.

fig. 1a Daniel Friederich using a device for gluing on the fan strutting

Guitar maker's cramp (9-22)
These can be purchased from luthiers' suppliers, but it is more economical to make them yourself. The commercial cramps operate on a cam principle, but the design given here has been developed in order to create a cramp capable of exerting greater pressure. It uses a screw-down bolt instead of a cam, and can therefore be tightened as much as required.

Spool cramps (also known as screw cramps) (9-23)
These are simple to make and are useful for gluing the ribs to the soundboard, and the back to the ribs. A length of threaded steel rod is passed through two discs of wood. The discs are tightened with wing nuts.

Sanding sticks
Sanding sticks have many uses, and it is worth making up several, both flat and round. Use lengths of dowel for the round ones, varying in diameter from 6 mm to 25 mm. Differing grades of abrasive paper can be fixed to the sticks with contact adhesive or double-sided tape.

Spirit-level sander
Abrasive paper fixed to a smooth, flat spirit-level is a useful tool for levelling narrow surfaces, such as the edges of the soundboard, back and ribs.

Jigs and Workboards

A number of simple devices are useful during the construction process.

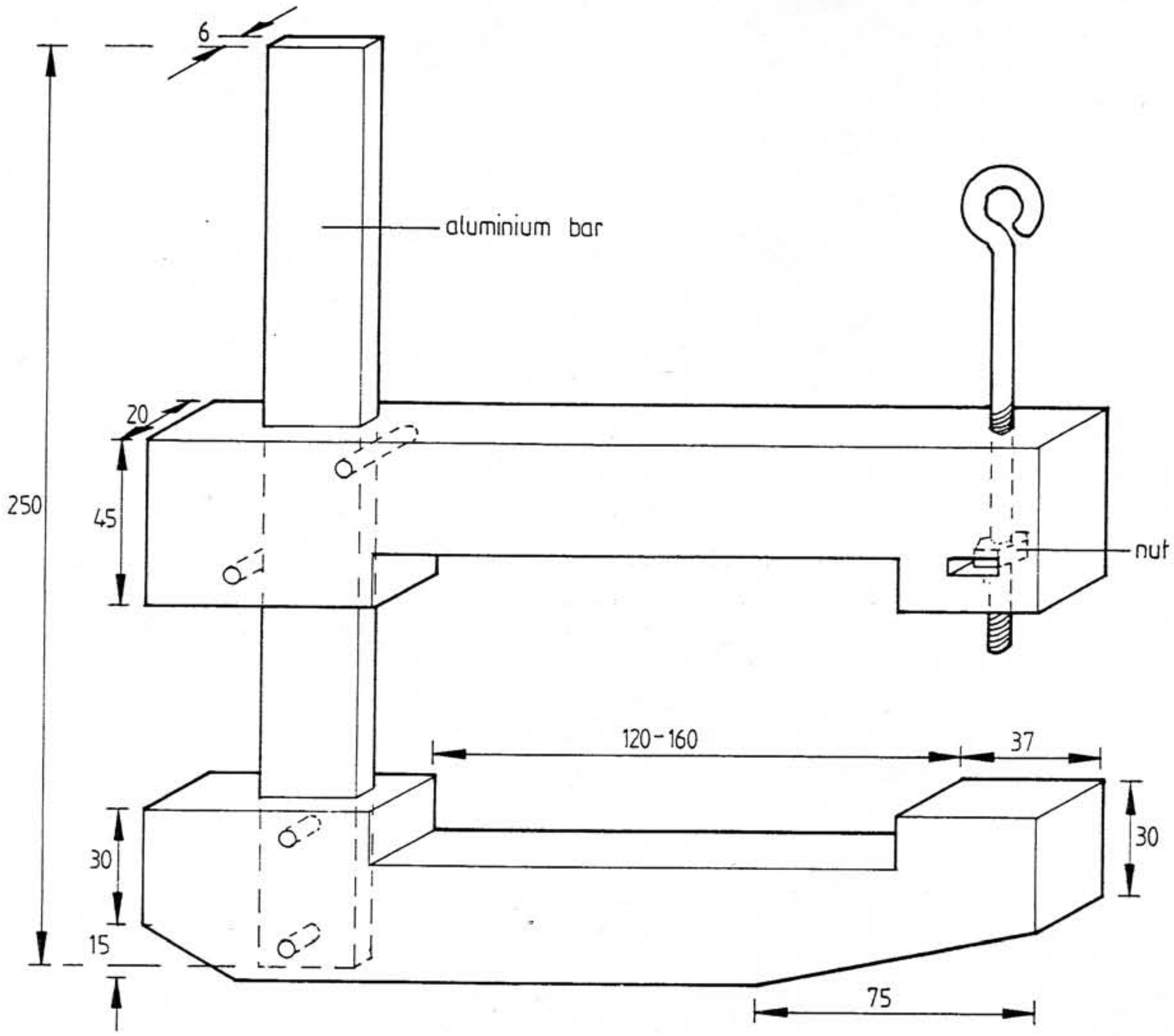
Solera
Template for plantilla, head shape, heel shape, and back bars
Mitre-box
Cramping-jigs for rosette-making
Cramping-blocks for bridge and fingerboard
Jig for bridge-making
Guitar-shaped board with slots for gluing the bindings.

Most of these are quite simple, and each is described in the text as it arises.

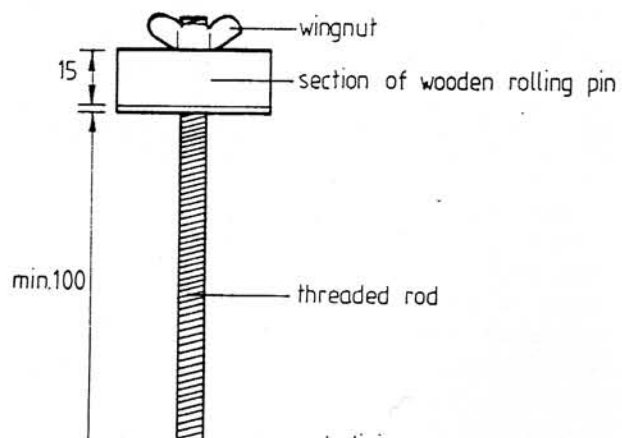
Sharpening Tools (9-24)

Chisels, planes and scrapers must be kept absolutely sharp if they are to produce smooth surfaces. Some of the woods used in guitar making are difficult to work. The exotic hardwoods – rosewood and ebony in particular, will only respond well to very sharp tools.

A new chisel or plane is supplied with the cutting edge roughly ground to an angle of 25 degrees. The first thing to do is to hone this edge on a sharpening stone until it is smooth and clean. Now a second bevel must be honed; at 30 degrees. This second angle is on the part of the blade that will do the actual cutting. The simplest and quickest way of sharpening these 'edge' tools is to use a honing guide. This is a holder which cramps the tool to be sharpened at the exact angle to produce the required edge. The honing guide, with chisel or plane blade in place, is moved back and forth along the sharpening stone until a burr forms at the edge. The assembly is then turned over and the burr removed by gently rubbing the top side of the blade on the stone, taking care to keep it flat. Repeat the procedure until no burr forms, and finally rub the blade along a leather strop to ensure that the cutting edge is smooth.



9-22 *Long-reach guitar maker's cramp (screw operated)*

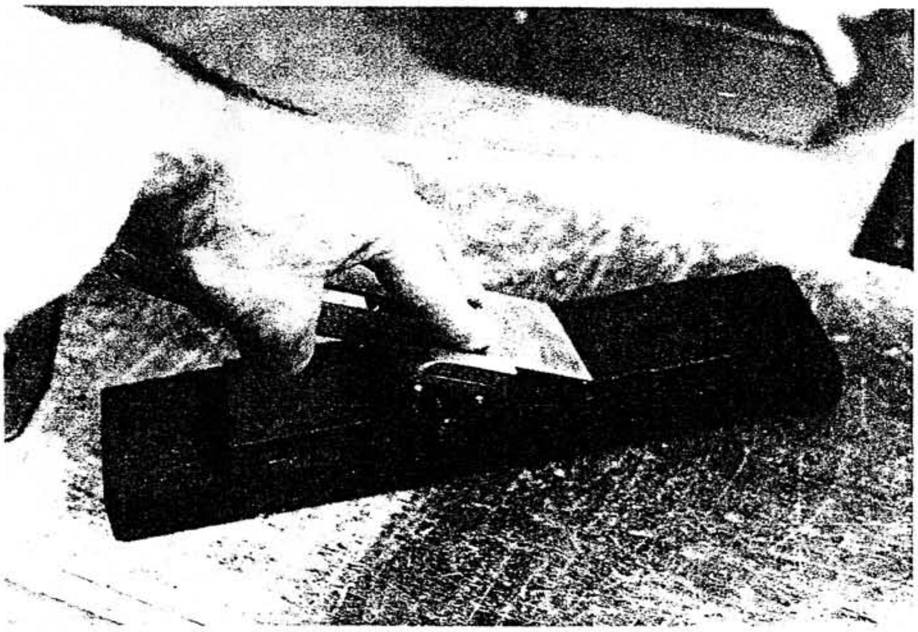


9-23 *Spool cramp*

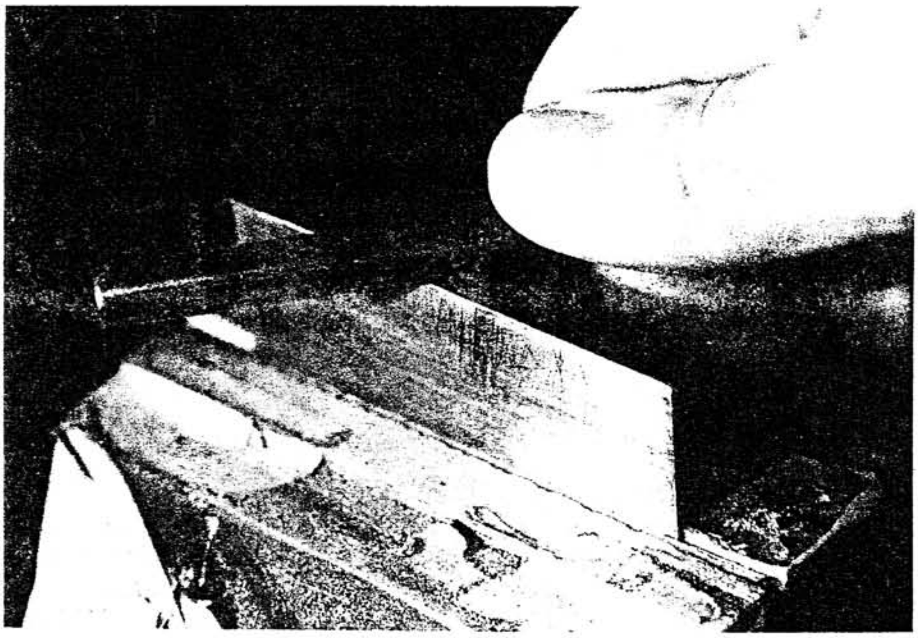
Cabinet scrapers and scraper planes operate on a different principle to chisels and smoothing planes – the 'scraper' tools cut with a burr that has been formed on to the edge of the blade. These are some of the most useful tools to the guitar maker as they sometimes provide the only means of smoothing rosewood and ebony, and, because they remove extremely thin shavings of wood, they can be used for accurate thicknessing of soundboards, backs and ribs.

Sharpening a cabinet scraper (9-25)

1 First make sure that the edges are flat and square. This is done by rubbing the scraper back and forth on an oil stone, using a square block of wood as a guide. Alternatively rub the edge, then the two wide sides, until the corners are sharp and no burrs are present.
2 Place the scraper flat on the bench, and use a round steel tool (such as a screwdriver) to draw the scraper steel towards the edge. Press down quite firmly, and move the tool back and forth at least a dozen times.



9-24 Sharpening a plane iron with a honing guide



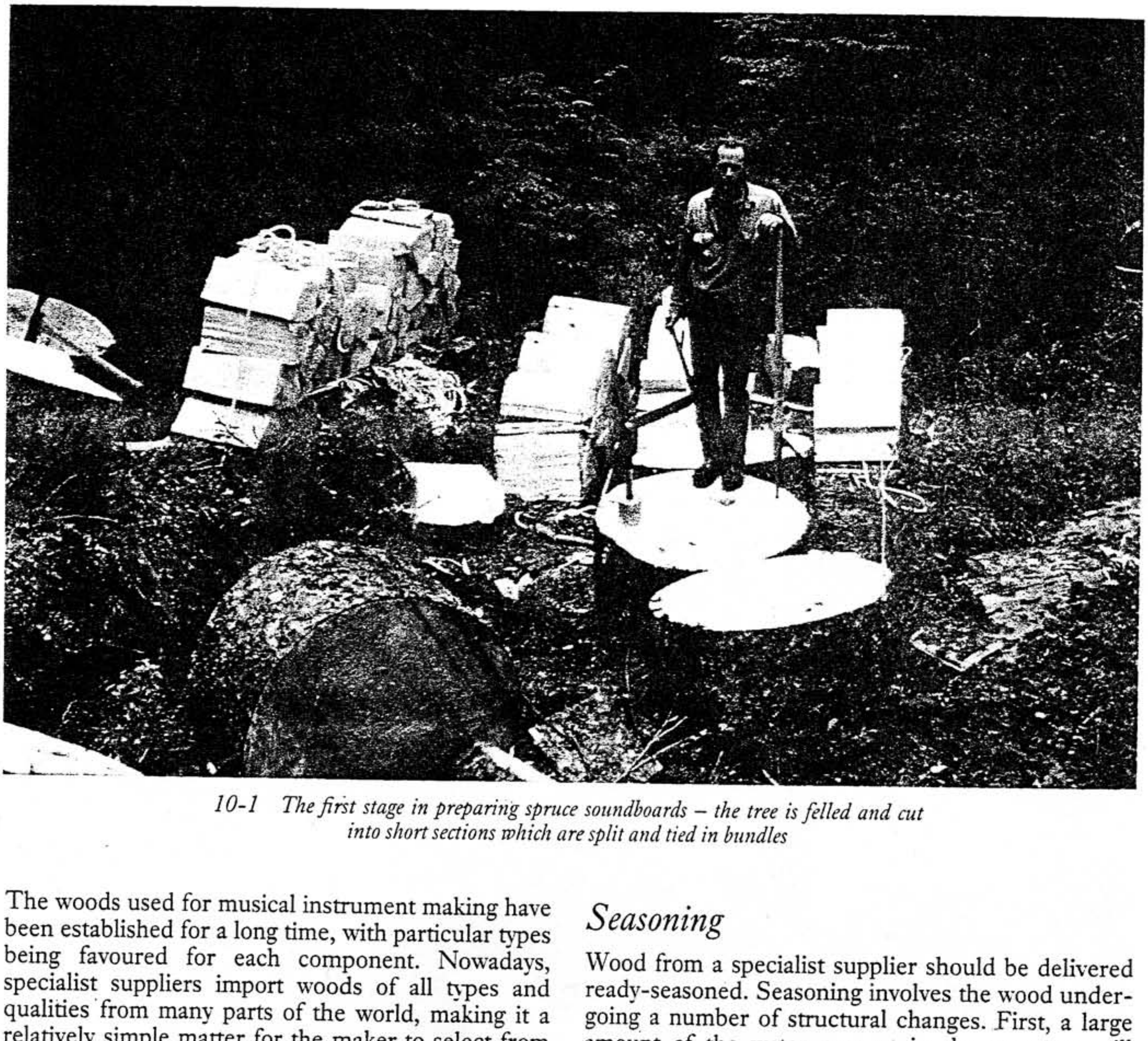
9-25 Forming the burr on the edge of a cabinet scraper

3 Grip the scraper in a vice, rub a little candle wax along the edge, and then form the cutting burr; the screwdriver or other burnishing tool is pulled along the top edge of the scraper three times. With the first pass, it must be held truly horizontal; with the second, it must be angled slightly; and with the third, the angle must be increased a little more. Considerable downward pressure is required, which forces the steel over the edge, and forms a small hook, or burr. In use, the cabinet scraper is pushed away from the operator, the thumbs being used to flex the centre of the scraper. The angle of the scraper to the wood is altered until the required shaving is removed. If the scraper only produces dust, rather than shavings, then the sharpening procedure must be carried out again.

Sharpening a scraper plane

The blade of the scraper plane is not ground to a right angle like the cabinet scraper; it has a 45-degree angle to start with. Nevertheless, the sharpening procedure is similar, except that the three strokes with the burnishing tool will be at an increased angle.

10 Materials

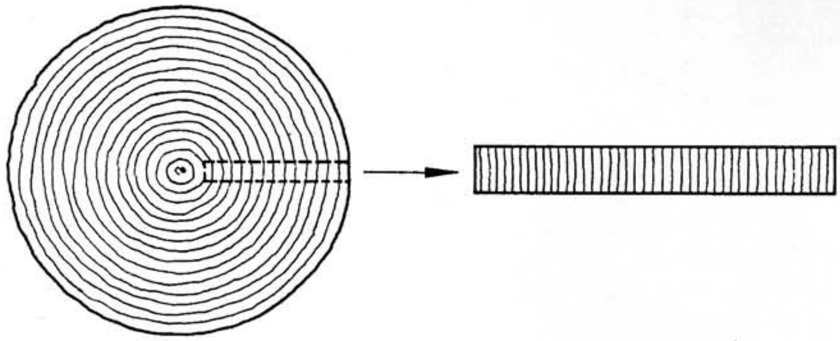


10-1 The first stage in preparing spruce soundboards – the tree is felled and cut into short sections which are split and tied in bundles

The woods used for musical instrument making have been established for a long time, with particular types being favoured for each component. Nowadays, specialist suppliers import woods of all types and qualities from many parts of the world, making it a relatively simple matter for the maker to select from the available stock. Woods have always been chosen with regard to a number of criteria; tonal quality, structural quality, beauty of grain and colour, and availability. The wood for the major components of the guitar should always be quarter-sawn. This means that the tree has been sawn in a certain way, which results in boards which have the grain running vertically when viewed from the end of the board

Seasoning

Wood from a specialist supplier should be delivered ready-seasoned. Seasoning involves the wood undergoing a number of structural changes. First, a large amount of the water present in the structure will disappear. Over a period of time, the oils and resins present in the wood will alter and harden. The wood will shrink a great deal across its width. Seasoning has to be carried out at a controlled rate, otherwise areas of stress will be fixed into the structure of the wood, and when it is later re-sawn, it may split and buckle. The traditional method of 'air-drying' is still favoured by many makers as producing better wood,



10-2 The major components of the guitar are made from quarter-sawn timber – the tree is cut in such a way as to produce planks in which the grain runs vertically, when viewed from the ends

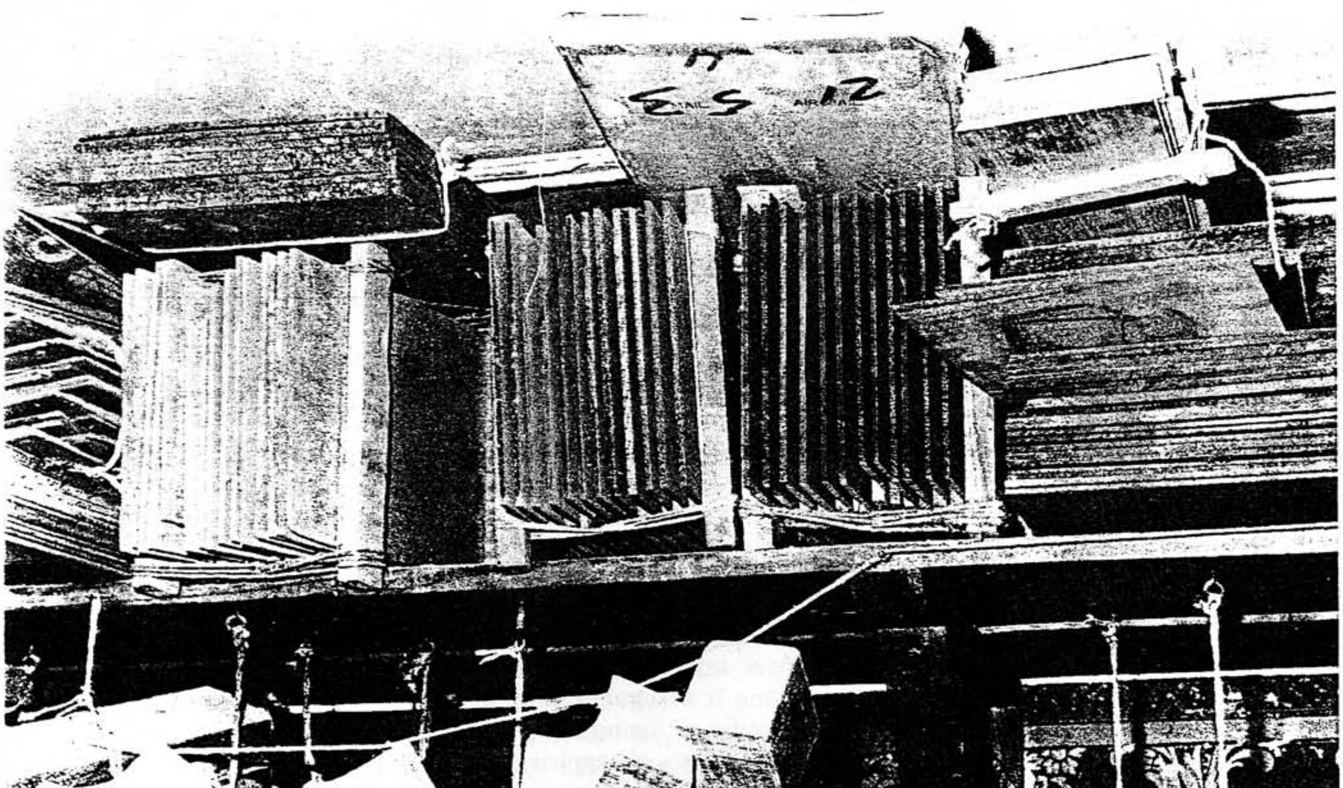
but 'kiln-drying' is now a quicker and more economical procedure. The ends of the planks being seasoned are coated with a sealer which slows down the rate of water loss, as it is the end grain that loses or gains moisture most quickly. Planks are separated with sticks so that the air can circulate freely and evenly over all surfaces. The wood is then either left to season naturally, which can take a number of years, or is dried in a kiln.

The Soundboard

It is often said that the soundboard is by far the most important part of the guitar. Whilst most makers would agree with this generalization, it is important to remember that it is the instrument in its entirety that matters even more. It is quite possible for one maker to produce a better guitar than another, even though inferior materials are used. Unless the guitar works as a whole, no one component will produce a miracle. In selecting wood for the soundboard, there is really a choice between only two types: spruce or Western red cedar.

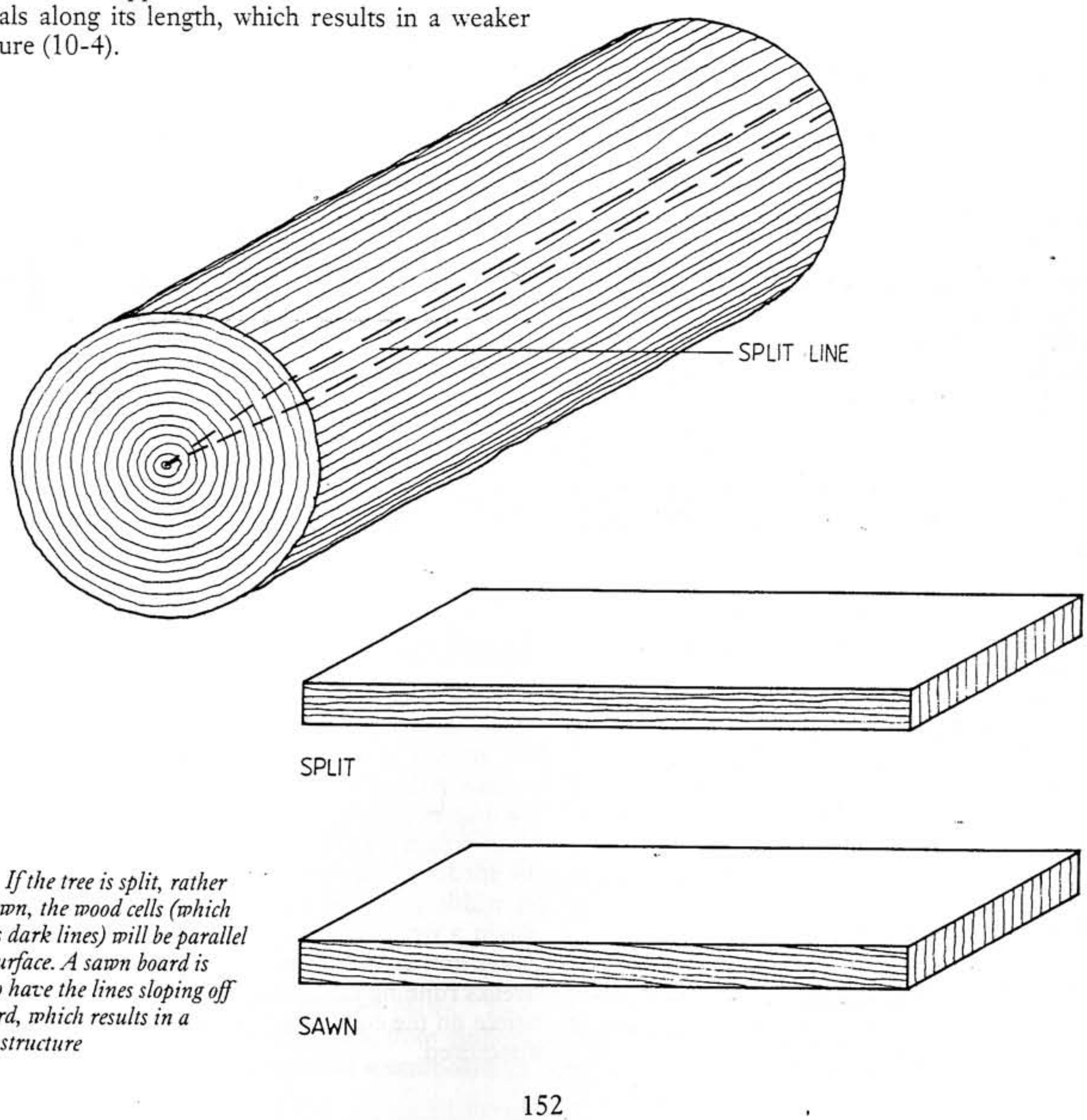
Spruce (Picea excelsa)

This is the traditional wood for all stringed instrument soundboards, and for a long time it came from Switzerland and Germany, but with dwindling supplies, the sources are now more widely 'European'. It seems that Torres sometimes used



10-3 Spruce and Western red cedar soundboards being stored at the Fleta workshop in Barcelona spruce that was imported for the carpentry trade, and was able to select out suitable pieces for his soundboards. Often, however, he could not obtain quarter-sawn planks, and he would have had to re-saw until he could obtain wide enough sections with the grain running perpendicular to the soundboard surface. The first consideration when assessing a soundboard is to be certain that it has been as closely quarter-sawn as possible. The annual growth rings should be perpendicular to the surface, or only slightly angled. This is easily seen by looking at the end grain of the board. It is this feature that is largely responsible for imparting stiffness to the wood, and, considering that the finished soundboard will be worked down to as little as two millimetres thick, this is important. Another factor in selecting wood for the soundboard is to see that the wood fibres run parallel to the soundboard surface. This is most likely if the tree was split along its own natural 'split line'. If the tree was sawn without any regard to this, then it is likely that the cut will not follow the 'split' line, and the lines representing the wood fibres will tend to disappear off the side of the board at intervals along its length, which results in a weaker structure (10-4).

A soundboard that has been split will often exhibit a 'silk' pattern across the grain, as this represents a plane which was structurally weaker in the tree and therefore more likely to provide a split. Another way to judge the character of a soundboard is to hold it up by one corner and tap it firmly with your knuckles. If there is an invisible crack along its length, this will be heard as a dull buzz. The tone produced will also indicate how 'lively' the board is, but remember that the thicker the board, the higher the note will be. Later, as it is planed down, this note will drop in pitch. Some makers think that if the thick, un-worked board has a reasonably high pitch, then it will still be relatively high at its final thickness, which is preferable for good tone production. A factor which is easily visible is the quality of the grain on the surface of the board. The annual lines should be straight and evenly spaced, although the gaps between the lines will increase towards the outer edges of the tree. The range should be between 10 and 25 lines per 25 mm. (On Torres' guitars, the annual ring spacing varies from 9 to 46 rings per



10-4 If the tree is split, rather than sawn, the wood cells (which show as dark lines) will be parallel to the surface. A sawn board is likely to have the lines sloping off the board, which results in a weaker structure

25 mm). Other spruces used are Sitka spruce (Picea sitchensis) for steel-string guitars, and Engelmann spruce (Picea engelmannii) which has many of the characteristics of European spruce.

Western red cedar (Thuja plicata)
Western red cedar has become popular for a number of reasons: it is more plentiful than spruce and therefore cheaper; the trees grow to a large size, and yield wide planks of good, even-grained timber; and an instrument with a cedar soundboard is often loud and vibrant immediately when it is strung up for the first time. (A guitar with a spruce soundboard often improves greatly over the first couple of years, and it is therefore not accurate to compare a new spruce guitar with an older one.) Although cedar also improves with time it is often more rewarding as a new instrument. A disadvantage with cedar is that the quality (in terms of tone production) varies greatly from one board to another. Spruce is reasonably consistent. Some makers like cedar because they have had good results with it. Others find it disappointing. The colour varies a great deal, and one view is that boards with a harder texture, usually of an orange/red colour, are better than the softer, more fibrous, brown-coloured wood. A bad cedar soundboard will produce an instrument with a characteristic 'thinness' in the treble notes, whereas a good one will be warm and vibrant. Cedar has the disadvantage of being quite soft, and it is easily damaged, but it is said to be less affected by changes in humidity, than spruce. For most of the master guitars referred to in this book, the choice must be spruce. The two exceptions are Ignacio Fleta and Daniel Friederich, who both produced fine guitars with cedar soundboards.

The Back and Ribs

Torres made use of a number of hardwoods for the backs and ribs of his guitars; rosewood, cypress, and maple were the most common. Rosewood has emerged as the favoured choice for the concert guitar, with cypress being preferred for flamenco instruments. Maple is now rarely used, although it is acoustically very good. Its lack of popularity is probably due to an aesthetic preference for the pleasing contrast between a light soundboard and a dark, rich coloured back and ribs.

In the seventeenth century, rosewood was often veneered on to other woods, being used mainly for its decorative effect. Later, as supplies improved, makers began using solid rosewood, and it seems that Torres was largely responsible for establishing rosewood as the finest wood for guitar making.

Two types of rosewood are commonly used: Brazilian rosewood (also known as Rio rosewood or Jacaranda), and East Indian rosewood (known as Indian rosewood).

Brazilian rosewood (Dalbergia nigra)
This is a very highly figured wood, often with a curly grain pattern, very hard, and considered to be the first choice by many makers. It is less popular now, as people become more concerned about dwindling resources and the destruction of forests. Due to its scarcity, a good set of Brazilian rosewood is very expensive.

Indian rosewood (Dalbergia latifolia)
This is not as dense or hard as Brazilian rosewood, and tends to have a straighter grain. Being more plentiful, it is available in good quality, quarter-sawn planks, and it is now widely used, actually being preferred to Brazilian by some makers.

Spanish cypress (Cupressus macrocarpa)
This wood is commonly used in flamenco guitars. It is light and durable, and as it grows near the Mediterranean coast, a plentiful supply has always been at hand for Spanish makers. Its unique aroma never disappears, and seems to filter out constantly through the soundhole.

The Neck

Two kinds of wood are commonly used for guitar necks: South American cedar (also known as Cuban cedar), and mahogany (also known as Brazilian mahogany or Honduras mahogany).

Cedar (Cedrela odorata or cedrela fissilis)
This is the more widely used of the two woods. It weighs less than mahogany, is easy to carve, and very stable, but often has resin pockets which are revealed as the wood is carved.

Mahogany (Swietenia macrophylla)
This is heavier and harder than cedar. The colour is reddish-brown. Care must be taken to obtain a plank with the grain running straight along its length.

The Fingerboard

Ebony (Diospyros piscatoria)
Ebony is the most popular wood for fingerboards. It is one of the densest woods available, and its hard surface makes it able to resist the constant pressure of the fingers pushing down on the strings. Its beautiful black colour contrasts well with the silver frets and the spruce soundboard. Ebony shrinks greatly across its width during seasoning, and it is important to obtain a dry plank, which is not cracked or twisted. Some boards will be jet black, but many have lighter streaks running along the grain. These tend to be less visible on the completed instrument, but can be dyed if required.

10-5 Guitar necks hanging up in the Fleta workshop

The Bridge

Most of the guitars featured in this book have bridges made from Brazilian rosewood, which is both very durable, and extremely attractive.

The Linings

The kerfed linings (or the individual blocks used by some makers) can be made from any of the following; mahogany, lime, willow, cedar, or spruce.

Internal Construction

Fan struts, harmonic bars, bridge plates, and soundhole reinforcing are usually made from spruce, which may simply be off-cuts from the soundboard. If possible, the struts and bars should be prepared from a plank which can be split, rather than sawn. This will produce the best quality components. The end block and the transverse bars on the back are usually mahogany or cedar.

The Rosette, Binding and Purfling

Long strips of different woods are available for all the decorative parts of the guitar. These may be 0.6 mm thick sheets of veneer; 1 mm x 1 mm square inlay lines; or ready-made purfling which has been laminated in contrasting colours, such as black/white/black. Rosettes can be made from these materials, or purchased ready-made.

Fretwire

Fretwire is made from 'nickel silver' which is an alloy that contains nickel. It is produced in a variety of sizes. The one suitable for classical guitars is approximately 2.1 mm wide, and 1.2 mm high. It has a lower tang which is set into a slot in the fingerboard – the tang itself has a number of studs on its side, which help the wire grip the sides of the slot.

The Nut, Saddle and Bridge Veneer

These were traditionally made from ivory, but bone is now commonly used. An artificial imitation ivory is also available.

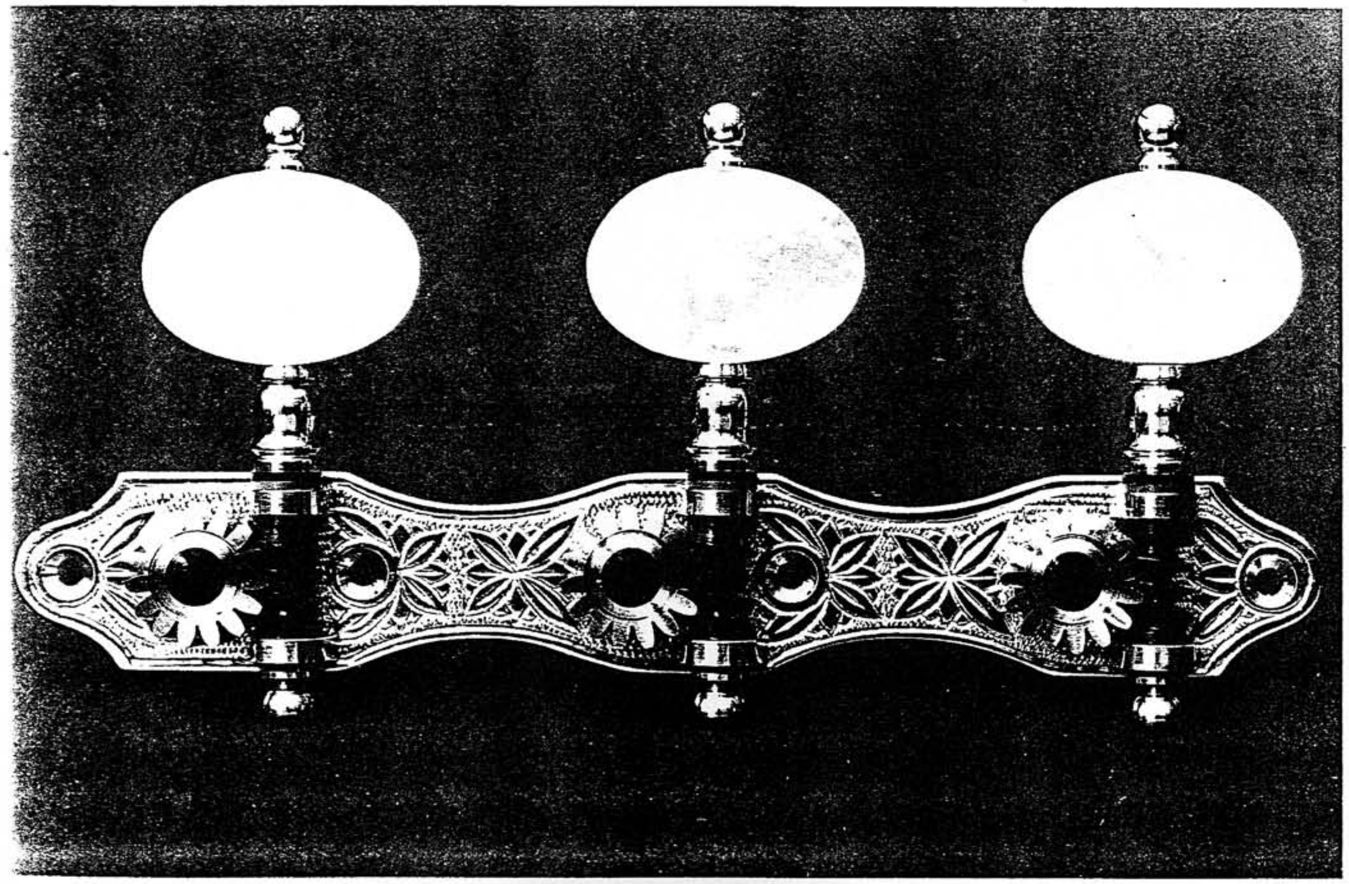
Machine Heads (or tuning machines)

These ~~are available in a range of~~ styles and qualities. The finest sets are hand-made. The most important consideration when selecting tuning machines (or machine heads, as they are also known), is to ensure that the gearing is well made. The barrels should turn as soon as the buttons are moved, and the tension of the taught guitar string must not cause the barrel to slacken, or the guitar will keep loosing its pitch and require constant re-tuning.

Glue

Animal glue

Some makers prefer the traditional animal glue that has been used for making stringed instruments for hundreds of years. This is made from the bones of animals, and it is combined with water, and then heated to make a usable mixture. The great appeal of animal glue to violin makers is that the joints are 'reversible'. A hot knife can be inserted around the edge of the soundboard to remove it for repairs. This aspect is not so useful to the guitar maker, as the more elaborate fixing of the soundboard to the ribs, which involves both purfling and binding, means that removing the soundboard or back does a substantial amount of damage. Most repairs can be carried out through the soundhole, which is large enough to take long, thin cramps and braces.



10-6 Hand-made machine head by David Rodgers. The decorative sideplate is sterling silver and the oval buttons are mother-of-pearl (see Appendix 3)

P.V.A. (Polyvinylacetate) glue
The common 'white' glues of this type are not strong enough for instrument making, and have a tendency to 'slide' under extreme stress. There are a number of much stronger varieties available, and many makers, including the Fleta brothers, Daniel Friederich, and José Romanillos have used them for some time. Examples are: Humbrol Carpenters Wood Glue, and Titebond. The Humbrol glue is particularly recommended. This is an aliphatic resin adhesive which is white in colour, but dries to a transparent film. Not only does it produce an extremely strong join, but it retains some flexibility. Rosewood is a difficult wood to glue successfully, as it contains its own natural oils, which can prevent a strong bond forming between two surfaces. These improved P.V.A. glues are able to make very strong joints on rosewood. You can carry out your own tests by gluing together small pieces of different woods with a variety of glues. Try rosewood to rosewood, rosewood to mahogany, ebony to mahogany, and so on. When dry, force the wood apart to determine which bonds are strongest.

Conclusion

Most specialist suppliers grade their wood according to both visual and tonal qualities. There may be a substantial difference between the lowest and the highest price range. Your choice of materials must depend partly on your own level of skill and confidence in using woodworking tools. Nevertheless, as you may spend 150 hours making your guitar, it does seem sensible to use the best materials that you can afford.

Part 3

Guitar Construction
The Spanish Method

facing page

fig. 2 The mould used by Ignacio Fleta for constructing his guitars. The neck-block and end-block are placed in cut-out sections at each end. The ribs, which have already been bent to the correct shape, and then placed around the mould, and glued to the two blocks. This is the method of construction used by violin makers

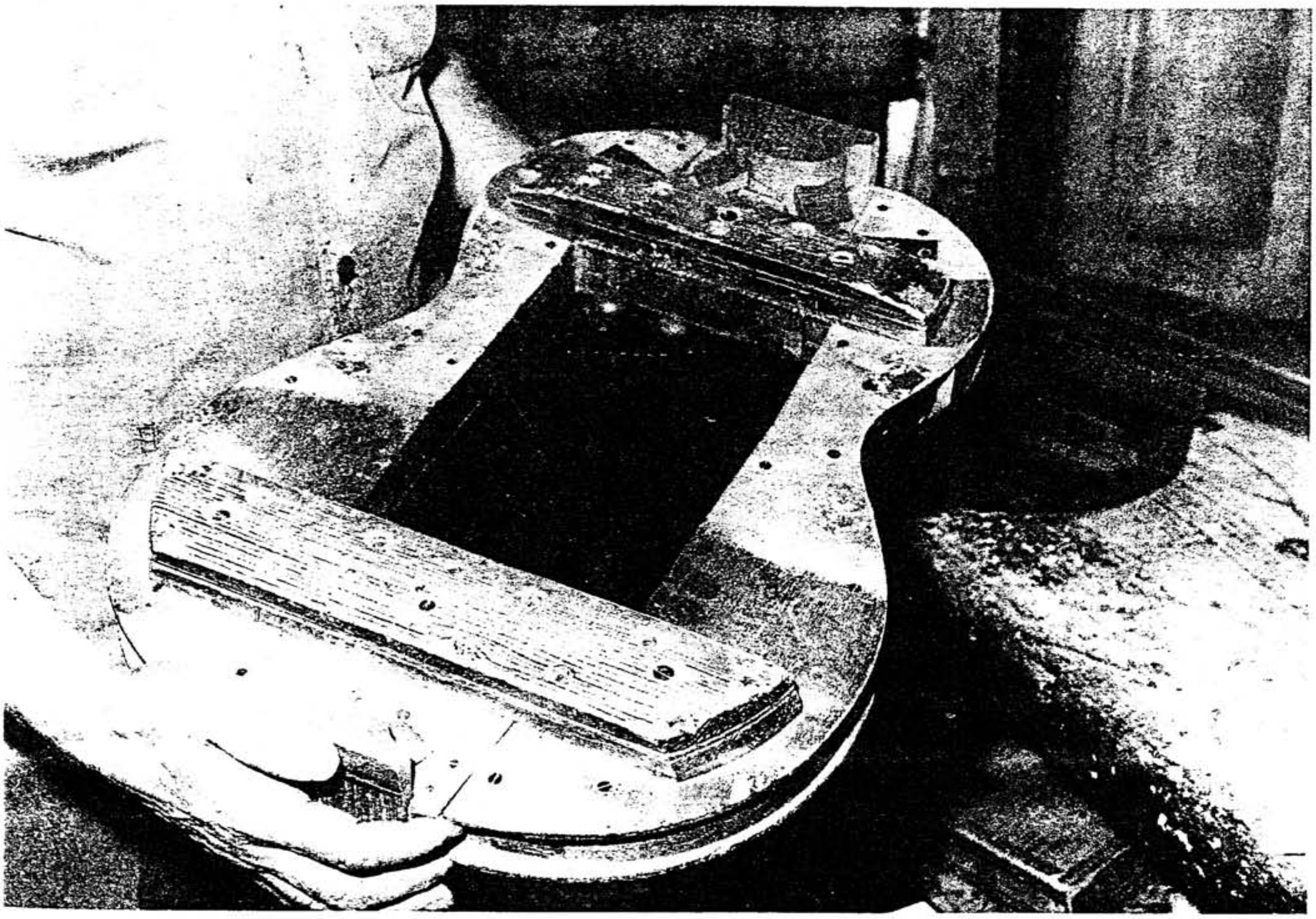
Introduction

Every luthier develops an individual approach to the process of construction. Most work on their own, carrying out every stage of the work themselves. A few partnerships have been successful – the most famous being the Spanish makers, Hernández and Aguado. The Fletas worked as a family – the two sons joining their father and then carrying on the Fleta name after his death. José Romanillos, who for many years worked on his own, is now in partnership with his son.

Guitar making involves so many separate stages that it is not possible to be dogmatic about the order of work, or the method of achieving the end result. The methods that follow incorporate many traditional techniques, and the sequence of steps is suggested as providing a logical development towards the complete instrument. Guitar making can be viewed on more than one level; the most basic is simply to perceive the process as a number of separate and unrelated steps – all the component parts can be made and assembled, and a guitar is produced. This approach is unlikely to result in an instrument that is out of the ordinary.

To achieve the unique character of their instruments, the best makers have a wider vision from the start. As with great works of art, the object appears to become more than the sum of its parts – however much a guitar is examined, analysed and measured, there is an element which defies definition. It is this extra quality – the creative, or the spiritual, or the chance ingredient, that gives life to the wood and strings.

It is therefore important to try and see the instrument holistically from the beginning. When working on the soundboard, for example, the maker needs to be sensitive to its texture, degree of flexibility, grain direction, and so on. How rigid is the unbraced wood? How does it alter as it is planed down to the final thickness, and what changes arise as the strutting imparts tension to the surface? Once complete, how does the soundboard, as an entity, relate to the back and ribs? When tapped, is there a sympathetic resonance between these parts? There is, of course, no definitive answer to this kind of question – there must be as many views as there are makers. Each completed instrument will suggest ideas for the next one.



Methods of Construction

There are various methods of making stringed musical instruments, and some guitar makers have evolved a system based on the traditional techniques used in violin and cello making, where the body of the instrument is assembled with the aid of a mould. The Spanish tradition developed differently; even before the time of Torres, Spanish guitar makers had established a fundamentally different approach. Torres perfected this method, which involves assembling the guitar without the constraints of a mould. Most of the makers covered in Part 1 of this book made their instruments in this traditional Spanish way – the notable exceptions are Ignacio Fleta and Daniel Friederich. Fleta used an 'internal' mould, similar to the type used in violin making (fig. 2). Friederich uses an 'external' mould (fig. 3), which is needed because of the way in which he laminates the ribs from two layers of wood; his entire construction method is elaborate and precise, and he has developed many tools and jigs designed specifically for his needs.

Most makers who have experimented with a variety of assembly methods come to the conclusion that the traditional Spanish method is the most structurally sound approach, as well as being logical and relatively straight forward. Amateur makers are often drawn to methods that utilize a mould, as this seems to offer the security of 'keeping everything in place'. In fact, experience of both methods will soon reveal that the Spanish method is no more difficult, and it fosters a much more open, lively approach to guitar making.

The Spanish method is to work 'free', building up the components on a guitar-shaped workboard called a 'solera'. There is no continuous support around the ribs although quite often a number of individual blocks are placed at strategic points around the outline of the guitar, to help locate the ribs accurately (fig. 4). The real advantage of the Spanish method is the sequence in which the instrument is assembled – this ensures that the central axis of the guitar is accurately maintained, and the entire structure is rigidly held to the solera by means of a large bolt which is passed through the soundhole and the solera. The instrument is assembled face down, and the large, lower bout area on the solera is scooped out so that the soundboard is pressed into this concave shape. All the fan struts and harmonic bars are glued to the soundboard while it is face down on the solera, and the fan struts, which are straight and flat along their gluing surfaces, are forced, under pressure from cramps or weights, to take up the domed shape of the solera. The solera has an extension to support the neck, and this is usually ramped down at the far end by about 3 mm, so that the correct angle between the neck and the body is built into the instrument.

The completed soundboard is positioned on the solera; then the neck and end-block are glued to it. Next, the ribs, which have already been bent to the shape of the guitar outline (plantilla), are positioned on to the soundboard, and fixed in place with small blocks, or strips of lining. Finally, the back is fitted and the basic structure is complete. In one sense, guitar making does not really involve complex joinery – there are very few 'difficult' joints. Most

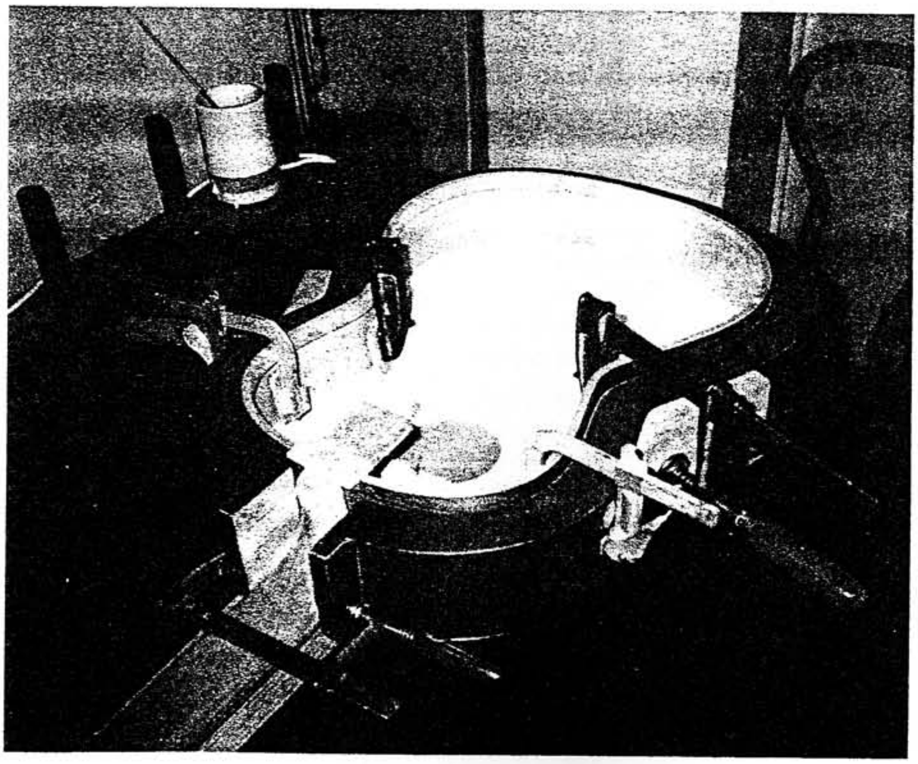


fig. 3 The 'external' mould used by Daniel Friederich

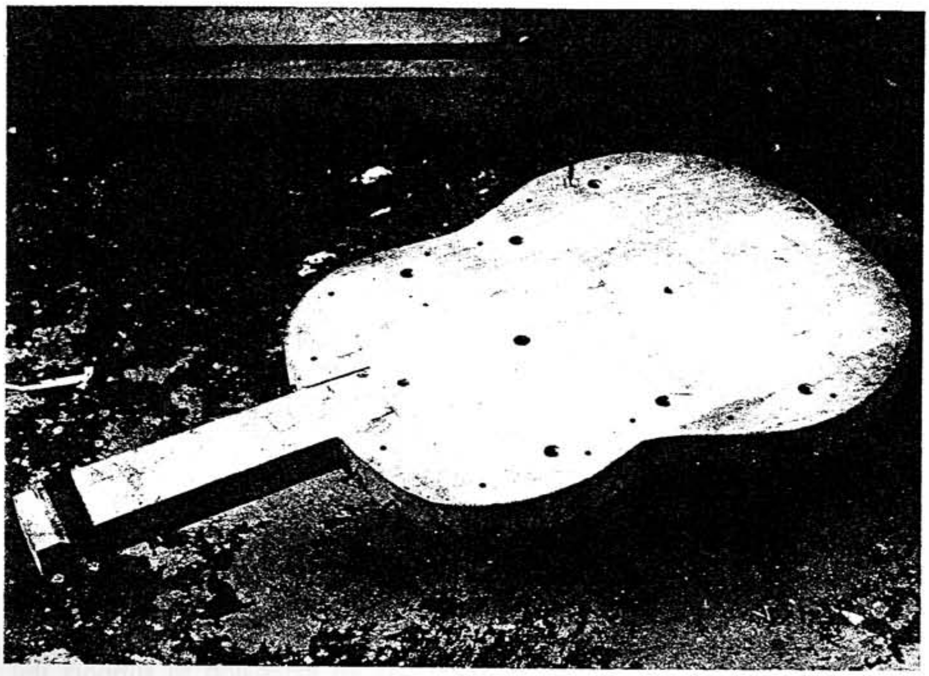


fig. 4 The solera used by José Romanillos for constructing his guitars. The neck extension is angled down about 3 mm at the far end, and the large surface of the solera has been slightly scooped out so that the soundboard, when placed face down, will take up the required doming. The large hole in the area of the soundhole allows a cramping-block to be tightened over the soundboard, and the other holes around the periphery are for right-angled blocks to be positioned around the outline of the guitar. These help ensure that the ribs follow the guitar outline

components are simply glued to one another along their matching flat surfaces. What is important is that the surfaces to be glued must match each other's contours perfectly. Many joints cover a large surface area; fingerboard to neck, head to neck, head veneers to head, and bridge to soundboard. Ill-fitting surfaces will mean that unwanted stresses are built into the instrument. Of the joints that are used, various options are available. Some makers, who complete the soundbox before joining on the neck, use a tapered dovetail at the end of the neck. The neck is then joined to a large block inside the guitar. Most prefer the traditional method of cutting deep slots into the neck itself, and inserting the rib-ends into them. One method of joining the neck to the head is with a 'V' joint, which leaves a definite 'V' mark on the wood. Most makers prefer to use a long spliced joint which is less obtrusive.

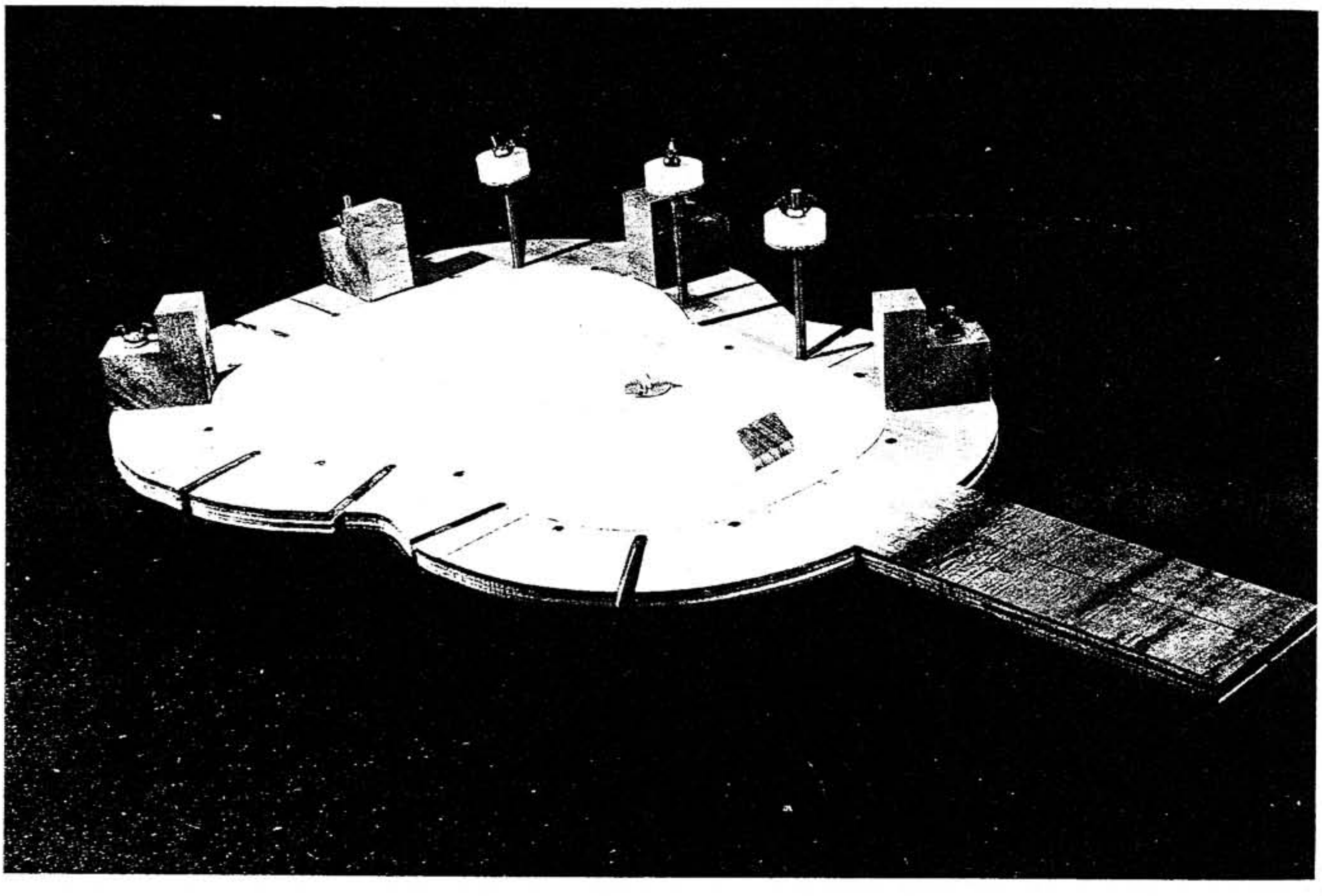
Sound Quality

Although not every guitar maker is a musician as well, it is useful for the maker to understand as much as possible about the way in which musical sound is produced by the guitar, and how the player may exploit the potential of a given instrument.

The number of factors which contribute to the overall character of a guitar are virtually limitless. A good instrument will be capable of producing a wide range of tonal colours, and will readily respond to the player's technique. It is, after all, the player who must become familiar with the idiosyncrasies of a particular guitar.

The more flexible the soundboard, the less effort is needed to produce a fundamental note. The fundamental is the note generated at the moment the finger strikes the string. This first note then acts to set up a range of further vibrations, or overtones, which together create the specific character of sound for that instrument. The flexibility of the soundboard results from a number of factors – the inherent structure of the spruce or cedar; the way in which the wood is thinned down; the number, dimensions, and pattern of strutting; and the degree of doming or flatness built in by the maker. The aim is not necessarily to make as flexible a soundboard as possible. Some control of the vibrations passing through the wood is needed, or the instrument will lack clarity. It is the degree of control which defines the sound quality, and this is where each maker follows a personal vision.

11 Solera



11-1 The completed solera – the slots allow rib-supporting blocks to be quickly inserted, and their precise position adjusted to the outline of the guitar. Spool cramps can be inserted both in the slots, and also through the holes. These are particularly useful when gluing the back to the ribs

The solera is not difficult to make but it needs to be accurately fashioned so that the soundboard will take up a gentle, domed shape, and the neck will lie at the correct angle to the body. It is the traditional 'workboard' on which the guitar is assembled and although a relatively simple structure, it serves a number of useful purposes. The design presented here includes a number of slots and holes which are cut and drilled around the periphery. The slots allow rib-supporting blocks to be placed against the outer surface of the ribs, which can help ensure that the ribs do not move away from the guitar outline while they are being marked and trimmed to length. The slots allow the precise position of the blocks to be quickly and easily adjusted so that the same solera can be used for a number of different plantillas. The slots can also receive spool cramps which are used for gluing on the back, as well as keeping the ribs in contact with the soundboard. The holes drilled through the solera are for additional spool cramps if needed. A block of wood can be bolted through the solera to hold the soundboard firmly in place. Thus the entire design is simple to make, convenient to use, and very versatile (11-1).

Tools

Straight-edge
Steel rule
Drill press or hand-drill
Bandsaw or jig-saw
Cabinet scrapers
Abrasive paper

Materials

Thin plywood or card for making a template of half the plantilla (approximately 500 mm × 190 mm).

18 mm thick plywood or MDF (medium density fibreboard) for making the solera (900 mm × 530 mm).

50 mm long bolt with wing-nuts.

Hardwood for making the cramping block (190 mm × 40 mm × 25 mm).

6 mm diameter threaded rod, washers and wing nuts for attaching the rib-supporting blocks to the solera.

Hardwood for making the rib-supporting blocks (600 mm × 70 mm × 70 mm).

Method

Make the template

1 Referring to Part 1 (Chapter 1 to 8), decide which guitar plan will be used as the basis for your instrument. Each chapter contains a full set of working drawings and these will be consulted throughout the construction process. Each set of drawings includes a plan of half the outline shape (plantilla) of the guitar, contained within a grid. The first step is to enlarge this plan to its full size by one of the following methods:

(a) Each square on the grid represents one centimetre, but is not shown full size due to the limitations of the book format. If you obtain graph paper consisting of one centimetre squares it is a simple matter to copy the outline shape one square at a time, carefully reproducing the exact position of the line on a given square. Once the basic shape has been drawn to its full size, the smoothness of the curves can be improved by use of a 'flexi-curve'.

or:

(b) Place a sheet of tracing paper over the drawing in the book and trace the outline of the guitar. This tracing can be taken to a good office supplier who will have a photocopier capable of enlarging it to the full size of the guitar.

or:

(c) Send for the set of full-size plans which are available for all the guitars. (Refer to Appendix 3 – Suppliers of Materials.) This is the most accurate method, as the shape can be traced directly from the drawing.

2 Having obtained a full-size drawing of half the plantilla, this must now be transferred on to a piece of stiff card or thin plywood, to make a rigid template. This will be used to mark out the shape of the guitar on the solera, the soundboard, and the back. Some carbon paper sandwiched between the card or plywood, and the drawing, will give a clear line. A flexi-curve will help make the final curves as smooth as possible.

3 Use a coping saw, bandsaw (or craft knife, if you are using card) and remove the waste. The final shape can be smoothed with files and sandpaper wrapped round a wood block. The curve of the waist can be shaped with sandpaper wrapped round a circular sanding stick. The accuracy of the final template must be checked by drawing a centre-line on a sheet of paper, and then drawing the complete guitar shape with this line as the central axis. Make certain that the lower end flows smoothly round, without a noticeable step where the two halves join. The template can be sanded more if necessary, until you are completely satisfied with the shape.

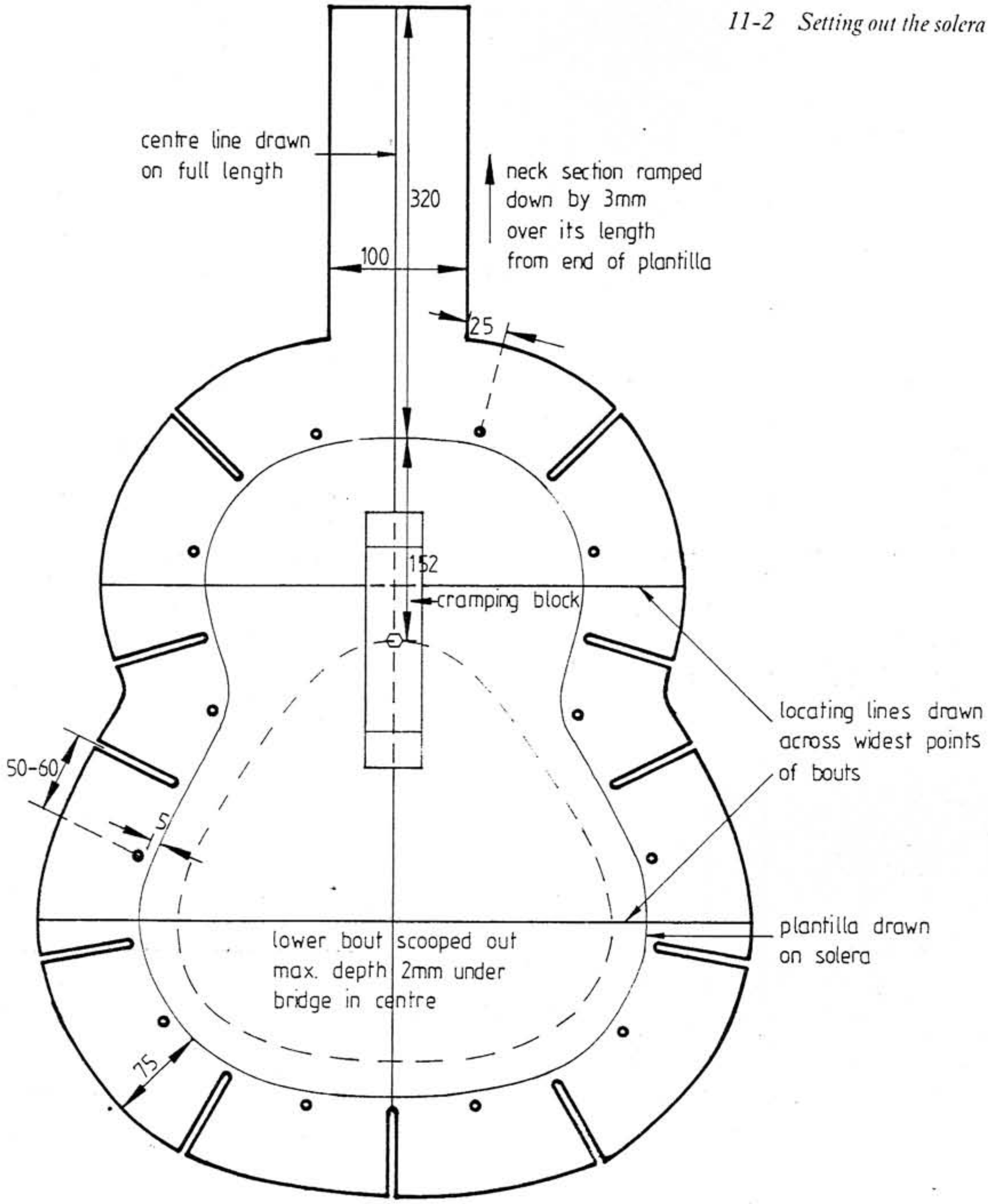
Marking out the solera (11-2)

1 Mark a centre-line on the plywood. Place the template in position on this centre-line and draw the outline of the guitar on to the surface. Draw a second line about 75 mm outside the guitar outline, to define the edge of the solera.

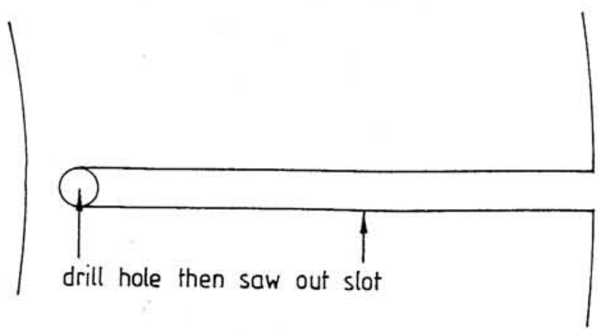
2 Mark out the neck extension, and the positions of the slots and holes all round the solera. Note that the slots and holes end about 5 mm outside the guitar outline.

Cut and shape the solera

1 Use a bandsaw or jig-saw to cut away the waste. The slots can be made by first drilling holes at the end of the slot, and then sawing out the two straight sides (11-3). The diameter of the holes for the slots should be slightly larger than the diameter of the threaded rod used for making the spool cramps (see Chapter 9). The distance between the slots and holes should be calculated so that when spool cramps are placed all round the guitar, they are equally spaced.



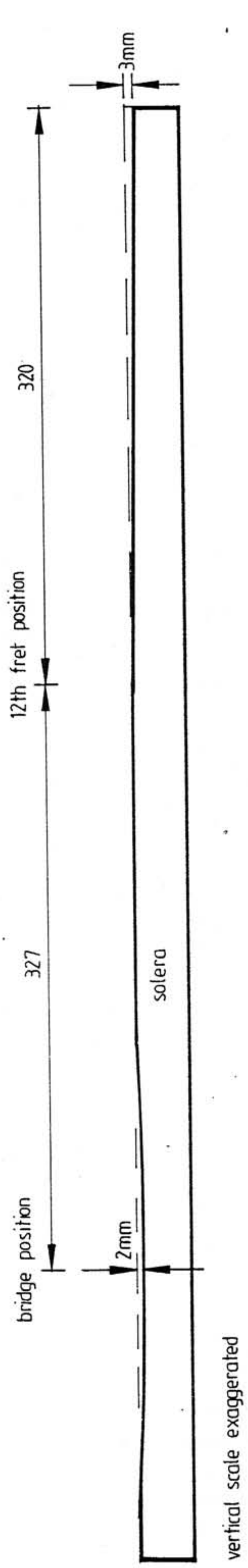
11-2 Setting out the solera



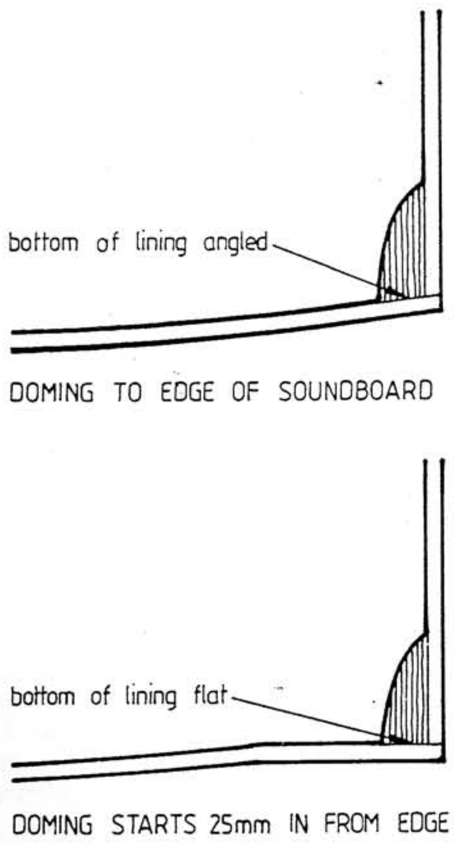
11-3 Forming the slots

2 The far end of the neck extension should be ramped down 3 mm (11-4). This will create the correct angle between the neck and body. Scribe a line on the edge of the neck extension, then plane down until a straight-edge placed on the surface shows a level ramp from the outline of the guitar (at the point where the neck joins the soundboard), to the end of the neck extension.

3 The large lower bout area of the solera must be slightly hollowed out with scrapers and sandpaper to provide the required doming for the soundboard. (Fibreboard is more easily shaped than plywood.) Mark the bridge position and gradually lower the surface. Check frequently with a straight-edge to ensure that the scooped-out shape is smooth and even both across the lower bout, and along the centre-line. A maximum depth of 2 mm is sufficient. The scooping out should extend to the soundhole, but gradually become less pronounced. Leave a small area around the periphery unshaped, so that the ribs will have a flat surface with which to make contact. If the shaping is started right at the periphery of the guitar, the lining on the ribs will have to be sanded to the correct angle before the ribs will be seated vertically on the soundboard (11-5).



11-4 The neck extension is ramped down by 3 mm



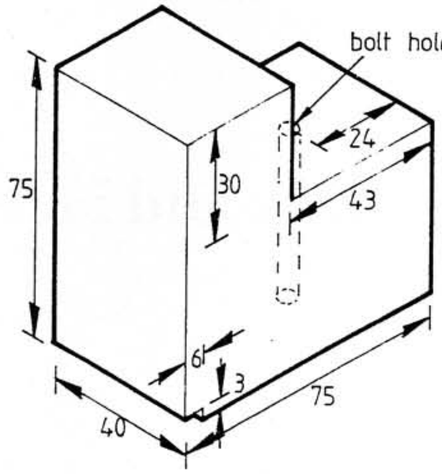
11-5 By leaving a flat edge around the periphery of the guitar outline, the ribs will be simpler to fit

Make the cramping-block (11-6)

1 Prepare the rectangular cramping-block. Drill a hole through it and through the solera (at the soundhole centre), so that the bolt can pass through both. Slots can be cut in the cramping-block so that it drops in place over the two harmonic bars, although this is not essential.

Make the rib-supporting blocks (11-7)

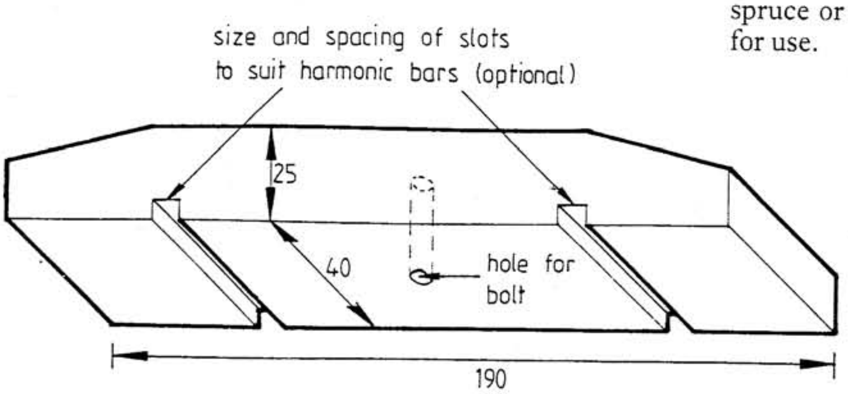
1 Cut the rib-supporting blocks to the dimensions given. It is important that the base of the block is perfectly square to the side of the block that will butt up against the rib. If a number of blocks are being made, the quickest method is to first prepare a length of hardwood 75 mm × 75 mm, ensuring that one corner is perfectly square. The small rebate at the base of the block allows the block to pass over the slightly over-large soundboard. This can be removed in one operation with a router, before the wood is sliced up into individual blocks.



11-7 A rib-supporting block

Finishing

1 Seal the surface of the solera with a coat of sanding sealer or varnish.
2 When dry, rub down until absolutely smooth. The soundboard will be cramped firmly to this surface, so it is important that there are no rough spots or grit that could damage the delicate spruce or cedar surface. The solera is now ready for use.



11-6 The cramping block

12 Neck and Head

Tools

Smoothing plane
Carpenter's square
Rule
Marking guage
Marking knife
Tenon saw
Straight-edge
16 mm saw-tooth drill bit
11 mm wood drill bit
Coping saw
Tenon saw, re-cut to produce a 2 mm wide cut. (Take a saw to a good saw sharpening service, where this can be done.)
Cramps

The entire neck unit, consisting of head, neck shaft, and heel/foot section, could be made from one thick length of wood – by simply bandsawing the profile to shape. The changes in direction of the grain would, however, make certain areas inherently weak, as well as being wasteful of wood (12-1). Most makers laminate the neck in sections – the head is made by sawing off a short length from one end of a plank, and turning it over to form a spliced join at the desired angle. The heel/foot section is formed by stacking three or four layers of wood together, to create the required depth. This is the most common method, and will be described in detail here. The best way of joining the ribs to the neck is the traditional Spanish method of cutting slots into the end of the neck, and letting the ribs into these slots.

There are other methods of joining the head to the neck, and of joining the ribs to the neck. Ignacio Fleta always used a tapered dovetail joint to connect the neck to the body, in which case the body unit must be completed first. (The measurements are given in Chapter 5.) José Romanillos uses a variation of the usual slot method of joining the ribs to the neck, which is described at the end of this chapter.

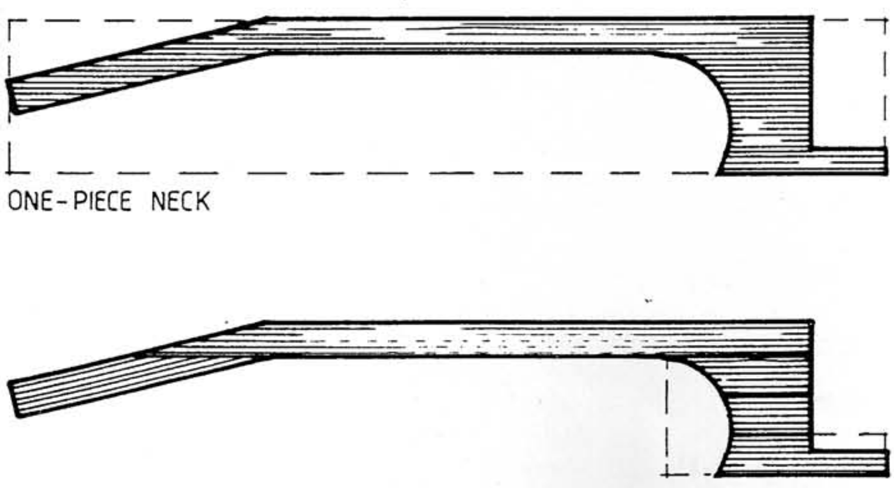
Materials

Straight-grained, quarter-sawn mahogany or cedar (1000 mm × 80 mm × 25 mm)
Rosewood for head veneer (200 mm × 80 mm × 2 mm)
Sycamore veneer (200 mm × 80 mm × 0.6 mm)
Set of machine heads
Glue

Method

Preparation (12-2)

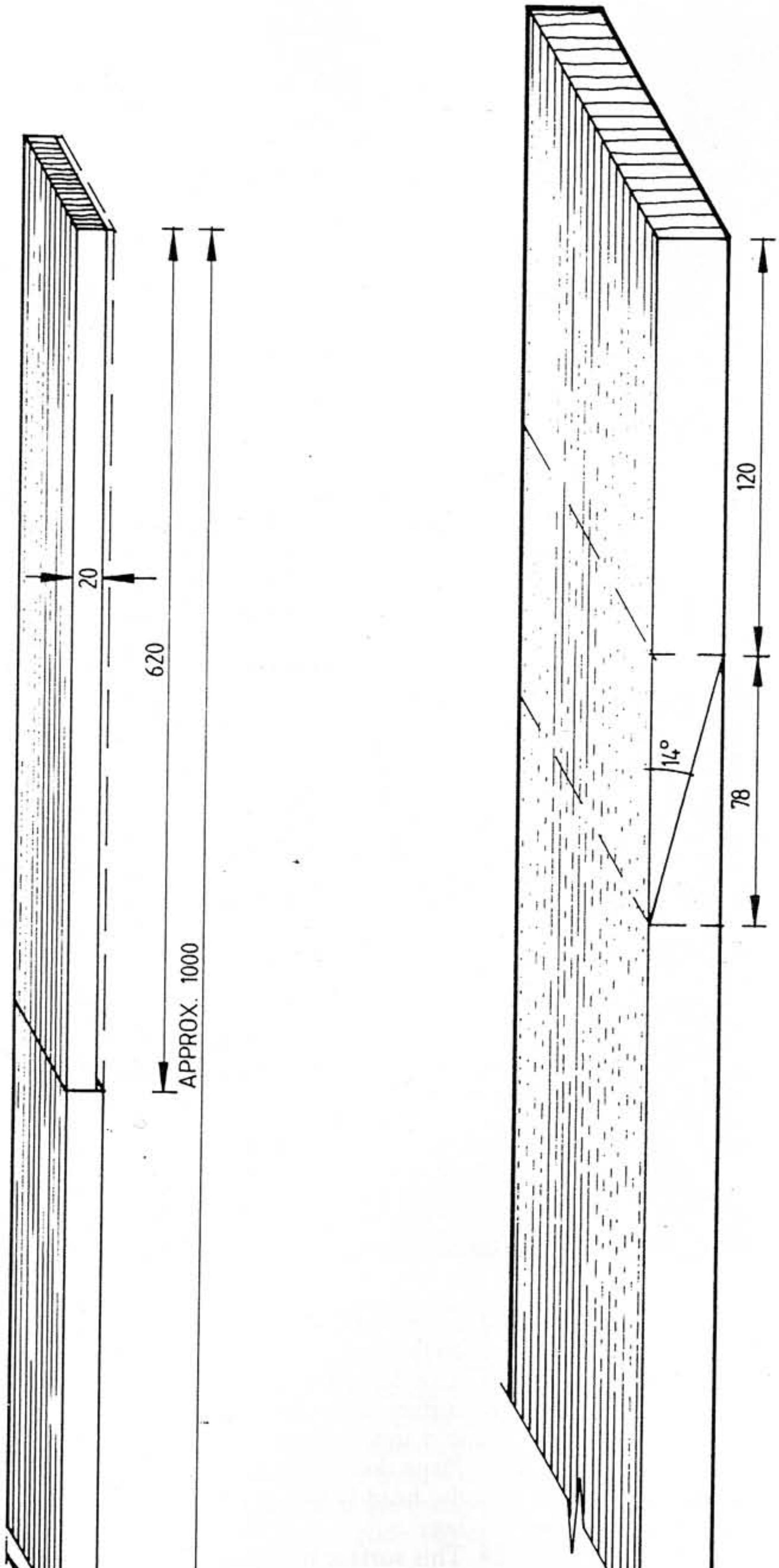
1 Hold the neck blank down with a cramp, and plane it lightly on all four sides until the surfaces are smooth.
2 Use a straight-edge to decide which surfaces are the most flat, and plane these further until there is a length of about 650 mm that is absolutely flat and square all round.
3 Measure 620 mm from the end, square across, and cut off. This length will be used to make the



ONE-PIECE NECK

LAMINATED NECK

12-1 The laminated neck is stronger, because the grain follows the direction of the head



12-2 *Preparing the neck blank*

neck shaft and the head. The shorter section is set aside to be cut up later and laminated into the heel and foot.

4 Set a marking gauge to 20 mm and scribe a line along both sides of the 620 mm section. Plane it accurately from both ends until it is 20 mm thick, and the surfaces are all level.

5 Measure 120 mm from one end, and square a line across. Carry the line down the two edges, and join them up on the back.

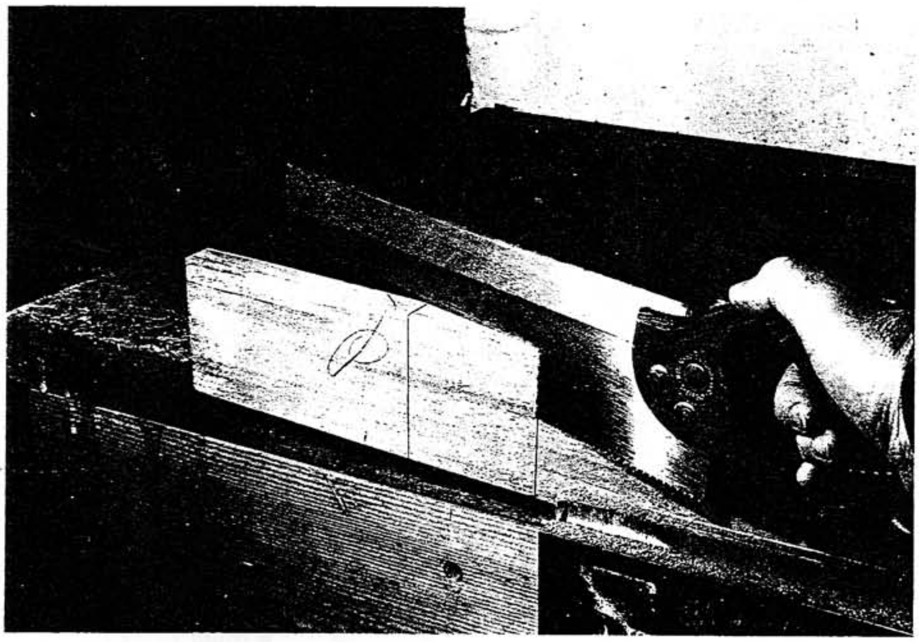
6 Measure a further 78 mm and mark this all round as before.

7 Turn the wood on edge and join up the two lines to form a diagonal. If a protractor is positioned on the edge, you will see that an angle of 14 degrees has been formed. (If you require a different angle, simply alter the 78 mm measurement until the required angle is obtained.) Some makers prefer an angle of only 8 degrees, while others prefer up to 17 degrees. 14 degrees is recommended as it provides sufficient change in the angle of the strings as they pass over the nut, to provide a definite 'break', and this contributes to a clear sound.

10 Turn the short head section over and place it beneath the long neck section. If there are any gaps between the gluing areas, they can be firmly rubbed on a sanding board until they are absolutely flat.

11 Place the two pieces on edge, and position them on a raised board so that cramps can extend underneath (12-5). Short battens either end will help prevent the assembly from sliding once the glue is applied. Measure across the edge of the head/neck join, and make certain that the depth (as measured on the edge) is not less than 20 mm. Make certain that the neck is cramped vertically to the board – if the edges of the neck are not square to the face, it will slope off at an angle. This should be corrected now, as the neck and head should be glued in alignment. Prepare some short battens to help distribute the pressure of the cramps, and to prevent the neck from being damaged.

12 Remove the cramps, place some paper below the gluing area, and spread glue on to the two surfaces. Assemble with cramps, clean away excess glue and leave overnight to dry.



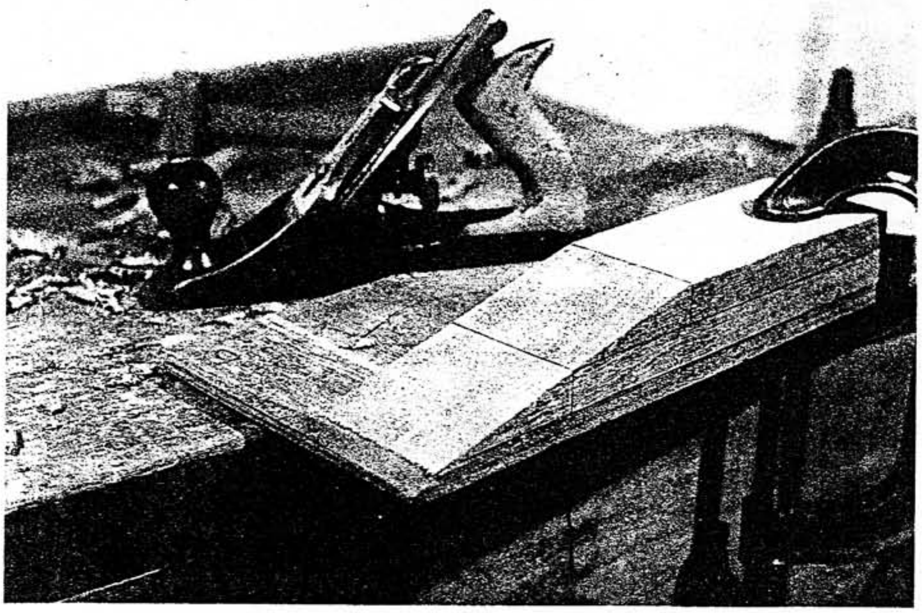
12-3 Sawing the head section from the main neck blank

8 Hold the wood in a vice and carefully saw through the diagonal line (12-3). If the tenon saw is not deep enough to cut right through, stop half-way, turn the wood over and complete the cut from the other side. Be careful not to let the saw wander away from the line.

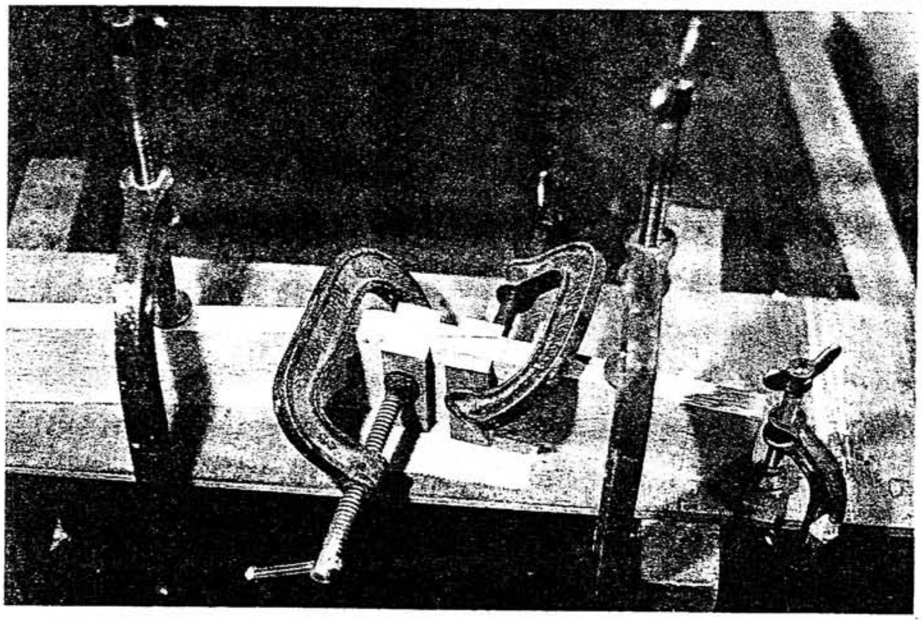
9 Turn the short section over and place it on top of the longer piece to form a continuous slope (12-4). Cramp firmly, and clean up the rough surfaces with a smoothing plane. Make frequent checks with a square to ensure that the ends of the pieces remain at right angles to the edges.

13 Set a marking gauge to 19 mm and scribe a line on the two long sides of the head, and on the end. The line will be only slightly below the top surface of the head. Extend the lines with a rule, and square them across the surface of the neck. Plane down to this line, so that the top surface of the head is flat, and reduced to 19 mm thick all over.

14 This surface must now be covered with a piece of thick veneer; both for strength and for decoration (12-6). The top, exposed veneer is usually rosewood, and one or more thin veneers can be



12-4 *Smoothing the splice joint*

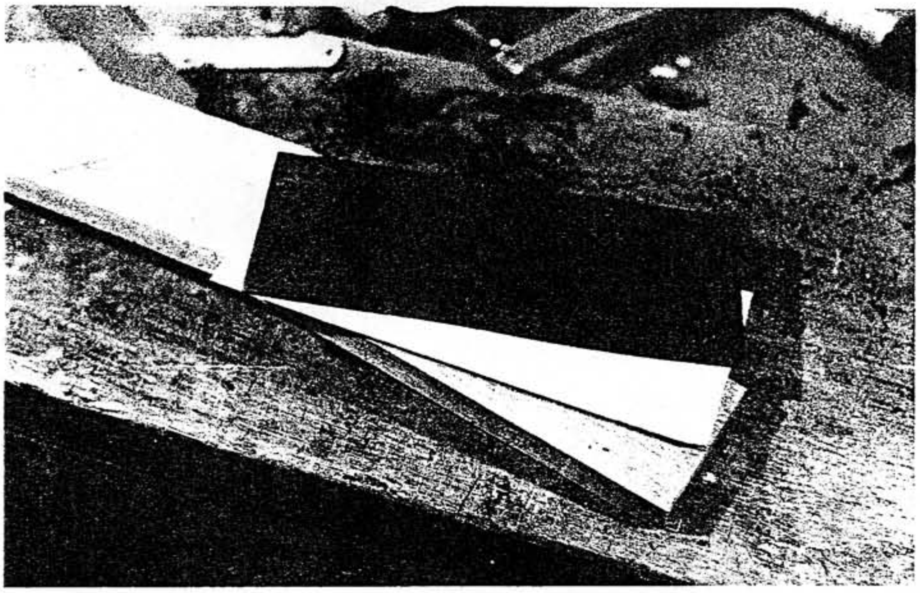


12-5 *Gluing the neck to the head*

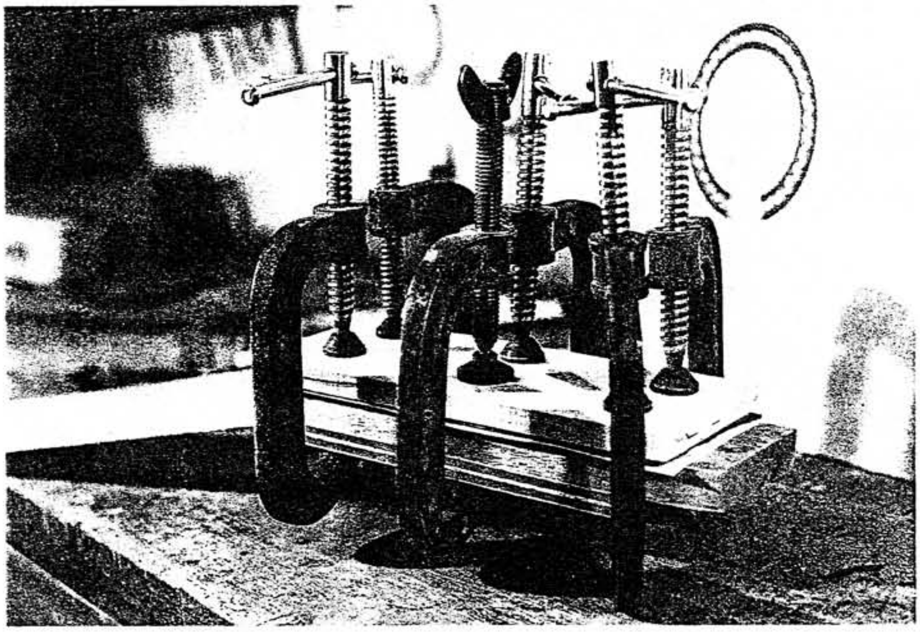
sandwiched between this and the head to provide a decorative line. Prepare the required veneers, and ensure that the rosewood is flat on its gluing surface. (It is usually easier to leave the face side rough until the assembly is complete, as it can then be planed and scraped with the head held in a vice.) Prepare two flat rectangles of plywood packing, which can be placed, one below the head, and the other on top of the veneers. Spread glue on the head, then slide the first veneer in position. Spread glue on to this, and slide on the next veneer. Cramp the veneers to the head with the two pieces of packing, tightening the cramps gradually so that the veneers do not slide out of alignment. Leave to dry (12-7).

15 The rough edges of the layers of veneers can now be smoothed level with the sides of the head; and the top surface of the rosewood veneer can be planed and sanded smooth. It is important to ensure that the 'face edge' of the neck, from which all the marking out will be done, is absolutely straight all along its length, including the head. Check with a straight-edge for any bumps, and either plane these away, or sand the entire edge on a flat sanding board (12-8).

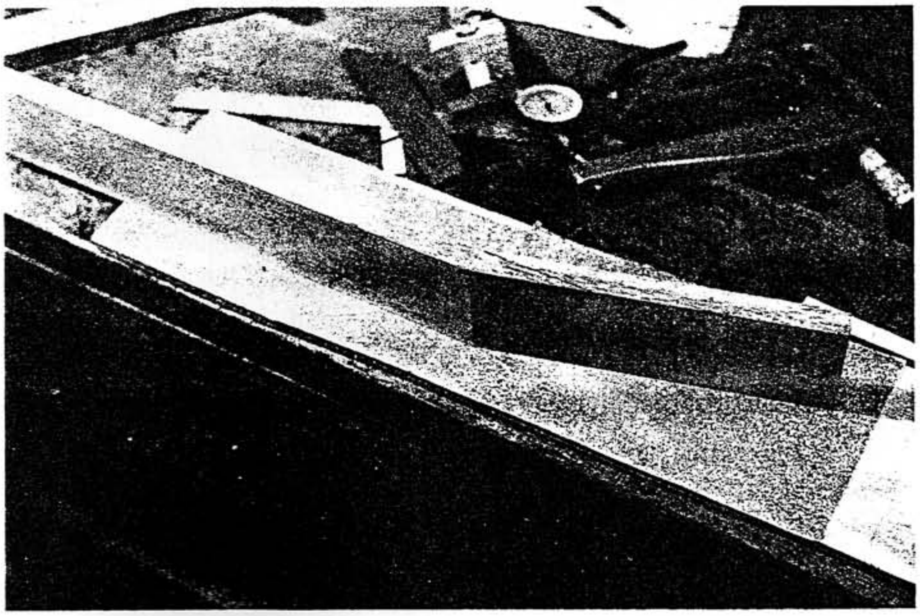
16 Cramp a large carpenter's square against the neck, so that a line can be marked on the veneer, at the point where the change in angle occurs between the neck and the head (12-9). With a marking knife, scribe a deep line. Remove the cramp and use a chisel to cut a small ramp from the waste side of the line. This will assist the saw to cut straight across. Saw down so that the cut is perpendicular to the neck (not the head). This is because the bone nut will rest on the neck, and butt up against the end of the head veneers.



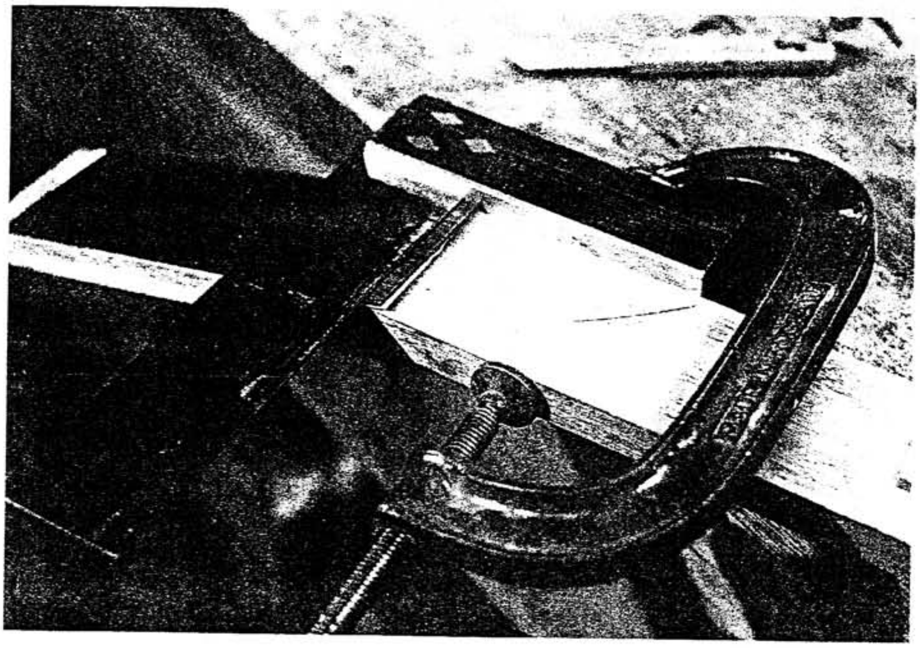
12-6 Rosewood and syncamore veneers



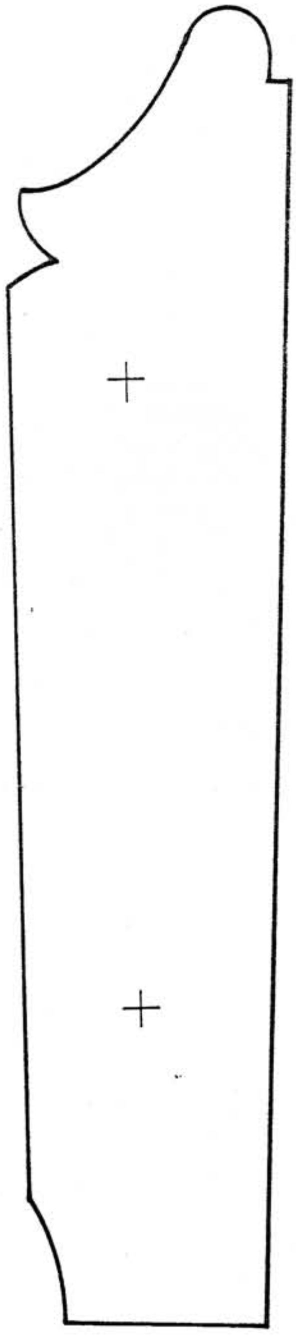
12-7 Gluing the veneers to the head



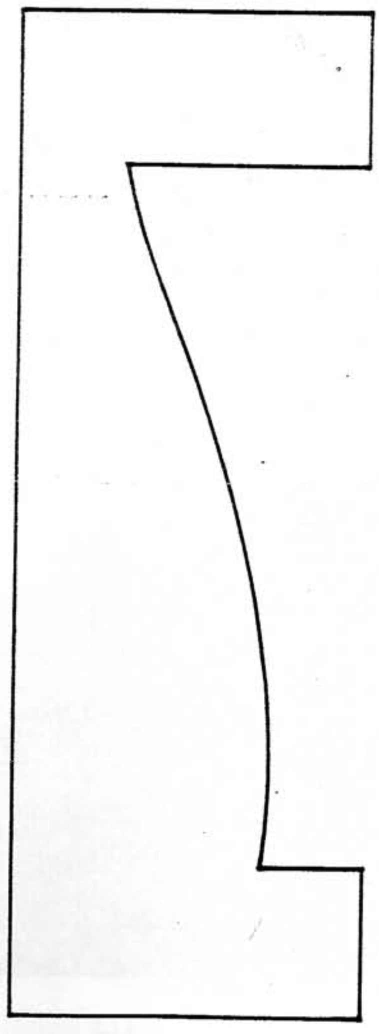
12-8 Levelling the side of the neck on a sanding board

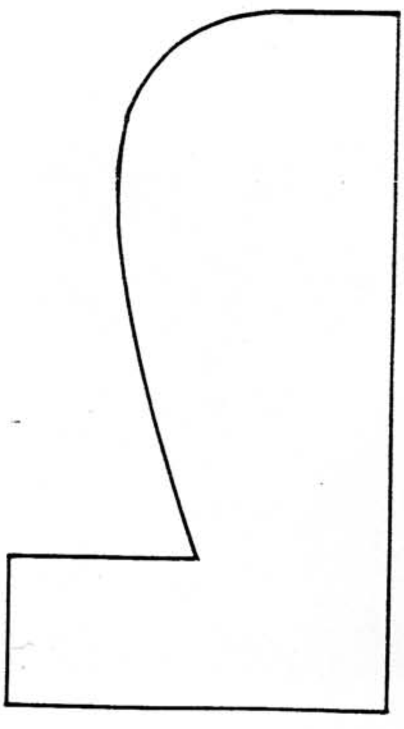


12-9 A large carpenter's square is cramped to the neck so that a line can be marked across the head veneers at 90 degrees to the neck



12-10 Right to left: three useful templates. Template for the head, with the positions of the slot holes marked; template for the neck where it adjoins the rib slots; template for the profile of the heel





17 Working from the same straight side that was used to mark the cut in the head veneer, set a marking gauge to half the width of the neck and mark a centre-line on both sides of the neck, stopping at the head veneer. Carry the centre-line on to the head veneer and on to the back of the head with a pencil, so as not to scratch the surfaces.

The head

1 Refer to the relevant drawing of the head and make a template on a thin piece of card by tracing half of the shape (12-10).

All that is required is the outline shape and two tiny holes pierced exactly at the centres of the drill holes at the ends of each slot. Place the template on the centre-line of the head, and draw the outline with a sharp pencil. Also pierce through the two holes. Flip the template over, and mark the other side (12-11). Square lines across the head at the positions of the holes, and check with a pair of dividers that each pair of holes is equidistant to the centre-line. The template outline should also be marked on the back of the head, although the four holes are not needed. By carrying lines to the back, showing the positions of the four holes, and of the top of the head design, you can ensure that the template is placed correctly.

2 (12-12) Draw a line across the neck at the position of the nut; 5 mm from the head veneer, and then measure along the centre-line to mark the position of the 12th fret. The 12th fret is exactly half of the scale length – most guitars have a scale length of 650 mm, so the 12th fret will be 325 mm from the leading edge of the nut. (The total length, from the head veneer to the 12th fret, will be 330 mm, which includes the area to be occupied by the nut.) If your guitar is to have a different scale length, then alter this measurement accordingly.

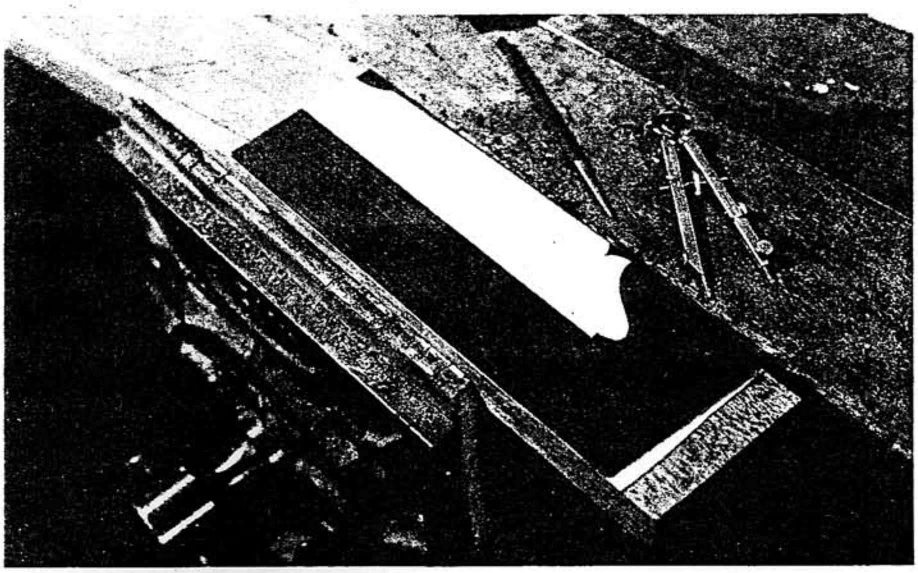
3 Draw across the neck at the 12th fret position. Mark the width of the neck at the nut and at the 12th fret, and join up these points with a straight-edge. Carry all the lines over to the back of the neck (12-12).

4 The head can now be cramped on to a flat surface, and holes bored at the marked points (12-13). A drill press with a saw-tooth drill bit will make the cleanest hole. The diameter of the hole will depend on the head design being followed, but is usually 15 mm to 16 mm. Once the holes have been drilled, mark lines across the head, at the inner edges of the holes – this will help you position the machine heads accurately.

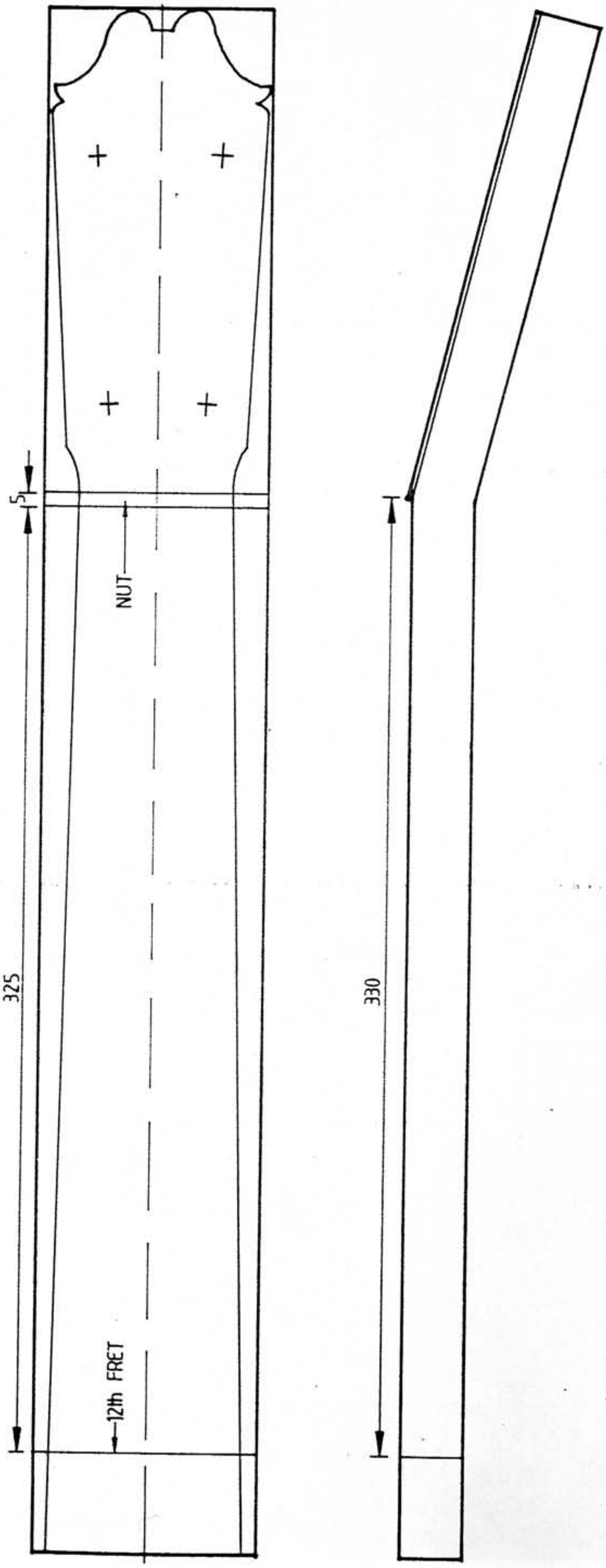
5 Join up the lines connecting each pair of holes, with a marking knife, to define the areas to be removed for the slots. The narrow, outer edges of the head should not be less than 6 mm wide. Ensure that the distances from the slots to the outer edges of the head are correct, and mark these lines clearly with a knife. Cut away some of the neck waste so that a smoothing plane can be used to taper the edges, which must be both flat, and square to the face of the head.

6 The position of the machine heads must now be marked. Although the distance between the centres of the barrels is usually 35 mm, this may vary according to the type being used. The safest way to mark the barrel positions is to unscrew the barrels from the side plates, which can be used as templates. Position the side plate centrally in relation to the slot, and mark the centre of each hole, ensuring that the cogs are towards the nut.

7 Most machine head barrels are 10 mm in diameter, and require a flat-bottomed wood drill bit of 11 mm diameter to bore their holes. (The barrels must be free to turn.) The holes must be drilled at a right angle to the side of the head, or the barrels will not seat properly. A drill press vice is the best tool for holding the neck at the correct angle, which can be measured against the drill bit



12-11 Using a template to mark the head shape



12-12 Typical layout for the neck and head. The specific dimensions for the width of the neck at the nut and twelfth fret can be taken from the plans in Part 1

with a small engineer's square (12-14). The holes should be bored slightly deeper than the length of the barrels, so that they can turn freely, but try to avoid drilling all the way through, as this will weaken the head (12-15). Reassemble the machine heads, and check that they fit, and that the barrels turn easily.

8 Cut away the waste from the slots with a coping saw (12-16). (Masking tape stuck against the lines will make them easier to see.) Keep the blade of the saw well away from the line, and then use a chisel and sanding stick to perfect the shape (12-17 and 12-18).

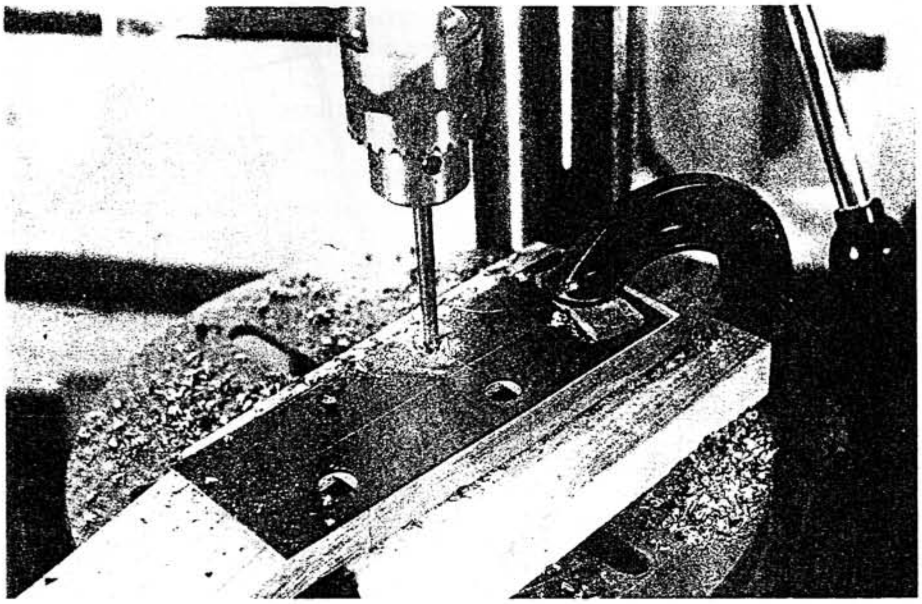
9 The nut ends of the slots are shaped to provide clearance for the strings. Some makers create a rounded ramp, others prefer a flat one. A round file or sanding stick can easily produce a rounded ramp, and a narrow chisel can be used to make a flat ramp (12-19). The decorative veneers will be revealed as you cut the shape, and they will provide a guide to achieving straight lines that are parallel to the end of the head veneer, rather than square to the slots.

10 The final task is to shape the top of the head. Cut away the bulk of the waste, and then chisel down carefully from both sides, until the shape emerges. Finish with flat and round sanding sticks (12-20).

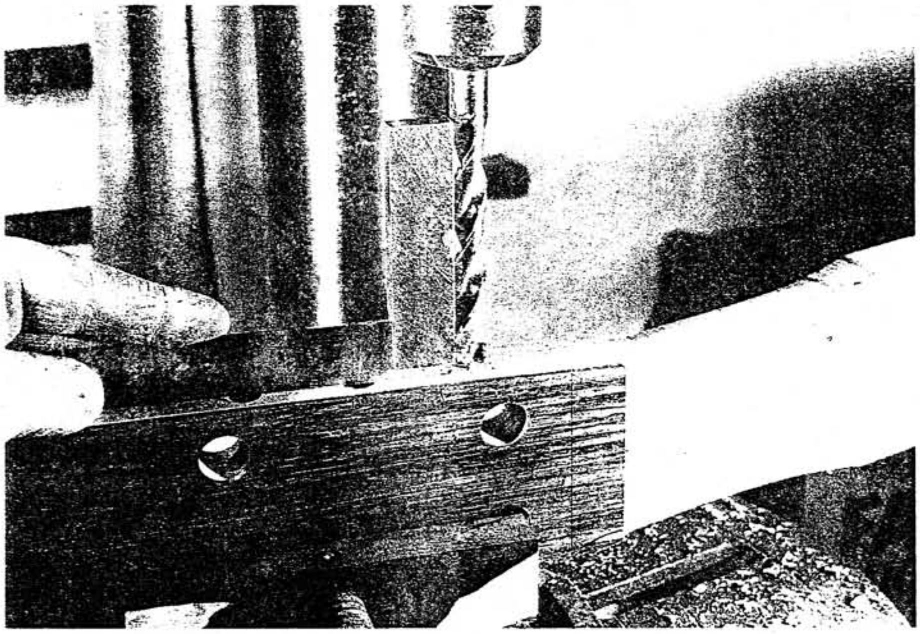
The heel and foot

Refer to the relevant drawing of the heel profile, and make a card template. The short length of neck wood that was cut off earlier, is now itself cut into three shorter sections, which are glued in a stack, on the heel side of the neck. Together, these pieces should provide sufficient depth for most guitars. The precise length of each piece is not important, provided that the heel and foot fall within the overall dimensions. Typical measurements are given in (12-21). If you keep the short sections in the same order as they were before being cut, the grain pattern will match, making the joins almost invisible.

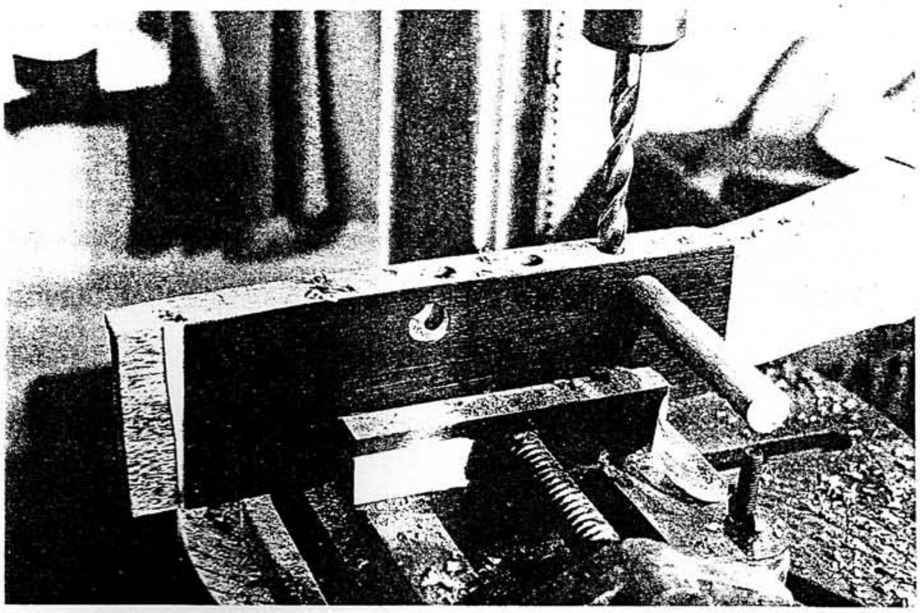
1 Plane both sides of the wood flat, so that they will fit together without any gaps.
2 Cut the wood into three sections.
3 Stack them against the neck, marking their position by drawing the heel profile. The blocks will probably not fit together perfectly – each one can be rubbed on a flat sanding board, and its surfaces checked with a straight-edge. Do not expect cramps to force them together, or the joins may open up later on.



12-13 Drilling the holes for the head slots

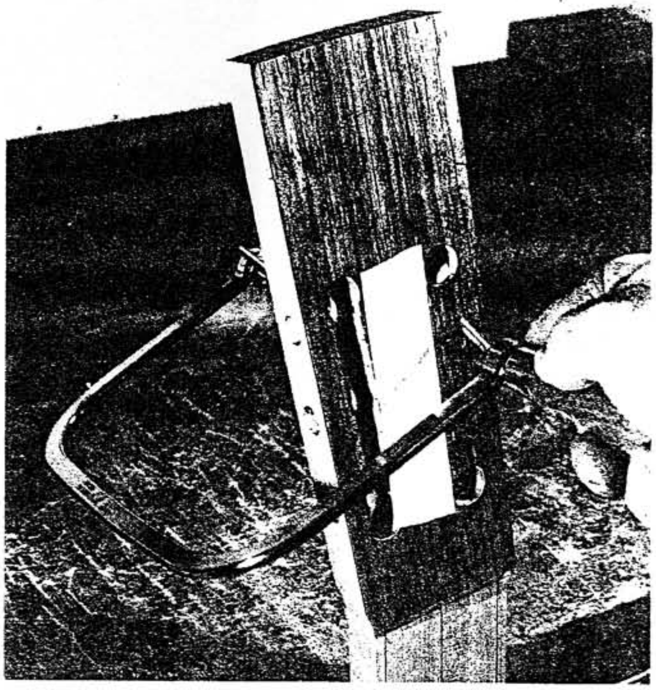


12-14 Checking that the drill is positioned at a right angle to the edge of the head



12-15 Drilling the holes for the barrels of the tuning machines. The dowel helps prevent the drill from wandering when it passes through the slot holes

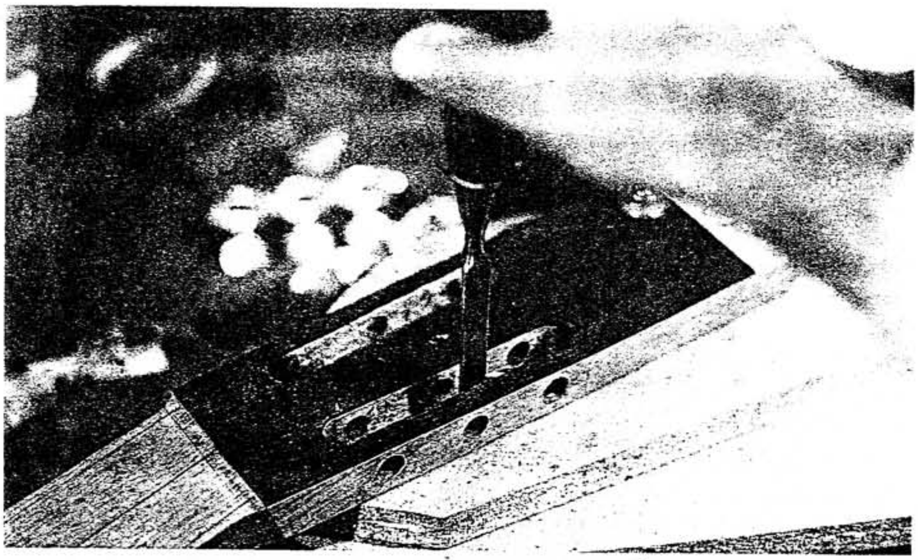
12-16 Removing the waste with a coping saw, to form the slots. As pencil does not show up well on dark rosewood, some masking tape is used to define the edge of the slot



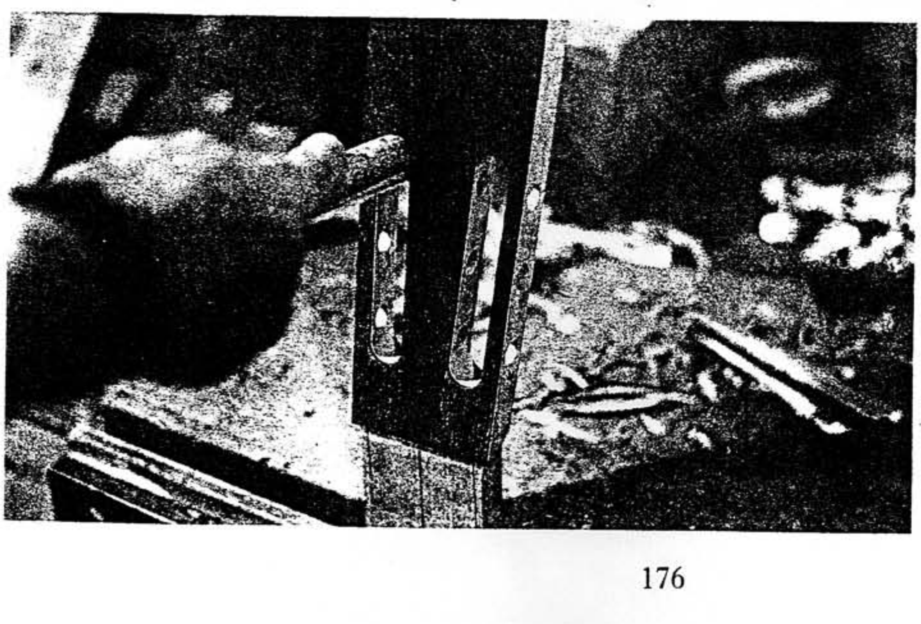
4 Once all the sections fit together perfectly, brush away the dust, and prepare the set-up shown in (12-22). A raised board enables cramps to be passed underneath. Four short battens will keep the blocks perpendicular. Cramps will be applied both vertically and horizontally. Tighten them gradually, to prevent the wood sliding out of alignment. Leave overnight to dry.

5 Plane the two sides of the heel until they are perfectly square with the top surface of the neck.

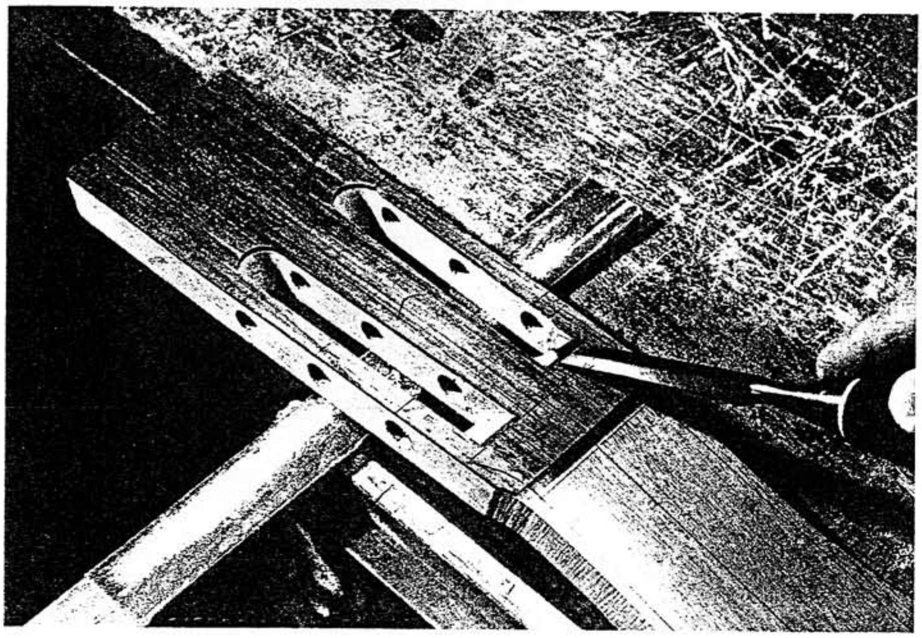
6 Refer to the relevant drawing which shows the depth of the guitar body. The depth of the heel must now be reduced to 2 mm less than the final depth of the guitar at the neck. For example, if the final depth at the back is 96 mm, you must plane down the heel section to 94 mm. The 2 mm is to allow for the added thickness of the back, which will be glued on top of the ribs. (No reduction is needed for the soundboard as it is housed flush with the surface of the neck.) Mark



12-17 Cleaning up the head slots with a chisel



12-18 Smoothing the head slots with a round sanding stick



12-19 Cutting the ramps with a flat chisel

the depth with a gauge and plane it down, checking that it is square with the sides of the neck.

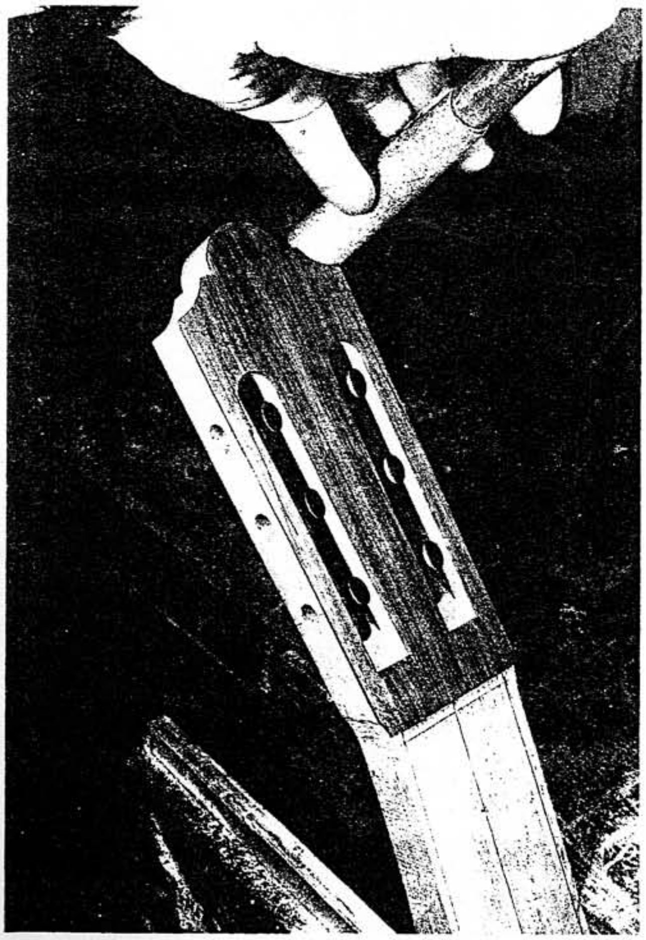
7 Refer to the relevant drawing which shows the dimensions for the neck slots and the foot. All these measurements must now be drawn on to the heel/foot section (12-23). Mark the top surface first. Because the ribs do not enter squarely into the heel, but at an angle, it is necessary to start the lines for the slot cuts 2 mm in front of the 12th fret line (towards the head) on the centre-line. Mark a line from this 2 mm position, and continue it through the intersection of the 12th fret line with the final outer edge of the neck. Mark a second line, parallel to the first, but 2 mm behind, to represent the channel in which the saw will cut. Square these lines down the sides, and mark the bottom of the heel. To do this, you must first find the centre, and then mark outwards from it.

Cut the rib slots

Once all the marking out is complete, support the neck in a vice, and cut the rib slots. It is best to use a tenon saw that has been specially prepared to produce a 2 mm wide cut. Saw slowly, and ensure that the saw follows the guidelines exactly. Note that the bottom of the slot is not flat; it slopes down on the heel side (12-24).

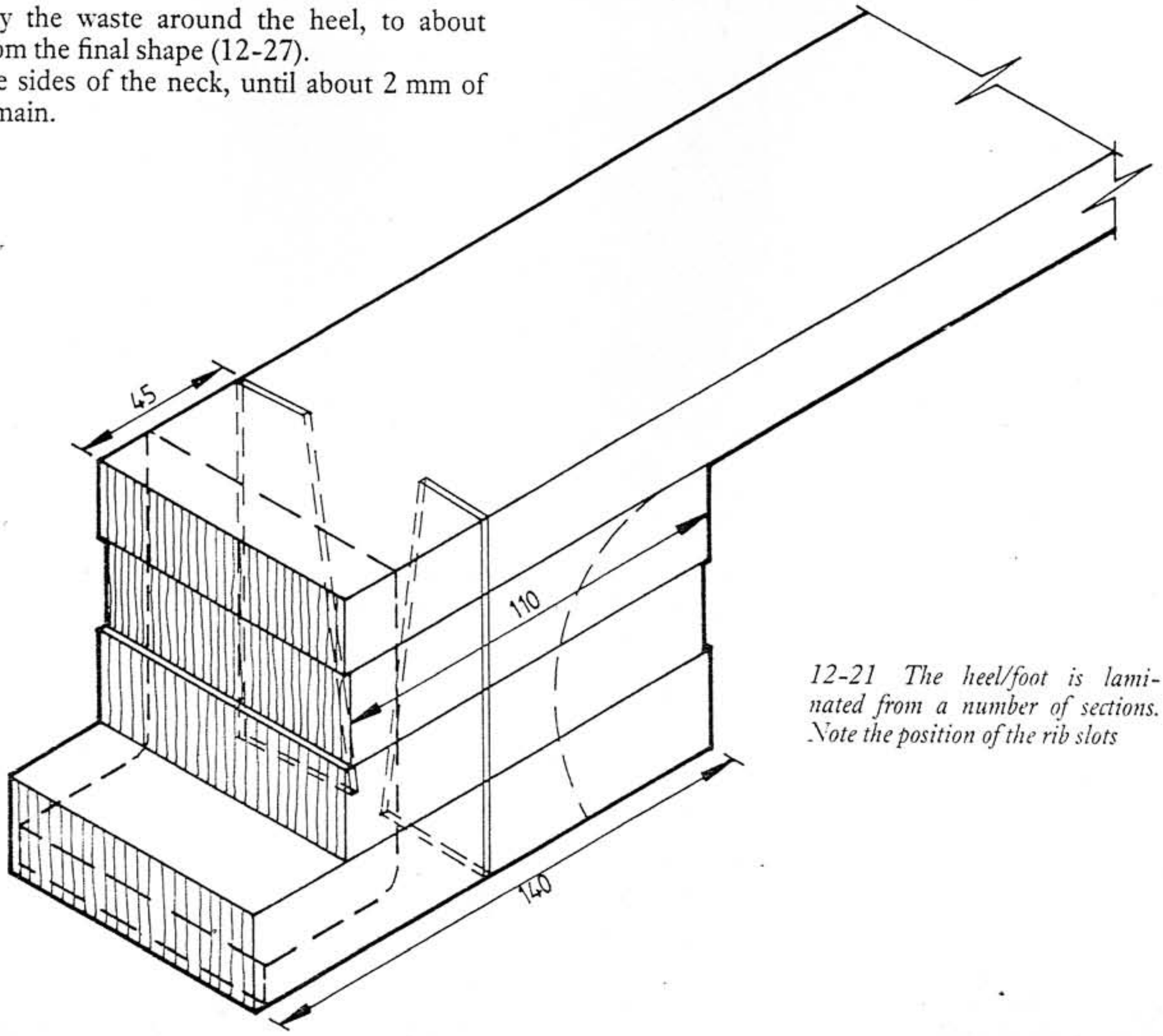
Shape the foot

1 Cut the main sections of waste from the foot (12-25), and then use chisels and sanding blocks to shape and smooth it (12-26).

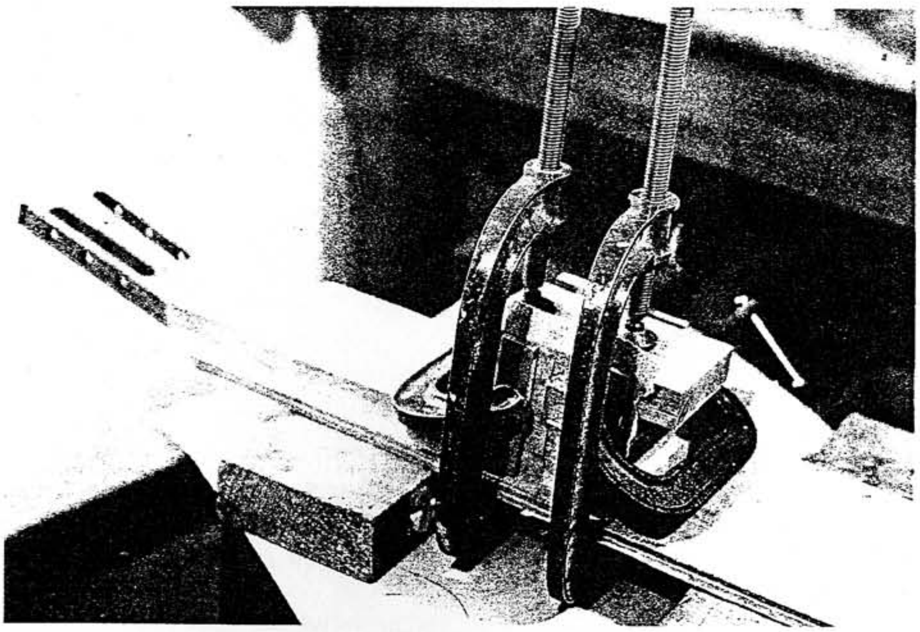


12-20 Smoothing the final head shape

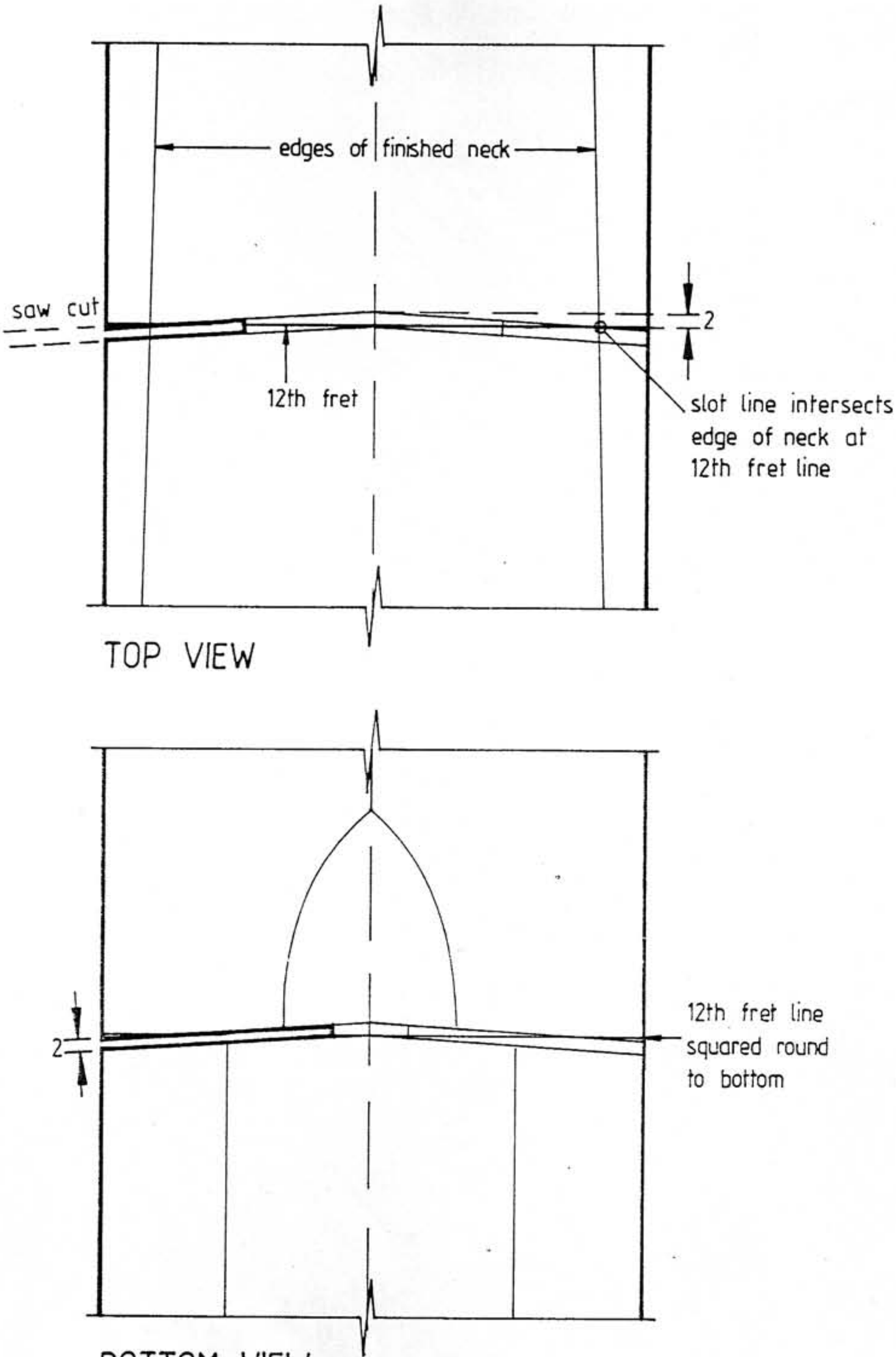
2 Cut away the waste around the heel, to about 2 mm from the final shape (12-27).
3 Plane the sides of the neck, until about 2 mm of waste remain.



12-21 The heel/foot is laminated from a number of sections. Note the position of the rib slots



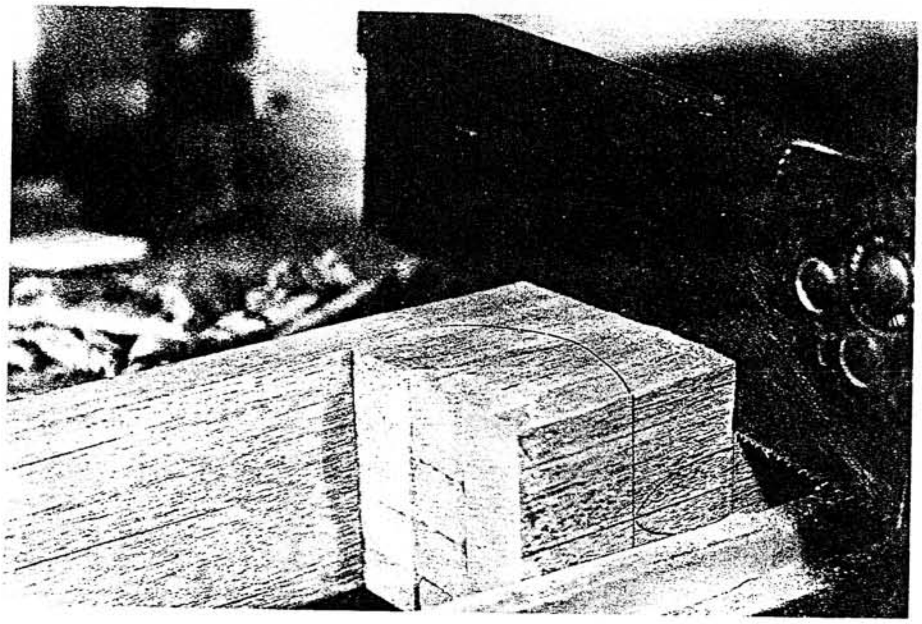
12-22 Gluing the laminations for the heel/foot



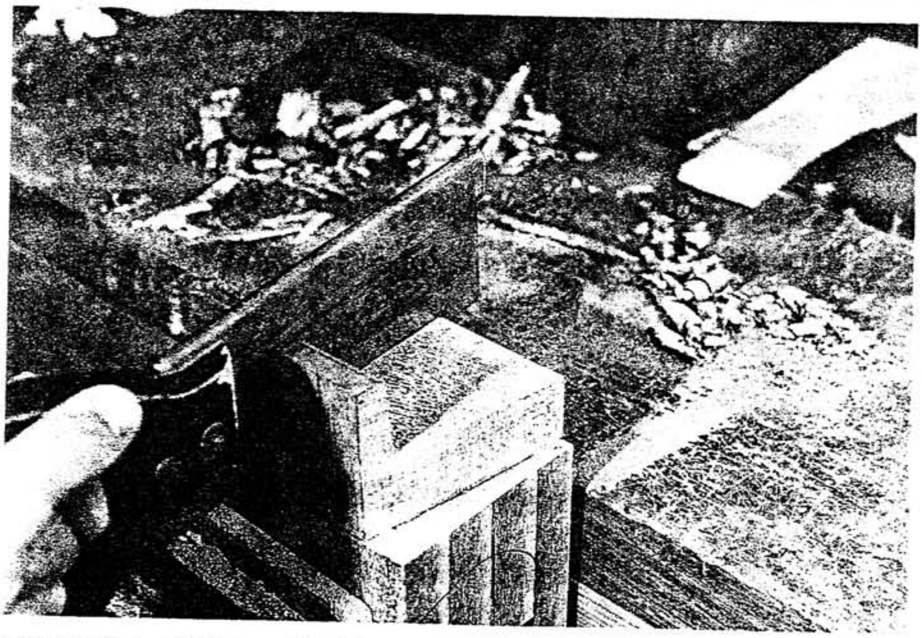
12-23 Layout of the neck at the 12th fret

Carve the heel
Carving the heel is best approached in a series of steps, rather than launching in at random with a chisel. The three-dimensional shape can be broken down into several profiles – if you tackle each one individually, the complete shape will emerge quite easily. Essentially, there are three separate operations to carry out; first, carve the profile of the heel only at the points which adjoin the neck slots. Second, carve the side profile of the heel curve. Third, remove enough material between the first two profiles, until the final, elegant shape is defined (12-28).

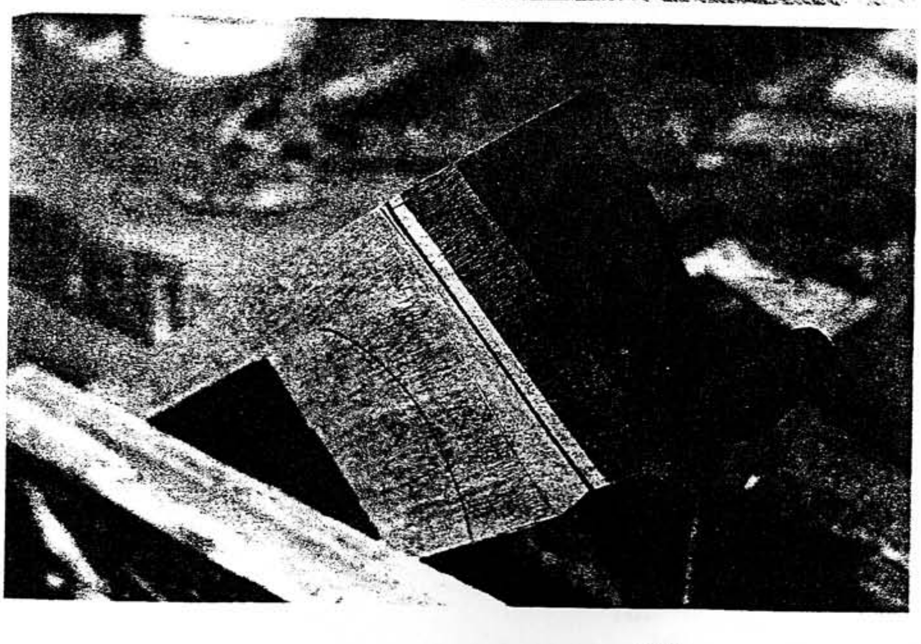
1 Cramp the neck face down to a board, ensuring that the head veneer protrudes over the end (12-29). Carve the heel with a 10 mm wide chisel. Mallets and gouges are not necessary – a sharp chisel can easily remove the wood, and produce



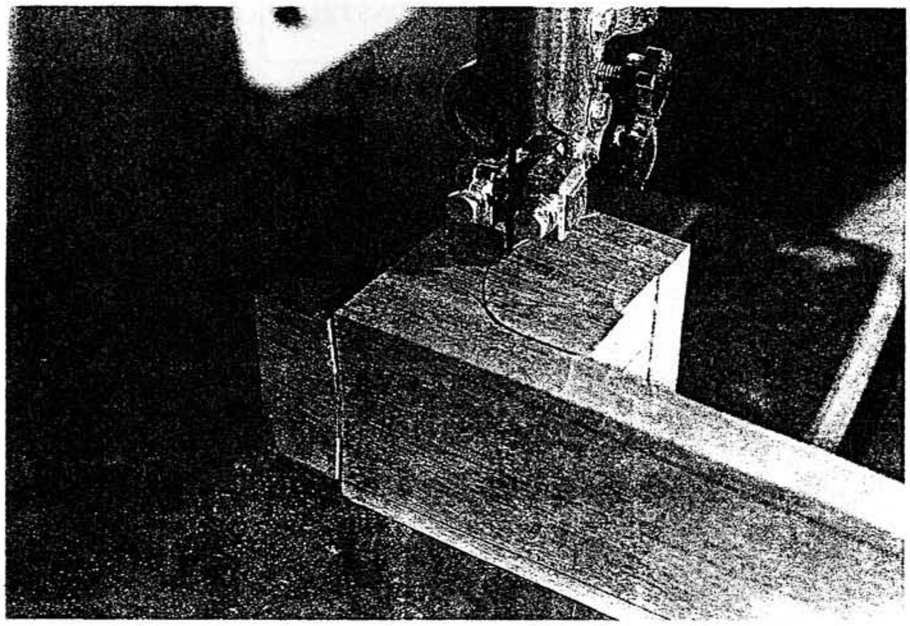
12-24 Sawing the rib slots – the saw has been specially set to produce a 2 mm wide cut



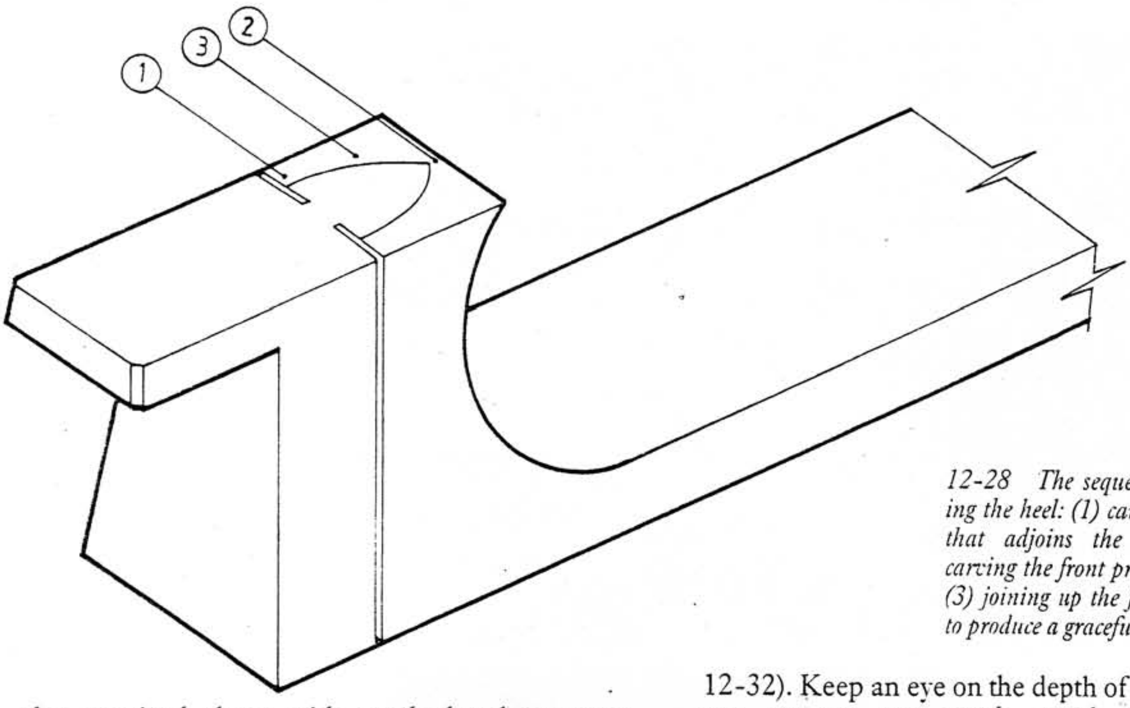
12-25 Cutting the waste from the foot



12-26 The completed foot is coated with sanding sealer



12-27 *Cutting the heel profile on a bandsaw*



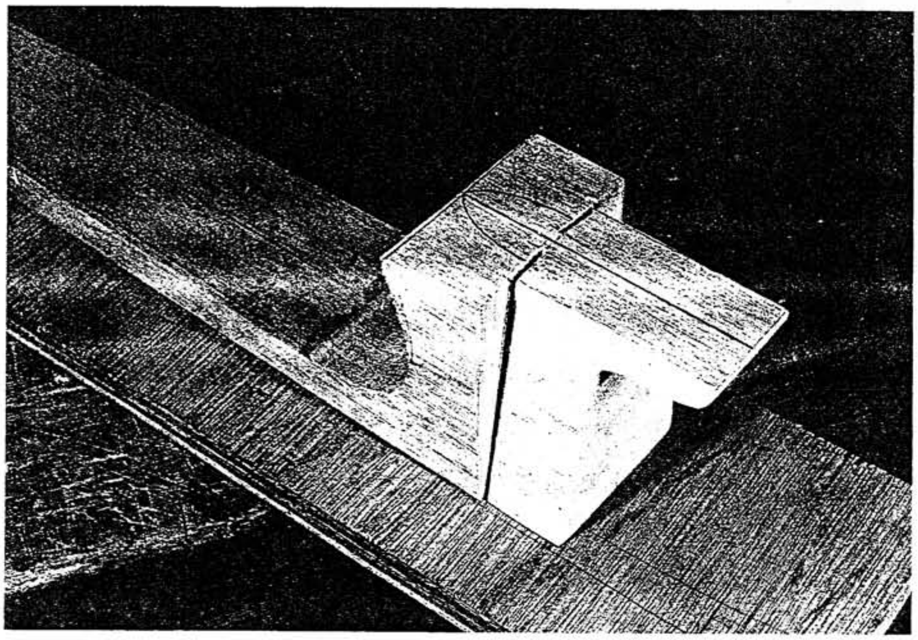
12-28 *The sequence for producing the heel: (1) carving the section that adjoins the rib slots; (2) carving the front profile of the heel; (3) joining up the first two profiles to produce a graceful shape*

the required shape with gentle hand pressure alone. Heel shapes vary from one maker to another; Torres and Romanillos favour a small, semicircular design, while others are quite angular. Whatever shape you prefer, the method of carving is similar. It may help if you prepare a card template which can be held against the heel, next to the slots, to judge the symmetry of the two slides (12-10).

2 With the neck cramped face down, start by carving away the waste adjoining the slot. At this stage, the shape can follow the taper of the foot (12-30). Now begin to remove more wood from the centre of the heel, next to the slots, and check frequently with the template, until a smooth curve emerges all the way down to the board (12-31 and 12-32). Keep an eye on the depth of the slots – do not remove too much wood or the slots themselves will not retain enough depth for the ribs to be securely housed. Provided the chisel is sharp, and only thin shavings are removed with each pass, the resulting surface will be quite smooth.

3 Now turn to the profile of the heel, which is carved in a similar way. A large circular sanding stick made by wrapping abrasive paper round a rolling-pin, will help create a smooth, flowing profile.

4 Determine the position of the 9th fret, and if the neck is thicker than 20 mm at this point, reduce it to this dimension. The profile of the heel should flow smoothly to meet the main under-surface of the neck.



12-29 The neck cramped to a board, ready for the heel to be carved

5 It now remains to carve away enough between the slots and the heel profile, to reveal a pleasing shape. This will take some time. Use the chisel to make the surface as smooth as possible, then turn to a cabinet scraper, and abrasive paper wrapped round a small eraser to finish off (12-33).

6 Seal all the exposed end-grain surfaces of the heel and the foot with sanding sealer, to prevent moisture absorption, but keep the slots themselves clean. (The back of the neck is not shaped at this stage, but is left until the frets have been installed.)

Make the soundboard platform

The soundboard will rest on the section of the neck behind the rib slots, which will be positioned inside the guitar body. This platform must be reduced in height by the thickness of the soundboard at this area (2.5 mm is a usual dimension), so that the soundboard will fit flush with the top surface of the neck. Mark the thickness of the soundboard on the end of the neck, and remove the waste with a chisel or router (12-34).

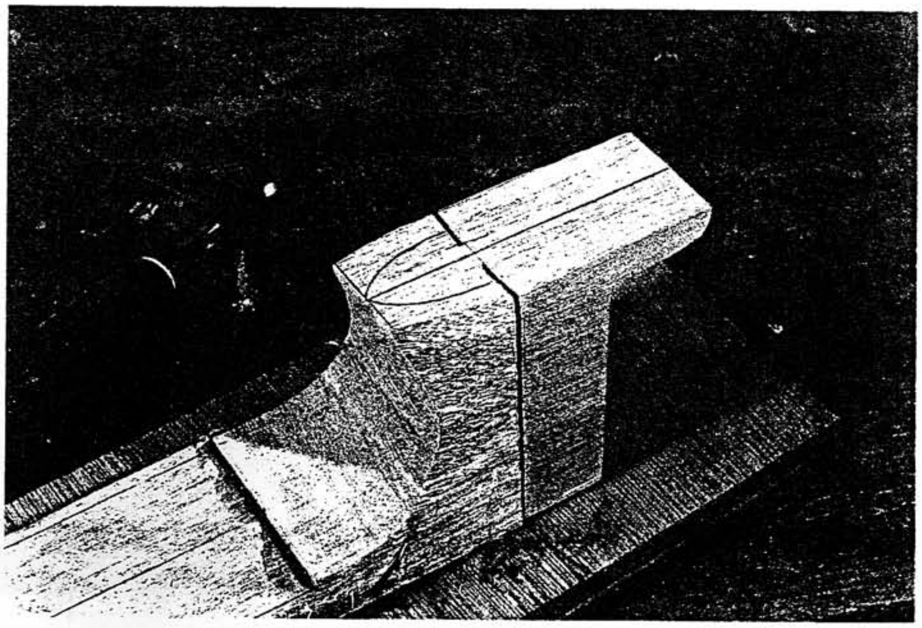
Alternative neck joint

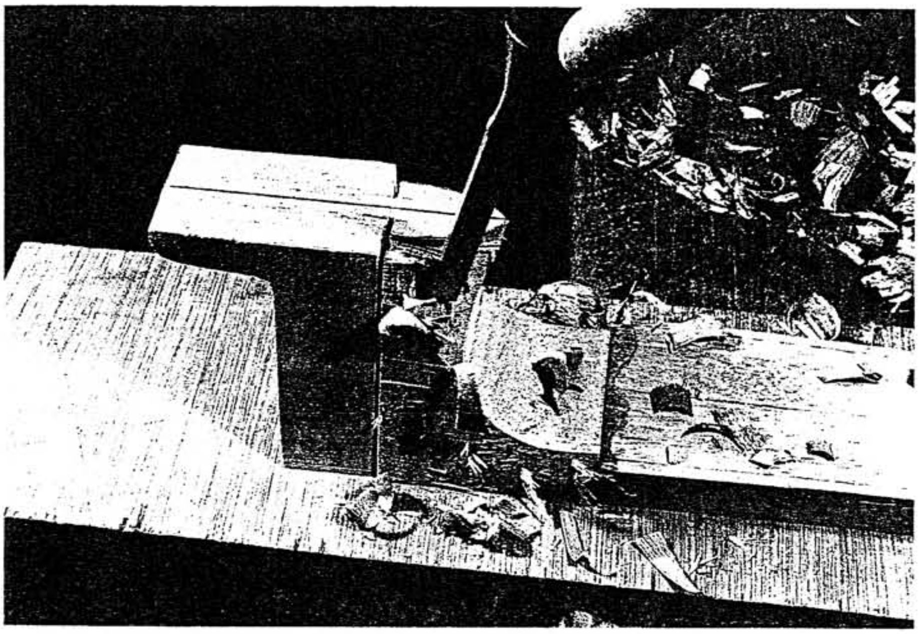
Rather than house the ribs into 2 mm wide slots, it is possible to cut much wider, tapered slots, into which the ribs are fitted. Wedges are then tapped down into the slots, behind the ribs, forcing the ribs up against the front of the slots. The wedges must first be made up to the same taper as the slots (12-35). (See Chapter 8, 'José Romanillos'.)

Alternative head joint

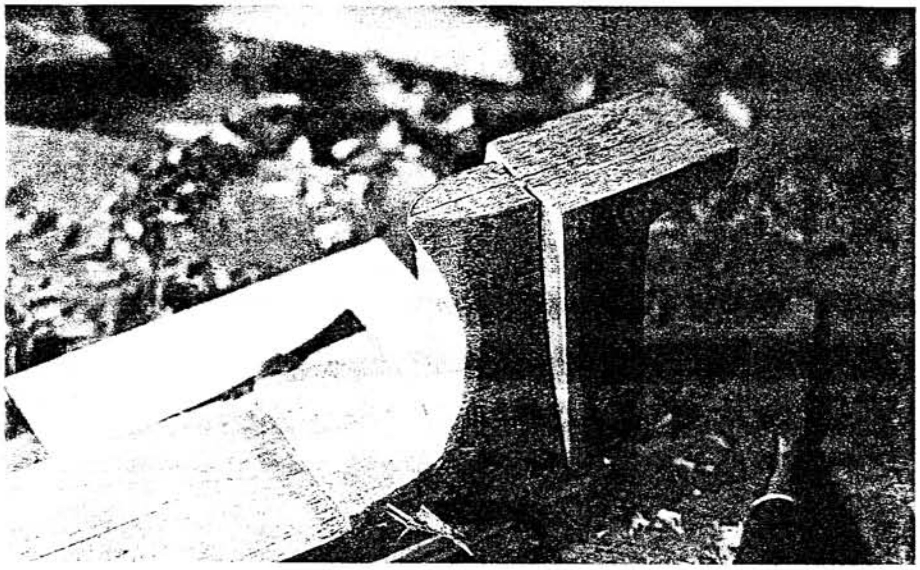
The 'V' joint used by makers like Hauser and Romanillos for forming the head is shown in (12-36).

12-30 The sides of the heel are first carved flush with the foot

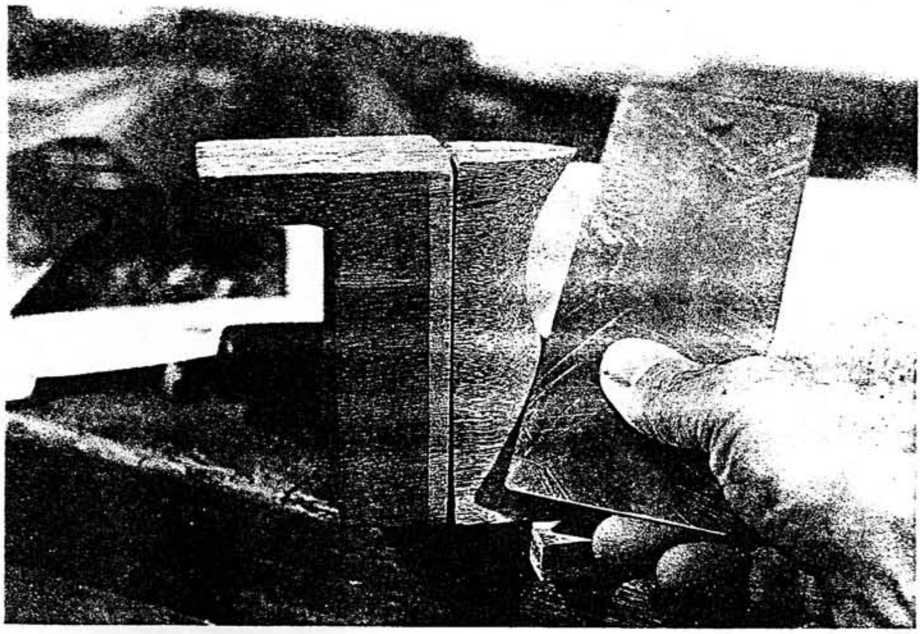




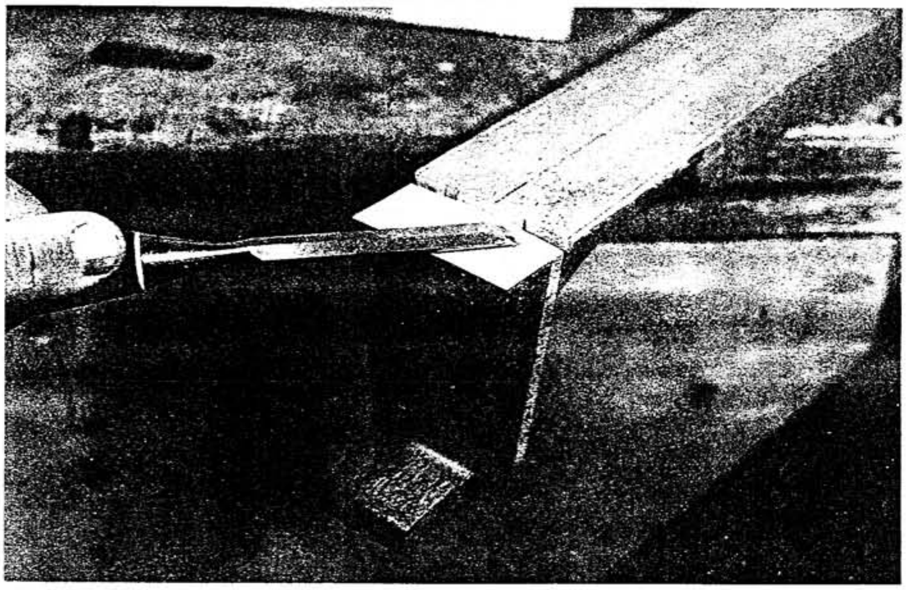
12-31 Carving the heel where it meets the rib slots



12-32 The profile at the rib slots is completed

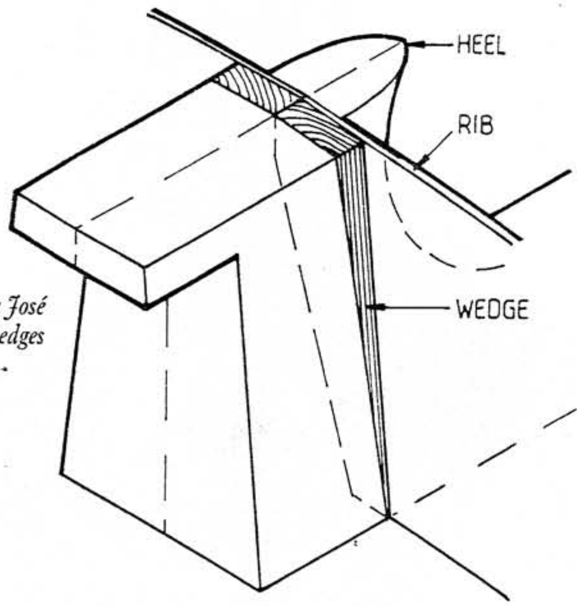


12-33 Smoothing the final shape with a cabinet scraper



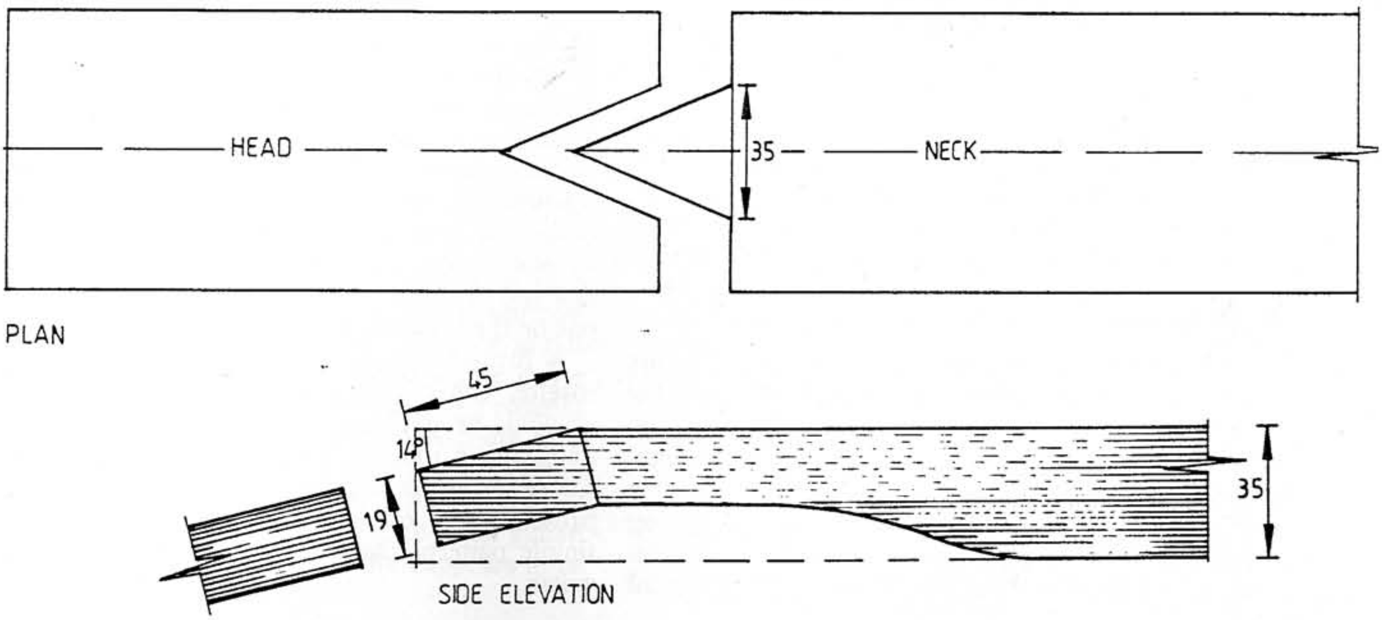
12-34 Forming the recessed platform to which the soundboard will be glued

The long neck section has a pyramid shaped extension on the head end. A matching 'V' shaped cutout is formed on the head section. The angle of the head is created by shaping the pyramid neck extension to the required angle before gluing the two components together.

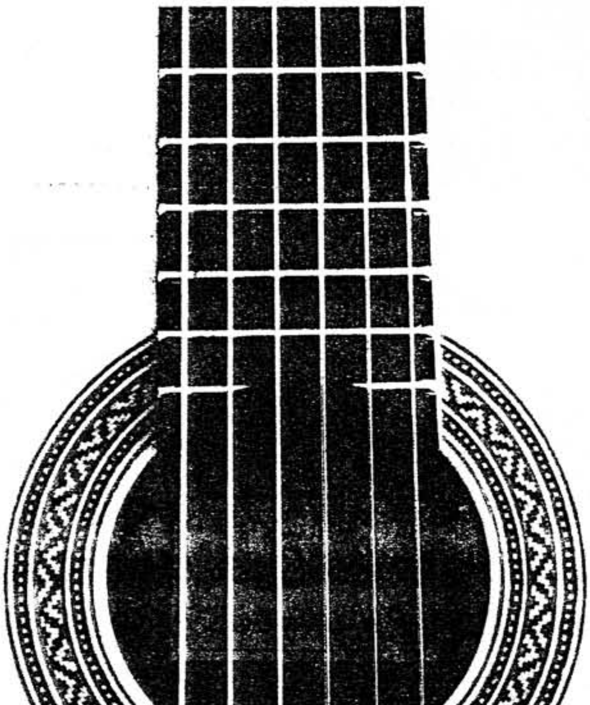


12-35 The method of joining the ribs to the neck used by José Romanillos. The rib slots are wide and tapered, so that wedges can be drives down once the ribs have been inserted

12-36 The 'V' joint between neck and head



13 Rosette



13-1 Rosette design

Background

The tradition of ornamenting musical instruments with various wood inlays has been established for many centuries. The design of the classical guitar, with its circular soundhole and gently curving outline, lends itself to this kind of decoration. One of the most common methods of inlay is to build up a repeating pattern which continues right around the soundhole. A kind of 'wood mosaic' has become the traditional method of making this motif. The Spanish word for 'wood mosaic' is 'taracea' and this art was perfected in the sixteenth century, often being used to embellish keyboard instruments. A similar kind of craft developed in Tunbridge Wells, England, in the nineteenth century, when it was used to decorate trinket boxes and other small wooden items. It became known as 'Tunbridge-ware'.

There are several different methods of making the mosaic designs – basically, they are obtained either by using thin strips of wood, 1 mm × 1 mm in section, or by using sheets of thin veneer, about 0.6 mm thick. The first method involves gluing together a number of the thin strips of wood, of differing types and colours, into tiny planks. For example, nine strips, each 1 mm × 1 mm, glued together, will give a plank 9 mm wide. If eight such planks are made, and then all glued together, a solid log will result, 9 mm × 8 mm. The two ends of this log will reveal the pattern, according to the differing woods that were used. The log is then sliced up like a loaf of bread to produce many individual tiles which are all identical. These tiles form the basis for the rosette design.

The second method, which results in a finer pattern made with even smaller squares, is to build up the planks from strips of veneers which are usually 0.6 mm thick. By gluing together stacks of veneers, and then cutting thin strips off each stack, the final plank appears to have been made from 0.6 mm × 0.6 mm squares.

A simpler form of decoration is to inlay long strips of veneer of contrasting types and colours, around the circumference of the soundhole. Mother-of-pearl was a popular inlay material in the nineteenth century.

So there are a number of ways of dealing with the rosette design for your guitar. If you are making a faithful copy of the original, you will need to build up the various sections of wood mosaic and borders, and inlay them as shown on the plans.

A simpler solution would be to buy a ready-made rosette which approximates the design of the original. These mass-produced rosettes do vary a great deal – some are quite beautiful, and are based on the traditional patterns that the master makers used. Others, made from artificial fibre material, are unattractive, and will do nothing to enhance the beauty of your guitar. If possible, try to visit the supplier in person so that you can choose a rosette that you like, and one that bears a resemblance to the one on the instrument you are copying.

A further option is to make your own personal rosette, either based loosely on the design of the original, or perhaps entirely your own idea, thus imparting a unique 'signature' to your instrument. Above all, be guided by your own level of skill and patience, and remember that it is often the more simple patterns that 'read' better on the completed guitar.

Making Your own Rosette

There are many methods of making rosettes, and various ways of inlaying them into the soundboard. Some makers build up a wood mosaic log, cut it into slices, and assemble the complete rosette around a wooden disc roughly the size of the soundhole. Once complete, the rosette is inlaid in the same way as described in Chapter 14, 'Inlaying a ready-made rosette', p. 200.

The methods that follow differ from this, as the individual tiles and lines that will make up the finished design, are glued directly into a pre-cut groove in the soundboard. This has the advantage of ensuring a perfectly circular shape, as the circle is first formed in the soundboard and the individual sections will then conform to this shape. It also allows you to have greater control over your work – each tile can be sanded and shaped until it fits perfectly with its neighbour, and then glued in place.

Making the Central Motif – Method 1

(using 1.0 mm × 1.0 mm square inlay strips)

Tools

Small G-cramps
Two 300 mm steel rules (straight-edges)
Cabinet scraper
Wood blocks and battens as shown in the drawings

Materials

1 mm × 1 mm square inlay strips in a variety of colours and types are available:
rosewood (dark brown)
walnut (light brown)
padauk (dark red)
box (yellow)
sycamore (white)
Stained sycamore can also be obtained:
red
green
black
blue
Glue

Method 1

1 Select a design from those illustrated in each chapter of Part 1 of the book, or create your own design referring to the examples provided in this chapter. The classical proportions of the guitar determine that the most visually pleasing rosettes are no less than 16 mm wide, and no more than 25 mm wide. (A rosette that is narrower than 16 mm tends to leave too much area of soundboard between it and the edge of the guitar. A rosette that is wider than 25 mm appears to be too close to the edge.)

2 Draw out your chosen design on to squared paper – one centimetre squares are a manageable size – and identify each square with numbers (horizontally), and letters (vertically), as shown in (13-2). Use coloured crayons or inks to distinguish the different woods. Draw the repeated motif side by side several times to gain an impression of the overall pattern. Once you are happy with the design, proceed as follows:

3 Calculate the length of log that will be needed to provide enough 'tiles' for one rosette. This can be done simply by using the formula for the circumference of a circle;

$$3.14 \times \text{diameter}$$

(13-3) Draw a circle the size of the soundhole (usually between 42 mm and 44 mm radius). Then draw more circles to represent the position of the central motif, and the two borders. Remember that the inner edge of the rosette stops 2 mm or 3 mm before the soundhole. It is now evident that the outer radius of the circle in which the central motif falls is:

$$44 + 2 + 1 + 3 + 1 + 8 = 59\text{mm (diameter} = 118\text{ mm)}$$

The circumference, at this radius is therefore:

$$3.14 \times 118 = 370 \text{ mm}$$

Each tile in this design will be 8 mm long. By dividing the circumference by the length of the tile, the number of tiles needed to complete the circle is known:

$$\frac{370}{8} = 46 \text{ tiles}$$

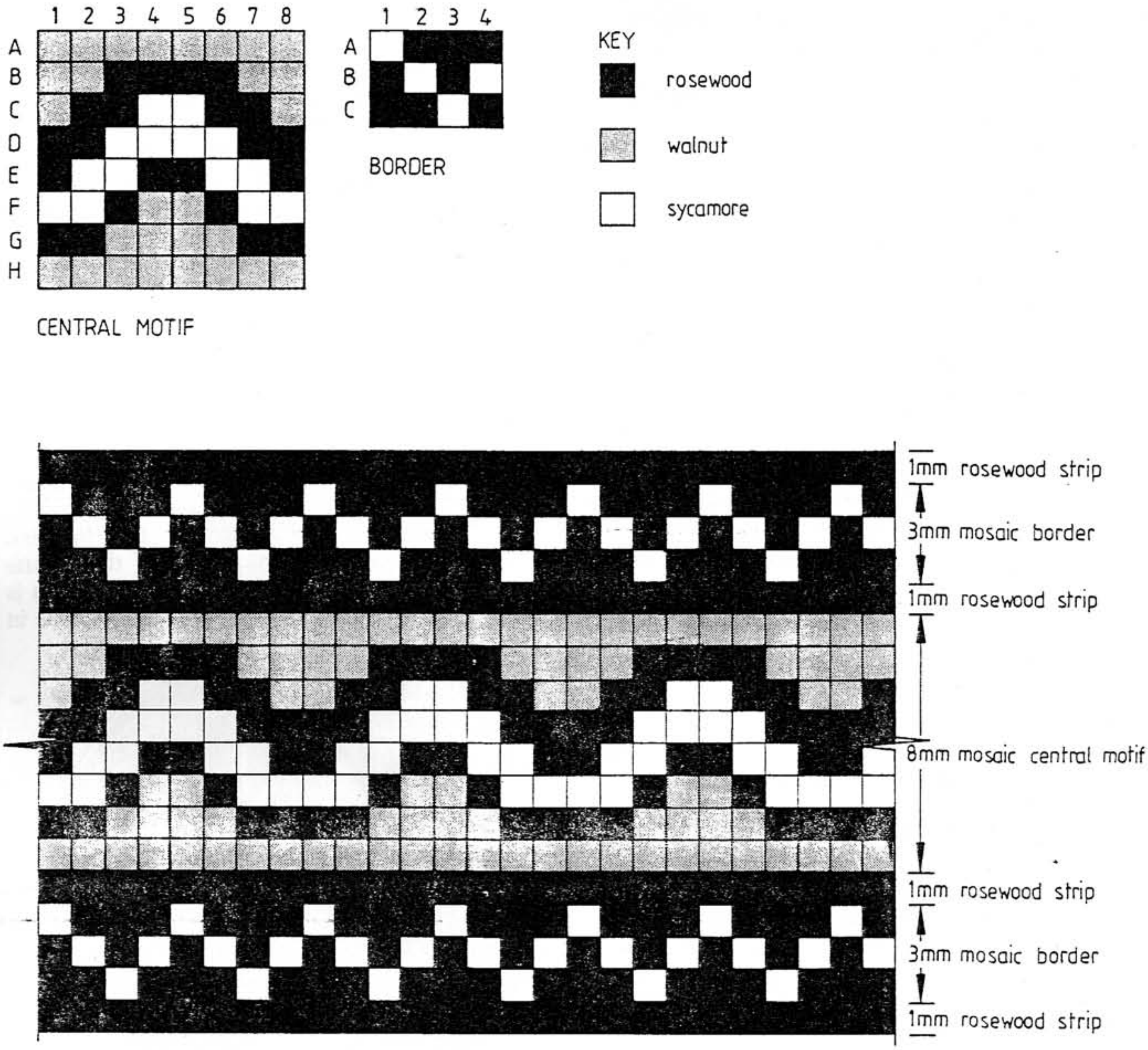
Each tile will be sawn off the log at 2 mm intervals. The saw-cut itself takes off about 1 mm, so 3 mm of log length must be allowed for each tile:

$$3 \text{ mm} \times 46 \text{ tiles} = 138 \text{ mm of log}$$

A similar calculation will be needed to determine the number of tiles for the borders.

In practice, there is no need to inlay the rosette in the area above the soundhole, where the fingerboard will be glued, so the length of log calculated will leave a few extra tiles. Now that the minimum length of log needed is known, the individual strips of wood can be prepared:

4 Cut sufficient 150 mm strips to make up each row of the design. In the example, eight strips of walnut are needed to make up Row A. Row B requires four walnut and four rosewood; Row C requires two walnut, four rosewood, and two sycamore strips. Place them in their correct order and fasten small pieces of masking tape across the resulting rows to keep the strips in place (13-4).



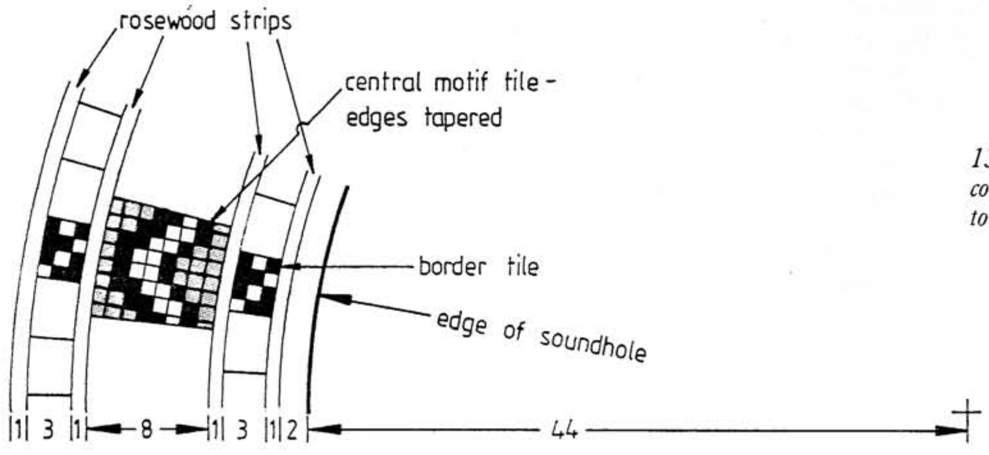
13-2 Designing the central motif and borders

Once all the rows have been prepared, start gluing them into small planks.

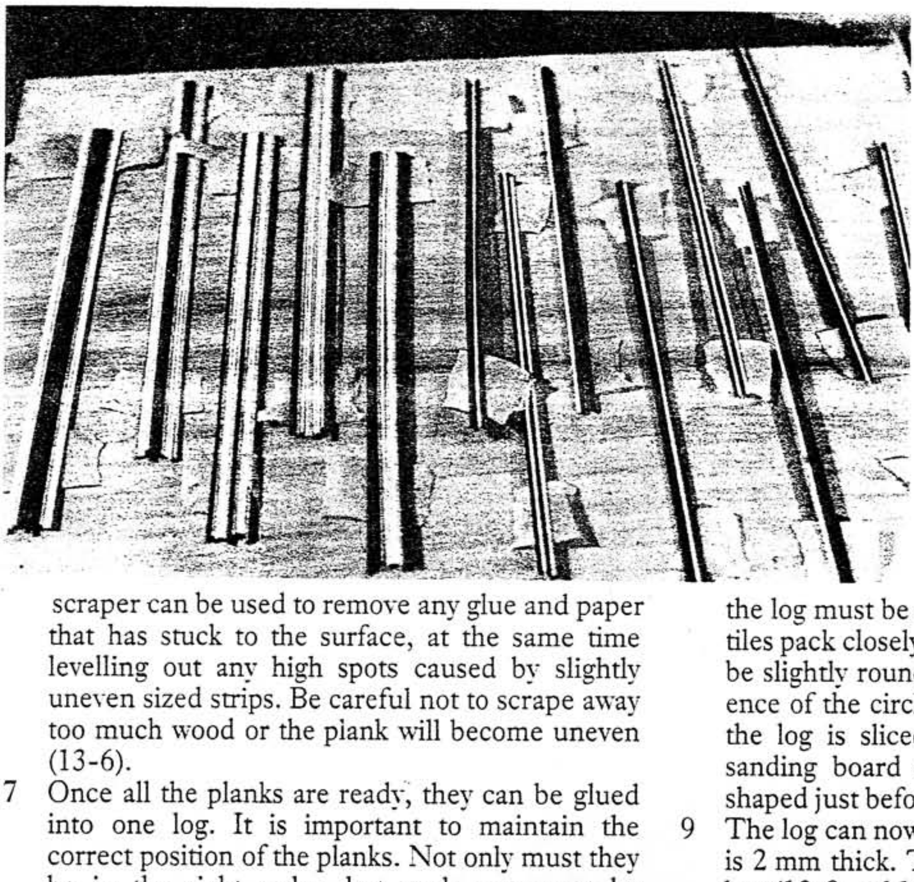
5 Prepare the set-up shown in (13-5). Basically you require a way of supporting the planks so that they remain both flat and straight while the glue hardens. The two 300 mm steel rules are ideal straight-edges because they are about 1 mm thick – the same thickness as the wooden strips. This means that the batten can be cramped down over both strips and rules, ensuring they all remain quite flat.

The gluing procedure is a little tricky, because it involves handling such tiny pieces of wood, and covering them with glue. The way to work neatly is to prepare everything needed beforehand, so that one can work quickly, but in a logical sequence of steps. Spread glue on to the side of the plank without the masking tape. Then turn it over, and place it tightly up against one straight-edge which is already cramped in position (with paper beneath to prevent sticking the plank to the board). Remove the pieces of masking tape and spread a little more glue on the upper side of the plank and then bring the second straight-edge up against it. Try to maintain the same width across the plank at both ends by keeping the two straight-edges parallel. Now place two small cramps on to the free straight-edge, cover with a scrap of paper, and put the batten over the top. Once the batten is lightly cramped down, put the assembly aside for at least thirty minutes, before removing the dry plank and repeating the procedure with the next one.

6 The dry plank can now be cleaned up; by cramping one end gently to the bench, a cabinet



13-3 The position of each rosette component is drawn out in relation to the soundhole centre



13-4 1 mm x 1 mm inlay lines are cut to length, and taped together to represent each row of the required design

scraper can be used to remove any glue and paper that has stuck to the surface, at the same time levelling out any high spots caused by slightly uneven sized strips. Be careful not to scrape away too much wood or the plank will become uneven (13-6).

7 Once all the planks are ready, they can be glued into one log. It is important to maintain the correct position of the planks. Not only must they be in the right order, but each one must be accurately placed above its neighbour, or the design will become distorted (13-7 and 13-8). Rather than gluing them all together at the same time, you may find it easier to glue two or three together first, carefully maintaining correct alignment. They are cramped between two pieces of flat wood, care being taken to tighten the cramps evenly all along, otherwise the width of the log will not be consistent. Remember to place some paper between the log and any wood used as cramping-blocks.

8 When the log is dry, it can be gently smoothed on a sanding board so that all four sides are both flat and square. Because the tiles will be following a circle rather than a straight line, the two sides of the log must be slightly tapered to ensure that the tiles pack closely together, and the top surface can be slightly rounded to conform to the circumference of the circle. This can be done now, before the log is sliced up, with a sharp plane and a sanding board or each tile can be individually shaped just before gluing it in position.

9 The log can now be cut up, ensuring that each tile is 2 mm thick. This is best done in a small mitre box (13-9 and 13-10).

Making the Central Motif – Method 2

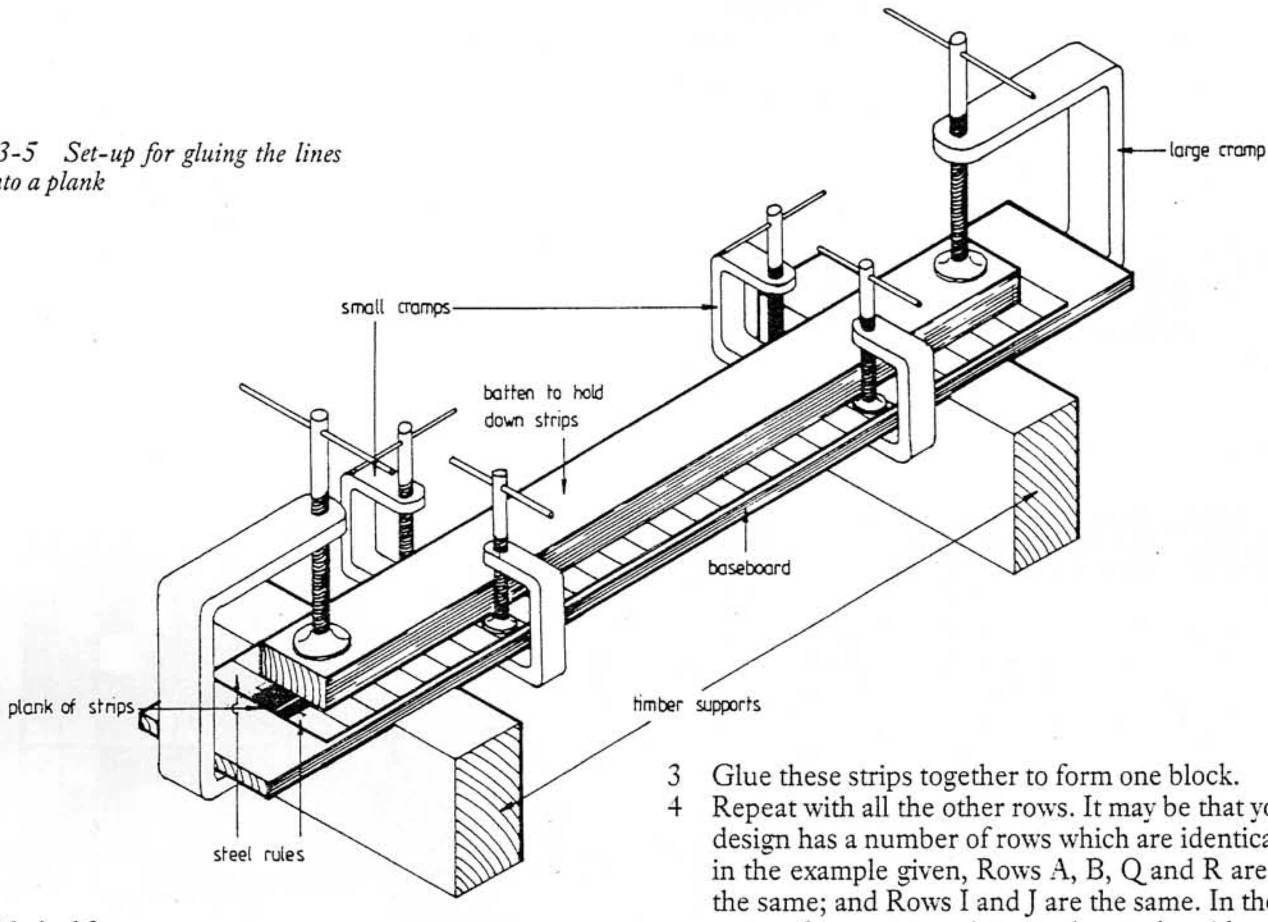
(using 0.6 mm thick veneer sheets)

Tools

Several small G-cramps
Two 300 mm steel rules (straight-edges)
Cabinet scraper
Wood blocks and battens as shown in the drawings

Materials

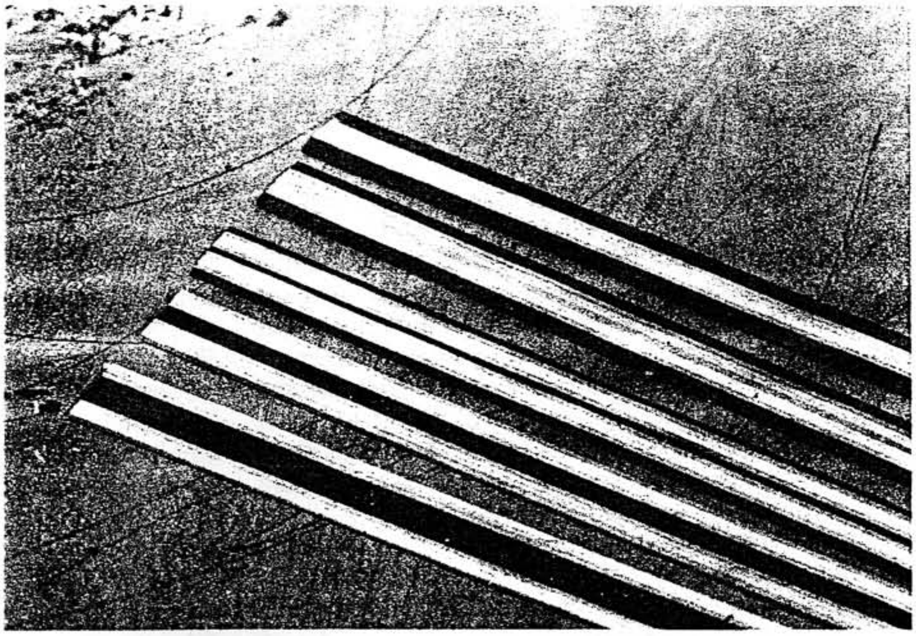
Sheets of 0.6 mm thick veneers in various colours and types.
Glue



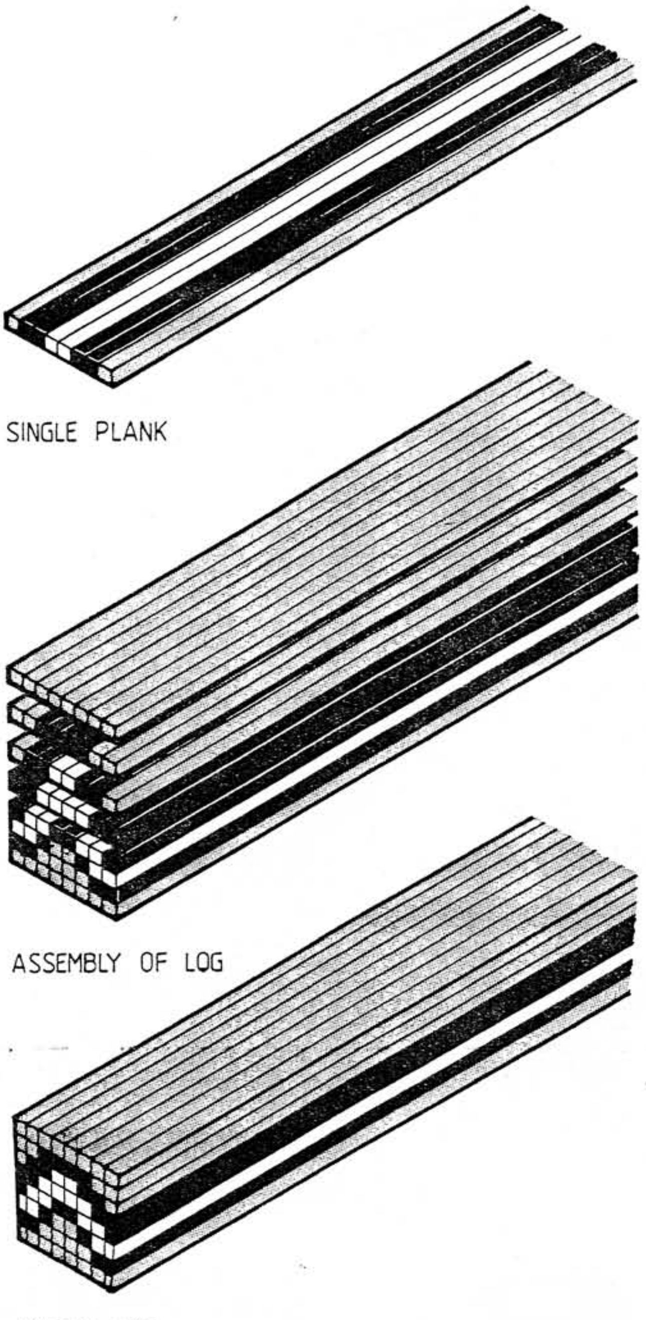
13-5 Set-up for gluing the lines into a plank

Method 2

1 Prepare a design on squared paper as described in Method 1 (pp. 186–8). In this case a greater number of squares can be used as each one will be almost half the size of those in Method 1. This means that a finer pattern can be created (13-11).
2 Cut strips of veneer at least 150 mm × 15 mm, to represent each square in Row A. (In this case, they will all be black.)
3 Glue these strips together to form one block.
4 Repeat with all the other rows. It may be that your design has a number of rows which are identical – in the example given, Rows A, B, Q and R are all the same; and Rows I and J are the same. In these cases, the veneer strips can be made wider, so that more slices can be taken off them.
5 When dry, each block must be planned straight and square, so that thin strips, about 1.5 mm thick, can be cut accurately from them. This can be done on a bandsaw, or by hand (13-12).
6 Each strip must now be scraped flat, and to a final thickness of 0.6 mm. This can be done as shown in (13-12) where two pieces of 0.6 mm veneer are



13-6 Planks scraped clean and smooth – ready for gluing into a log



13-7
The planks are glued together to form a log, which is then tapered so that the tiles will butt together around a circle

stuck on to a board with double-sided tape, leaving a gap between them, in which the strip is placed. The scraper plane or cabinet scraper can then be used to level down the surface until it is flush with the two pieces of veneer packing which surround it.

7 The planks must now all be glued together, as in Method 1, making certain that they are correctly aligned vertically.
8 The log is then planned and sanded flat and square, its sides tapered, and finally it is sliced up into individual tiles (see Method 1 above).

Having followed either Method 1 or Method 2, you will now have enough tiles to complete the central section of the rosette.

Making the Borders

Traditional rosette designs often include matching patterns which surround the central motif; these can be made up in a similar way to the central motif, but are usually narrower.

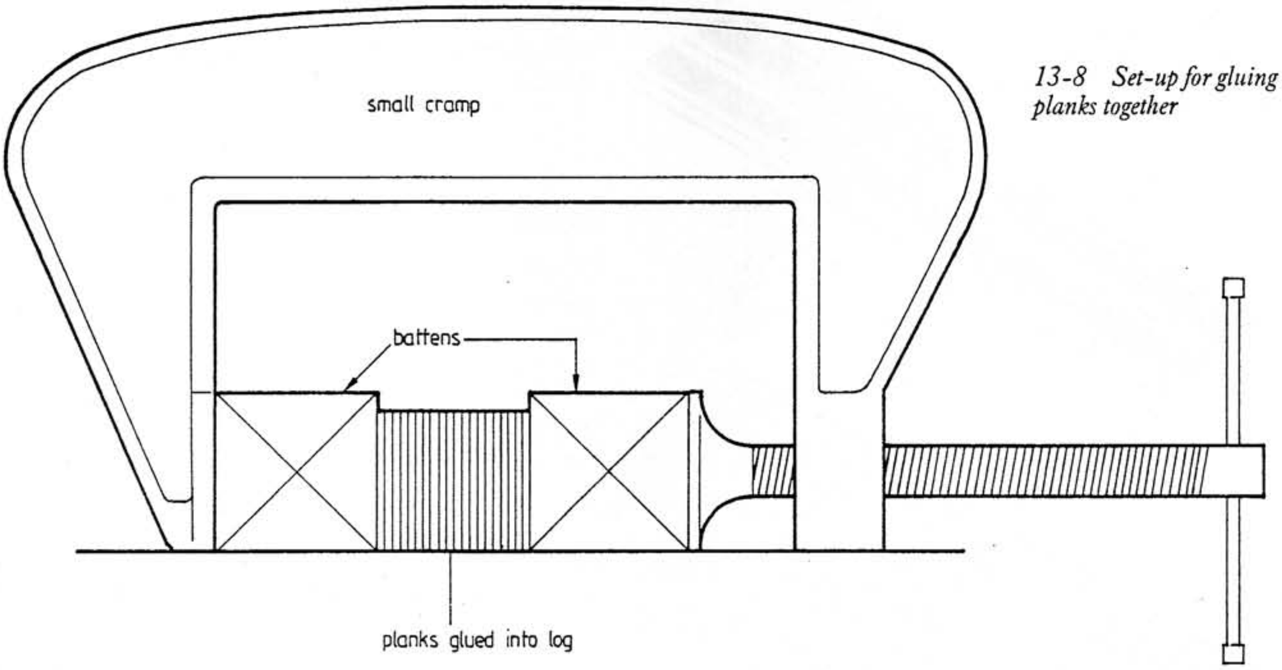
Many rosettes use a border of herringbone-patterned purfling which can be bought ready-made, or constructed as follows:

Making Herringbone Purfling

Materials
0.6 mm veneer in contrasting colours; e.g. black and white
Glue

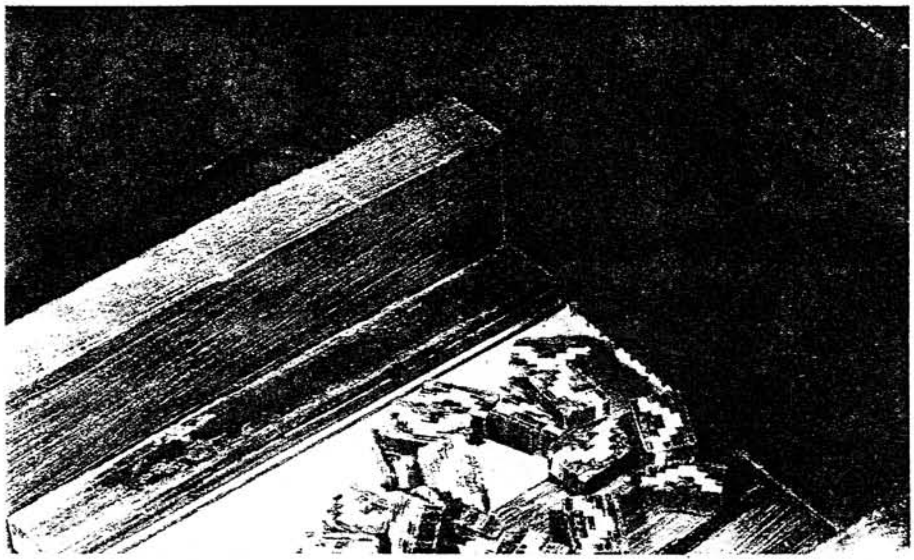
Method
1 Cut a number of strips of 0.6 mm thick veneer; each strip should be about 150 mm × 25 mm. Make up groups of eight white strips and eight black strips, and glue each group into a stack. Continue until there are enough black stacks and white stacks to form a reasonable length.
2 Glue the stacks together, in a stepped formation, alternating black and white. They can be clamped together between two flat pieces of wood (13-13).
3 When dry, plane off the steps, to give a flat surface and plane the sides of the block square.
4 Cut a strip off the block – the thickness of the strip will determine the width of the herringbone – anything between 0.6 mm and 1.0 mm (13-14).
5 Plane the main block flat again, and cut off a second strip (13-15).
6 Smooth all the sides of the two strips, and glue them to each other, matching the dark and light areas of both strips. (A thin veneer can be glued between the two strips of herringbone. This makes it less important to match the pattern so precisely.)
7 (Added strength, and further decoration, can be achieved by now gluing strips of veneer to either side of the herringbone.)
8 Slices (1.5 mm to 2.0 mm) can now be cut off for inlaying into the rosette (13-16).

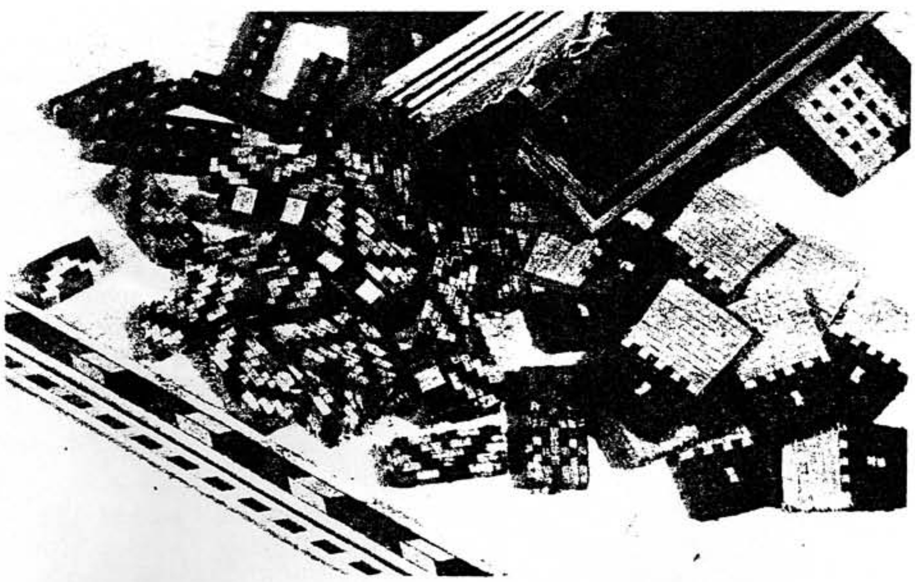
Having made both the central motif, and the inner and outer borders, you are now ready to start preparing the soundboard. The actual inlaying of the various sections of the rosette will be explained in the following chapter.



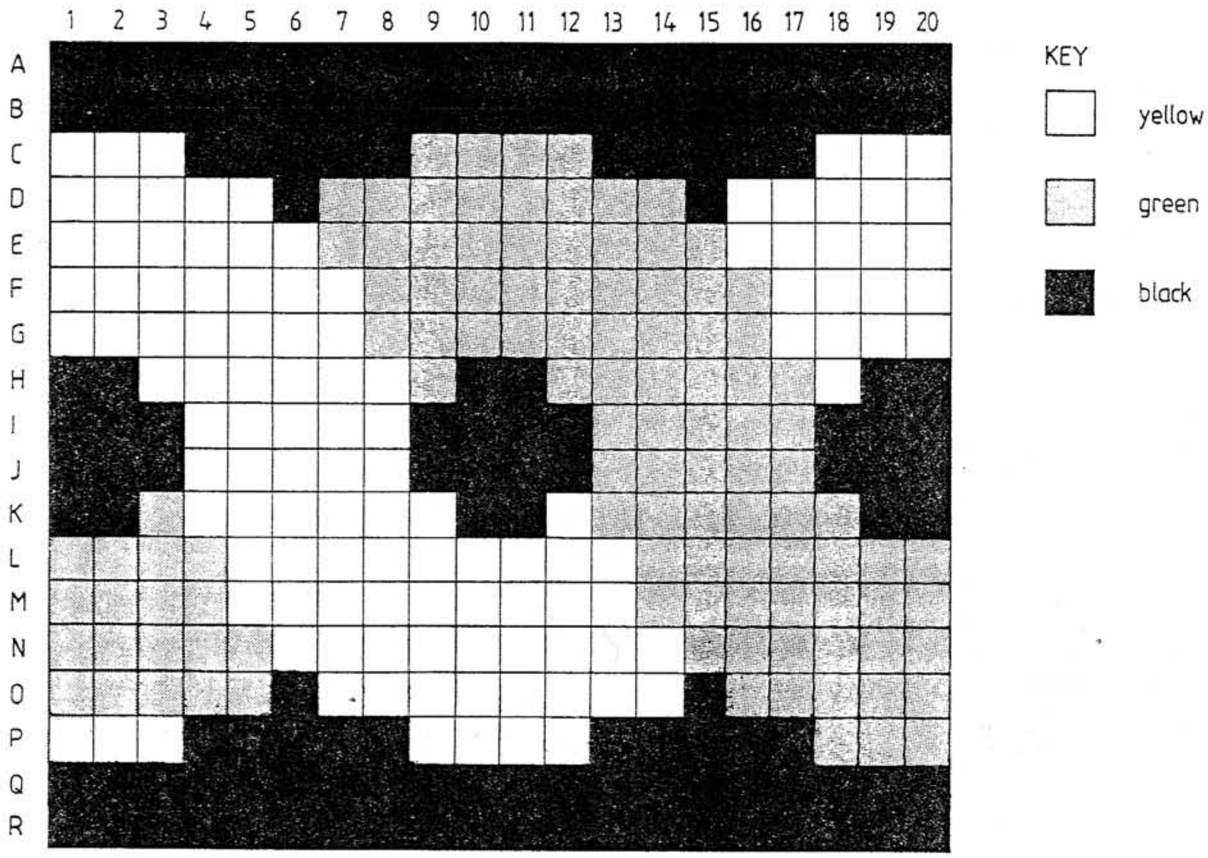
13-8 Set-up for gluing the planks together

13-9 Sawing the log into 2 mm thick tiles



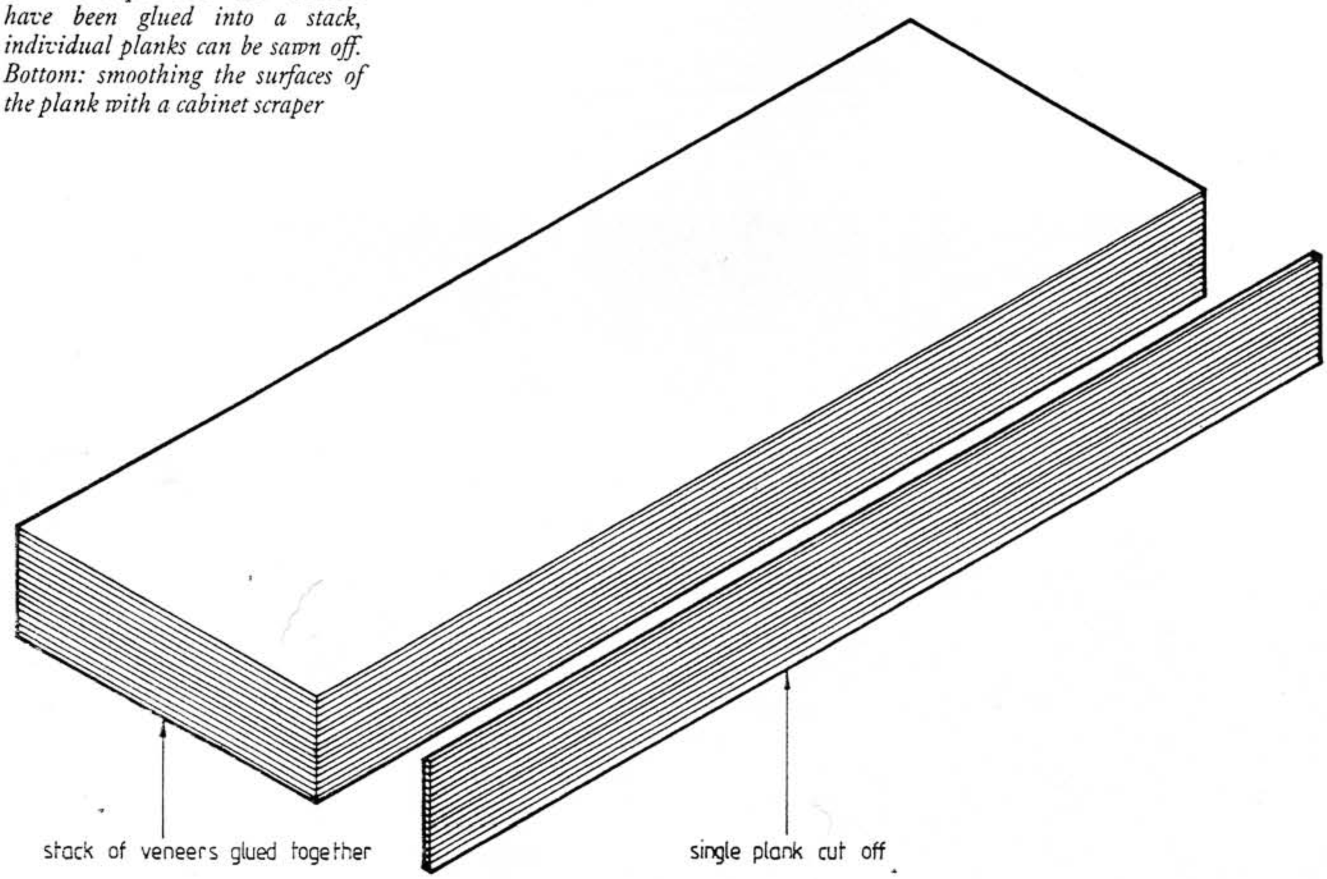


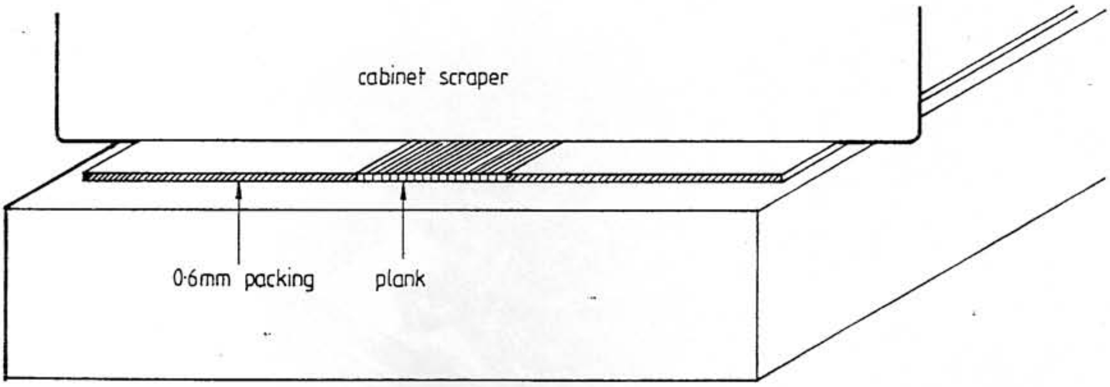
13-10 A collection of logs and tiles, ready for inlaying into the soundboard

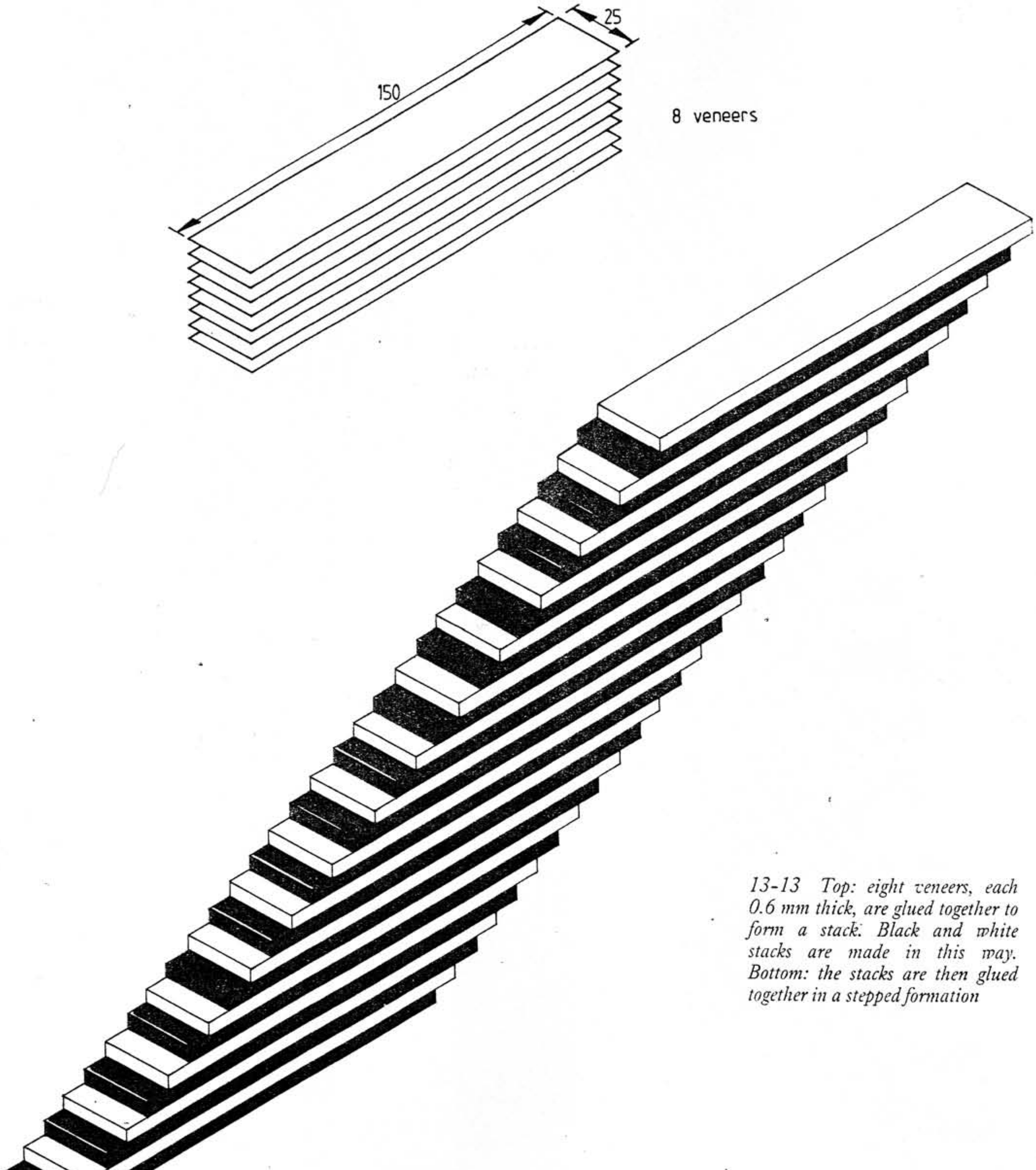


13-11 This 'rope' motif can be made from sheets of 0.6 mm thick veneer

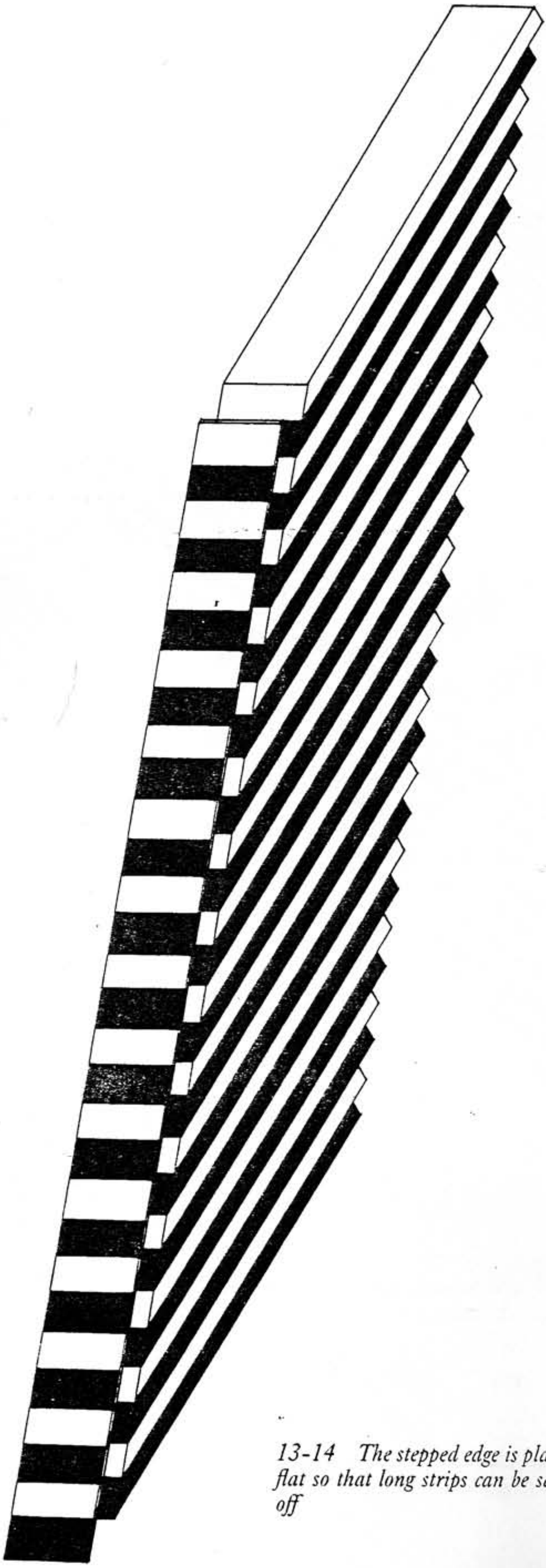
13-12 Top: once the veneers have been glued into a stack, individual planks can be sawn off. Bottom: smoothing the surfaces of the plank with a cabinet scraper



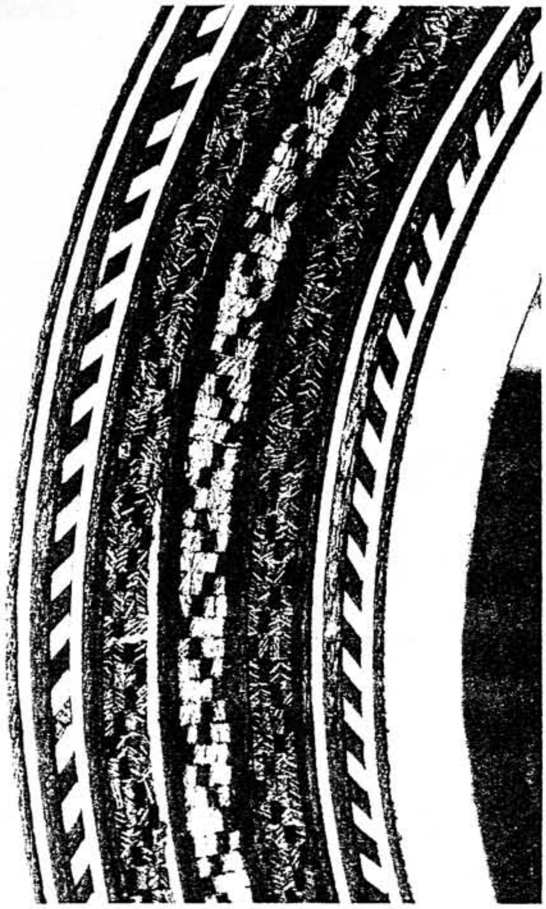




13-13 Top: eight veneers, each 0.6 mm thick, are glued together to form a stack. Black and white stacks are made in this way. Bottom: the stacks are then glued together in a stepped formation

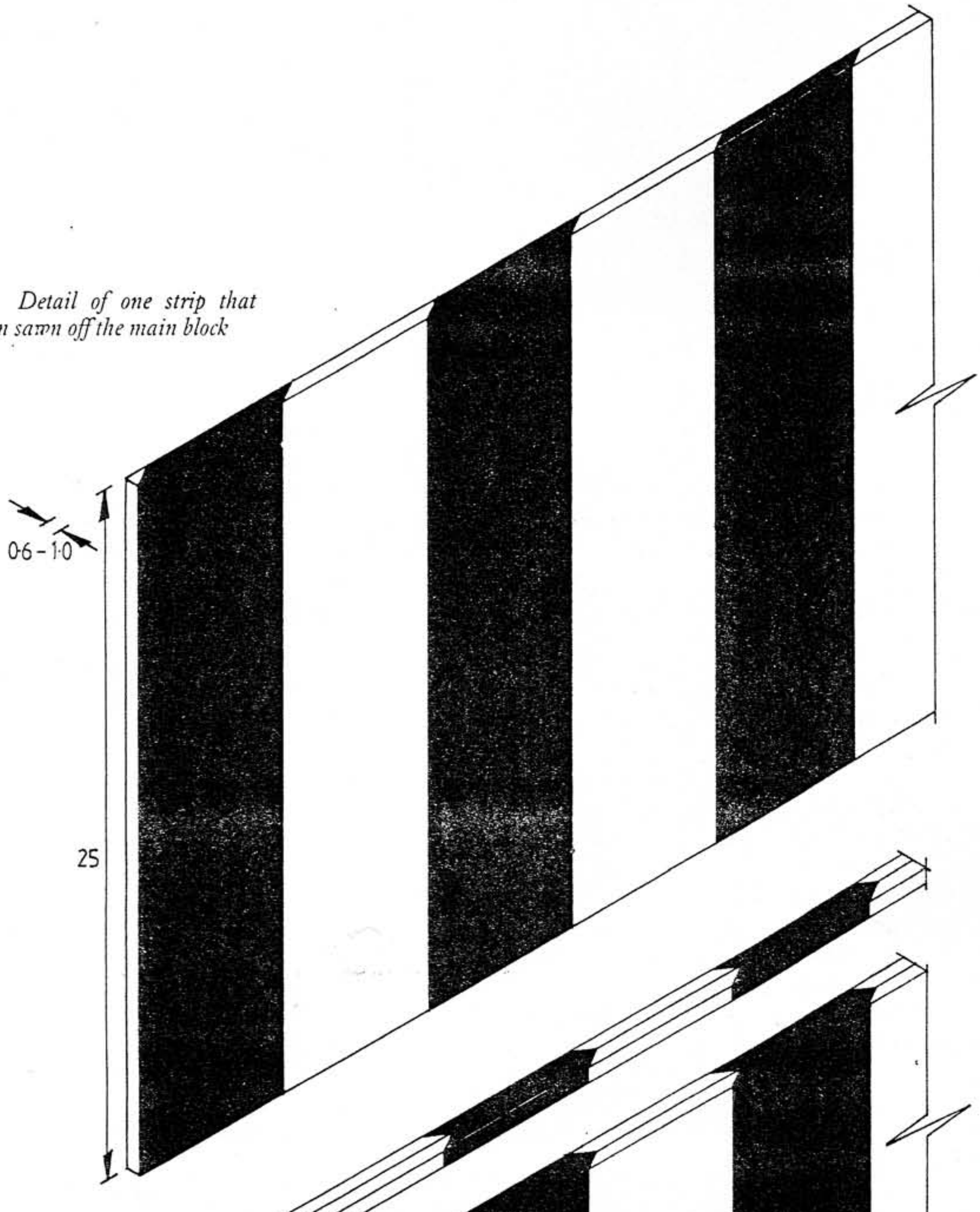


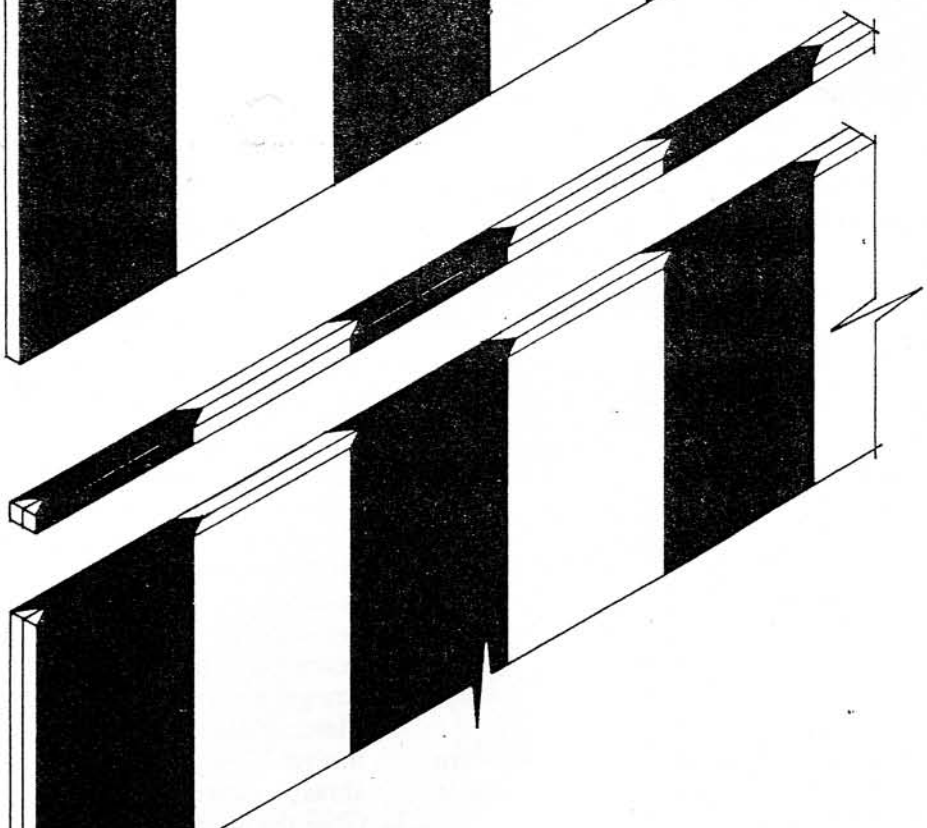
13-14 *The stepped edge is planed flat so that long strips can be sawn off*



13-17 *Section of a rosette featuring three rows of end-grain motif with half-herringbone borders by Jacob van de Geest*

13-15 Detail of one strip that has been sawn off the main block





13-16 Two strips have been glued together so that lengths of herringbone purfling (about 2 mm thick) can be sawn off and inlaid

14 Soundboard

Each maker approaches the construction of the soundboard in a different way – it is probably the one component about which the strongest views are held. Previous experience leads to certain conclusions, and these then become 'rules' for the future. The problem is that it is virtually impossible to define a particular characteristic as being responsible for a certain outcome – cause and effect are difficult to establish, simply because there are so many contributing factors to the final sound of the instrument. Some attempts have been made to define the scientific principles involved in tone production, but the reality is that the best guitars are still those made intuitively. The suggestions in this chapter concerning thicknessing, tension, stiffness, and so on, should therefore be seen as but one view among many. If you develop your own sensitivity to the material, you will form your own conclusions about how to obtain the optimum tonal response.

Tools

Smoothing plane
Straight-edge
Scraper plane
Cabinet scraper
Thicknessing caliper
Sash cramps
G-cramps
Circle cutter
Drill to match circle cutter
Chisels

Materials

Quarter-sawn spruce or cedar soundboard, two halves, book-matched (two pieces each 520 mm × 200 mm × 4 mm)
Rosette; either ready-made, or individual tiles and borders made up previously (see Chapter 13)
Glue

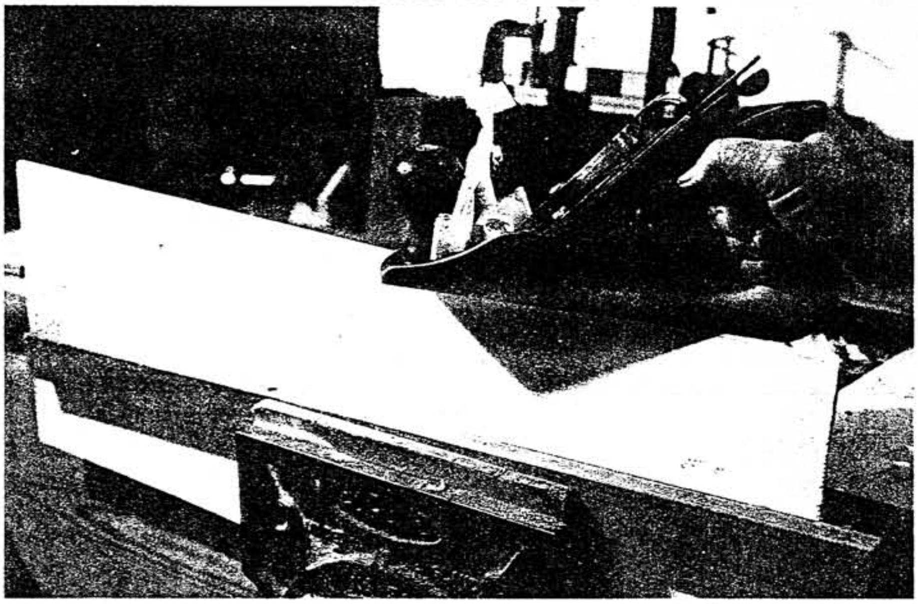
Method

Prepare the soundboard

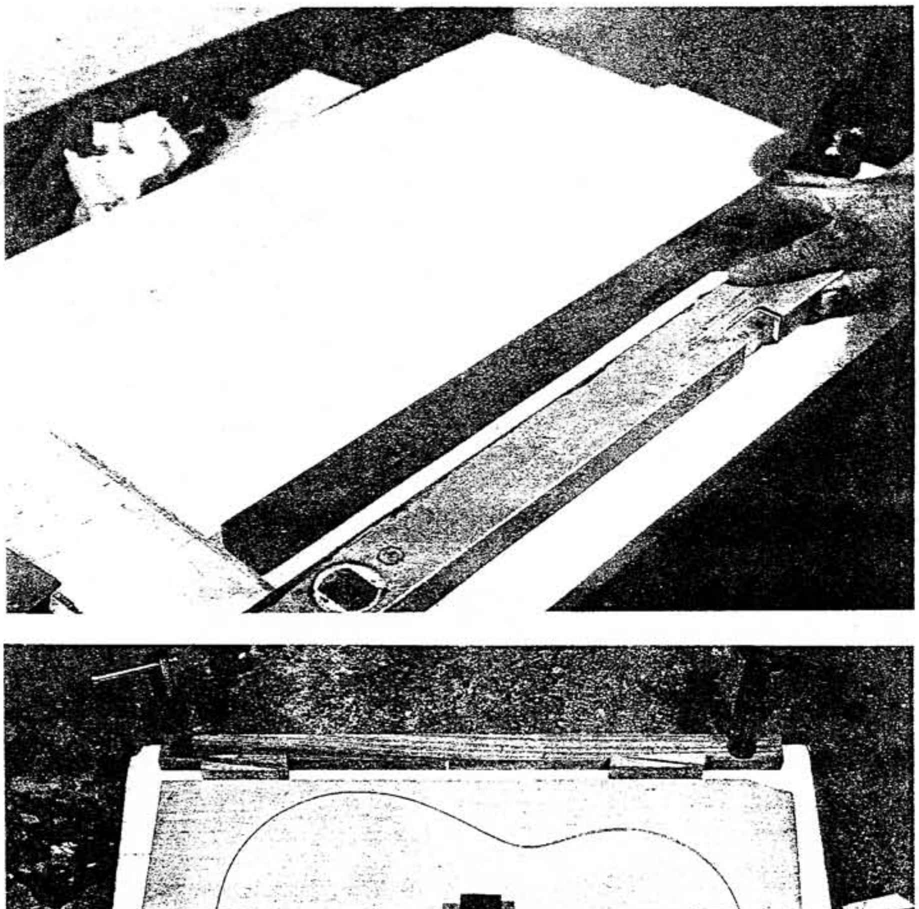
1 The soundboard is supplied in two matching halves, which must be glued together to form one board. The thickness of most commercially supplied boards is between 4 mm and 5 mm. The surfaces will be quite rough, making it difficult to distinguish the grain lines and colouring. The first step is to fasten down each half separately, and lightly plane it until smooth all over. This will reveal the grain pattern, and made it possible to match up the two halves so that they are perfectly symmetrical. If a long strip of wood is cramped to one edge of the soundboard, it is possible to plane right along the surface. The board can then be turned round so that you can reach the section that was hidden under the strip. Remove the minimum amount of wood, to obtain smooth, clean surfaces. The soundboard needs to be left as thick as possible at this stage, so that the rosette can be safely inlaid to a depth of between 1.5 mm and 2.0 mm, without any danger of cutting right through.

2 Place the planed wood on to a flat work-board, and position the two halves so that each is a mirror-image of the other. You will notice that the grain is closer together on one side of the boards than the other. The wood is stiffest and strongest where the grain is closest, and for this reason it is best to make the join along the close-grained sides. This will become the centre of the soundboard, where the pull of the strings exerts most force. Cramp a straight-edge along the narrow-grained sides of each board, and scribe a guideline all along. It may be possible to make the guideline follow one particular grain line in the wood. If you select the identical, matching grain line on both halves, they will glue together without any sign of where the join was made. However, many boards have a more curved grain pattern, so this may not be possible. Bear in mind that the centre-line in the upper area of the soundboard will be hidden, either by the fingerboard, or by being cut out to form the soundhole. The most important part in which to obtain an invisible join is therefore the lower bout to end-block area. Support each board vertically between two battens held in a vice, and plane down to the line (14-1). Check with a straight-edge that the planed surface is flat. Match the gluing edges up on the workboard. If further levelling is required, use a spirit-level with abrasive paper glued to its edge (14-2).

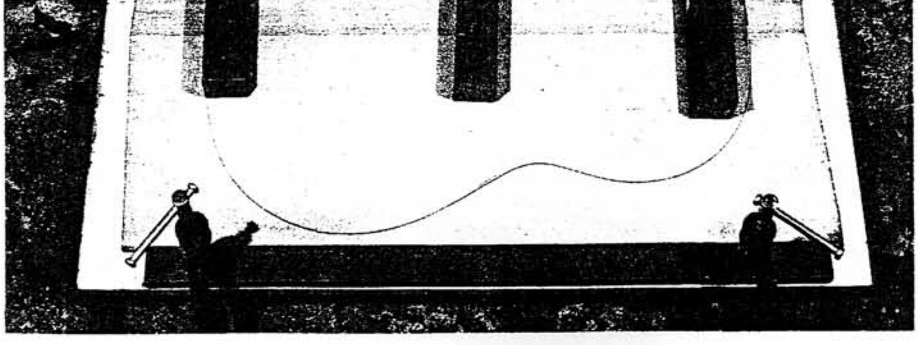
3 Glue the soundboard together with sash cramps, or battens and wedges (14-3). Place a strip of paper under the glue join. Very little pressure is needed to bring the two halves of spruce together,



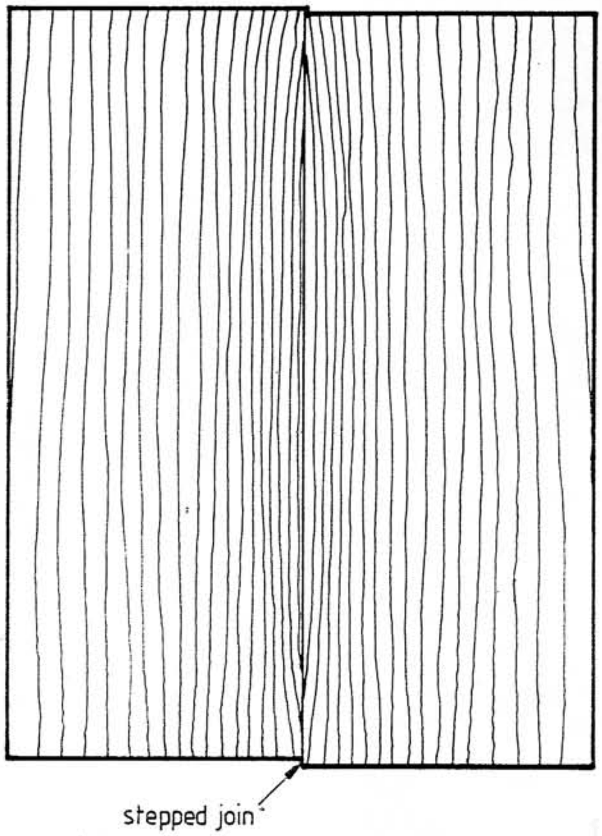
14-1 Two battens support the soundboard so that the gluing edges can be planed flat



14-2 Using the spirit-level sander to level the edges



14-3 Gluing the two halves of the soundboard together with wedges and weights as the wood is very soft. The join should be totally invisible, so it helps to stagger the two boards slightly – 1 mm is enough – so that the centre can easily be found (14-4).

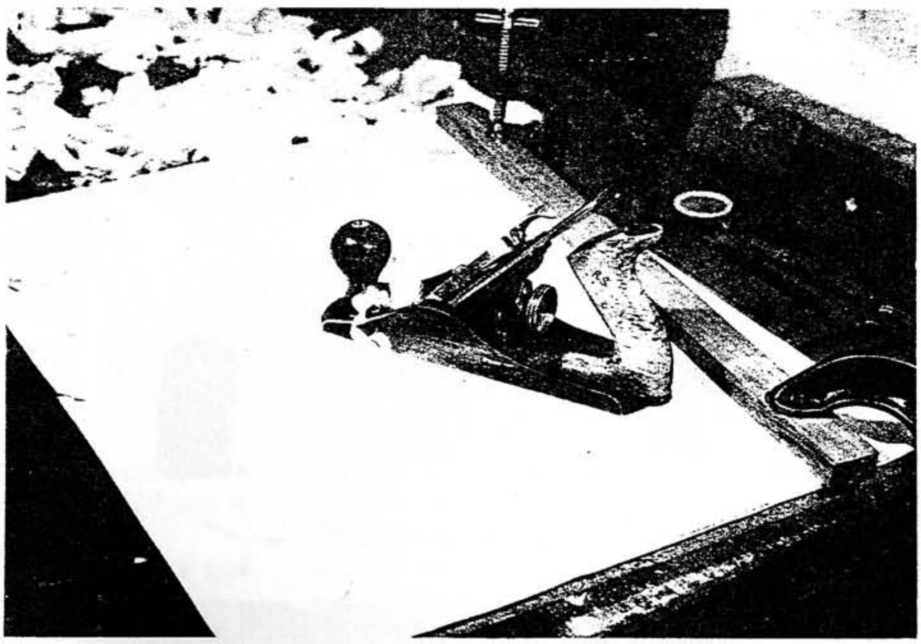


14-4 The two halves of the soundboard are slightly off-set so that the join can later be located

4 When dry, plane lightly to level the board, and check that the centre join is perfect (14-5). Decide which surface should become the outer one. Any obvious visual faults will be best concealed on the inside of the guitar. The soundboard needs some tension built into it, and this is usually achieved by doming it when the fan struts and bars are attached. If it has already taken up an arched shape at this early stage, then the various bars will not really add any further stiffness to the overall structure. It would then be better to turn the board over, and use the 'concave' side as the outer surface. From now on, make certain that the soundboard is always worked on a clean, smooth workboard. The soft spruce or cedar will be damaged very easily by virtually any of the other woods. The chosen outer surface must now be made absolutely smooth and level.

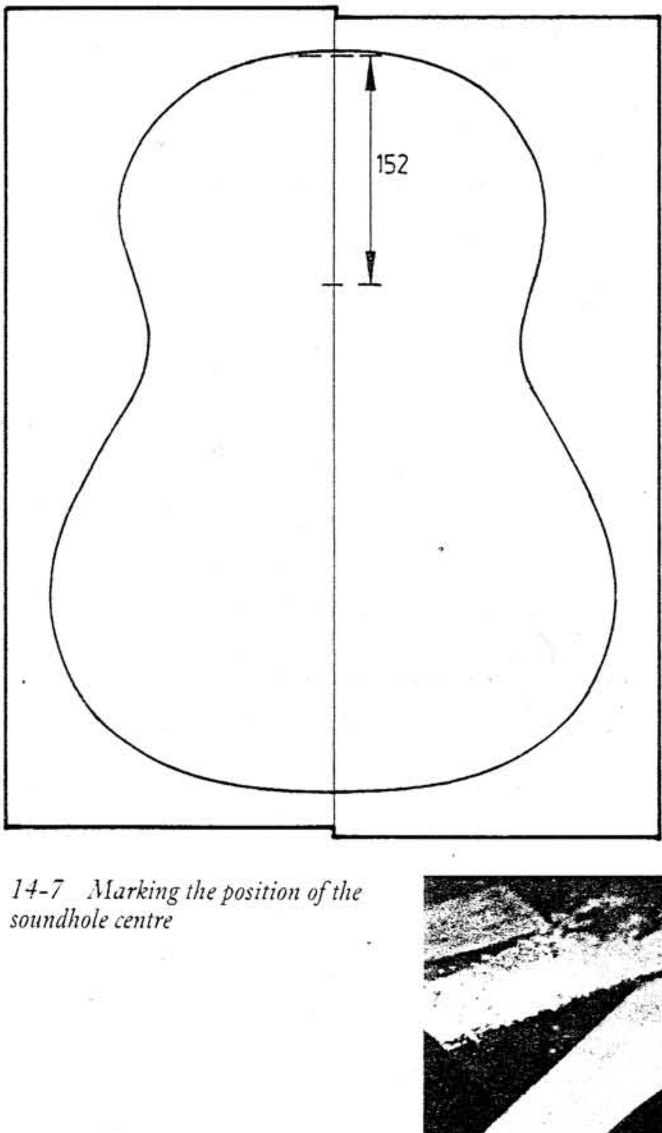
It is at this stage that you will begin to become familiar with the characteristics of your particular soundboard – it may become evident that all planing on one side of the centre-line must be done in a certain direction, while the other side requires the plane to be reversed. This means that every time the plane crosses the centre-line, it will gouge out some wood on the other half. Try planing diagonally across the entire board. Eventually, you may have to use a scraper plane and then abrasive paper. This is a feature of the grain structure, and it varies considerably from one board to another. Examine the surface carefully in natural daylight, to ensure that no deep scratches have gone unnoticed. Check also that the soundboard is flat across its width. Once this outer surface is virtually perfect, brush away all dust, and seal the surface with a coat of sanding sealer.

14-5 A long batten cramped at one side of the soundboard allows the smoothing plane free access to most of the surface



Inlaying a ready-made rosette

1 Mark the centre-line at both ends of the soundboard – do not draw it all along as it will damage the surface. Lay the half-template of the plantilla against the centre-line and draw round it (14-6). Mark the centre of the soundhole. The distance from the centre of the soundhole to the neck-end of the plantilla is given on each soundboard plan, and this varies from one guitar to another, as they do not all have the same soundhole diameter (14-7).



14-7 Marking the position of the soundhole centre

2 A ready-made rosette should first be set dry into a groove cut in a scrap of plywood. This will enable you to be quite certain that the width of the recess has been accurately calculated. Place a rule across the rosette, and find the widest points, for both the inner and the outer diameters. Divide these distances in half, to obtain the radii, and adjust the circle cutter accordingly. Drill a hole in the scrap of plywood, to match the bolt on the circle cutter. The fit must be tight, so that an accurate circle is formed. The bevel on the blade must face the correct way for each cut, that is, towards the inner, waste area. The vertical cut must be on the outer circumferences of the rosette (14-8). Cut the circles, gradually increasing the depth of the blade, until a depth of 1.5 mm to 2.0 mm is reached. (Measure the rosette thickness, and aim to set it almost flush with the surface of the soundboard.) Remove the waste between the two circles with a chisel or a router. Try the rosette in place. The groove may have to be increased in width if the rosette will not fit. If there are large gaps around the inner or outer circumferences, make a new test groove. Once you have a groove into which the rosette fits accurately, it is a simple matter to set the circle cutter, using the test groove as a guide. You can then cut the actual soundboard with confidence.

3 The soundboard should be cramped firmly to a workboard. Drill a hole through the centre of the soundhole position, of exactly the same diameter as the centre bolt or pivot pin of the circle cutter. Greater accuracy will result if the first hole is of a smaller diameter, and acts as a pilot hole. The hole must extend through the workboard as well, so that the bolt of the circle cutter can pass through.

14-6 Marking the plantilla on to the soundboard

4 Set the circle cutter to match exactly the inner diameter of the rosette, and cut a line right round, starting nearest the upper end of the soundboard (near the fingerboard position).

5 Now set the circle cutter to the outer diameter, and cut this circumference. Both cuts should be almost the full depth of the rosette's thickness. Remember to position the bevel of the blade the correct way (14-8).

6 Pare away the waste between the two cuts, using a sharp chisel, until you have created a groove that is clean and flat. Place the rosette in it. If you have carefully followed the settings on the test circle, the rosette should fit first time. If it is too tight, adjust the circle cutter slightly, and make another cut, to increase the width of the groove.

7 When the rosette fits, spread glue into the groove, and place the rosette into it. Wipe away any excess glue, cover with paper, and place a scrap of plywood over the rosette. A weight can be put onto this, and left until the glue has dried. Another method of applying pressure while the glue dries is to cut a circle of plywood, through which a bolt and wing nut are passed.

8 Let the glue harden thoroughly before any cleaning up is done – soft glue will tend to pull up the grain of the spruce if scraped or sanded. Remove the coverings, and carefully clean up the rosette with a cabinet scraper. Abrasive paper can also be used, but it may spread the dark-coloured rosette dust into the grain of the spruce. Continue until the rosette is flush with the soundboard. Once this entire outer surface of the soundboard is absolutely smooth and clean, seal it with a thin coat of sanding sealer. This will protect it, and prevent any stray glue and dust from discolouring the spruce.

Inlaying a rosette you have made (See Chapter 13)
Having prepared the various components of the rosette – a log for the central motif, and herringbone or other borders, you are now ready to inlay each individual piece into the soundboard.

1 If you have not already done so, slice up the logs into separate tiles, each 2.0 mm thick, and rub each tile on a flat sanding board so that its gluing surface is level.

2 Place the half-template of the plantilla on to the soundboard, positioned exactly on the centre join, and draw round it (14-6). Measure the distance from the neck-end of the plantilla to the centre of the soundhole, and mark this point accurately on the centre-line of the soundboard (14-7).

3 Set a pair of compasses to mark the distances from the centre of the soundhole to:
(a) the edge of the soundhole
(b) the positions of the various elements of the rosette

Mark sharp pencil lines for these distances, just for about 25 mm at the top (fingerboard end) – there is no need to mark all round (14-9).

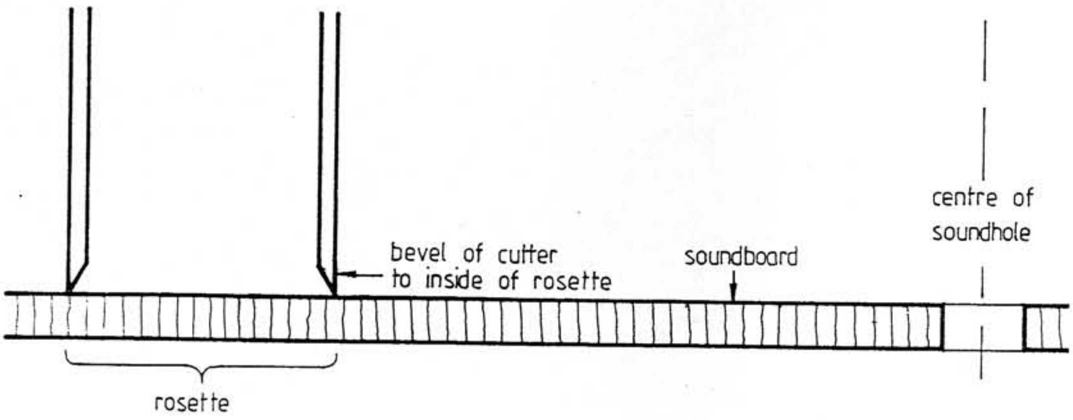
The various rings of tiles are best inlaid separately, in this order:
central ring of tiles
lines to border it on both sides
outer ring of tiles, or herringbone
lines to border it (outer edge of rosette)
inner ring of tiles, or herringbone
lines to border it (inner edge of rosette)

4 Set the circle cutter to the inner edge of the central ring of tiles, and cut around the circle. Make certain that the bevelled side of the blade is facing the waste area (14-8). Place a tile against the line, and mark the position of its other side. Set the circle cutter to this distance, and make another cut (14-10). Remove the waste with a narrow chisel, to a depth just slightly less than the thickness of the tiles (14-11). There is no need to inlay the rosette in the area that will be covered by the fingerboard – mark the width of the fingerboard, and start the excavation about 10 mm in from this position (14-12).

5 Starting one side of the fingerboard position, begin inserting the tiles (without glue) one at a time (14-13). The taper of each tile must be checked, and altered if necessary, until each one fits accurately against its neighbour (14-14). Use a flat sanding stick. It may also be necessary to round the top of each tile so that it matches the circular shape of the groove, although this is unnecessary if the tiles are not too wide. You should also place a straight-edge against each tapered edge, to see if it aligns with the centre of the circle. Otherwise, any inaccuracy will increase, and the pattern become distorted.

6 When the tiles are in place half-way round the circle, it may become clear that the tile covering the centre-line of the soundboard is not symmetrically placed in relation to the centre-line. Its position can easily be adjusted by increasing the area of groove at the fingerboard end, so that all the tiles move round a couple of millimetres (14-15). Continue inserting tiles until the groove is filled, and then number each tile on its upper surface with a soft pencil. (This is only necessary for large tiles – smaller, border tiles should butt together without needing individual fitting of one to the next.) Remove the tiles, keeping them in order, and place them in a row on the soundboard.

7 Spread some glue into the groove, and push the tiles in place. A blunt chisel or screwdriver is useful for butting the tiles close together. Continue until all the tiles are fitted, and then check once more that they are all firmly bedded into the groove. Wipe away excess glue, and leave to dry.



14-8 The bevel of the circle-cutting blade must face the inner, waste area of the rosette

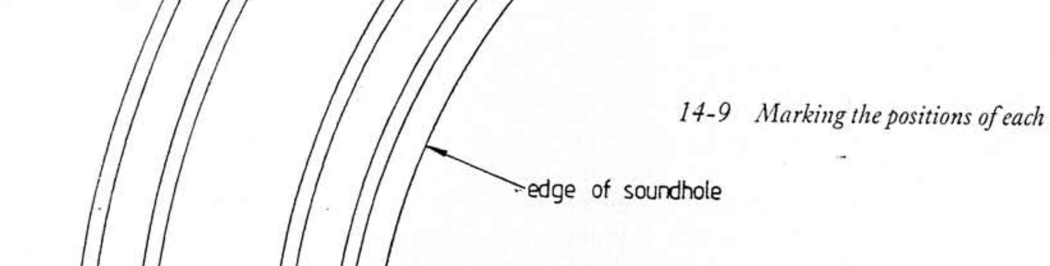
8 Great care must be taken when smoothing the tiles down to the level of the soundboard – their surfaces will be uneven, and the first step is to level the tiles themselves. Use either a hard, flat sanding block, a chisel, or a scraper plane and cabinet scraper, but beware of breaking the edges of the tiles. The surface must then be brought down flush with the soundboard (14-16).

9 The central motif is usually separated from the border motif by one or more lines of inlay. These can be 1 mm × 1 mm strips, manufactured purfling, or thin strips of veneer. The circle cutter must be adjusted to mark a suitable groove, and the waste removed with a narrow chisel. The strips are then glued in place, and left to dry (14-17). Many types of wood will bend round the circular shape without snapping, but hard, brittle woods like rosewood or padauk will have to be pre-bent on the bending iron.

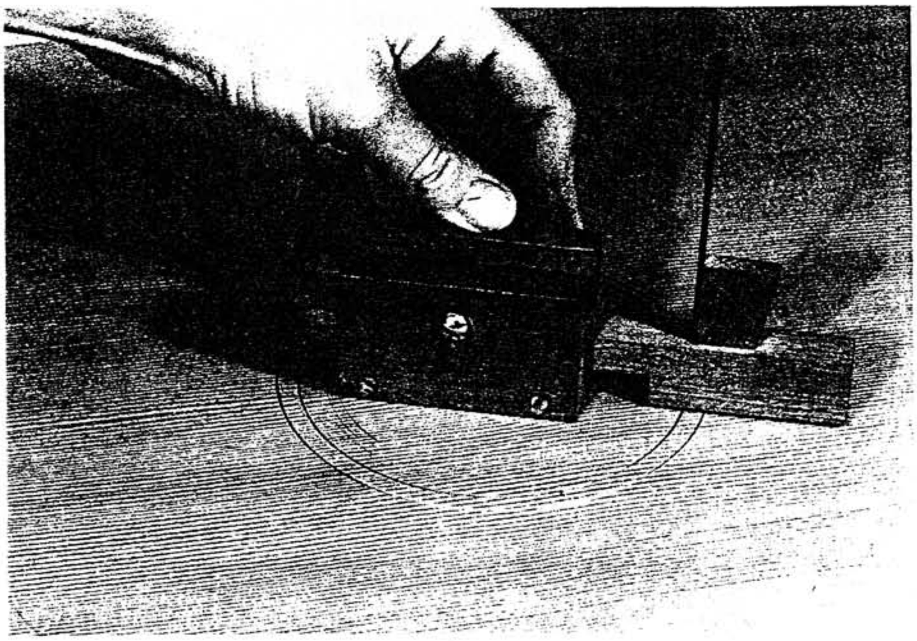
10 The rosette is completed by repeating this procedure for each ring of tiles and lines (14-18 and 14-19). When all the inlays are in place, sand and scrape the entire soundboard until it is smooth and flat all over. Seal with a coat of sanding sealer. Do not cut out the soundhole at this stage.

Thicknessing the soundboard

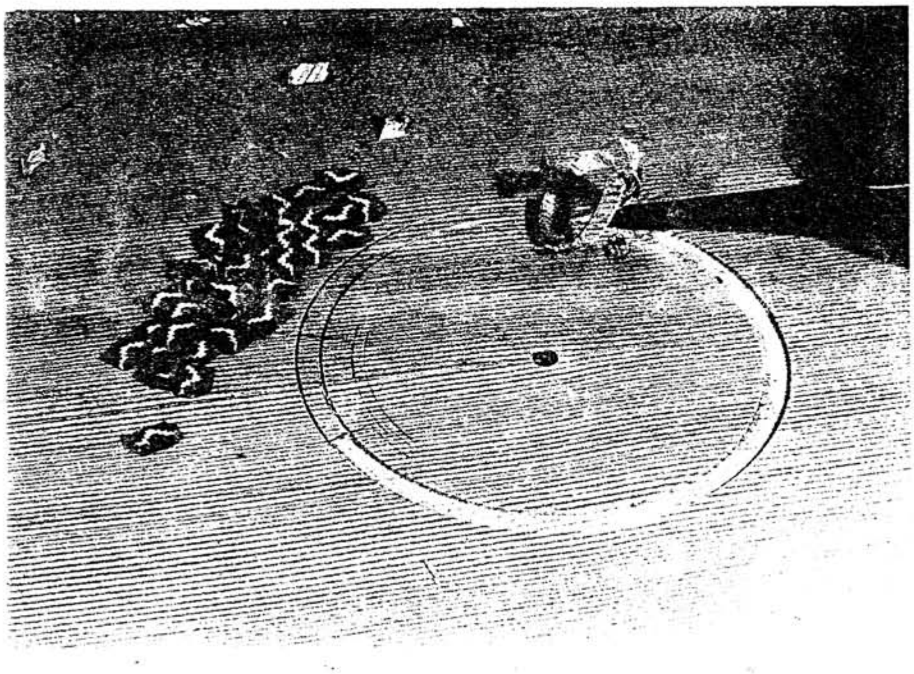
The final thickness of the soundboard will to a very large extent determine the character of the guitar. The procedure itself is quite straightforward – a smoothing plane and cabinet scraper are used to gradually remove wood from the reverse of the soundboard, until the optimum thickness has been reached. First decide whether the board is particularly stiff, or rather flexible; hold it up in both hands, and bend the sides up and down slightly. A stiff board is a strong board, and can therefore be



14-9 Marking the positions of each rosette component

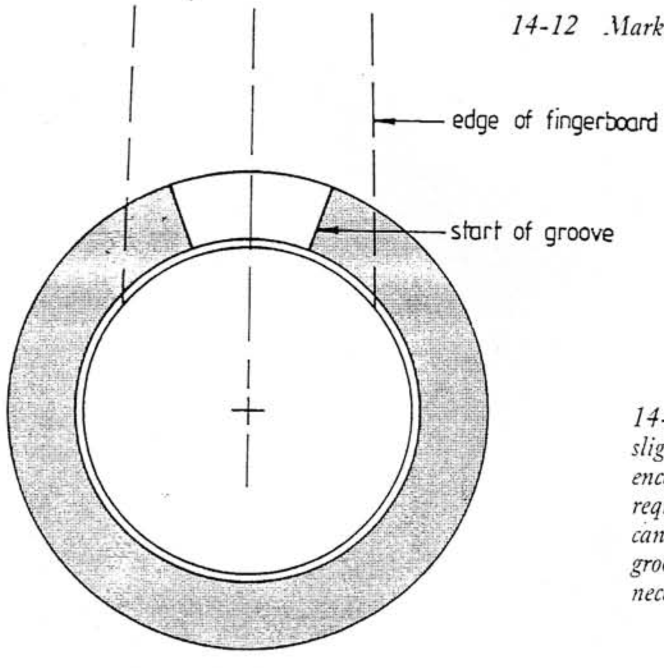


14-10 Cutting the groove for the central motif tiles

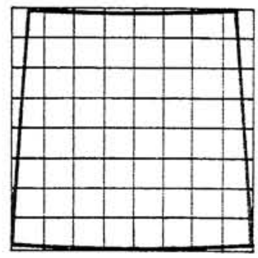


14-11 Removing the waste with a narrow chisel. The groove will be 1.5 mm to 2.0 mm deep, so that the tiles can be fitted almost flush with the surface

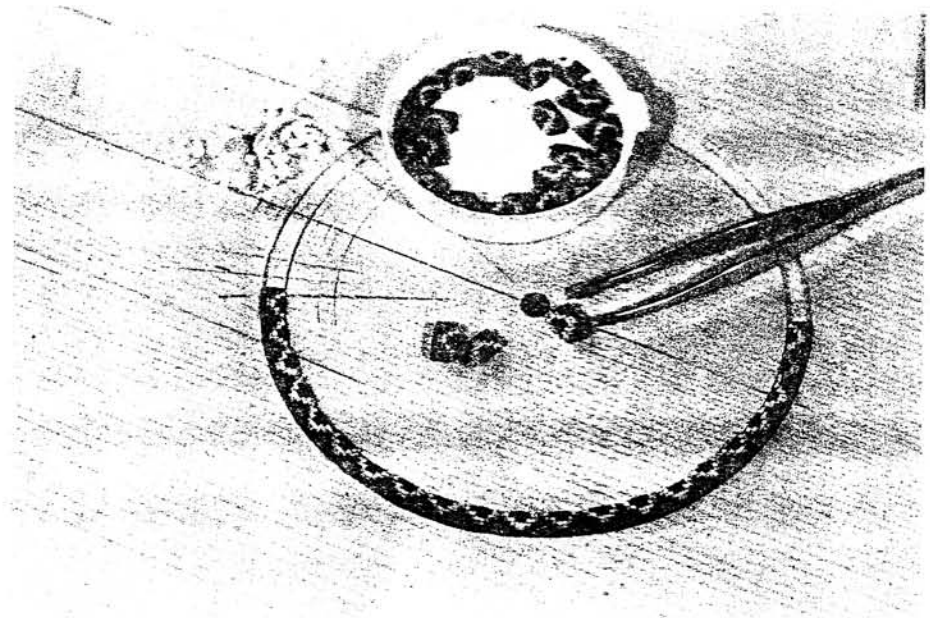
made thinner than one which is floppy before you start thicknessing. Grip one corner of the soundboard, hold it up close to your ear, and tap it firmly with a knuckle. Tap it all over, and build up a mental picture of the vibrancy produced, as well as the level of the note. As the board becomes thinner, the note produced will become lower, and this should be constantly checked as the planning progresses. Most soundboards reach an optimum degree of flexibility and vibrancy when they are approximately 2.5 mm thick. You must remember, however, that the strutting will greatly restrict this free movement of the soundboard, and the aim of the strutting is to channel the vibrations, creating a balanced response from the lowest to the highest note. The finer points of thicknessing involve reducing certain areas of the soundboard below this 2.5 mm average. A common view is that the central area, where the bridge is fixed, should be the thickest, as the pull of the strings is greatest. The periphery can be taken thinner, except that the treble side of the lower bout is often thicker than the bass side. The idea is that strong treble notes are produced from a more substantial area of wood, whereas vibrant basses can be best achieved from a thinner area. Some makers, however, prefer a more unified, symmetrical approach, and maintain the same thickness throughout. The choice must be based on your own feeling about the soundboard you are using, as well as your vision of the ideal instrument (14-20).



14-12 Marking the start of the groove



14-14 Each tile must be tapered slightly towards the inner circumference. Some shaping may also be required top and bottom so that the tile can follow the circular edges of the groove. (With small tiles, this is not necessary)



14-13 Inserting the tiles for the central motif

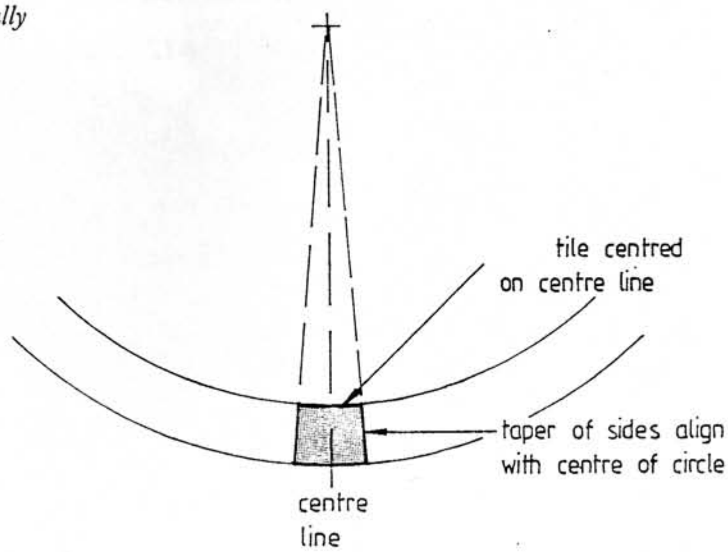
1 Cramp the soundboard face down, to a clean, smooth workboard, using a long batten down one side (14-5). Plane the wood either in straight sections, working your way gradually across the board, or diagonally, if the grain tears. Make frequent measurements with the thicknessing caliper, reducing the entire soundboard to no less than 2.5 mm thick.

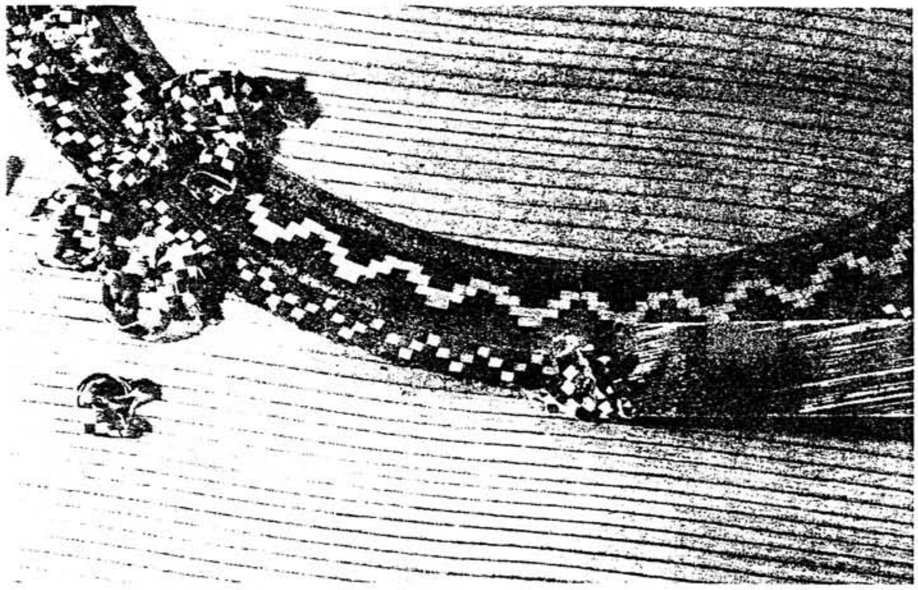
2 The final thicknessing is more easily done if the soundboard is first cut roughly to shape. Use the template to draw the body outline, and cut this out, allowing 20 mm extra for trimming off later.

3 If you want to reduce the thickness further, make pencil marks to define exactly which parts are still too thick, and carefully remove more material with a cabinet scraper. The minimum thickness at any area should be 2.0 mm. Check frequently with the thicknessing caliper, and, more importantly, keep tapping and listening. Finally, sand the entire surface smooth, ready for the strutting to be glued in place.

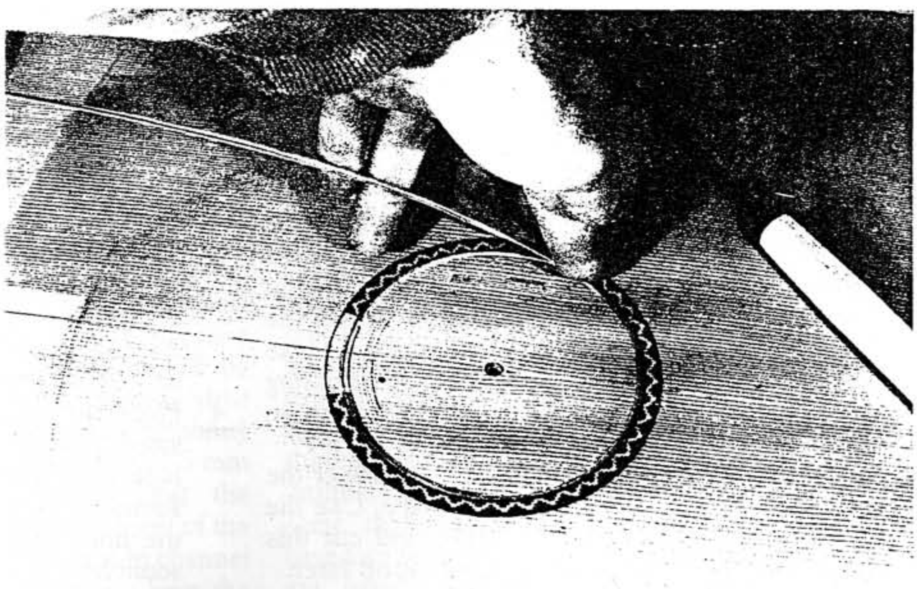
4 Place the soundboard rosette-side down on a smooth surface. Before cutting out the soundhole, draw a centre-line all along the back of the soundboard. It must pass through the centre of the hole used by the circle cutter. (Once the soundhole is cut, it will no longer be easy to find the centre-line if it has not already been marked.) Turn the soundboard over. The circle cutter is now adjusted to remove the soundhole – usually a

14-15 To retain the symmetry of design, the tile that falls on the centre-line of the soundboard should be positioned centrally

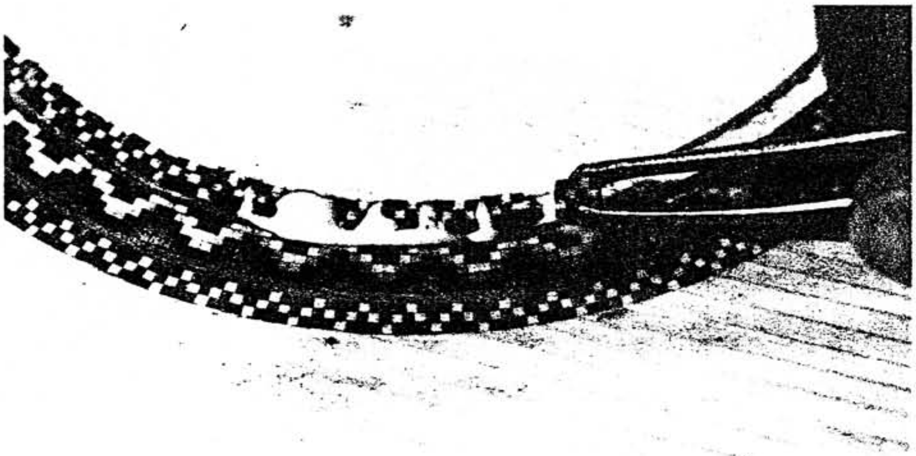




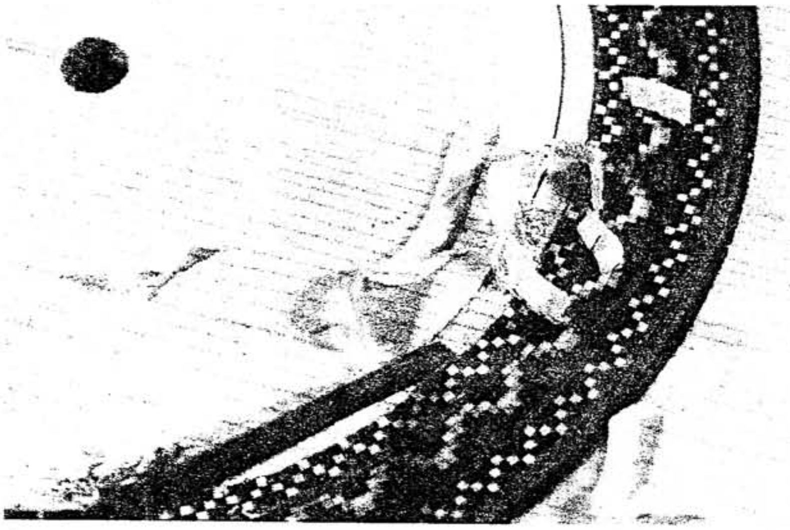
14-16 Carving the tiles that form the outer border so that they lie flush with the soundboard surface



14-17 Inserting the veneer lines into a groove adjacent to the central motif tiles

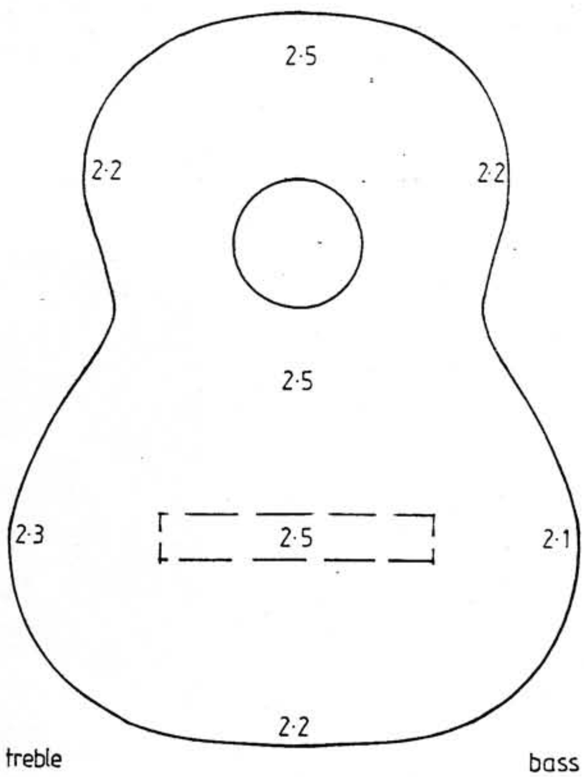


14-18 Gluing in the tiles to form the inner border. Small tiles are more easily gripped with tweezers

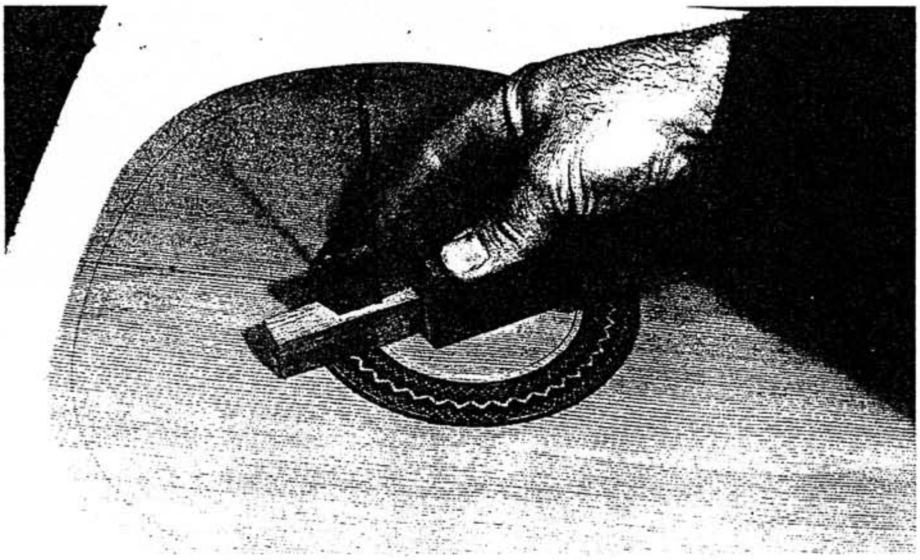


14-19 Removing the waste to form the groove for veneer lines that will define the inner circumference of the rosette

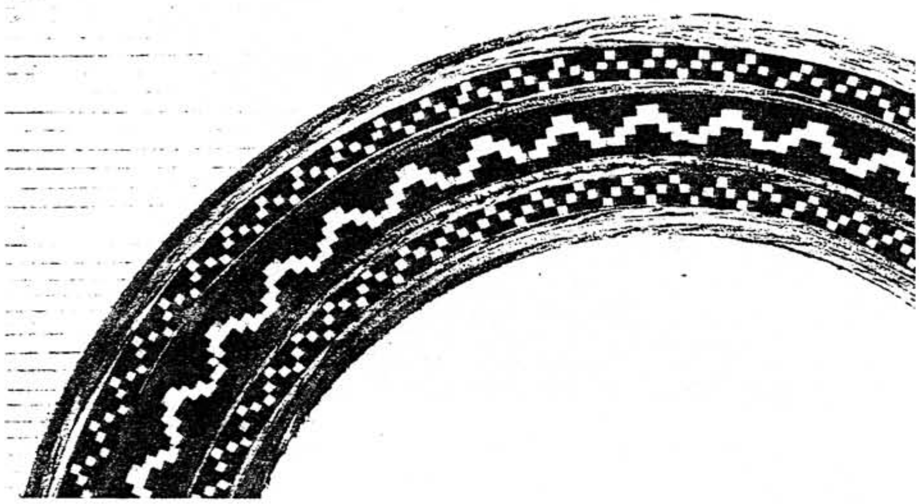
diameter of 84 mm. There should be between one and three millimetres of soundboard wood between the rosette and the edge of the soundhole. Gradually increase the depth of the blade, until the board is cut right through (14-21). The soundboard is now ready to receive the strutting.



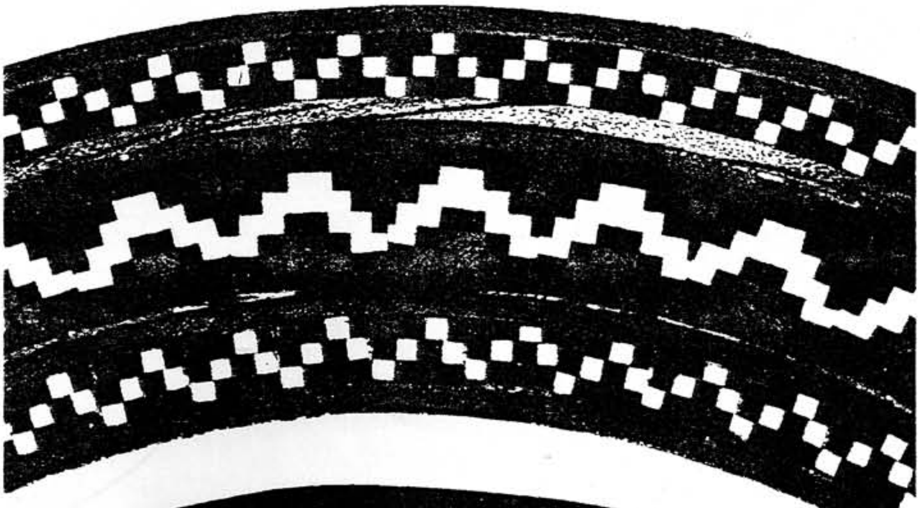
14-20 Typical dimensions for thickessing the soundboard



14-21 Using a circle cutter to form the soundhole



14-22 Detail of a completed rosette – the lines separating the motifs are walnut



14-23 Detail of a completed rosette – the lines around the circumference are rosewood

15 Strutting

Part 1 of the book has demonstrated the great variety of approaches to guitar strutting systems. This really is the most individual aspect of guitar design, although it has not been established that one system is better than another. The basic purpose of any system is to provide support for the thin soundboard, and to distribute the vibrations caused by the strings, as evenly as possible throughout the entire surface area. The most important part of the system consists of a series of struts which are usually laid out in a fan-like pattern, and have become known as 'fan-struts'. These are responsible for bracing the large expanse of wood in the lower bout area. There are also two or three much taller bars, known as 'harmonic bars', which run across the guitar, above and below the soundhole. Some makers include small struts in the upper bout area, either side of the soundhole. The final kind of bracings are the thin reinforcing plates surrounding the soundhole, below the fingerboard, and sometimes, below the bridge.

Tools

Smoothing plane
Marking gauge
Tenon saw
Long-reach cramps
Weights
Chisels

Materials

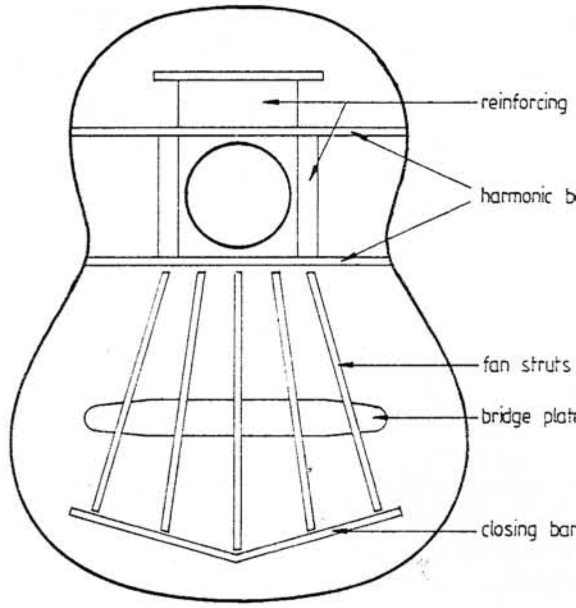
Prepared soundboard, with rosette inlaid
Quarter-sawn spruce for fan struts, harmonic bars, and reinforcing plates
Mahogany off-cuts for making cramping-blocks
Glue

Method

Using the solera

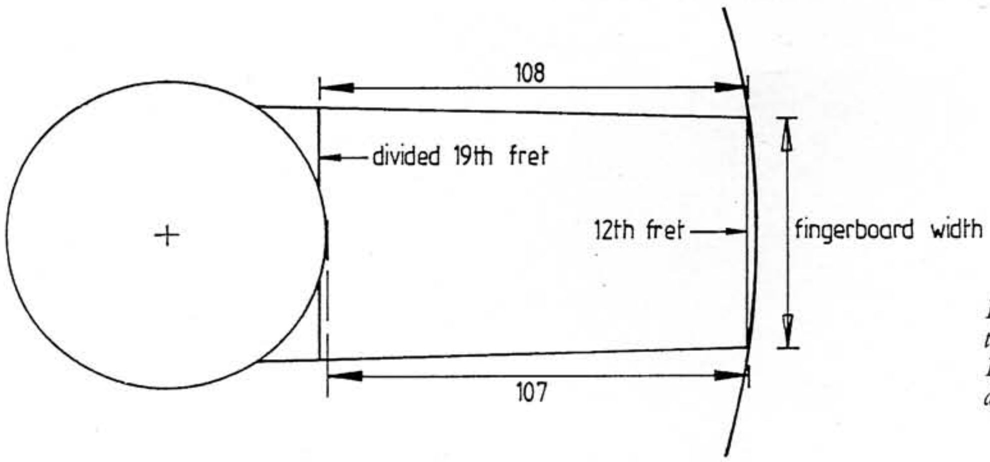
Many makers use a shaped solera when gluing the strutting in place. The fan-struts are prepared perfectly flat along their gluing surfaces. The soundboard is placed face down on the solera, and the struts are glued in position, sufficient force being applied by cramps or weights to ensure close contact between the surfaces. The result is that both the soundboard and the fan-struts are forced into the domed shape of the solera, which is permanently maintained once the glue has dried. The soundboard has therefore been arched simultaneously both across its width, and along its length. The resulting structure is much stronger and stiffer than if the struts were glued to a flat soundboard.

Set out the strutting pattern



15-1 Strutting components

1 Place the soundboard face down on the solera and check that the centre-line is accurately drawn. Use the half-template of the guitar to accurately draw the final outline shape of the guitar on to the soundboard. These lines are important, as the ribs will be positioned along them. Draw locating lines across the soundboard at the widest points of both the upper and lower bouts. These lines must match those drawn on the solera, and will make it possible to reposition the soundboard accurately on the solera each time it is removed. Mark the position of the 12th fret correctly; now that the soundhole has been cut out, it is possible to mark the precise distance from the 19th fret to the 12th fret (15-2). The 19th fret usually falls between 1 mm and 2 mm over the edge of the soundhole. This has the effect of dividing it into two shorter frets. A scale length of 650 mm gives a distance of 108 mm from the 12th to the 19th fret. As the 19th fret falls just over the soundhole, it follows that the



15-2 Marking the distance from the edge of the soundhole to the 12th fret (where the 19th fret is divided)

distance from the edge of the soundhole to the 12th fret should be 107 mm. Measure this distance from the edge of the soundhole, and mark it across at 90 degrees to the centre-line of the soundboard. The soundboard will later be trimmed on this line so that it can be glued to the neck. Some makers prefer not to divide the 19th fret. In this case the soundhole must be positioned slightly further from the 12th fret (15-3).

2 Mark all positions of reinforcing, fan struts, and harmonic bars. Makers who constantly use the same strutting usually make a template which is the shape of the soundboard, and cut small holes to define the ends of each strut and bar. The template is then placed on the soundboard, and the strut positions marked through the holes. For a one-off instrument, the measurements can be marked by referring to the strutting plan provided.

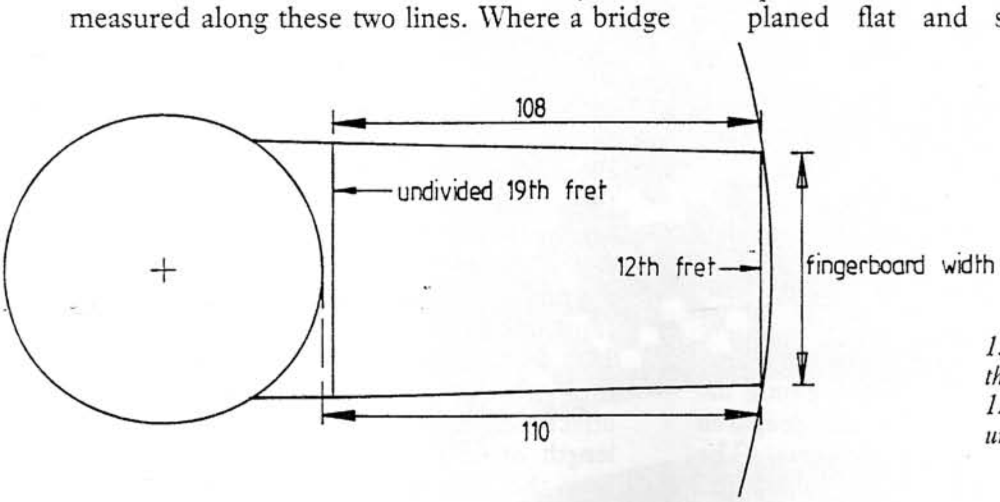
The simplest way of transferring the strutting layout from the plan to the soundboard is use the line drawn across the lower bout at its widest point, and another line drawn to represent the lower harmonic bar (below the soundhole). These lines are shown on all the soundboard plans. Also shown are the distances from the centre of each strut to the centre of the next strut, when measured along these two lines. Where a bridge plate is used (Hauser, Hernández y Aguado, and Fleta), be certain to calculate its position accurately by measuring from the 12th fret. First mark the saddle position – if the scale length is 650 mm, then the distance from the 12th fret to the front of the saddle is theoretically half of this distance: 325 mm. In fact, the position of the saddle must be increased by 2.0 mm, to compensate for the way in which the pitch is distorted when the fingers press the strings down on to the fingerboard. (This is discussed fully in Chapter 24). The distance from the 12th fret to the front of the saddle is therefore 327 mm. The bridge plate should be slightly wider than the bridge itself, so that the bridge is fully supported. Remember that the front of the bridge is about 5 mm forward of the front of the saddle (15-4).

3 In the case of Bouchet, where a bridge bar is attached, it is important to measure accurately so that the saddle of the bridge falls centrally above the bridge bar (15-5).

4 The Friederich strutting system also includes a bridge bar, although he positions the front of the bridge directly above the front of the bar.

Prepare the struts, bars, and reinforcing (15-6)

1 Now prepare enough lengths of quarter-sawn spruce for all the fan-struts. They should be planed flat and square, to the maximum



15-3 Marking the distance from the edge of the soundhole to the 12th fret (where the 19th fret is undivided) dimensions of the largest strut. The struts are glued in place, and then shaped as required afterwards.

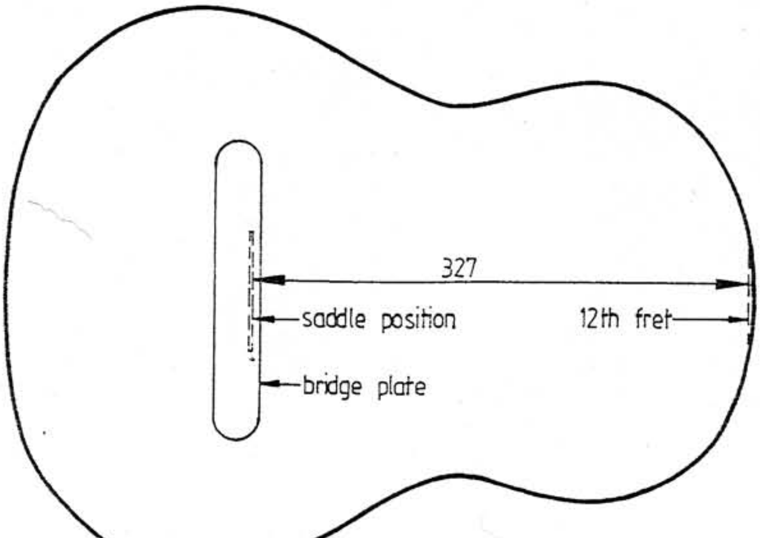
2 Also prepare the long harmonic bars. These too will be shaped once they have been glued in place.

3 Finally, prepare the thin reinforcing plates for the soundhole and the fingerboard positions, and, if the plan calls for a bridge plate, then this must also be cut to size. The reinforcing and the bridge plate are usually made from spruce, similar to the soundboard, but thin sycamore veneer can also be used. If spruce off-cuts from the soundboard are available, they may be more manageable if glued in place slightly thicker than required, and planed or sanded to their final thickness when in place. The thicknessing caliper can be used to measure the overall dimension. Circular reinforcing for the soundhole can be made with the circle cutter.

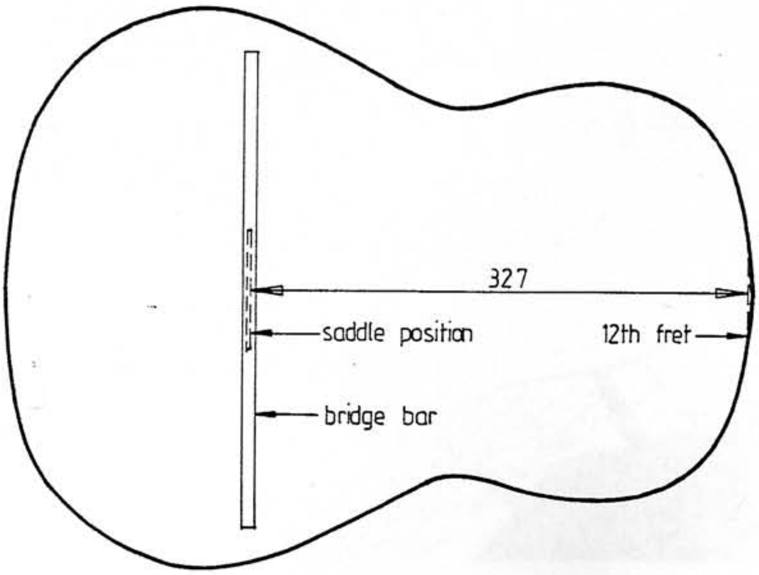
Glue on the reinforcing

It is best to glue the thinnest components first, and work up towards the tallest. This allows easy access for shaping and sanding as the work proceeds.

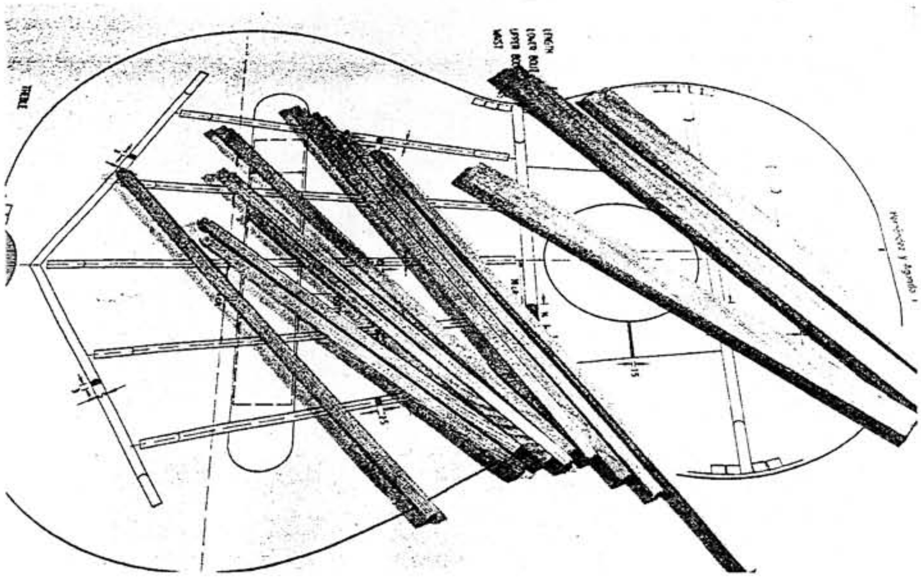
1 Glue the soundhole reinforcing and the rectangle of reinforcing that lies under the fingerboard first (15-7). Masking tape applied round the edges will keep the thin wood in place, and a flat board with weights, or a plywood disc held on with a bolt, can be used to ensure a good bond (15-8). Although thin, the gluing areas are wide, so a reasonable amount of pressure is required. These two components are often positioned with the grain running across the guitar, at a right angle to the soundboard grain. This provides more strength than if their grain is parallel to that of the soundboard.



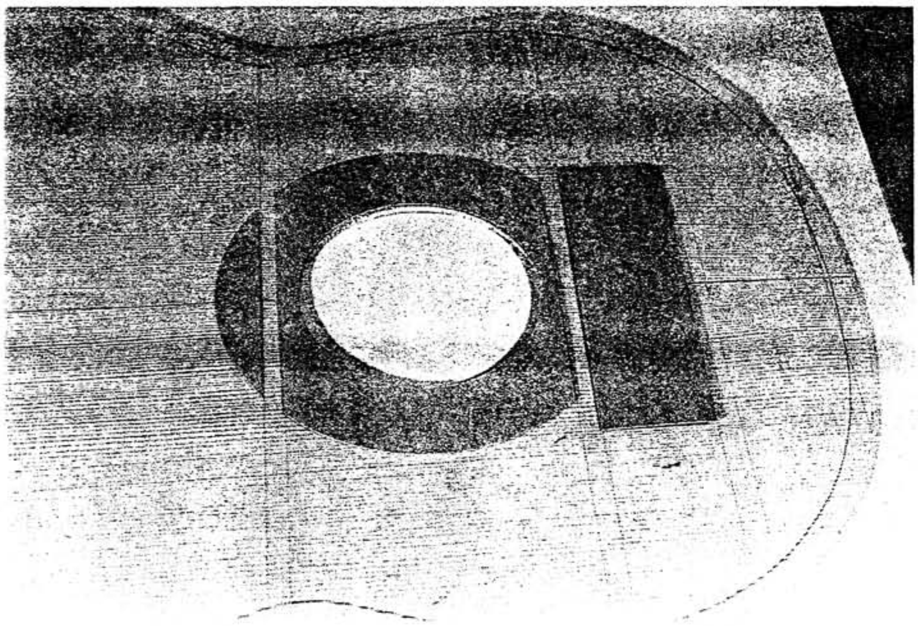
15-4 Marking the distance from the bridge plate to the 12th fret



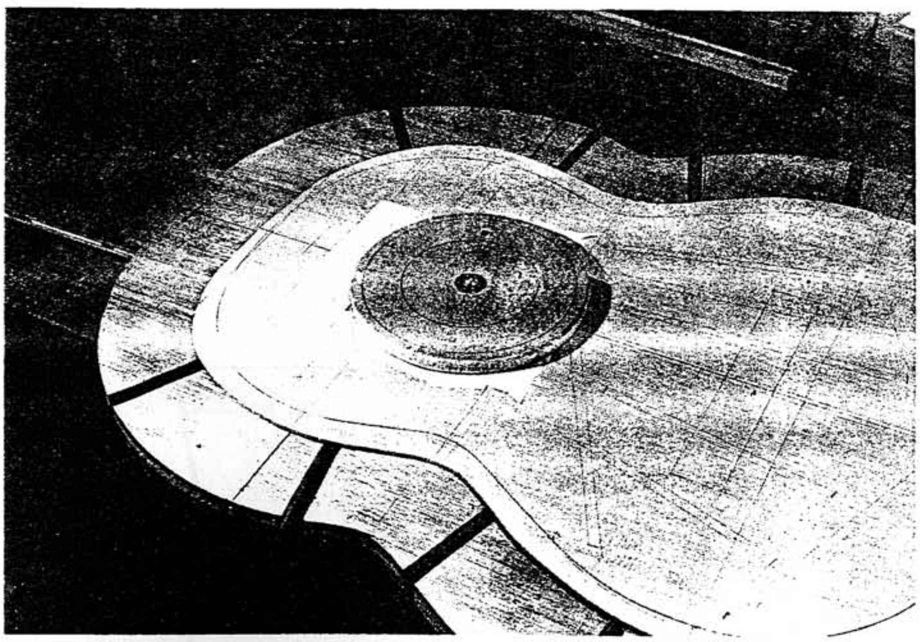
15-5 Marking the distance from the bridge bar to the 12th fret



15-6 The fan-struts and harmonic bars prepared for cutting to length



15-7 The reinforcing ready to be glued in place



15-8 A plywood disc with bolt is used to cramp the reinforcing to the soundboard

2 When the glue is dry, remove the masking tape, scrape away any excess glue, and sand the surfaces smooth.

3 The bridge plate should be glued next (if applicable). This must be prepared with a flat gluing surface, but its shape will conform to the curve of the solera. It is therefore important to use only light, flexible packing between the bridge plate and any cramps, so that it is free to take up the curved shape.

4 When dry, scrape away excess glue, and shape the edges as required. Some makers leave the bridge plate flat and level, and do not bevel the edges. Others, including Fleta, carve the edges down to meet the adjoining soundboard.

Glue the fan struts

A 'fast-grab' P.V.A. glue, or animal glue, is ideal for attaching all the strutting, as it allows a degree of flexibility. The fan-struts can either be glued two at a time, with two or three steel weights spanning them, or they can be glued individually with long-reach cramps. If you use cramps, be careful not to apply too much pressure, as the shape of the struts will then be visible on the outer surface of the guitar due to the wood being compressed. This will show up clearly once the instrument is varnished. Light pressure, spread over a wide area, is the best method. If your design incorporates a bridge plate, then small notches must be cut and chiselled out of the fan struts, so that they can rest on the soundboard surface, with the bridge plate housed into them. Alternatively, sections of the bridge plate itself can be removed, to allow the fan-struts to make contact with the soundboard.

1 The solera cramping-block can be positioned across the soundboard and tightened. This will prevent the soundboard moving while the fan-struts are glued in place. Spread glue on the lower surface of a fan-strut and push it into position, applying hand pressure until the glue grabs sufficiently to prevent the strut sliding about. All the strutting should be placed with the grain rising vertically from the soundboard (15-9). A small wooden spatula can be scraped along the edges of the strut to remove any excess glue, before the cramps or weights are applied. Avoid using a damp cloth to remove glue, as it will simply spread it over a wider area, and discolour the wood (15-10 and 15-11).

2 When all the fan-struts have been glued, they should be shaped with a miniature plane or a chisel, to the required thickness and profile (15-12). Many makers work the fan-struts to a triangular, gable shape, although some leave them flat on the top. Often the struts are left highest in the bridge area, and tapered down slightly towards the two ends. Carry out the basic shaping now – final adjustments can be made when the entire strutting system is in place, and the soundboard can be flexed and tapped.

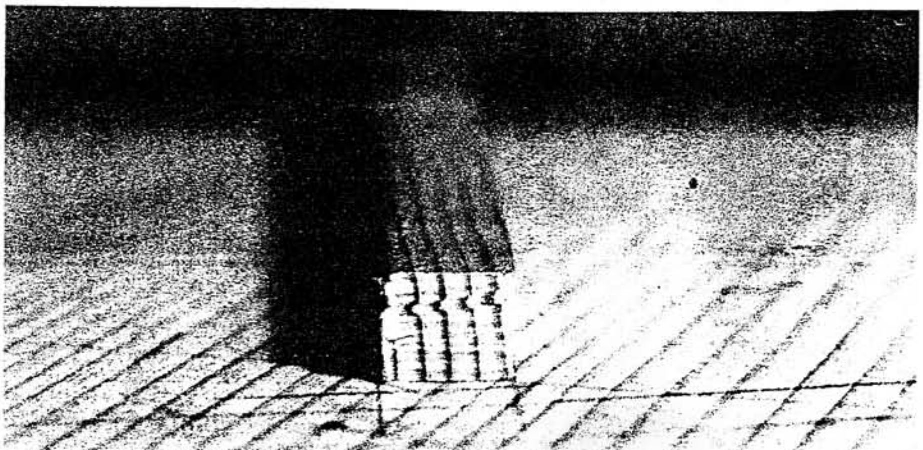
Glue the closing bars

The fan-struts should be shaped before gluing the two diagonal, closing bars (if applicable), because they get in the way of the chisel or plane, which will keep knocking into them. The closing bars are glued and shaped in a similar way to the fan-struts (15-13). Now glue any other small struts required, usually in the upper bout area.

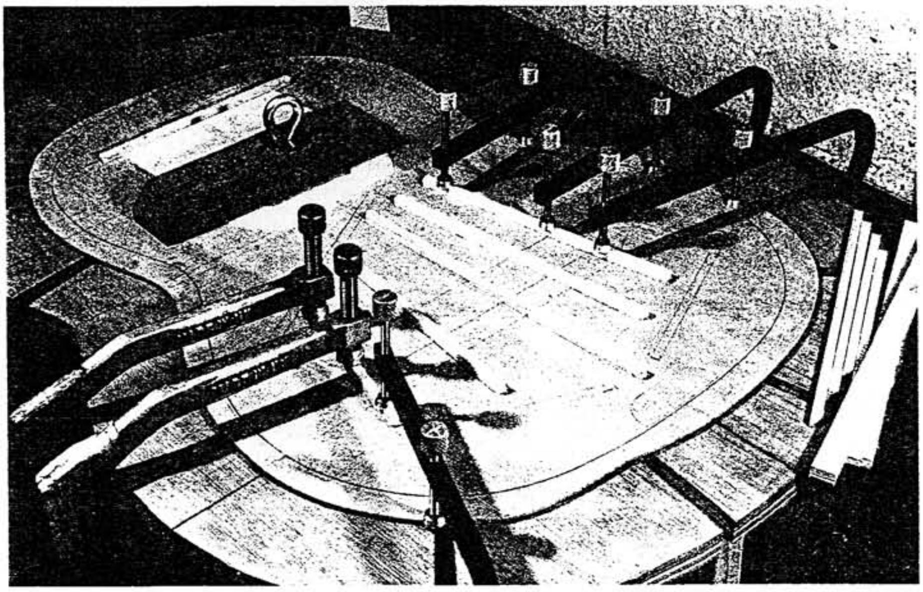
Glue the harmonic bars

The order of work here will depend on which strutting system you are following.

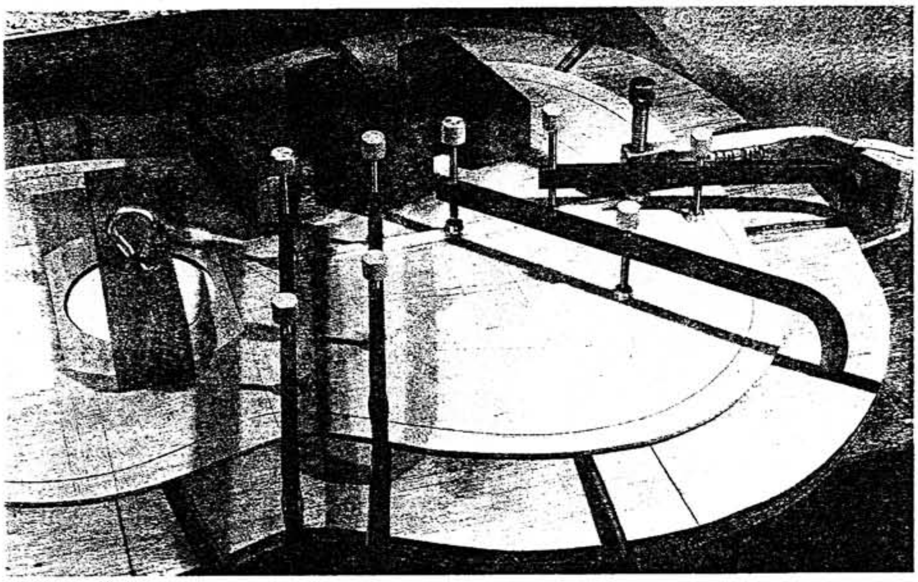
1 The simplest designs use only two main bars, one above and one below the soundhole, as well as the shorter bar that is positioned below the fingerboard. In general, work from the fingerboard area, down to the lower bout area.



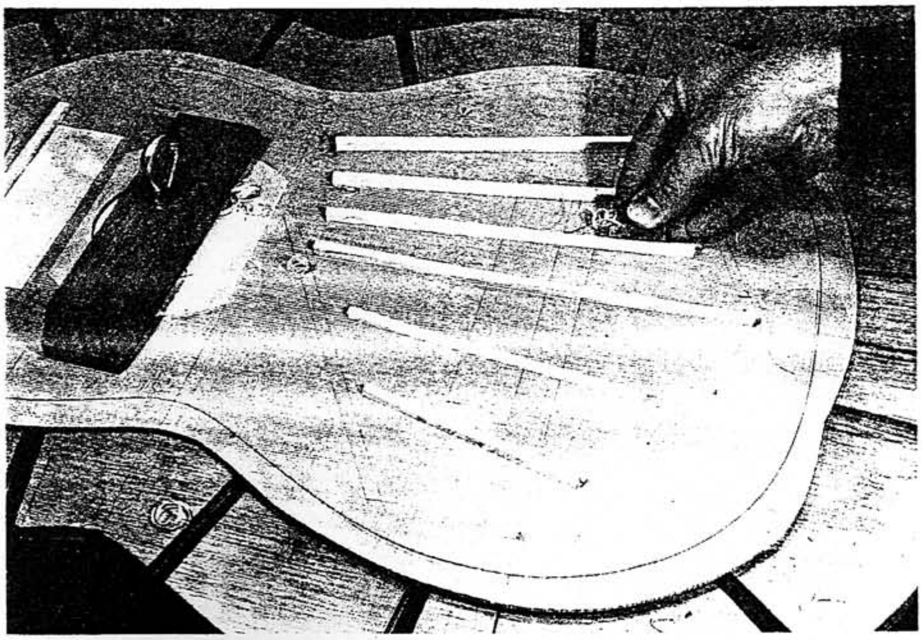
15-9 Detail of a fan-strut, showing the direction of the grain which should rise vertically off the soundboard



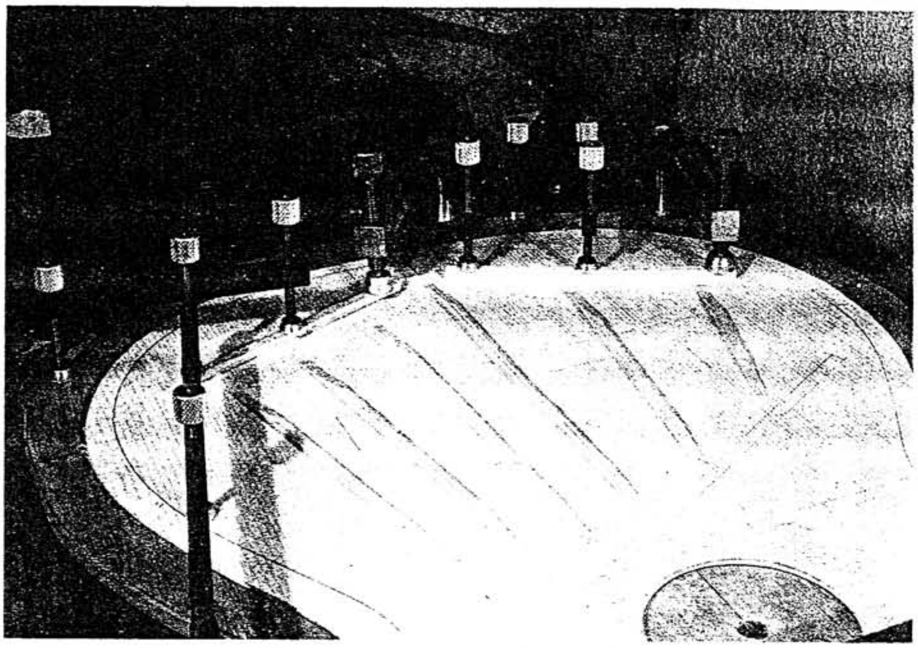
15-10 Gluing the fan-struts to the soundboard with long-reach cramps. The solera cramping-block is tightened across the upper bout to prevent the soundboard from moving



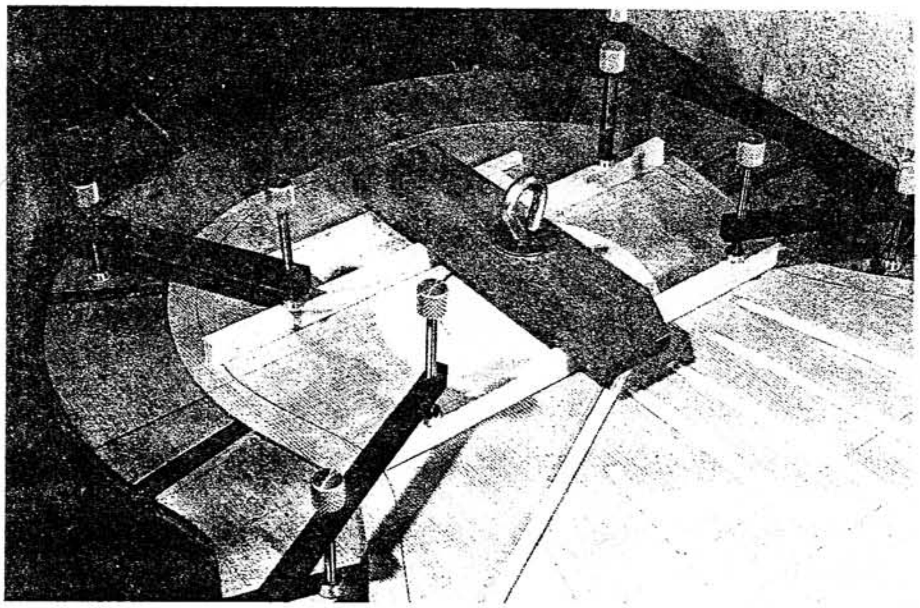
15-11 Gluing fan-struts with weights and cramps



15-12 Shaping the fan-struts with a small plane. This should be done before the closing bars are glued



15-13 Gluing the closing bars



15-14 Gluing the harmonic bars. The cramping block secures the central area of the bars. Both bars can be glued simultaneously

First glue the short bar (if applicable) which is usually below the 17th fret. It should be absolutely flat along its gluing surface. The two harmonic bars, one above and one below the soundhole, can be glued simultaneously, making use of the solera cramping-block and several other cramps (15-14). These two bars should be arched slightly to conform to the shape of the solera. Try the bars in place, and adjust them until they make contact with the soundboard right along their length.

2 If an additional harmonic bar is involved, as in the case of Fleta, it can be shaped in the same way.

3 In the case of harmonic bars with apertures, the gluing surface should first be correctly shaped, before the apertures are cut out. Make certain that a fan-strut passing through an aperture is entirely free from contact with the harmonic bar, or buzzing may occur – it should either be completely independent, or else be glued and housed into the bar. Do not apply cramps directly over the arched section (15-15). Whereas Bouchet forms an aperture in the harmonic bar so that the outer fan strut can pass through it, Friederich cuts a notch in the fan strut itself so that it can pass over the harmonic bar.

4 The Bouchet and Friederich systems both incorporate a bridge bar which passes beneath the bridge. The bar should be shaped to the curve of the solera before being glued. As the bridge bar is relatively large, there would be considerable stress caused if it was glued to a curved solera while itself having a flat gluing surface. The bridge bar is placed over the fan-struts, and marks made on both sides to represent the path of the fan-struts. Small notches are then cut out of

the bridge bar, so that it can make contact with the soundboard. The fan-struts must be firmly housed into the bridge bar.

5 The upper surfaces of the harmonic bars are sometimes gable-shaped, in the same way as the fan-struts. In this case, approximately 30 mm at the each end of the bars is scalloped down in a gentle curve, so that the bar is about 5 mm high where it meets the kerfed linings. Carry this work out with a chisel, and sand smooth (15-16 and 15-17).

6 In many guitars, the upper surfaces of the harmonic bars are left square along their full length, and are not scalloped at the ends. Torres usually tapered the bars slightly towards the top, although they are not rounded off.

7 Clean away all excess glue, and sand the struts and bars as smooth as possible. The solera rib-supporting blocks can be used to hold the soundboard in place (15-18).

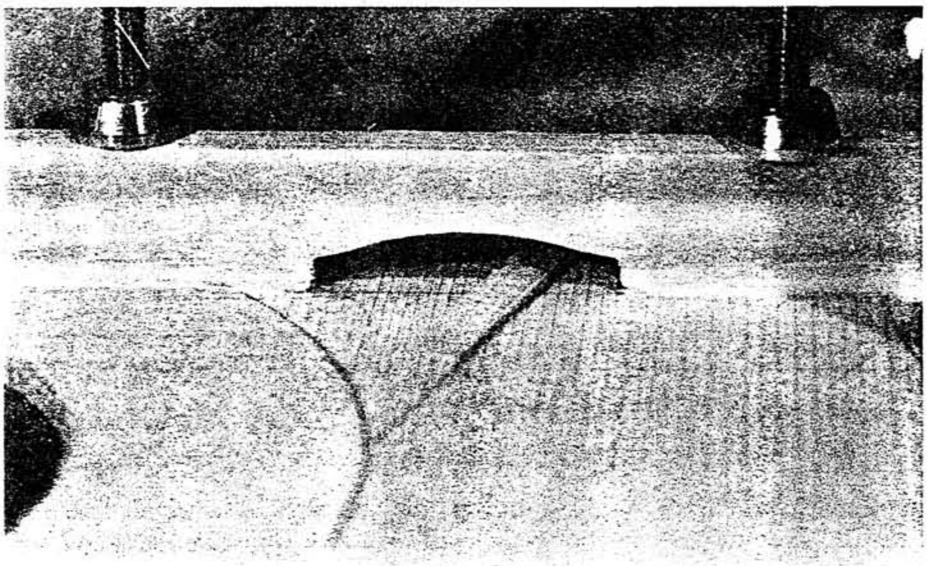
Make the bridge cramping-block (15-19)
A cramping-block is now made which will spread the pressure of the cramps when the bridge is later glued to the soundboard.

1 Prepare a hardwood blank. Its depth must be kept to the minimum needed to house the fan-struts in it, as well as enough thickness for it to maintain its strength. Make sure that the long-reach cramps you will use to glue on the bridge have sufficient jaw-depth to span the soundboard, bridge, any packing, and the cramping block. A depth of 12 mm is sufficient in most cases, but where a bridge bar spans the fan-struts, the thickness will be greater (15 mm). The precise length will depend on the layout of the fan-struts. It should be somewhat longer than the bridge, and span most of the fan-struts. The width must be slightly greater than the width of the bridge (approximately 40 mm to 45 mm).

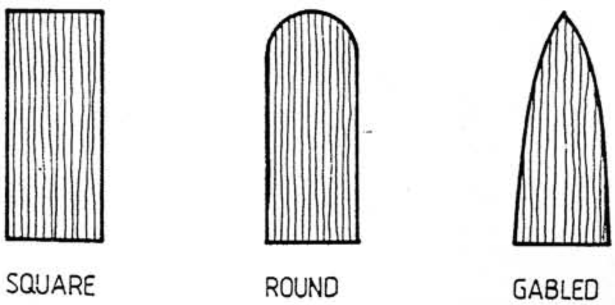
2 Plane and scrape one surface of the block until it conforms to the shape of the solera at the bridge position.

3 Rest the block on the fan-struts, exactly over the bridge position, and mark on both edges where the fan-struts pass below. Join up the lines, and remove the waste with a saw and narrow chisel, to a depth slightly greater than the depth of the fan struts. The block should now fit tightly in place over the fan struts, and rest on the soundboard (or bridge plate).

4 Where a bridge bar is included, first cut a long channel to house the bridge bar, then mark the positions of the fan struts.

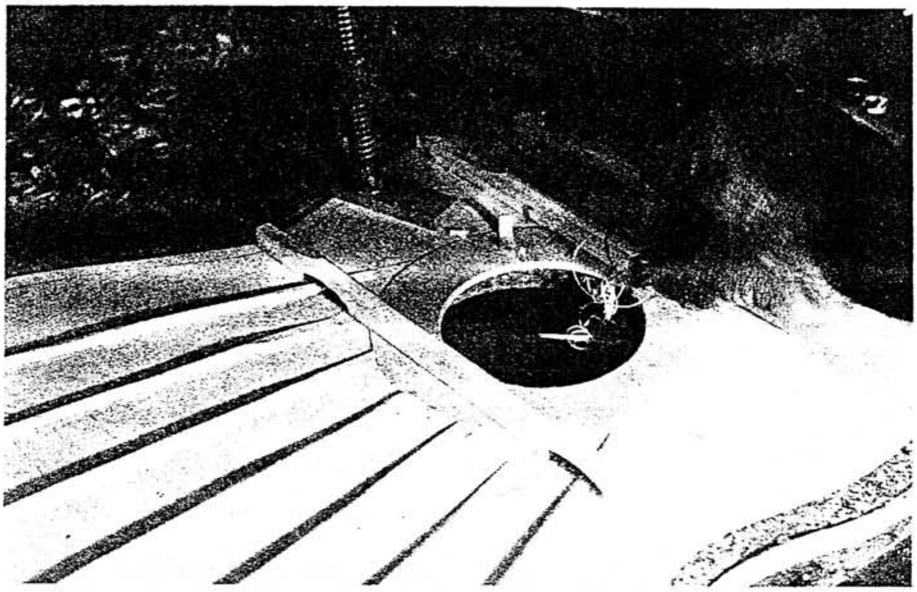


15-15 Gluing an harmonic bar with an arch – the cramps are not placed over the arch

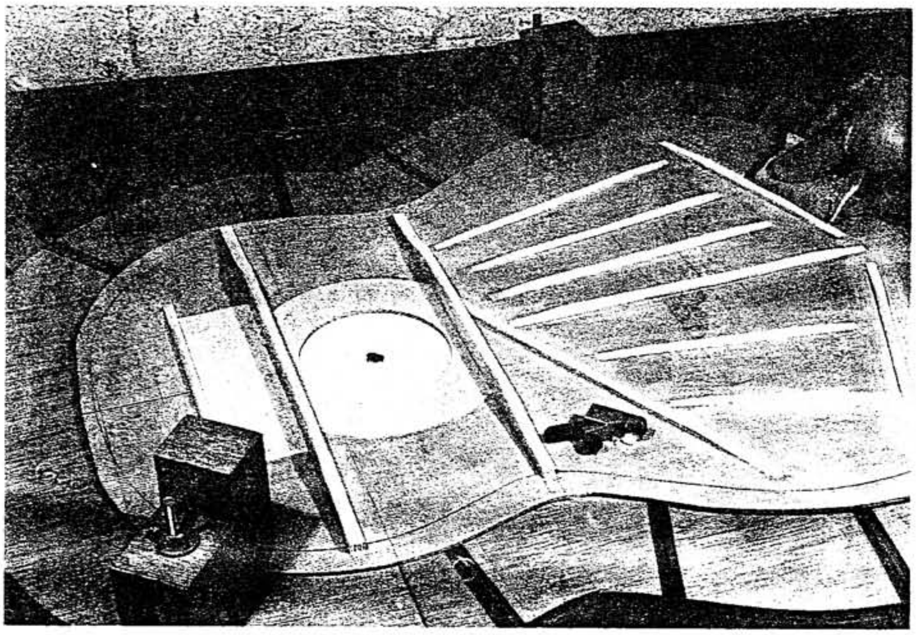


15-16 Three typical cross-sections of harmonic bars

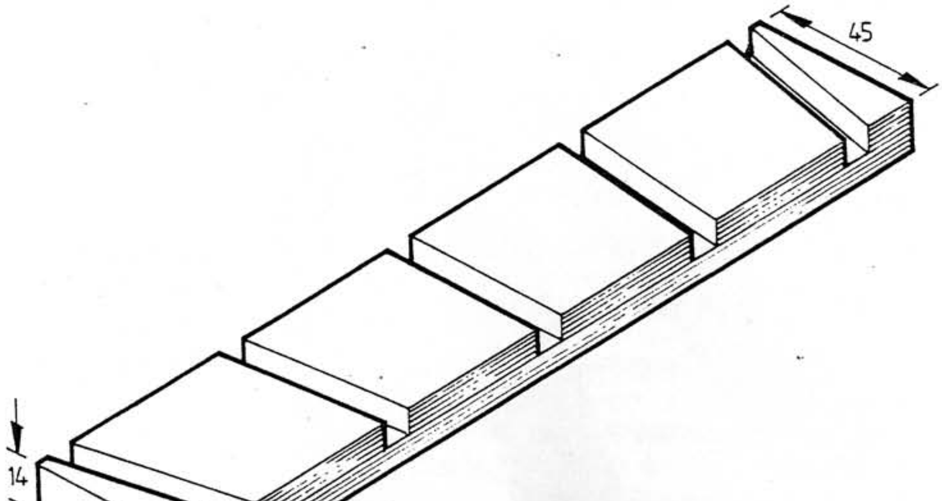
Make the fingerboard cramping-block (15-20)
A block is also needed to span the upper harmonic bar and other bracing between the soundhole and the neck. This will provide support for the cramps when the fingerboard is glued to the soundboard, as well as being useful for cramping the last few frets into the fingerboard.



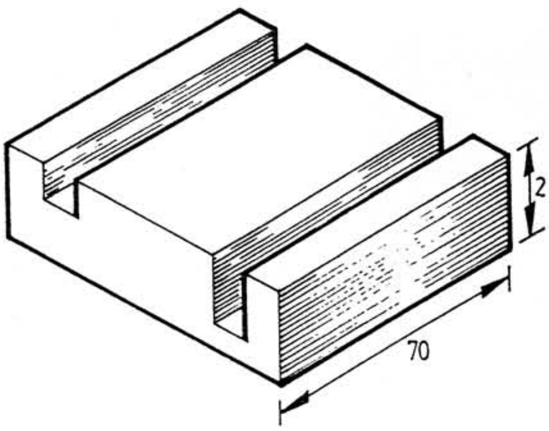
15-17 Shaping the harmonic bars with a small plane. The ends of the bars have been scalloped



15-18 Smoothing the soundboard and strutting with fine garnet paper. (A couple of rib-supporting blocks are useful for cramping the soundboard to the solera. The main cramping-block would obscure the strutting)



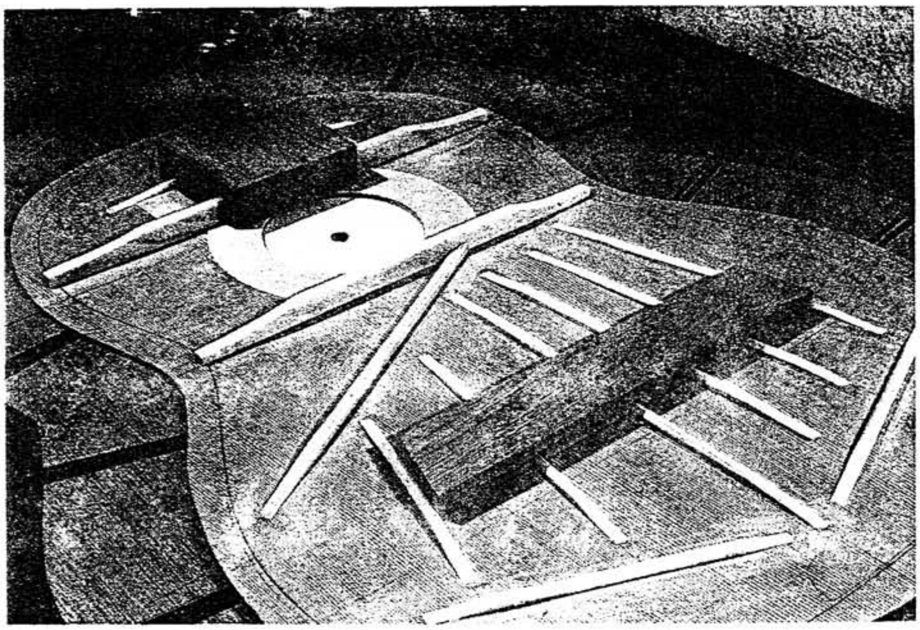
15-19 Typical dimensions for the bridge cramping-block



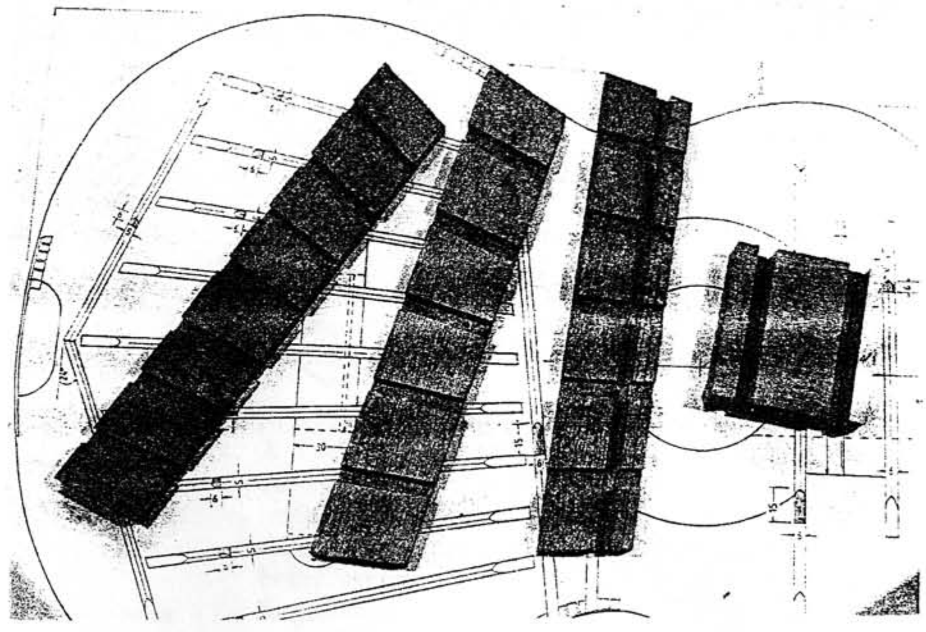
15-20 Typical dimensions for the fingerboard cramping-block

1 Prepare a block approximately 80 mm × 75 mm × 24 mm. Mark the positions of the bars that lie between the soundhole and the beginning of the foot.
2 Remove the waste with a saw and chisel. Place the block over the bars. It will come to rest on the reinforcing just above the harmonic bar. Increase the depth of the front of the block by gluing on one or more layers of veneer, until the block makes contact all along (15-21).

Trim the soundboard all the way round, leaving no more than 5 mm of waste. It is now ready for joining to the neck.



15-21 The bridge cramping-block and fingerboard cramping-block in position



15-22 A selection of cramping-blocks to suit various strutting designs. The Bouchet design requires an extra groove for the bridge bar (third from left)

16 Back

The colour and grain of the back should closely match that of the ribs. It will have been supplied as two matching halves. These must be accurately joined together before being planed to between 2.0 mm and 2.5 mm thick. A rosewood back requires considerable effort to plane and scrape with hand tools, and it is essential to use a sharp smoothing plane and scraper plane.

Tools

Smoothing plane
Scraper plane
Cabinet scraper
Thicknessing caliper
Straight-edge
Spirit-level sander
Sash cramps
G-cramps

Materials

Two-piece back, of quarter-sawn wood to match the ribs (two pieces, each 520 mm × 200 mm × 4 mm)
Inlay strip and veneer (optional)
Mahogany or cedar reinforcing strips, cross-grain, (450 mm × 15 mm × 2 mm)
Straight-grained mahogany or cedar, 15 mm × 6 mm, enough for three back bars
Glue

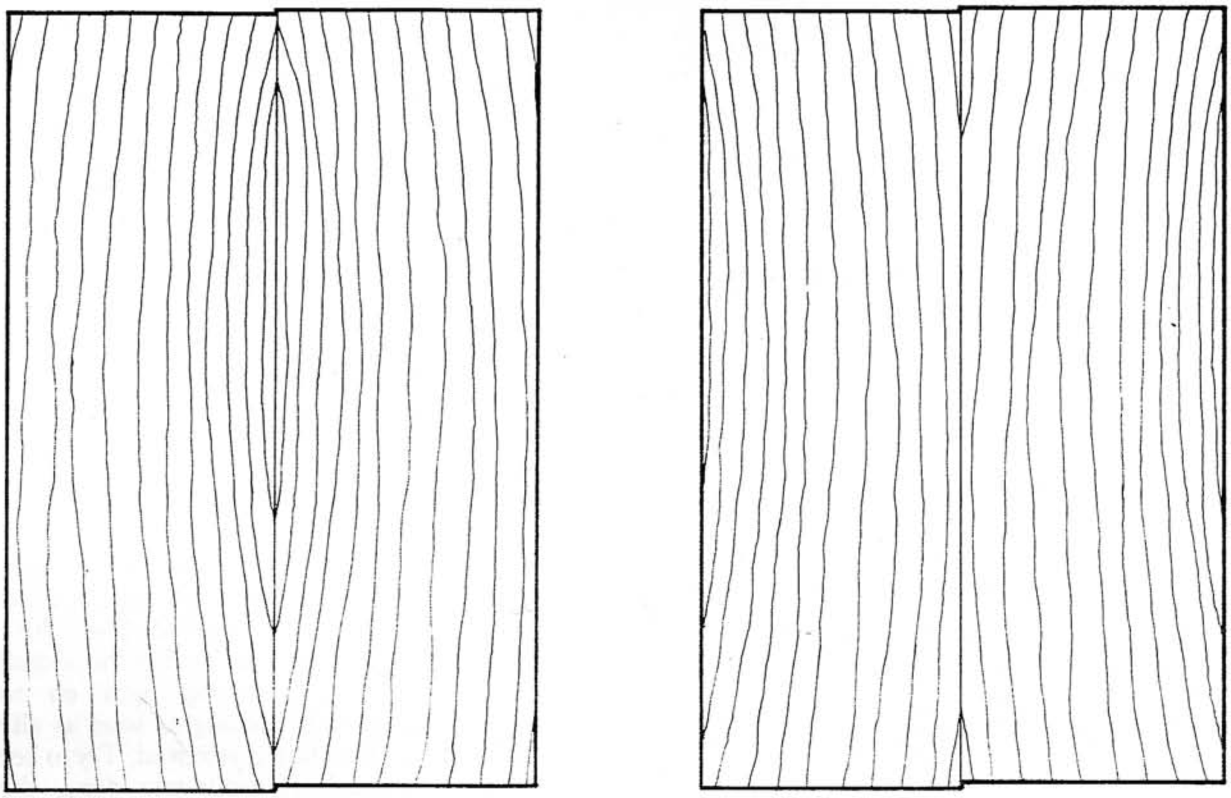
Method

Prepare the wood

1 Secure one half of the back with a batten running along one side, fastened with two cramps.
2 Begin planing with a very sharp, finely set smoothing plane, and remove all the ridges and saw marks, until the surface of the wood is reasonably smooth. Turn the wood around, and smooth the side that had been hidden under the batten.
3 Repeat this initial cleaning up of the surfaces on the reverse side, and then on both sides of the second half of back.
4 Butt the two halves together, positioning them so that the grain pattern is symmetrically matched. Rosewood backs usually exhibit a grain pattern that curves across the board, and the traditional way of joining is to make the curves meet in the centre, as this echoes the outline of the guitar (16-1).
5 Place the half-template of the guitar outline on to the back to determine how much excess wood is available. Provided that the lower bout area is at least 10 mm to 20 mm inside the outer edge of the back, it is safe to scribe a line with a straight-edge about 5 mm in from the gluing edge. Mark a similar line on the other half, trying to select the same grain line, so that the back will appear matched (16-2).
6 Each half of the back must now be supported vertically between two battens, held in a vice, and planed down to the marked line (the same method that was used for joining the soundboard together). Shine a strong light on to the rosewood, and stop planing as soon as all wood above the scribed line is removed. Try to keep the plane horizontal. If accurately done, the two halves of the back will now meet up when brought together on a flat surface. Hold them up to a strong light, and examine the join carefully for any sign of light shining through.
7 If further levelling is required, the simplest method is to use the flat spirit-level sander. Place one half of the back on top of the other, closed like a book, and bring the top edge 10 mm over, so that it can be sanded without the spirit-level touching the lower board. Hold the wood down firmly with a long batten, and work the spirit-level back and forth, applying pressure evenly along the entire distance. Check progress by holding the wood up to a strong light, and if further adjustment is needed, try to apply sanding pressure at the high spots which are preventing the two halves making perfect contact. Repeat with the other half.

Glue the back together

1 Once the join is perfect, prepare a flat board on which to glue the two halves together.
2 If sash cramps are available, two can be placed below the board, and one above. A few battens will help keep the back flat. Before applying glue, place some paper below the join to prevent the back sticking to the board (16-3). If no sash cramps are available, use battens and wedges (16-4). Place several weights over the join to prevent it rising in the centre, and when dry, release the wedges before removing the weights.
3 When the glue has dried, the back is cramped to a flat board and planed systematically from one side to the other. One long batten and two cramps are needed to secure it. Plane both sides of the board



16-1 The traditional way of joining the back is shown at 'A', where the curved figure of the rosewood meets at the centre of the back

until they are level (16-5).

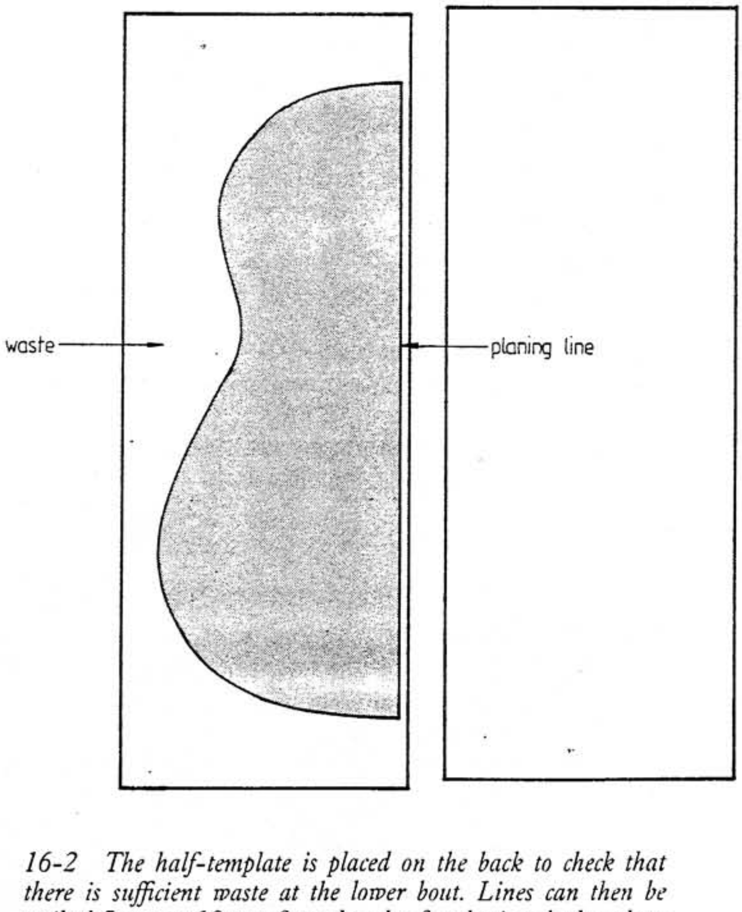
4 Remove any remaining roughness from the outer surface with a scraper plane or cabinet scraper.

Inlay the back (optional)

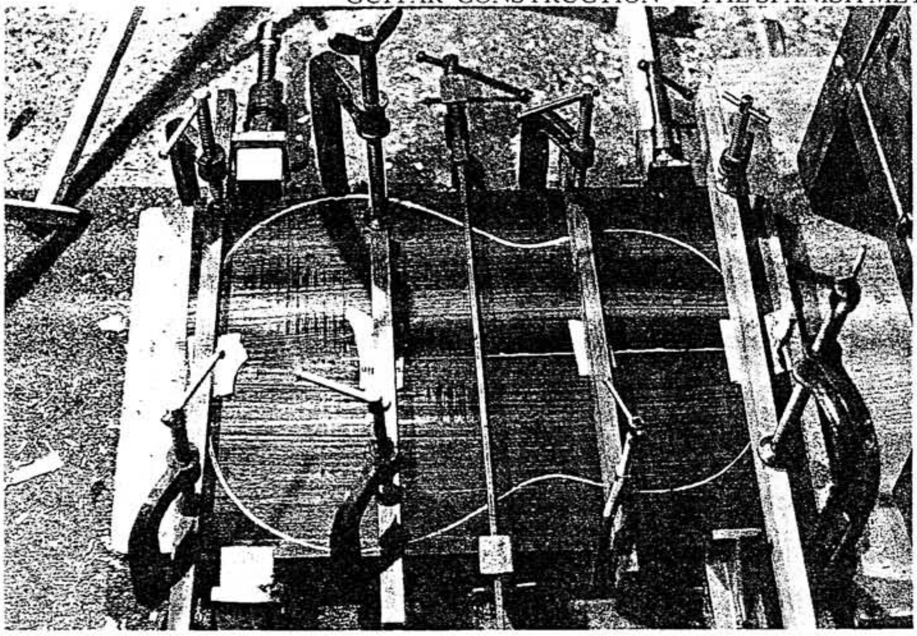
Some makers inlay a strip of wood along the central join of the back. Often this will match the purfling or binding, and can serve to define the back visually into two distinct halves. Many contemporary makers prefer the less fussy appearance of an undivided back. If you want to inlay over the seam, then prepare a suitable strip of wood, approximately 10 mm × 2 mm, and glue a contrasting strip of veneer to both edges. Mark the position of the inlay, which should span the centre join, and use a straight-edge to guide a scalpel along the two lines. Cut a channel with a chisel or router to a depth of 1.5 mm. The strip of inlay can then be glued in place and covered with a batten and a few weights until dry. Finally, scrape the surface of the inlay flush with the surrounding back.

Thickness the back

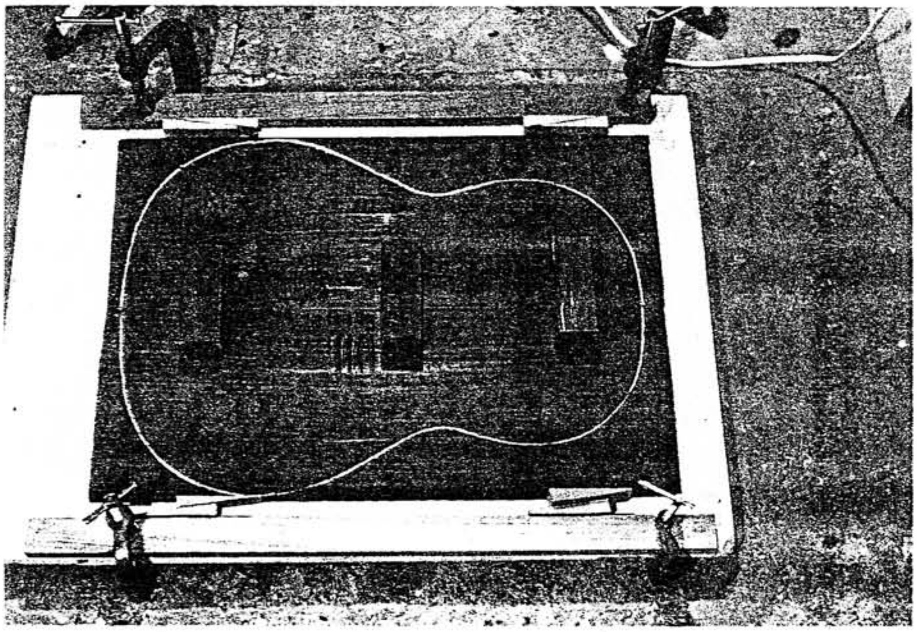
1 The back is now brought to its final thickness by planing and scraping from the reverse side. Check the thickness frequently with the thicknessing caliper, and aim for an initial measurement of 2.5 mm over the entire surface. Some rosewood planes well, but often the grain is so interlocked that no matter how sharp the plane, some tearing will occur. If this happens,



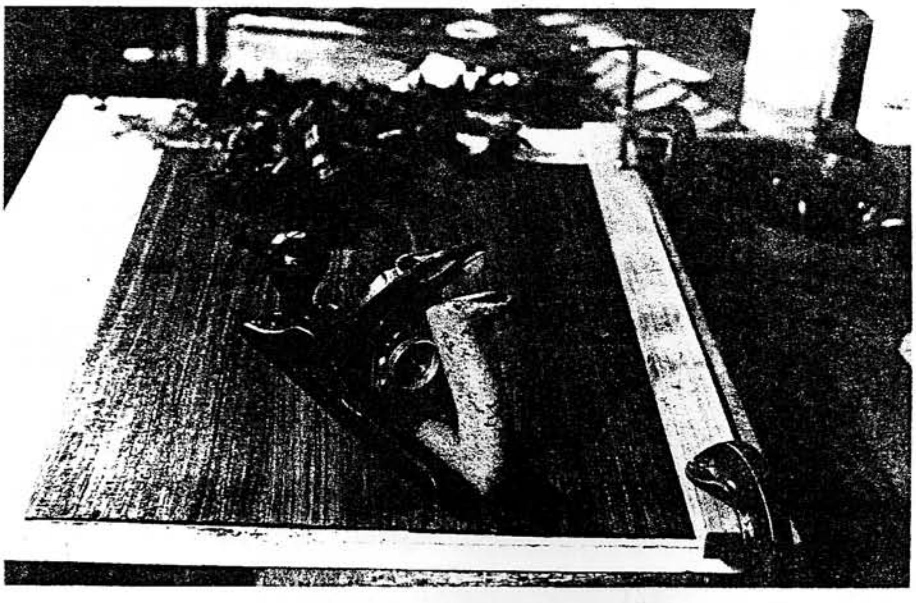
16-2 The half-template is placed on the back to check that there is sufficient waste at the lower bout. Lines can then be scribed 5 mm to 10 mm from the edge for planing the boards to fit



16-3 Using sash cramps for gluing the two halves of the back together. The battens and G-cramps keep the back flat



16-4 If sash cramps are not available, the back can be glued together with battens, wedges and weights



16-5 Planing the back

change over to a scraper plane and then a cabinet scraper for the final smoothing.

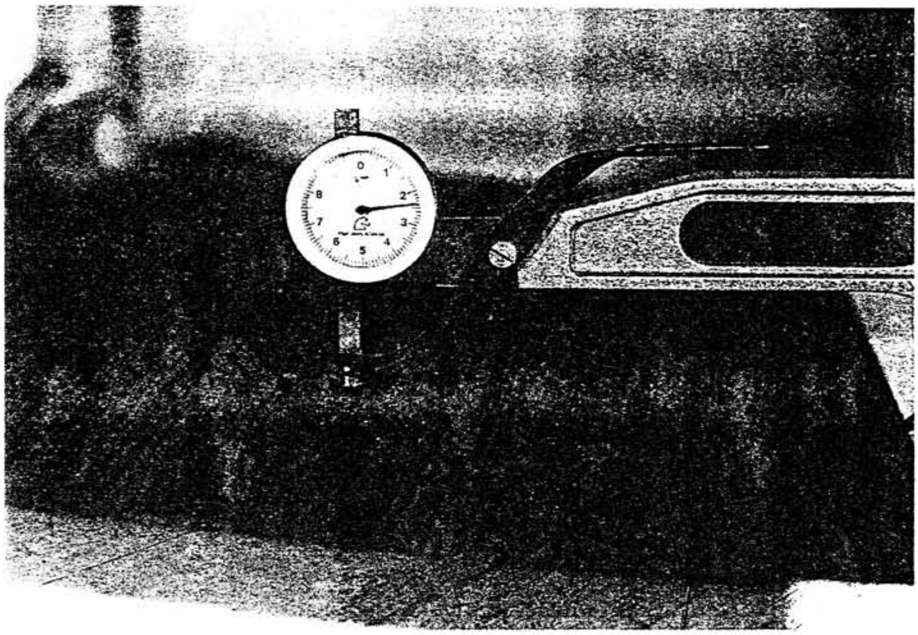
2 The usual method of thicknessing the back is to gradually remove more wood from the periphery, so that there is a range of thicknesses, from approximately 2.5 mm at the centre, to 2.0 mm around the periphery. These figures should be taken as a guide, but the final thickness will be determined by the flexibility and strength of the wood, and the sound when tapped with a knuckle. The final thickness should not be less than 2.0 mm in any area (16-6).

3 Draw the outline shape of the guitar on the back. Draw a second line 10 mm beyond this, to act as a cutting guide. Cut out the shape, and check the thickness and flexibility once more. Mark in the positions of the end-block and the foot of the neck.

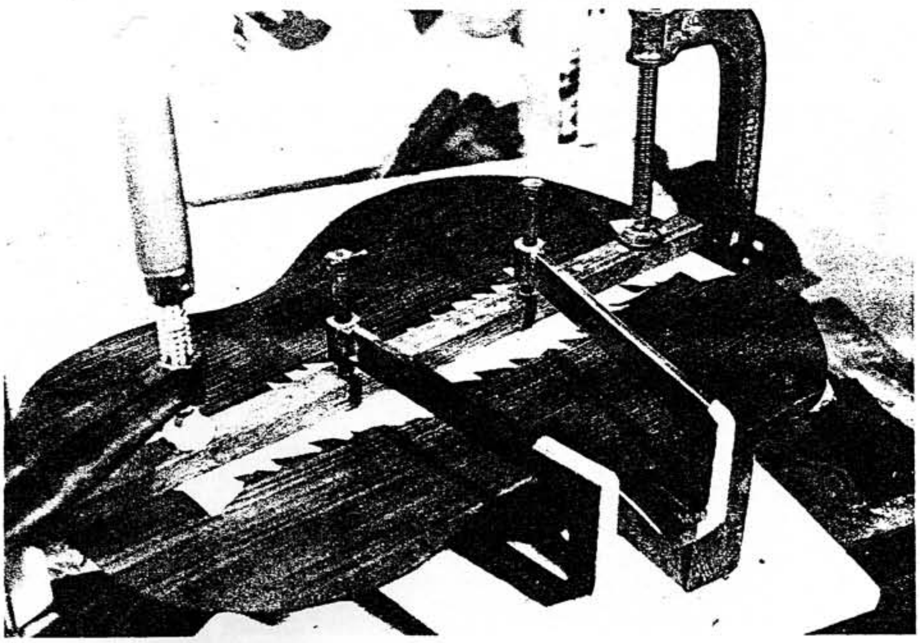
Reinforce the back join

1 The density and hardness of a rosewood back means that, however well it has been joined, the seam is likely to open up eventually, as the wood expands or shrinks across its width. To guard against this, some cross-grain reinforcing strips must be glued along the seam, between the end-block and the foot of the neck. The grain must run at a right angle to that of the back if it is to have any strength, and the strips are usually about 15 mm wide. Prepare enough pieces to span the required distance, and ensure that they are all of equal width. Sand the edges smooth.

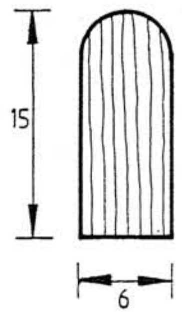
2 Mark guidelines either side of the centre-line, so that the reinforcing will be glued centrally, and then glue the strips down, covering with masking tape as you proceed. This will prevent them sliding out of alignment.

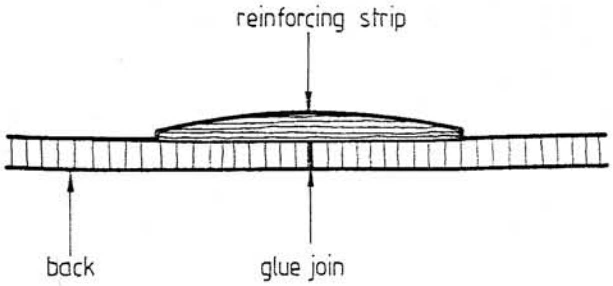


16-6 Measuring the thickness of the back



16-7 Gluing the reinforcing over the centre back joint. The back is placed on a flat workboard



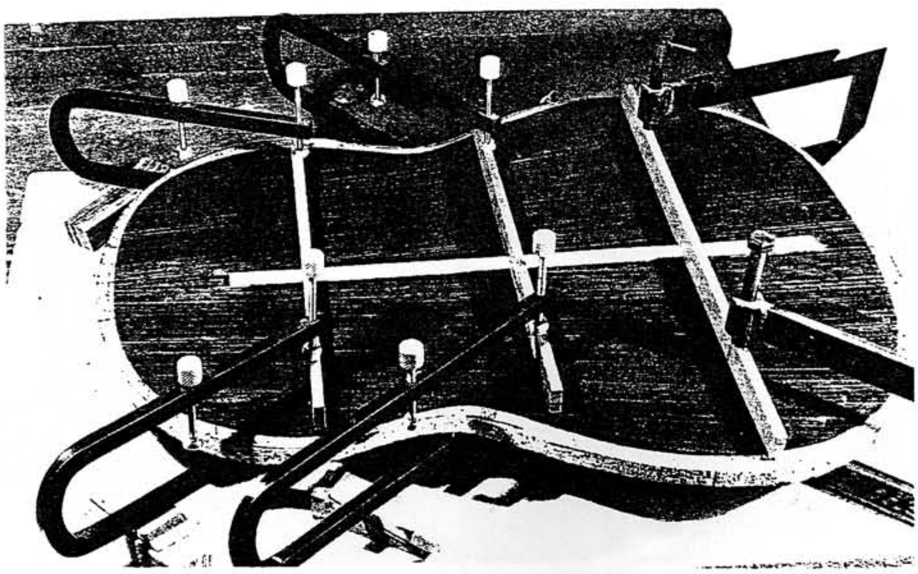


16-8 Top: typical dimensions for the back bars. Bottom: the back reinforcing is positioned with the grain at a right angle to the grain of the back. Once glued, it is shaped to a gentle curve but not taken down to a feather-edge, which would become ragged

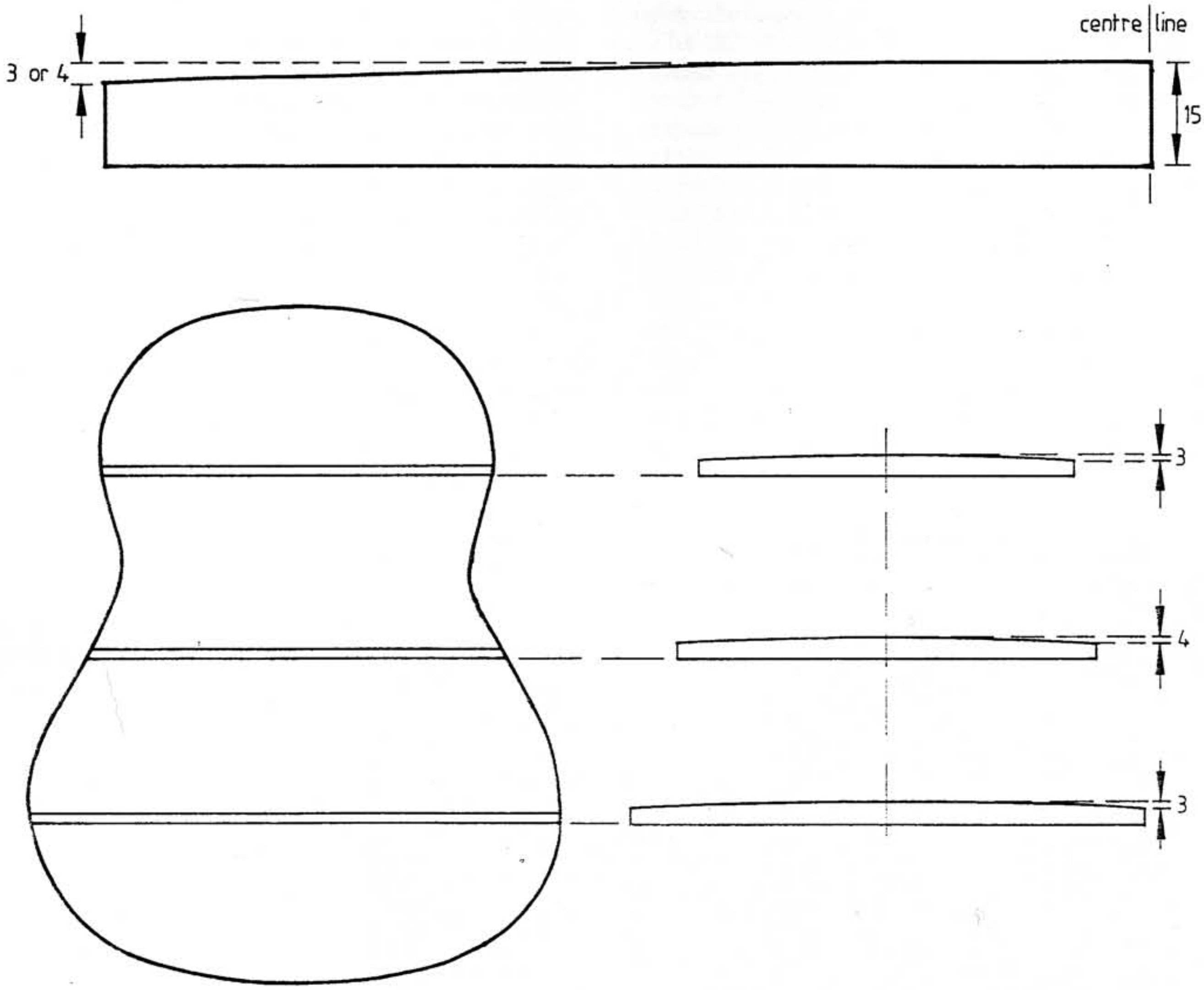
3 When the strips are all in place, cramp a batten on top, and leave to dry (16-7).
4 Remove the masking tape and scrape away any excess glue. Sand the strip along its top surface, and curve the sides down with a chisel or a small violin maker's plane (16-8). This strip will be visible through the soundhole of the guitar, so make sure it is neatly finished. Avoid creating a feather-edge, as this will appear jagged.

Make the back bars (transverse bars)

1 Mark the positions of the back bars on the back, and prepare enough wood for all three.
2 Most guitars have backs which are arched, rather than flat. Some makers use a solera for both the soundboard and the back. The solera for the back must be hollowed out to a greater degree than that for the soundboard, as the back usually has a far more pronounced arching (16-9). Although this method is essential for the soundboard, a simpler way to achieve the back-arch is first to shape the bars to the required curve along their gluing surfaces, and then glue them to the back, which will take up the shape of the bars. The more extreme the arch, the more difficult it will be to fit the back to the ribs, and the suggested dimensions are as follows:
   Bar 1: 3 mm
   Bar 2: 4 mm
   Bar 3: 3 mm
   Prepare a half-template for each bar by drawing along a flexed steel rule (16-10). Transfer these curves to the bars and plane them to shape. Ensure that they are square all round, or the pressure of the cramps will distort the gluing angle.
3 Hold each bar in place on the back and scribe its position on the reinforcing strip with a marking knife. Remove the portion of reinforcing between the marks, so that the bar can make contact with the back (16-11).
4 Ideally, the relative humidity in the workshop will have been regulated from the start. It is especially important, however, that the air is fairly dry before and during the time when the bars are glued to the back. Glue them in place one at a time, using a thin, flexible backing strip to prevent damaging the outer surface of the back. Clean away any excess glue, and leave to dry (16-12).

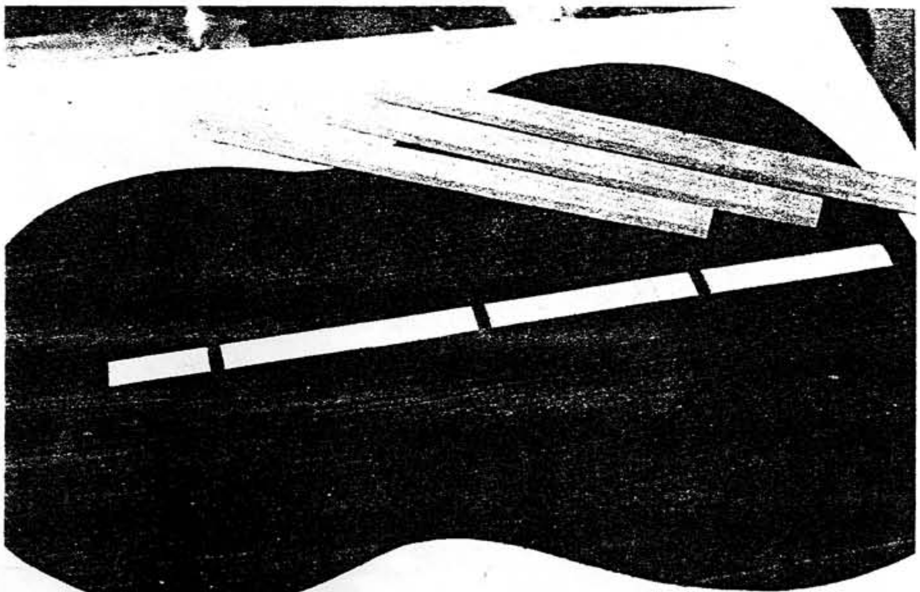


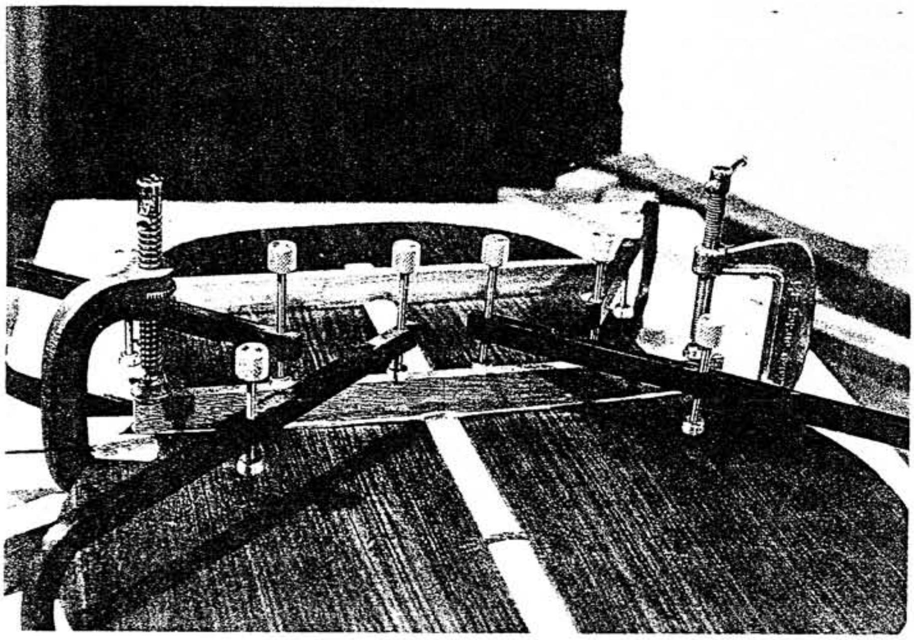
16-9 Gluing the back bars to the back on a shaped solera. The bars have been shaped to the curve of the solera before gluing



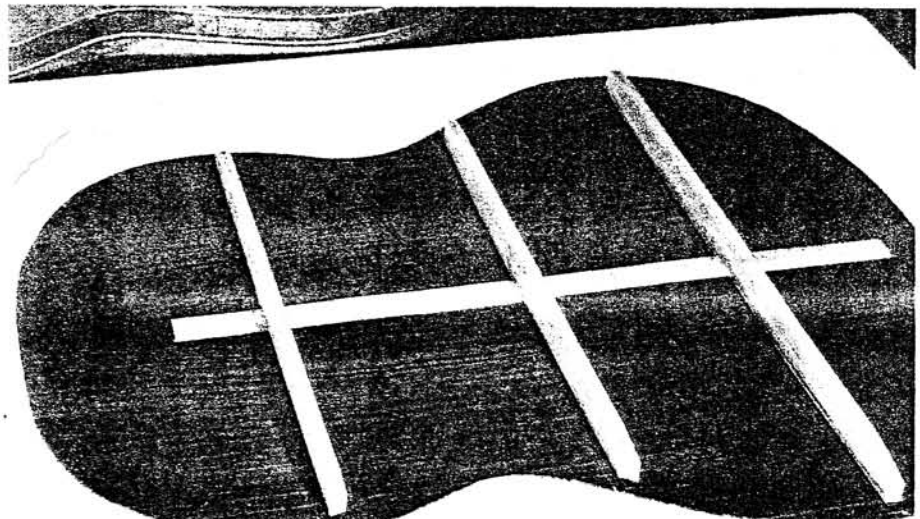
16-10 Top: typical half-template for the back bars. Bottom: typical arching for the back bars

16-11 Sections of reinforcing have been removed so that the back bars can be glued to the back

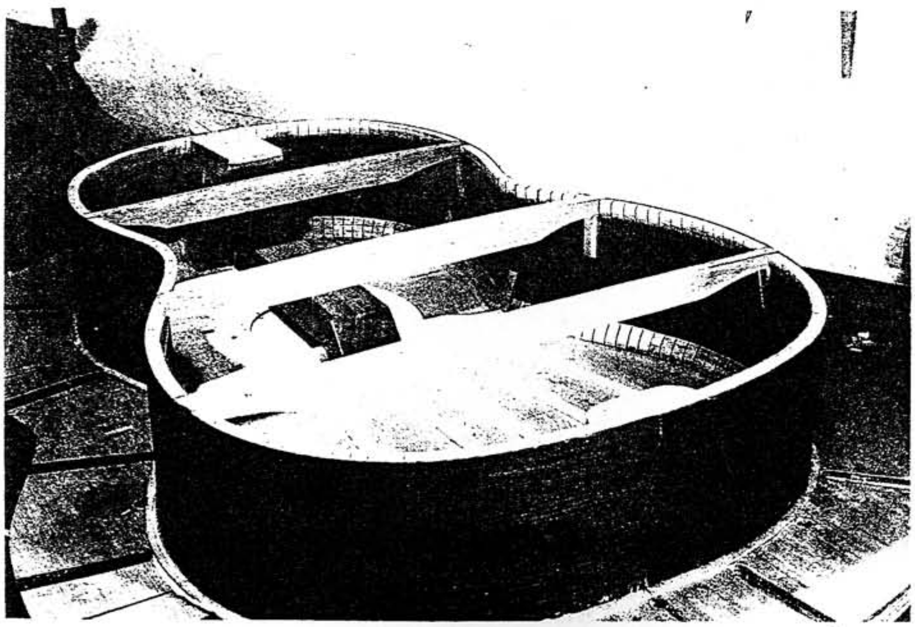




16-12 If a shaped solera is not used, the bars can be glued one at a time with a flexible backing strip underneath to protect the back from being dented by the cramps



16-13 The back ready for fitting to the ribs



16-14 Torres' method of fitting the back – the arched back bars are first fitted and glued to the linings, and supported with rib-blocks. The back is then laid over the guitar and bound in position with thick string, thus gluing the back to both linings and back bars in one operation

5 The top of each bar must be slightly rounded with a small plane and sanded smooth. The precise profile of the bars varies from one maker to another. Some are left virtually rectangular, some are rounded, and some are gabled. The shaping is largely for visual neatness, although any reduction in weight is probably desirable. The ends of the bars can be scalloped (16-13).

Note

Do not leave too long a time between gluing the back bars in place and fitting the back to the ribs. Any changes in humidity may cause the arched back to alter its shape – if you expect a long delay, prepare the bars, but do not glue them to the back until a couple of days before assembly.

Torres sometimes used a different method of assembling the back – he first fitted the back bars to the ribs and then laid the back over them, gluing the back to the ribs, and the back to the bars, in one operation. Certain difficulties arise with this method – first, there is no way of cleaning off any excess glue from the bars; second, it is difficult to ensure that the back is making good contact with the bars at all places. String or elastic bands must be stretched over the back to bring it into contact with the bars. Animal glue sets so fast that it must have been very difficult for Torres to have positioned and cramped the back before the glue had set (16-14).

17 Ribs

The ribs are supplied as a matching pair – a fairly thick plank will have been sawn down its centre, and opened out like a book, to provide two ribs with matching grain. The source of the wood will determine its thickness – commercial producers of Indian rosewood usually cut the tree into planks, which are seasoned and sawn roughly to the dimensions for sets of backs and ribs. They are often generous with the thickness, perhaps supplying ribs about 4 mm thick. This will mean that half their thickness must be removed to prepare the ribs for bending.

Sometimes, planks may be imported, and then sawn locally, in which case the ribs may be supplied to you at almost the required thickness of 2.0 mm – light scraping and sanding may be all that is needed to prepare them for bending. Brazilian rosewood, being so scarce and expensive, is usually cut to the minimum thickness, so as to avoid any waste.

Tools

Smoothing plane
Scraper plane
Cabinet scraper
Straight-edge
Rule
Square
Thicknessing caliper
Bending iron
Dividers

Materials

Pair of ribs: rosewood, cypress, or maple (800 mm × 110 mm × 3 mm)
Thin card

Method

Prepare the ribs

1 Take a strip of thin card, approximately 25 mm wide, and lay it along the half-template in order to find the total length of one rib. Cut the card to this precise length. Hold it in place again, and mark the waist position. This is where the first bend will be made. Lay the strip on a flat surface, and measure 35 mm in from the neck end. Mark this position clearly – it represents the portion of rib that will be set into the slot of the neck, so it is important that this area of the rib is thicknessed accurately to the same dimension as the slot cut in the neck (17-1).

2 Assuming that the ribs are fairly thick, and that their surfaces are rough, the first step is to plane them lightly until all the saw-cuts and rough fibres have been removed. The aim is not to thin the wood down, but simply to reveal the grain pattern and quality of the material. A sharp plane is essential, or the rosewood will tear, and deep gouges will appear on the surface.

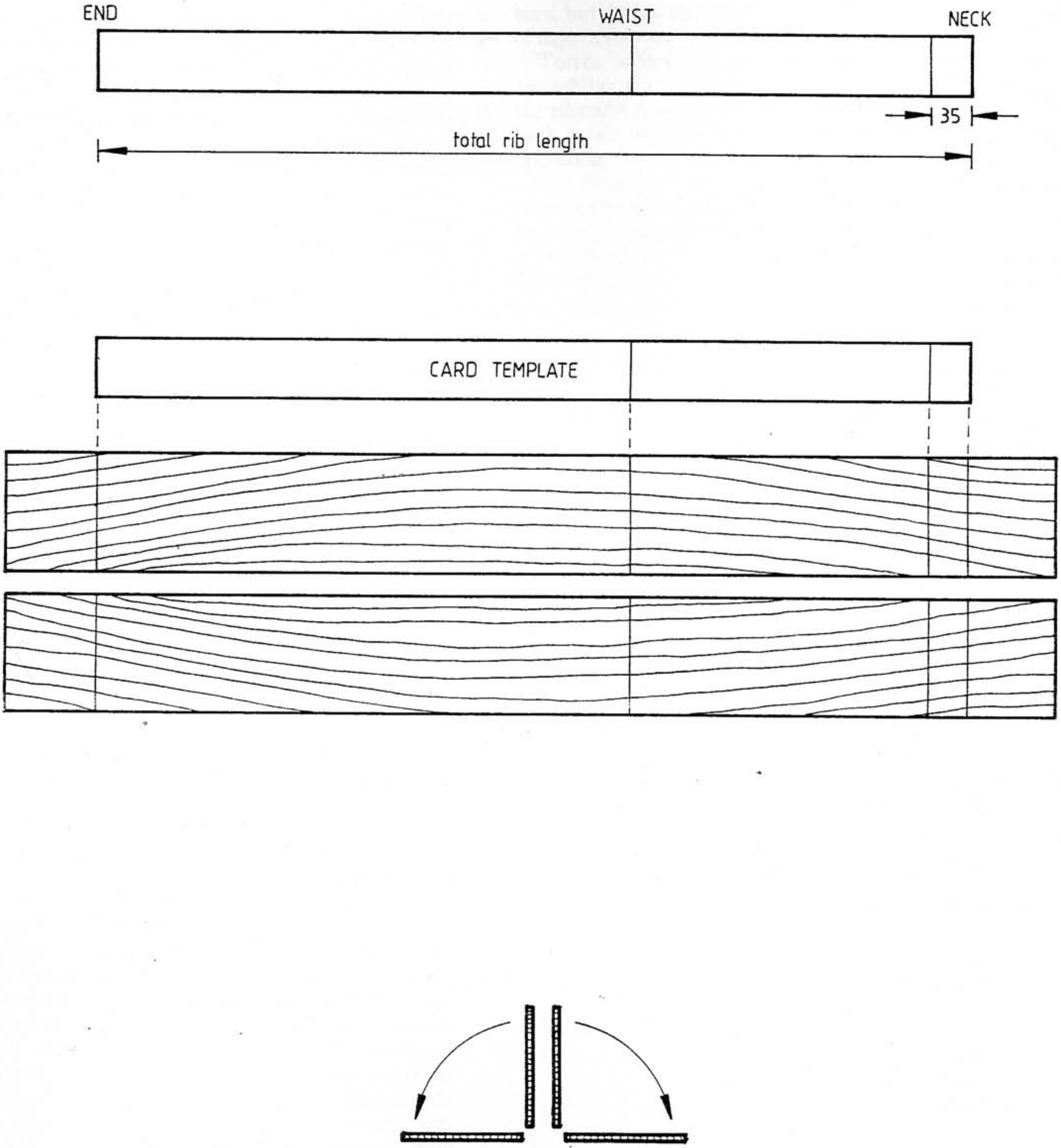
3 Place a rib on the workbench, and cramp one end down with a batten, to protect the surface. (If the bench is rough and uneven, place a smooth flat board below the rib.)

4 Retract the plane blade so that it removes no material at all. Begin planing from the cramped end, and gradually adjust the blade until it begins to remove thin shavings of wood. At first, the plane will only touch the high points on the rough surface, but soon it will begin cutting into the full area of the rib. Continue until the majority of the side is smooth, then turn it round so that you can plane the end that was hidden under the cramp. Once the first side is reasonably clean and smooth, turn it over and repeat the procedure on the other side. Do the same with the second rib.

5 Lay the two ribs next to each other, and adjust their positions until you notice that the grain pattern of one is a mirror-image of the other. Look for any obvious faults in the surface. Very often, the grain along one edge will be much straighter than that along the other. If one edge is particularly wavy or cracked, it can probably be excluded from the overall dimensions of the rib – the rough ribs are usually supplied wider than the required width. Select the edge with the straighter grain as the one that will join to the soundboard. Cramp a long straight-edge close to this edge of the rib, and scribe a line with a marking knife all along its length, leaving as little waste as possible. Mark the second rib as well.

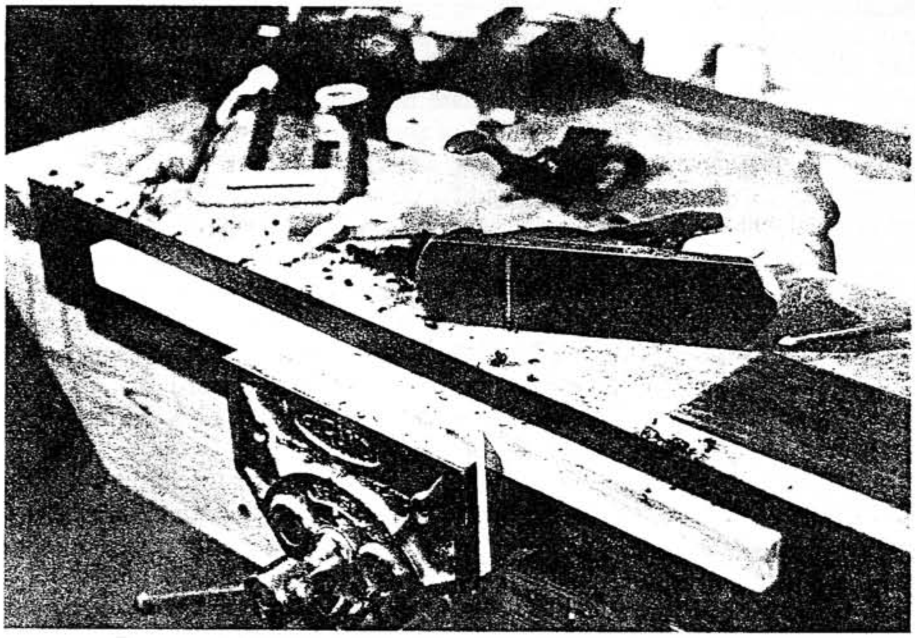
6 Cramp the rib in a vice, sandwiched between two long battens for support, and plane down to the scribed line (17-2). Check with a long straight-edge to make certain that this edge of the rib is level all along its length. Repeat with the second rib.

7 From the flat edge of each rib, measure across and mark the maximum width of the rib. This dimension varies according to which plan you are following. If the plan gives a body depth at the end block of 104 mm, then the depth of the ribs

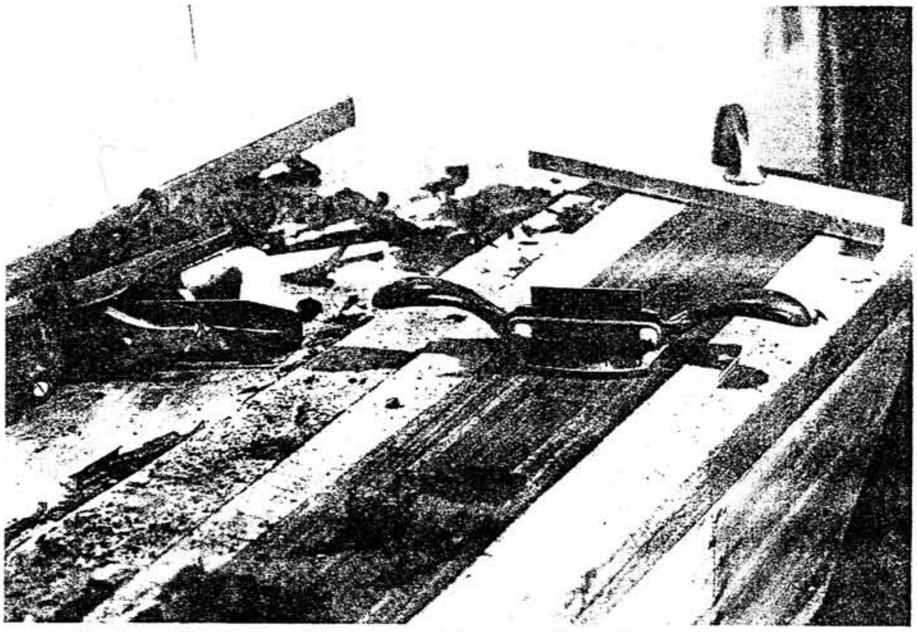


17-1 A strip of card represents the actual length of the rib. The positions of the neck, waist, and end can then be squared across the ribs. The 35 mm section at the neck end must be the same thickness as the slots cut in the neck.

The lower diagram shows how a plank is cut down the centre to produce two ribs with matching grain patterns



17-2 A rib is supported between two long battens so that it remains rigid while the edge is planed flat



17-3 Smoothing and thicknessing the rib while it is cramped firmly at one end

will be 100 mm (allowing 2.0 mm for the soundboard, and 2.0 mm for the back). Mark both ends, and join up with a marking knife. Repeat with the second rib. Cut the waste away on a bandsaw or with a coping saw, then plane the edges straight. The ribs should now have straight, flat edges, and be of equal width all along their length.

8 Examine the ribs and decide which sides look the most attractive. In many cases, there will not be any noticeable difference, but a small knot or other imperfection may be visible on one side, and not the other. Mark the chosen outer side on each rib.

9 These outer surfaces must now be smoothed to perfection. Cramp down one end of the rib, and begin with a sharp smoothing plane. If the blade immediately digs in, try reversing the rib, and planing in the other direction. You may now find that the plane cuts fairly smoothly. If the blade digs in, no matter which direction you plane, then put this tool aside and try the scraper plane (17-3). Although it removes less material, it is far more likely to create a smooth surface. By systematically working along the rib, and turning it round to reach the part hidden below the cramp, you should soon have a smooth surface. Try to always plane away from the cramped end, or else the rib may buckle and break. Check frequently with a straight-edge that the rib is flat across its width – it is easy to remove more wood from the two edges than the centre. If necessary, a cabinet scraper can be used to smooth out any stubborn areas. The grain direction will not necessarily be constant along the entire length. It may be necessary to work part of the wood in one

direction, and part in the other – this is one of the characteristics of rosewood and maple, which often have an uneven and interlocked grain structure. Continue scraping until the wood is smooth.

10 Now place the two ribs side by side, making certain that their grain matches as before. Place the strip of card on the outer, smooth side of the ribs, leaving an equal amount of waste either end. (The rough ribs will be somewhat longer than the card representing the final rib length.) Transfer the positions of the neck end, the 35 mm section that will enter the next slots, the waist, and the bottom end (see 17-1). Square all these lines across – they will be used as guides in the bending process. Do not cut off the waste portions at either end, as the rib may well shift slightly during bending – the full length is needed until the bent rib is in position on the solera, when its final length can be seen.

11 The ribs are now planed and scraped down to their final thickness. Deal with them one at a time – cramp a rib with its smooth side down, and remove thin shavings from the back. Check frequently with the thicknessing caliper, and work the rib down to about 2.2 mm. Although the final thickness can be as little as 2.0 mm, it is wise to leave some material for cleaning up and sanding once the guitar is complete. (There may also be some scorch marks in the waist area that will have to be scraped away.) The marked area of 35 mm at the neck end should, however, be carefully scraped down to exactly 2.0 mm, because the slots cut in the neck to receive these rib ends are no more than 2.0 mm. Once both ribs are smooth, and correctly thicknessed, they can be put aside, ready for bending (17-4).

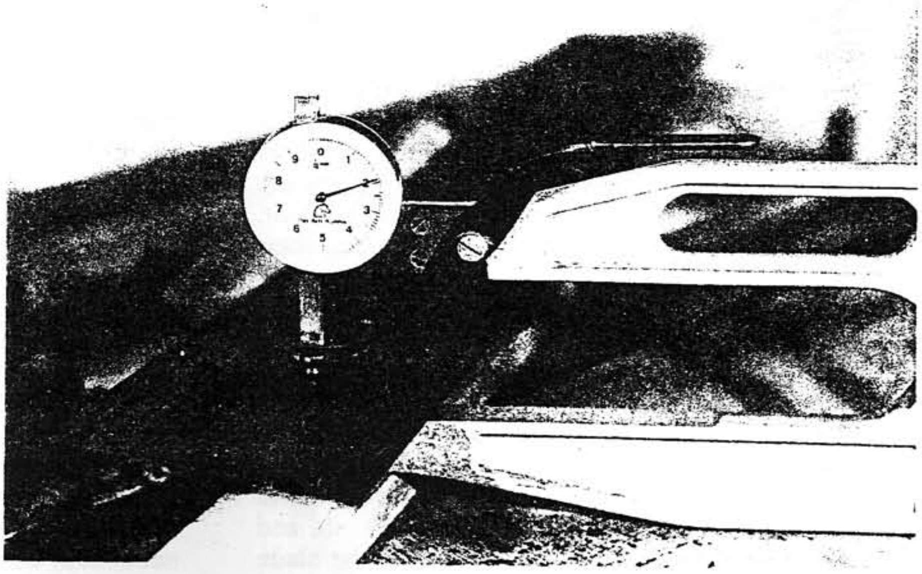
Bending the ribs

Looking at a beautifully flat, smooth rosewood rib lying on the bench, it may seem a daunting prospect to contemplate bending it on a hot iron. Uppermost in the mind of the inexperienced maker is the fear of snapping the rib in two. In fact, rosewood is not especially difficult to bend, as it has a high degree of elasticity when heated. Bending the ribs is one of the most sculptural aspects of guitar making – you are shaping and manipulating the wood into a series of smooth curves, and to a large extent, defining the aesthetic character of the instrument. The experience is all the more fascinating because of the powerful aroma produced as the oils and resins in the rosewood are heated.

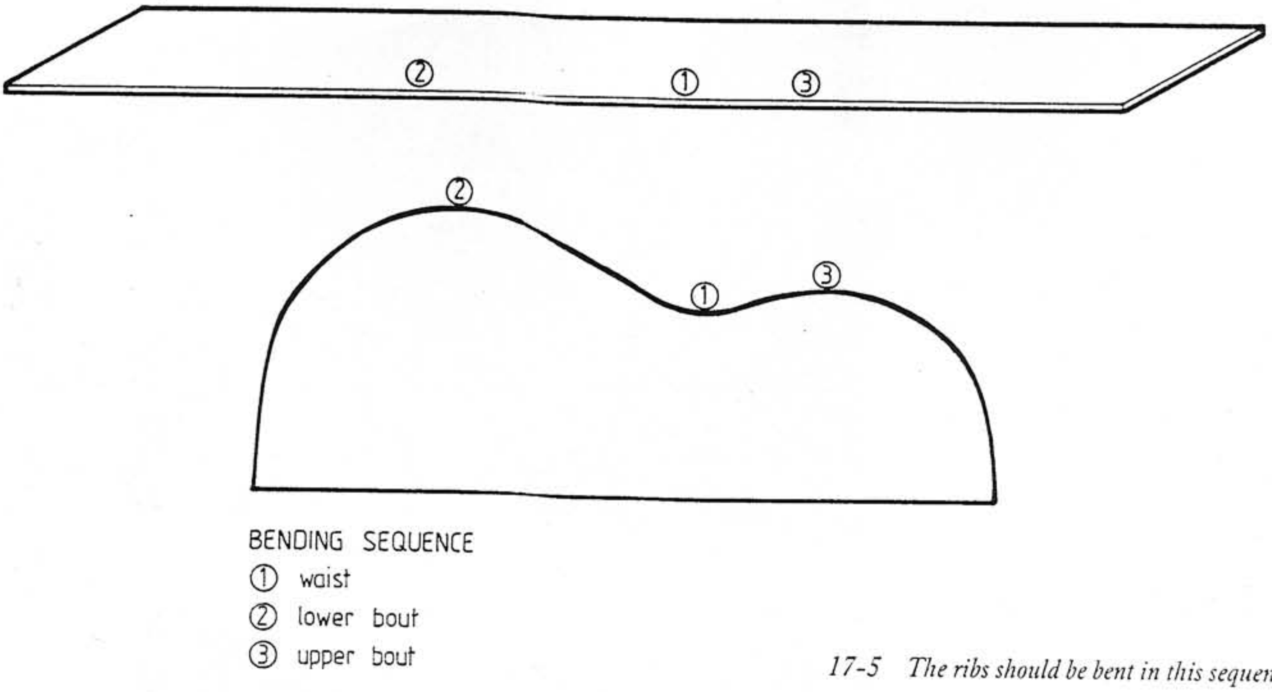
Guitar makers have in the past tried many different approaches to bending ribs. One method is to place the rib in hot or boiling water for several hours, and then bend it under pressure, to conform to the required shape. Another method is to soak it for a shorter time, and then shape it on a hot bending iron.

A better way is to bend the rib dry, using only the heated bending iron, and perhaps brushing a little water on to the waist area, if required. There is in fact no need to thoroughly soak the wood, as the heat, combined with the steam produced from small amounts of locally applied water, will allow the wood to bend quite easily.

It is important to create the bends in the correct area – not only must the rib conform closely to the template, but the two ribs must be as similarly shaped as possible. Close scrutiny of guitars by almost any maker will often reveal a slight lack of symmetry, with the curves of the bouts not quite matching. Your primary concern, while bending the rib, should be to make it conform to the template.



17-4 Measuring the thickness of a rib



17-5 The ribs should be bent in this sequence

1 Cramp the bending iron securely to one end of the workbench and switch it on. The half-template of the guitar should be close by so that the rib can be compared to it, or the outline drawn on the solera can be used. Also needed is a jar of water and a brush or rag. The ribs should by now have been clearly marked, to show which edge will face down onto the soundboard. Test the temperature of the bending iron by sprinkling a drop or two of water on to its surface. The drops should bounce off and evaporate. The iron must be reasonably hot, or the wood will not bend. But if the wood begins to scorch, turn the heat control down slightly.

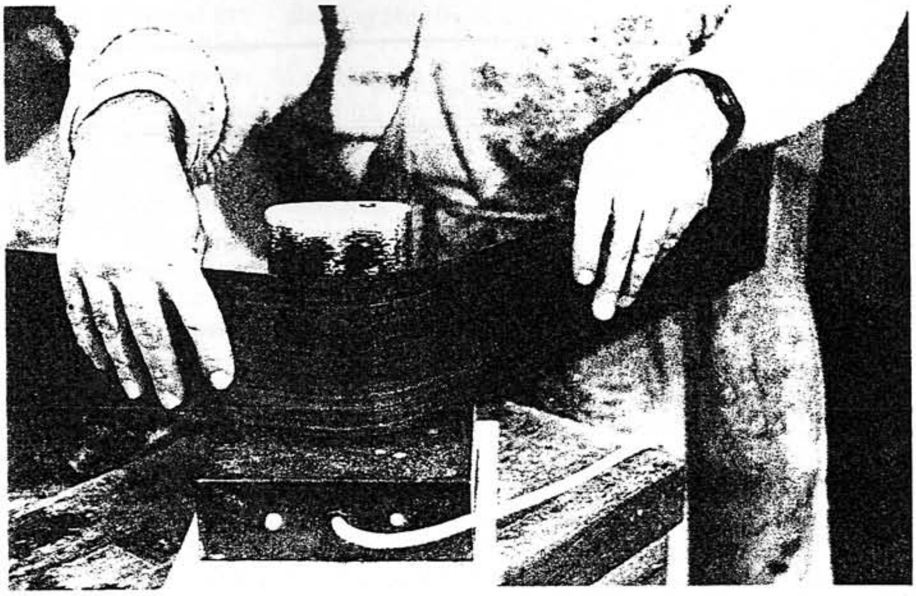
2 The ribs are best bent in the following sequence (17-5): first, the waist; second, the lower bout; third, the upper bout. Hold the rib against the bending iron with the waist mark placed centrally over the heated area. Gently rock it back and forth, gradually applying more pressure with your hands, and warming up the general area of the waist. Remove the rib frequently, and brush on a little water. This will turn to steam as the heat is applied, and the rib will gradually start to bend. This first curve is quite sharp, so concentrate the heat right on the spot where the line of the waist is marked (17-6). Start comparing the rib with the guitar outline on the solera, and continue increasing the curve until it accurately follows the shape. Avoid holding the rib for too long in any one position, or it will begin to be scorched. (Some superficial scorching is probably unavoidable, and can easily be scraped away later, but do not burn the rib too deeply.)

3 When the waist curve is complete, flip the rib over and start to bend the lower bout. First apply heat generally to the whole area from the end of the rib, to near the waist. Now work systematically, beginning with the section of rib closest to the waist. Only proceed further once this is correctly bent. If you progressively work outwards from the waist, the correct curve will begin to emerge quite easily (17-7). Refer the rib back frequently to the guitar outline. Continue downwards towards the end of the rib, until it curves round and past the centre-line on the solera. The curves of the lower and upper bouts are quite gentle, and the smoothest result is obtained if the wood is kept moving back and forth – do not hold it still for long periods while applying pressure, as you may create a stepped effect rather than a gentle curve.

4 Once the lower bout is complete, repeat the same procedure to bend the upper bout – as before, begin near to the waist, and move along systematically towards the section which will join into the neck slots.

5 A check can now be made to see how closely the entire rib resembles the plantilla, and you will probably have to carry out a few minor adjustments to bring it finally to shape (17-8). Any overbending can be corrected by applying heat on the reverse side, but try to avoid this if possible, as the curves may become distorted.

Once the ribs have been correctly shaped, they can be cramped to a half guitar-shaped jig, until needed. This will help retain the shape, and also be useful when gluing on the linings (17-9).



17-6 Bending the curve at the waist

17-7 Bending the curve at the lower bout

Trim the ribs

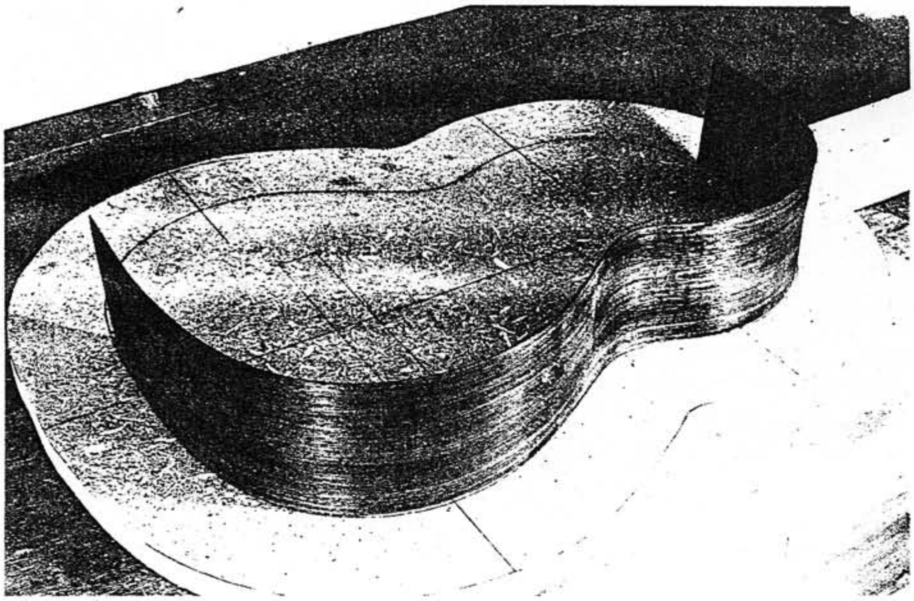
The ends of both ribs must now be trimmed so that they butt together on the centre line of the solera, while at the same time following precisely the outline of the guitar.

1 Work with one rib at a time. Make certain that it is correctly positioned on the solera. The rib can be held in place with spool cramps, so that it makes contact with the solera. The sides of the rib must be vertical, and the rib should closely follow the guitar outline drawn on the solera. A few supporting blocks may be useful, these can be bolted in place where necessary around the periphery, and will help keep the rib vertically in position. Mark the points where the rib crosses the centre-line, at both ends of the outline. Extend these lines up with an engineer's square (17-10 and 17-11).

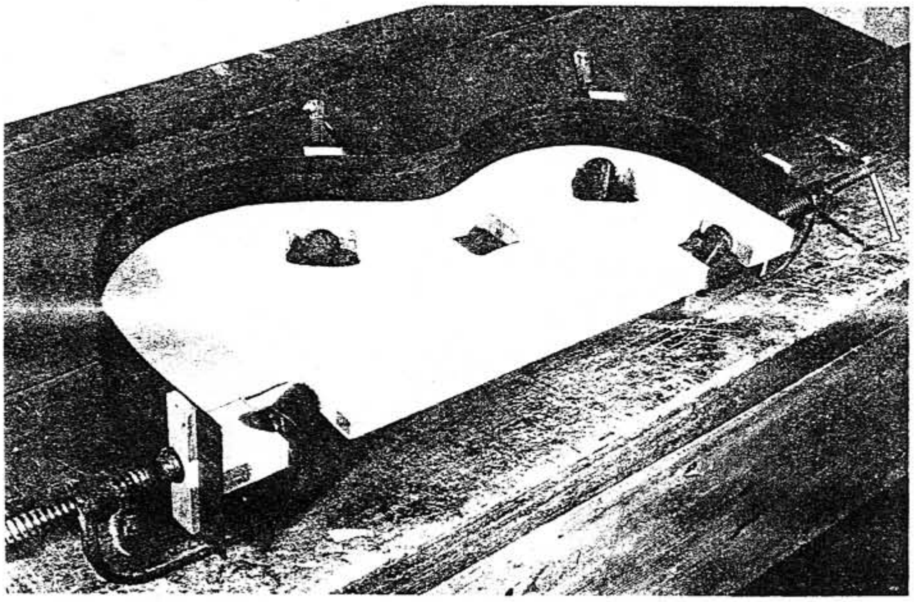
2 Remove the rib, and mark the pencil lines with a marking knife. Before cutting off the waste, it will help to chisel, a small ramp from the waste side of the line, so that the saw has a tiny groove to follow. This will result in a more accurate cut on the hard rosewood. Cut off the waste at both ends (17-12).

3 Replace the rib on the solera to check the accuracy of the cuts. The rib should now end exactly on the centre-line. Remove it, place the other rib in position, and repeat the marking and cutting as before.

4 It should now be possible to place both ribs on the solera, so that their ends butt together on the centre-line, whilst they closely follow the guitar outline. If the ribs have been cut short, try to butt them together at the neck, leaving a gap at the end-block. (This will later be covered with an inlay.)



17-8 Trying the bent rib against the outline of the guitar



17-9 The rib is cramped against a guitar-shaped jig. This will ensure that it retains its shape until needed for assembly. The jig will also be used to support the rib while the lining is glued in place (see Chapter 20)

Fit the neck and ribs

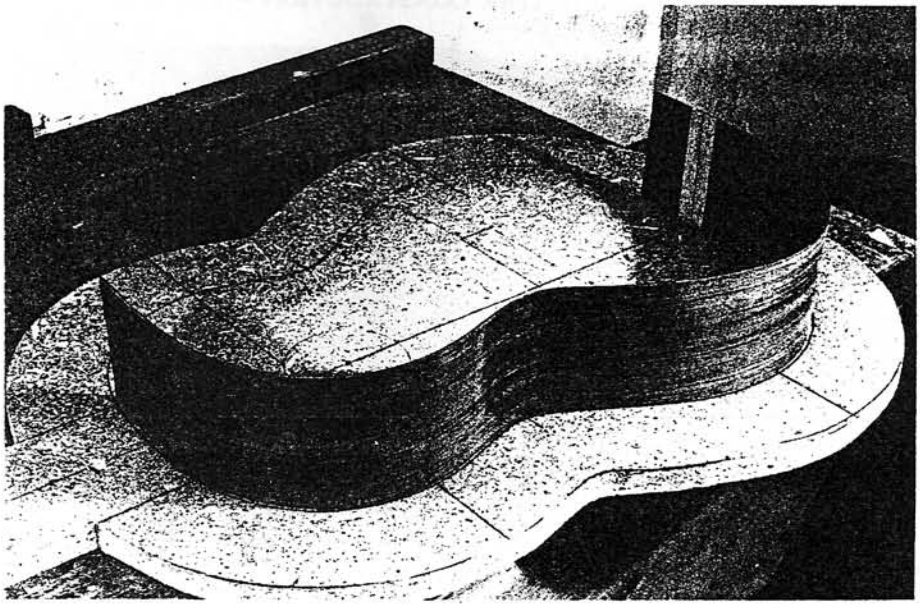
In order to fit the ends of the ribs into the neck slots, they must first be cut to the correct length and angle, so that they match up to the slots cut in the neck. This should be done now, while the neck and ribs are unattached to anything else (17-13).

1 Measure the total height of the heel end of the neck ('c' on 17-13). This varies according to which plan is being followed, and is equal to the depth of the guitar at the neck less 2.0 mm for the thickness of the back. (The soundboard is left out of this calculation, as it will be let in flush with the surface of the neck.) Place a rule on the solera, and measure up the height of the heel. Mark this on to the ribs. (Some masking tape stuck to the ribs will make it easier to see the pencil marks.)

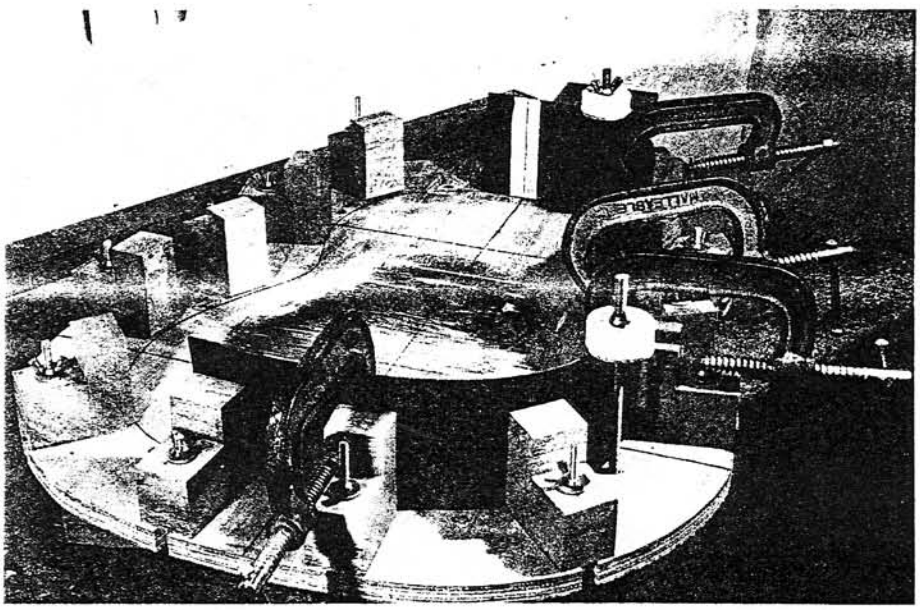
2 Place a small square on the solera to check that the join where the two ribs butt together is central, and vertical. If it is not, then stick some masking tape across the gap between the ribs, and use the square to mark the true centre on the tape. This central, vertical line will cross the horizontal line representing the height of the heel.

3 Now refer to the neck – place it fingerboard-side down, and set a pair of dividers to the distance from the centre of the neck to the beginning of the slot (approximately 5 mm). The distance should be the same either side, but if you have cut one slot deeper than the other, they will have to be dealt with separately. Use the dividers to transfer this measurement to the upper (heel) end of the ribs ('a' on 17-13).

4 Turn the neck over (fingerboard-side up), and use the dividers to mark the distance from the



17-10 The rib is placed accurately on to the guitar outline so that the point where it crosses the centre-line can be marked for cutting. The neck-end is marked in the same way. The masking tape makes the line more visible



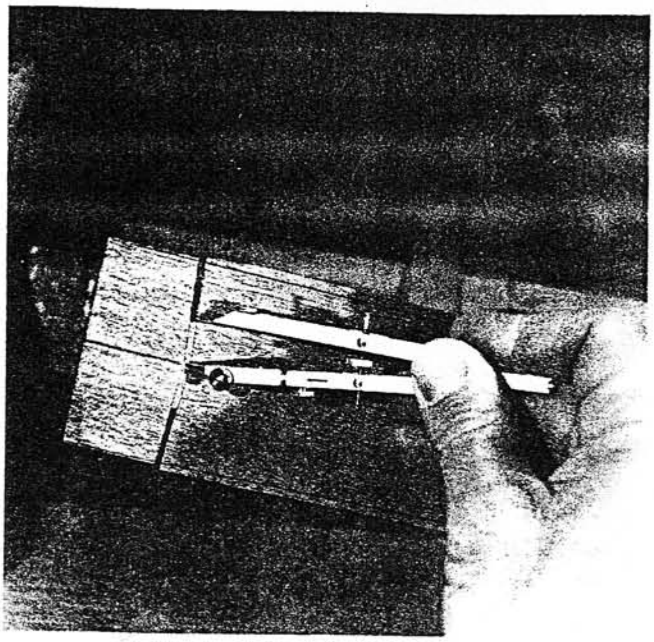
17-11 Blocks and spool cramps can be applied if necessary, to ensure that the ribs follow the outline as closely as possible

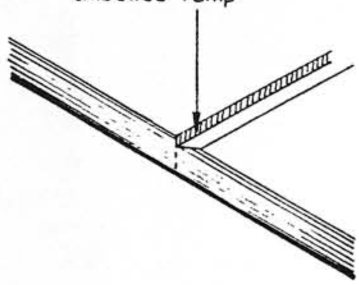
centre of the neck to the beginning of the slots (17-14). Transfer these distances to the lower (solera) end of the ribs ('b' on 17-13).

5 Remove the ribs, and join up the marks with a marking knife. Cut off the waste (17-15 and 17-16).

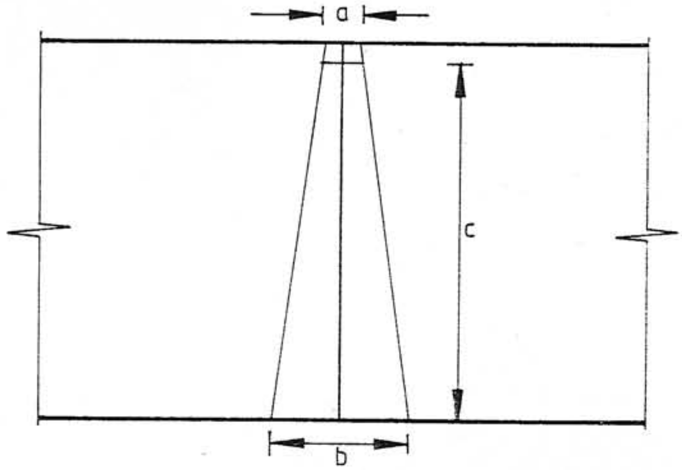
6 Each rib must now be fitted to its slot. Carry out this procedure slowly and patiently, because the neatness of the join between the neck and ribs depends entirely on achieving a close fit between these components. As the rib is 2 mm thick, and the slot is 2 mm wide, they should go together with only slight adjustment. Some medium grade garnet paper wrapped around a small sanding block will help reduce the rib if it is too thick. The slot can be cleaned out and enlarged by wrapping abrasive paper around a cabinet scraper and working it back and forth. Be careful not to round the leading edges of the slot, or a close fitting joint will not be possible. Carefully adjust the slot, and the end of the rib, until it is possible to slide the rib down into the slot (17-17). Do not force it in; if something seems to be preventing the rib from reaching the bottom of the slot, it is probably because one area of the rib is too thick – measure the end of the rib with the thicknessing caliper, and sand away a little more wood. Be aware that the end of the rib will be slightly curved, following the curve that was created on the bending iron; the slot, however, was formed by a straight saw-cut. Bear this in mind as you sand the end of the rib, and apply the sanding block so as to slightly flatten this end curve. When you are satisfied that the rib can be introduced into the slot fairly easily, put it aside, and fit the second rib in the same way.

17-14 The distance from the centre of the neck to the beginning of the slot is measured, and then transferred to the ribs

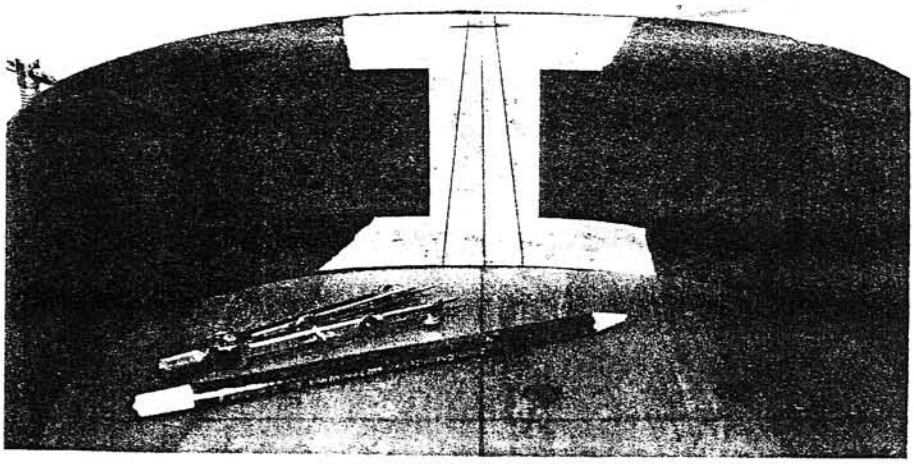




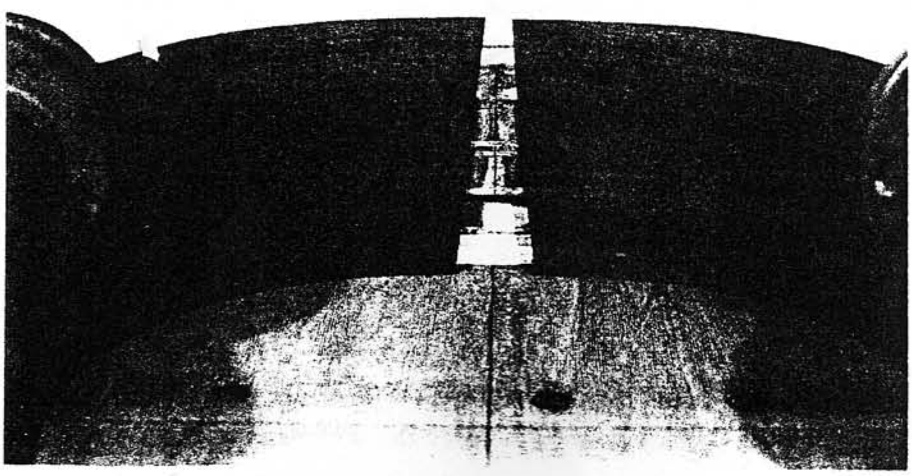
17-12 A small ramp chiselled on the waste side of the cut will ensure that the saw cut is accurate



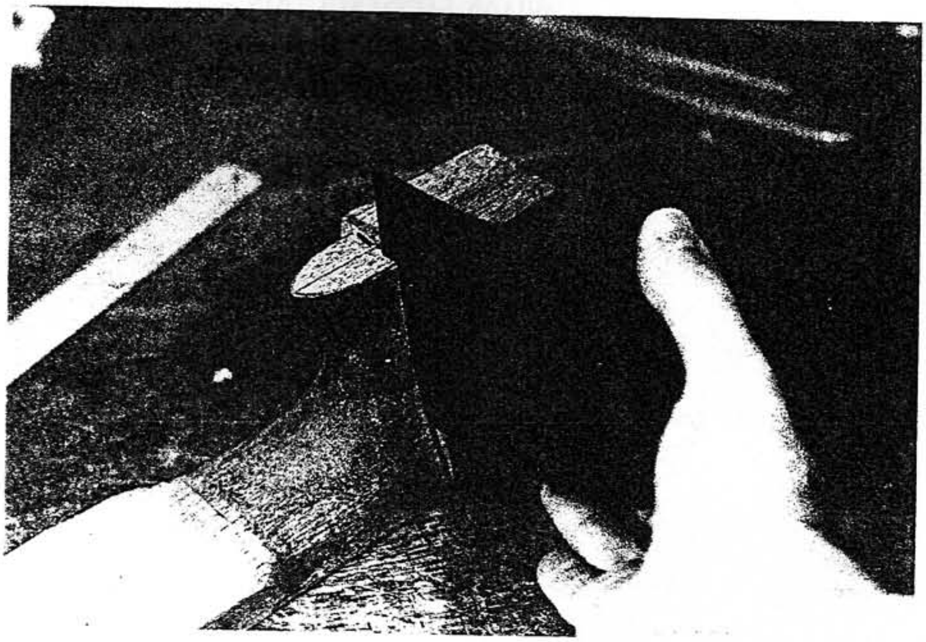
17-13 This diagram shows the marking out required at the rib ends that will join into the neck: 'a' is the central portion of neck on the heel side; 'b' is the central portion of neck on the fingerboard; 'c' is the full depth of the neck



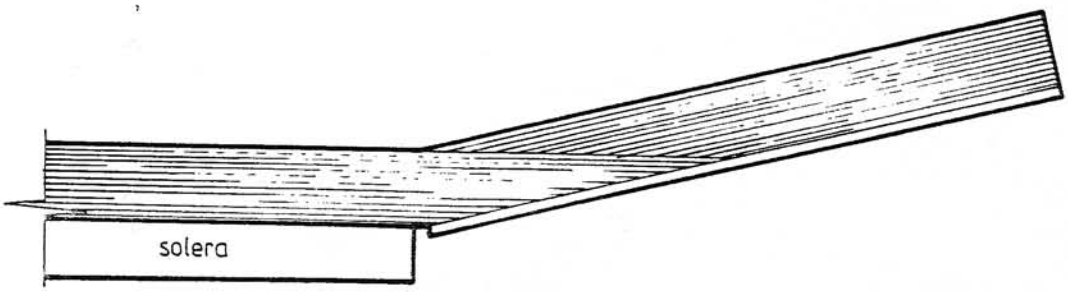
17-15 The marking out completed – the horizontal pencil line at the top defines the height of the neck; the two slanting vertical lines show where the ribs will be cut so that they can be housed into the neck slots. The distance from the centre-line to the vertical lines is taken from the same measurements on the neck

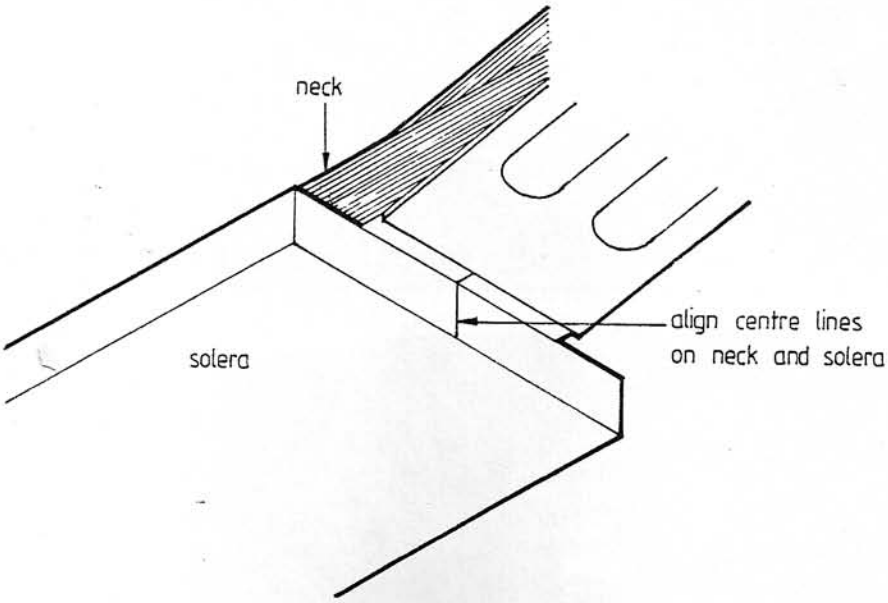


17-16 Once the ribs have been cut, they would meet as shown here. The gap represents that portion of neck not occupied by the slots. (There is no need to assemble the ribs in this way – the photograph is simply for clarity)

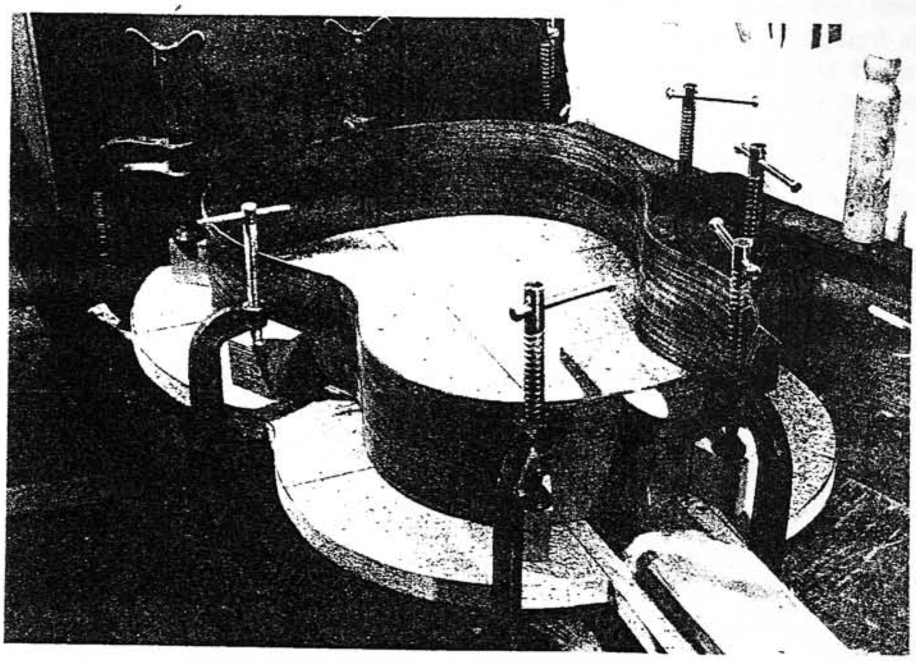


17-17 Fitting a rib into its slot





17-18 Top: the head veneers hang over the end of the solera so that the neck lies flat. Bottom: the centre-line of the neck is aligned with the centre-line of the solera

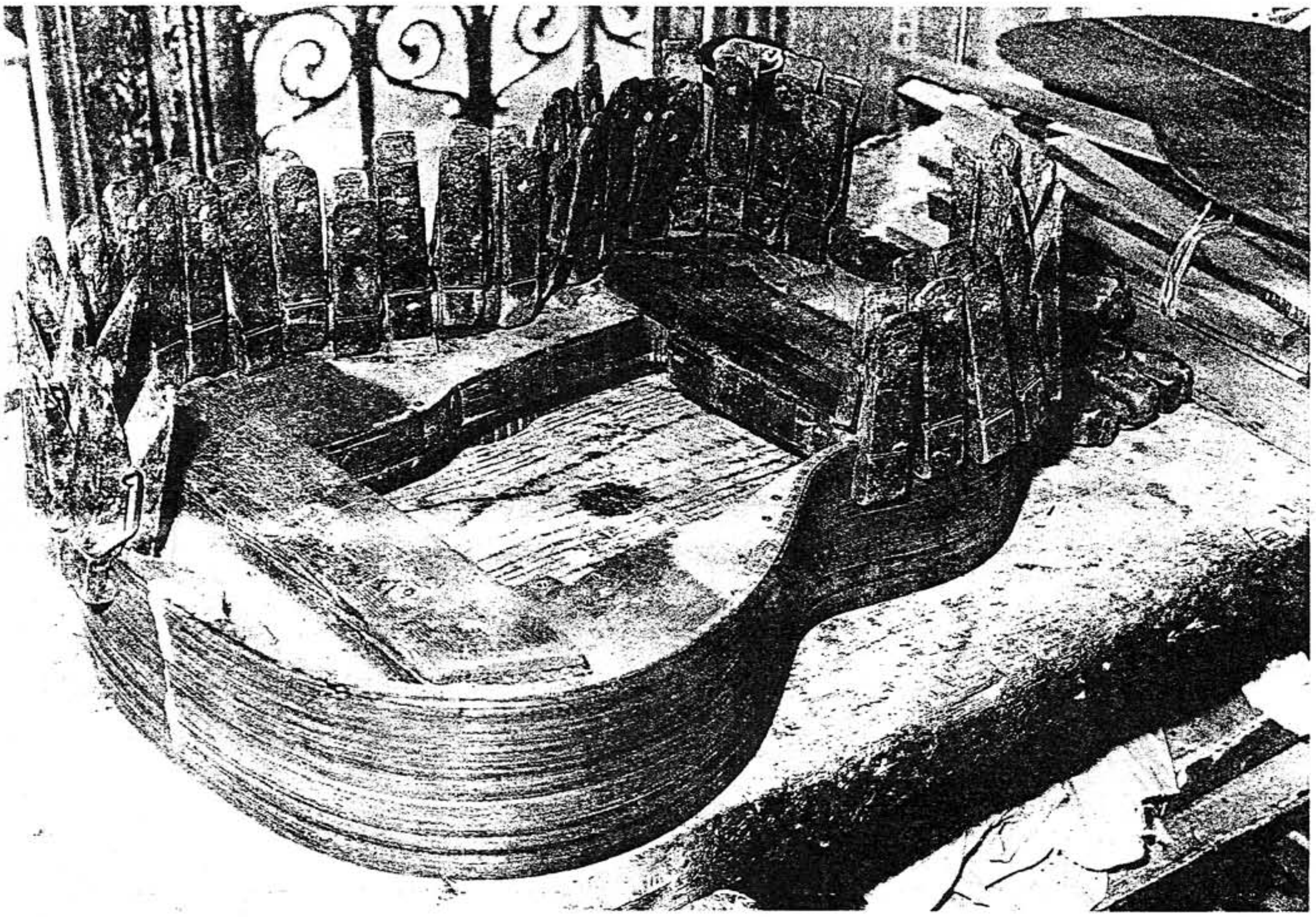


17-19 Checking that the ribs and neck can be assembled so that the ribs follow the guitar outline closely, and the neck is placed centrally on the board

7 It is now important to make certain that the centre of the neck can be positioned on the centre-line of the solera, whilst the ribs maintain their correct position around the guitar outline, otherwise the soundhole and fingerboard will not be centrally placed. The centre of the neck has already been marked, so it can simply be placed on the solera and tapped one way or the other until the two lines coincide. Now look under the head end of the neck; be certain that the head veneer is past the end of the solera, and that the neck lies flat along the ramp (17-18). (If you miscalculated the length of the ramp, you will have to shorten it slightly. This would also be the case if you made a guitar with a shorter string length.) Now align the centre of the neck (marked on the fingerboard side) with the centre-line drawn on the ramp. (This should be carried over the end of the ramp, and squared down so that it is visible when the neck obscures the main line.) Cramp the neck in place and check once again that it has not moved away from the centre-line at the foot end.

8 Introduce the ribs to the neck slots and make any final adjustments necessary until both ribs and neck fit together easily, and follow both the guitar outline and the solera centre-line (17-19). Remove the ribs and put aside – they are not glued yet.

18 Linings

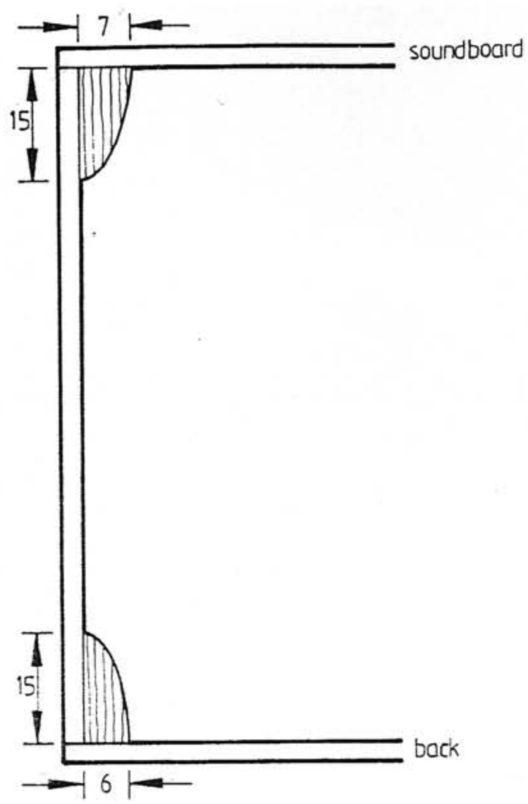


18-1 The Fleta workshop in Barcelona – large pegs are used to glue the kerfed linings to the ribs. The ribs have been glued to the top- and bottom-blocks which are set into cut-outs within the mould

A variety of woods can be used for the linings, the main consideration being that they should be dry and straight-grained; spruce, lime, mahogany and cedar are all suitable. One view is that the lining wood should match the soundboard, so that any changes in humidity will be reflected equally in both components.

The back is usually joined to the ribs with continuous kerfed linings, as these are easiest to glue in place. The soundboard is often joined to the ribs with individual blocks which are fitted once the ribs have been glued to the neck and end-block. Torres used both methods in his guitars, although he seemed to prefer continuous kerfed linings throughout, as these are used on the majority of his instruments. Continuous, un-kerfed lining can be made from a long strip of wood which is bent to the shape of the ribs before being glued in place. A continuous kerfed lining is more suitable, as it will conform easily to the shape of the ribs and not introduce any unwanted stresses to the instrument. 'Kerfing' involves sawing almost through a length of lining at frequent intervals, so that it becomes flexible.

Most linings are approximately 15 mm deep, but the top edge, to which the soundboard and back will be fitted, will vary depending on the type of purfling that will be used. The soundboard may be as thin as 2 mm at its periphery, and, if the purfling is let in to



18-2 Typical dimensions for the lining – usually the soundboard purfling is wider than that on the back; the soundboard therefore requires a wider lining to provide support

this depth, the soundboard would be cut right through. To guard against this, the linings should provide at least 4 mm of support to the soundboard alone. (Decide how wide your purfling will be, and then add on 4 mm.) The back purfling is often narrower than that of the soundboard, so its lining can be slightly narrower. (See Chapter 22.)

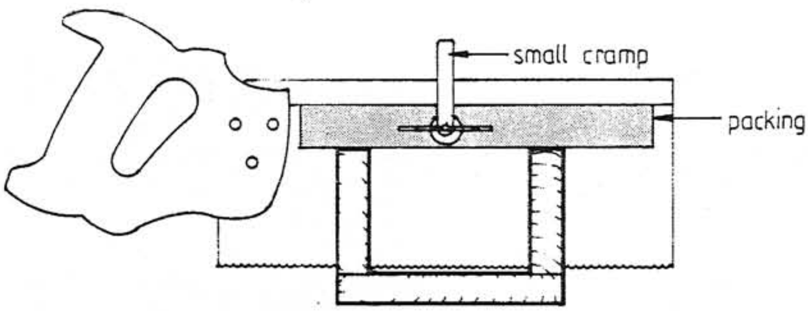
Typical dimensions are:
Lining for the soundboard: 6 mm-7 mm wide
Lining for the back: 5 mm-6 mm wide (18-2)

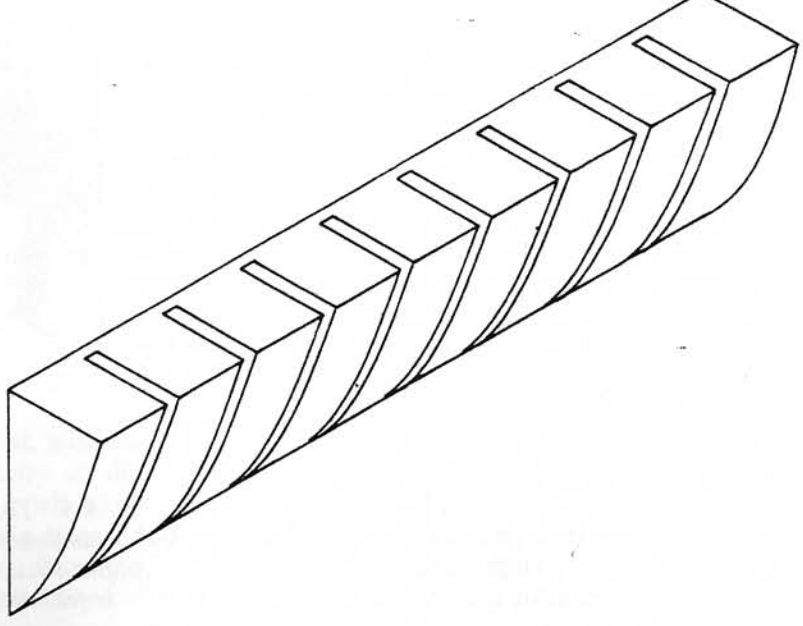
Tools

Smoothing plane
Block plane
Marking gauge
Tenon saw
Mitre box
Small cramp
Rule

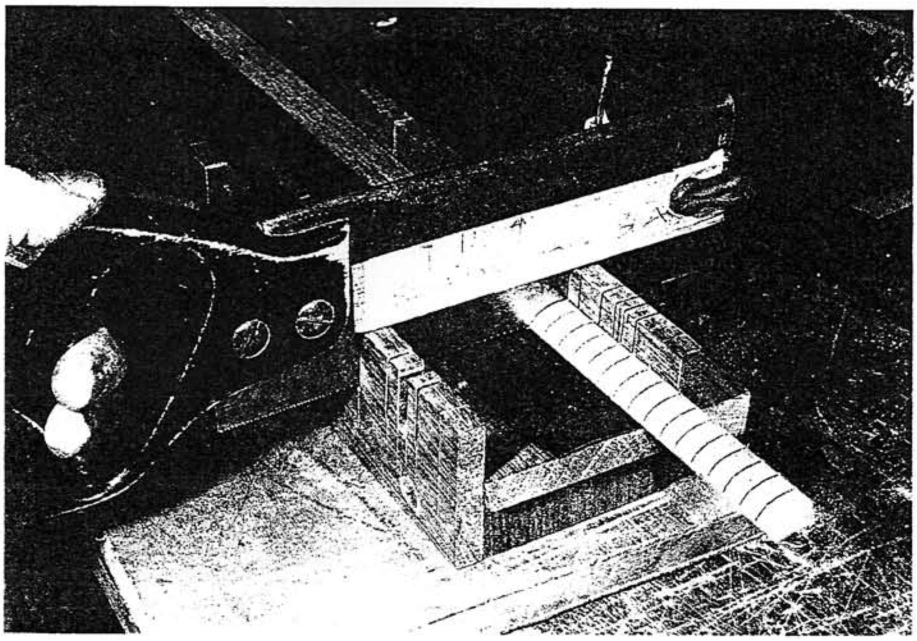
Materials

Wood for linings; 15 mm × 7 mm × 3 metres





18-3 Top: set-up for cutting the kerfed lining – a strip of packing attached to the saw will prevent it from cutting through the lining. Bottom: kerfed lining



18-4 *Making the kerfed lining*

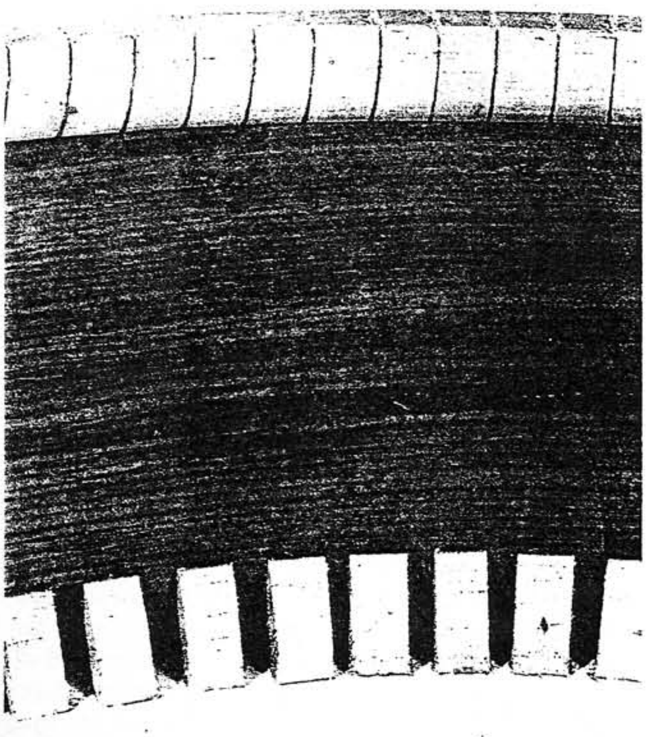
Method for Kerfed Linings

1 Plane the strips of lining to the required dimensions for the soundboard and the back.
2 Support each strip and plane one corner into a rounded or triangular profile. Smooth with medium abrasive paper.
3 Use a mitre box to cut the kerfs. Mark a vertical guide line about 5 mm to the right of the 90 degree cutting line. To avoid sawing right through the lining, prepare a rectangle of thin wood packing, which can be attached to the side of the saw with a small cramp. The depth of this wood must be adjusted until it acts as a stop, preventing the saw teeth from coming to rest on the base of the mitre box. This can easily be set up by placing a couple of veneer off-cuts on the base of the mitre box and then dropping the saw down on to them. Measure the distance between the top of the mitre box and the bar along the top of the saw, and make the packing accordingly (18-3 and 18-4).

Method for Individual Blocks

Individual blocks are made in the same way, but simply saw right through the wood.

Put the linings aside until needed (Chapter 20).



18-5 *The two common methods of lining – in this case the soundboard is attached to the ribs with individual rib- or glue-blocks (bottom), while the back will be fitted to a continuous kerfed lining (top)*

19 Assembly: Soundboard, Neck and End-block

The work up to this stage has been to make the components which will form the main structure of the guitar. The following three chapters describe the method of assembling these parts, and the drawing (19-2) summarizes the work to be carried out. The ease with which the guitar will be assembled depends to a large extent on the individual parts having been accurately made. Provided that the ribs were shaped to conform closely to the plantilla, and that they fit well into the neck slots, then the basic assembly should be quite straightforward and rapid. This is certainly one of the most rewarding aspects of constructing the instrument – seeing the guitar begin to take its final form.

Tools

Smoothing plane
Carpenter's square
Engineer's square
Rule
Tenon saw
Scalpel
Marking gauge
Cramps

Materials

Soundboard
Neck
Straight-grained mahogany, cedar, lime, or spruce (110 mm × 70 mm × 20 mm) for the end-block
Glue

Method

Glue the neck to the soundboard

In order to glue the neck to the soundboard, it is first necessary to trim the soundboard exactly at the position of the 12th fret. This ensures that when the soundboard butts up against the edge of the recessed platform on the neck, the overall length from the beginning of the soundhole to the nut is correct.

1 Trim the soundboard at the 12th fret with a sharp scalpel (19-3). (The position of the 12th fret was drawn on to the soundboard in Chapter 15.) Butt the trimmed edge up against the edge of the recessed platform – the soundboard and neck should form one continuous flush surface. If the soundboard is lower than the neck, the recessed platform is too deep. Place a thin veneer on to it and adjust until the surfaces are flush. If the soundboard is higher than the neck, use a chisel to reduce the platform slightly.
2 Place some transparent tape or paper on the solera at the area where the neck and soundboard join, to avoid gluing them to the solera.
3 Place the soundboard face down on the solera, and align the centre-lines at both ends. Secure the soundboard in place with the cramping-block and bolt.
4 Apply glue to the neck platform, and bring it down on to the soundboard. One large cramp will hold it in place, with a second one at the head end to keep the neck aligned with the centre-line on the solera. Clean out any glue that has entered the neck slots. Leave to dry (19-4).

Make the end-block

The end-block provides an area of wood to which the lower ends of the ribs are attached. The dimensions are similar on most guitars, and the first step is to prepare a block of suitable straight-grained wood from which it can be shaped. There are different views as to whether the grain of the block should run vertically, from the soundboard to the back, or horizontally, that is, parallel with the grain of the ribs. A block with the grain running vertically has the disadvantage of presenting an end-grain surface for gluing the soundboard and back to it. (The end-grain forms a weak butt joint, as the exposed wood fibres tend to soak up the glue.) If the block is made with the grain running in the other direction the gluing surface presented to the soundboard and back will be more satisfactory, as well as the fact that the wood has greater strength when its position in relation to the ribs is considered. A number of makers construct the end-block from three pieces of wood; the main part has the grain running vertically, and jointed into it at either end are small sections of wood with the grain running parallel to the ribs. This means that the soundboard, back, and ribs are not glued to an end-grain block (19-5).

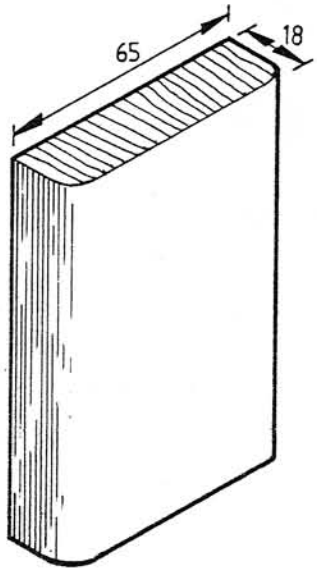
1 Plane the block to the dimensions given, but allow a few millimetres extra in height – if the rib depth at the end-block is 100 mm, the block should be 102 mm. This is because the back is arched, and meets the end-block at an angle slightly greater than 90 degrees.

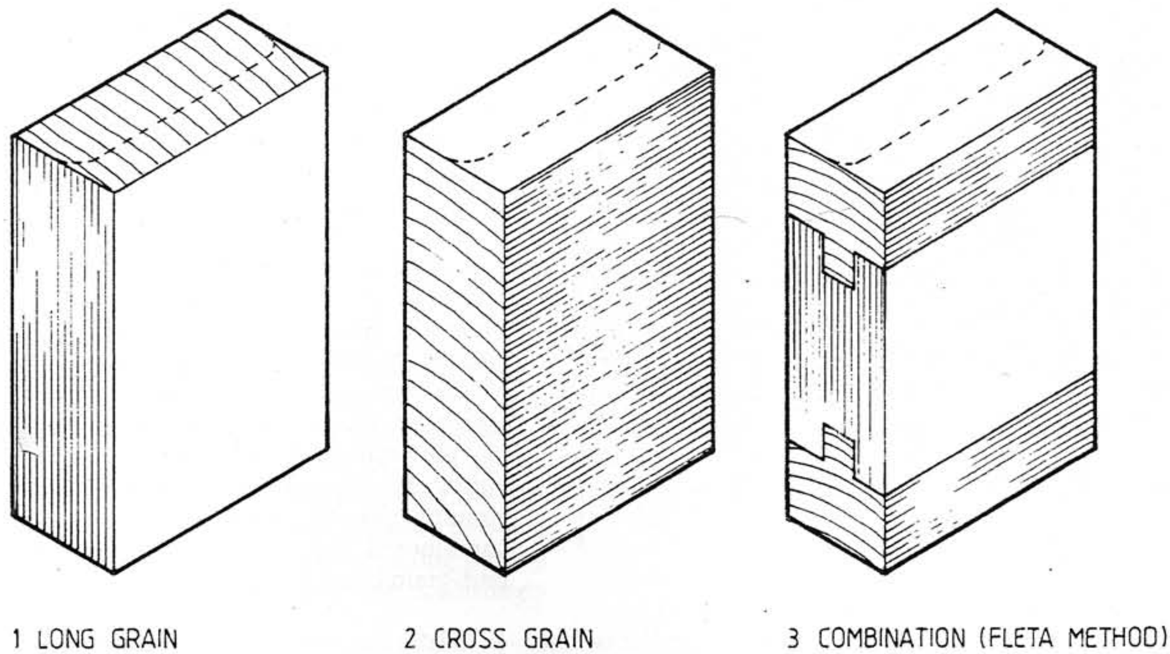
2 The lower surface of the block which rests on the soundboard must be flat and square to the sides of the block. Scribe a centre-line all round the block, and mark the radiused shape.

3 The block can be held in a vice while the curved surface is planned and then sanded smooth.

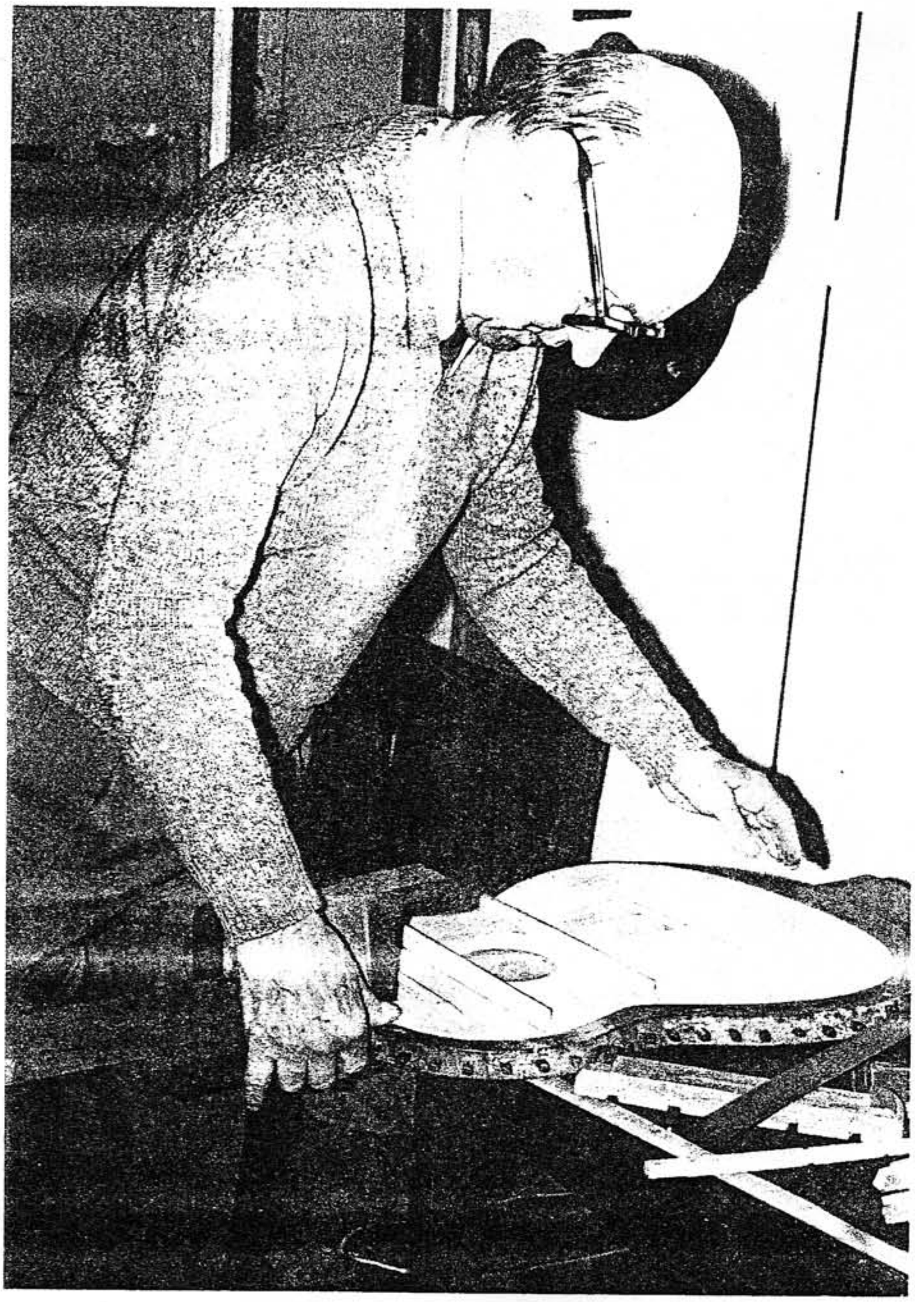
4 Now attend to the surface of the block which will be glued to the ribs – it must be shaped to conform to the curve of the ribs. Some guitars are virtually flat at this point, while others have a pronounced curve. The block can be held in a vice and thin shavings planed off both edges. Then sand it with a hard sanding block and try it against the guitar outline. Continue adjusting the end-block until it follows the outline exactly.

5 Glue the end-block in its place on the soundboard. It must be positioned 2 mm in from the guitar outline to allow for the thickness of the ribs. A small engineer's square placed on the outer part of the solera will confirm whether the end-block is vertically positioned (19-6). Adjust the position of the cramp until this is achieved (19-7). A batten can be temporarily nailed to the end-block and cramped to the foot of the neck to help maintain the position of the end-block. Leave to dry (19-8).



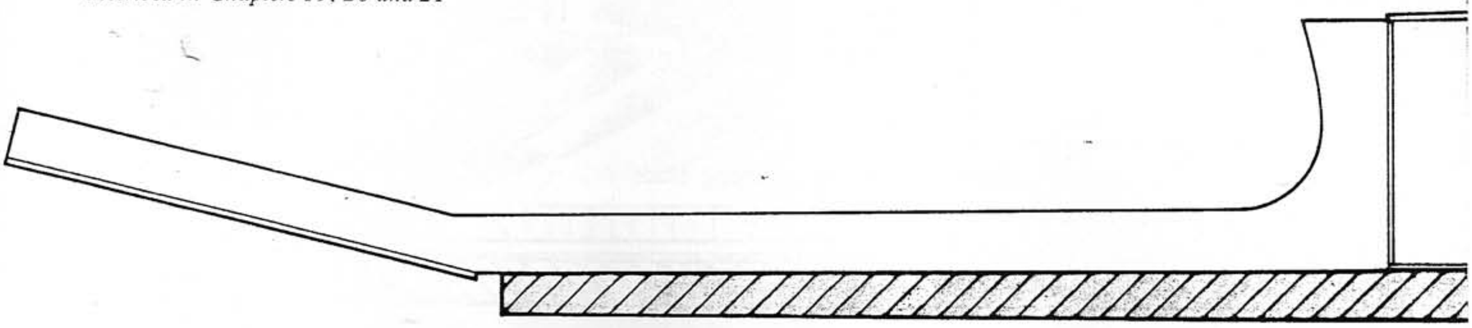


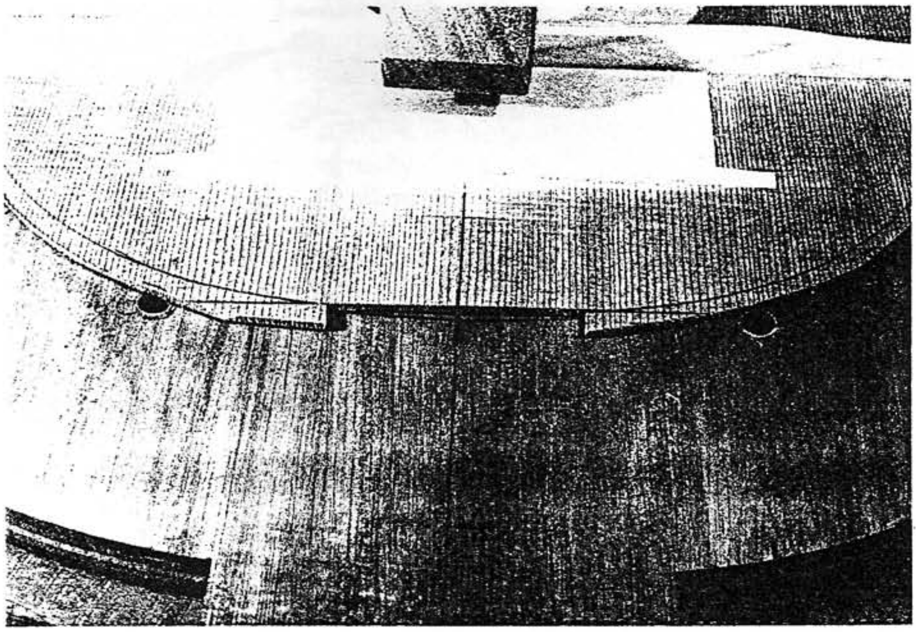
19-5 Top: typical dimensions for the end-block. Bottom: three methods of making the end-block



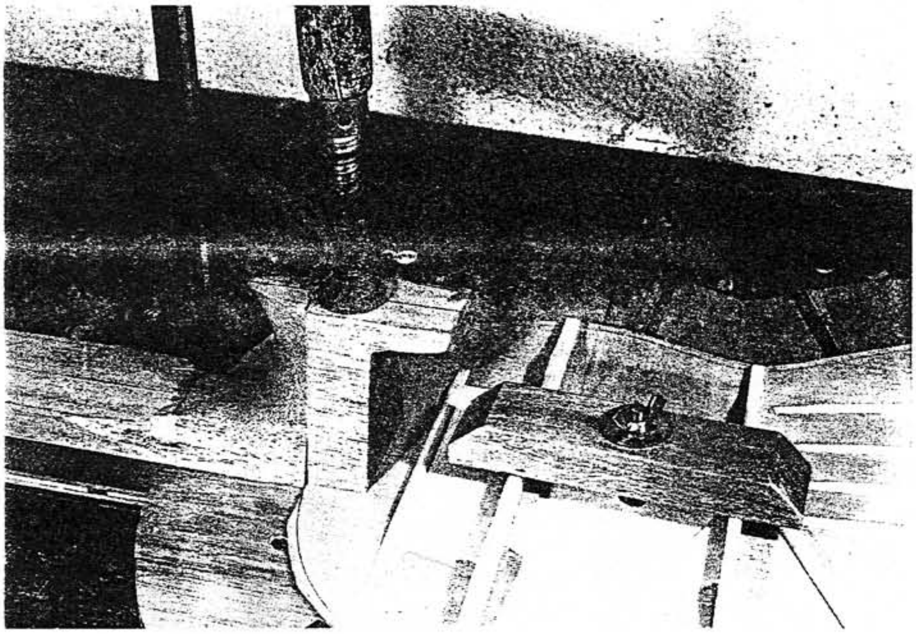
19-1 Robert Bouchet preparing to glue the neck to the soundboard. Note the bridge bar which is wider and taller on the treble side

19-2 This drawing summarizes all the stages of assembly described in Chapters 19, 20 and 21

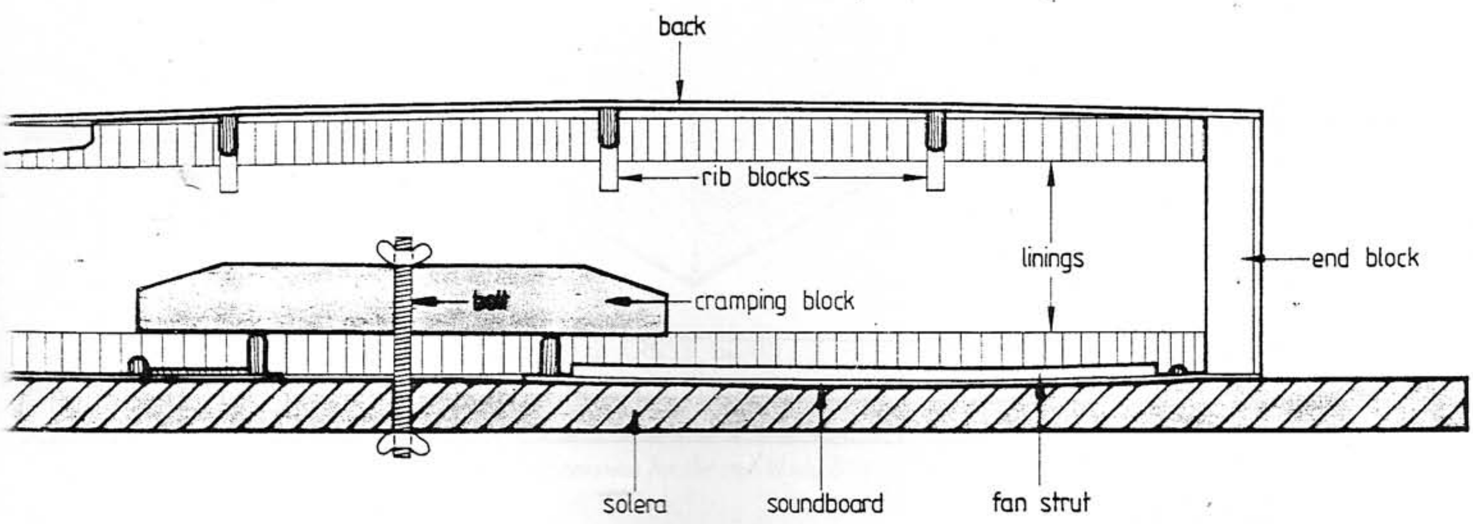


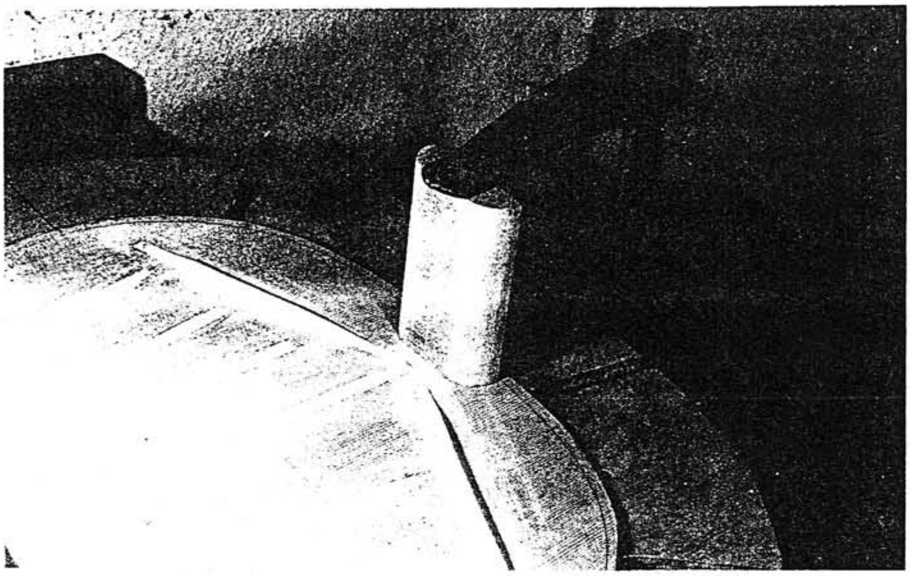


19-3 The soundboard has been trimmed at the position of the twelfth fret so that it will butt up to the edge of the recessed neck platform

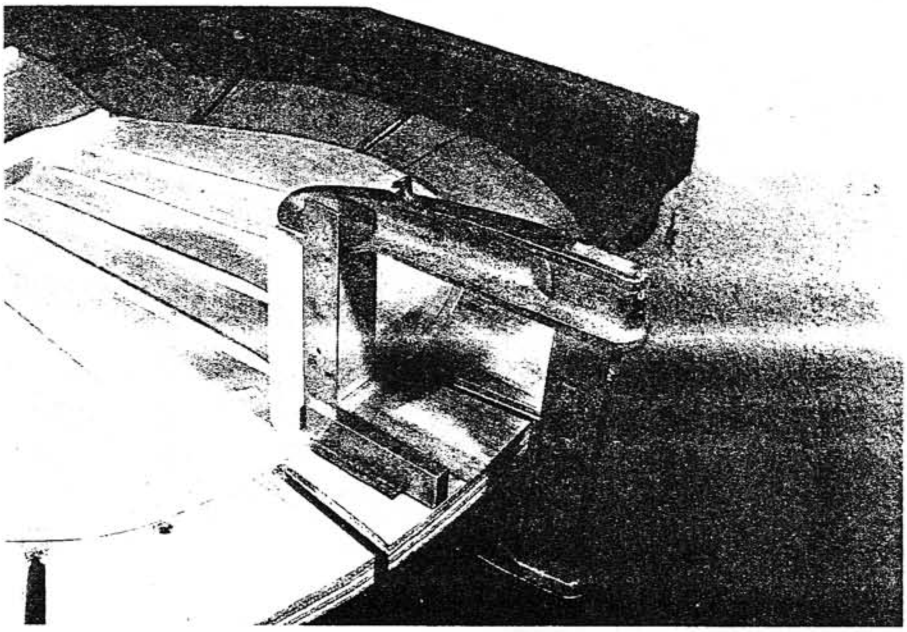


19-4 Gluing the neck to the soundboard – both have been aligned with the centre-line of the solera. A second cramp (not shown) is placed at the head end of the neck

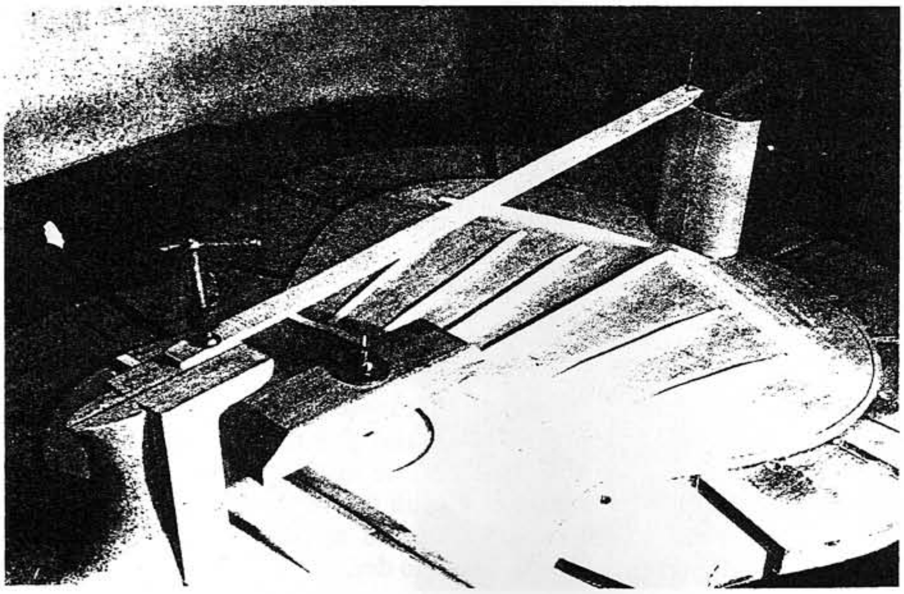




19-6 Checking the verticality of the end-block with a small square. The square is placed on some packing the same thickness as the soundboard



19-7 Gluing the end-block to the soundboard



19-8 The neck and end-block are both glued to the soundboard. The batten which is nailed and cramped between the end-block and the foot of the neck will keep the structure stable until the ribs are fitted

20 Assembly: Ribs and Linings

In the previous chapter we established the basic anchor points of neck and end-block to which the ribs can now be attached. The end-block is somewhat vulnerable at this stage – it is tall and thin. (The batten described in the previous chapter will help keep the end-block rigid while the ribs and linings are fitted.) There are two different methods of attaching the ribs to the soundboard – the first uses individual lining blocks or glue blocks, while the second uses continuous lengths of kerfed lining. Both methods are described here.

Tools

Chisels
Tenon saw
Cramps
Spool cramps
Block plane

Materials

Soundboard/neck assembly
Ribs
Lining blocks or kerfed linings
Glue

Method 1 – Individual blocks

Glue ribs to neck and end-block

1 The ribs are about 2 mm thick, so the ends of any bars or struts that will butt up against the ribs must now be trimmed back 2 mm from the guitar outline. Do this with a sharp chisel, and ensure that the ends of the bars follow the angle of the guitar outline (20-2).

2 The ribs should now slip quite easily into the slots in the neck as they have already been fitted in Chapter 17 (20-3). Clean the area of rib that will glue to the end-block with some medium grade sandpaper, as the bending iron will have left the surface shiny and not in the best condition to form a strong bond.

3 Apply glue to the end-block and to the neck slots. Drop the ribs in place and push them down firmly on to the surface of the soundboard. No glue is applied to the edges of the ribs, because the join will be made with the lining blocks that will be inserted next.

4 Clean away any excess glue that emerges on the outer side of the heel with a damp cloth, as this would be very difficult to remove once dry.

5 The other ends of the ribs are cramped firmly against the end-block, using packing to protect the surfaces.

6 A number of spool cramps can now be attached through the slots on the solera to ensure that the ribs remain in contact with the soundboard (20-4).

7 Rib-supporting blocks may also be useful for keeping the ribs accurately to the guitar outline. These are simply blocks of wood which have a bolt and wing nut passed through so that they can be fastened in place against the ribs by inserting them into the slots on the solera (20-5).

Linings (individual blocks)

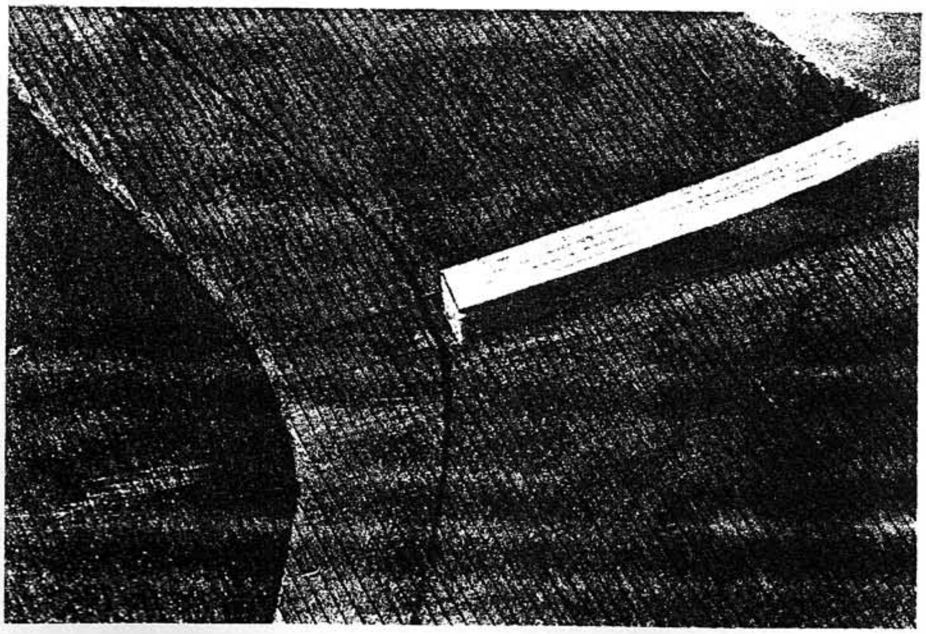
You can now proceed to glue the individual lining blocks in place at the junction of rib and soundboard. These were prepared in Chapter 18. Animal glue or thick P.V.A. glue is best as the blocks must be held in place until the glue sets sufficiently to maintain their position (20-6).

1 Apply glue to a block and push it into position against the rib and soundboard. Work quite rapidly, but backtrack frequently to push the blocks down. Some makers butt the blocks up tightly together while others leave gaps between them (20-7).

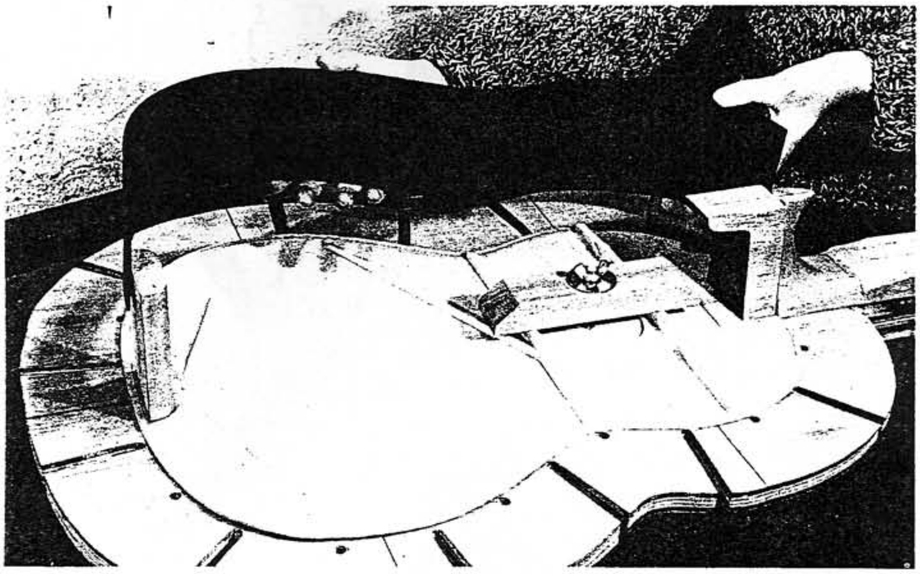
2 Butt the blocks up to the harmonic bars on the soundboard. Continue working all the way round the guitar.

3 The transverse harmonic bars on the soundboard now need some support. Make small, wedge-shaped rib-blocks similar to the lining blocks, but slightly taller, and glue these in place against the ribs (20-8). Some makers extend these supporting rib-blocks all the way across the rib to provide extra strength and to prevent the ribs splitting (20-9). Leave to dry.

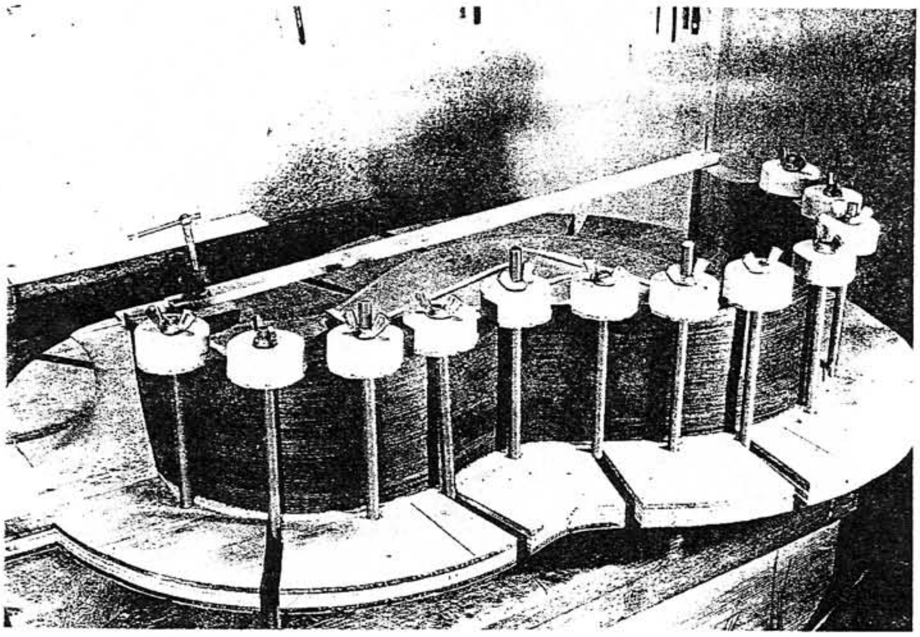
20-1 Robert Bouchet fitting the ribs to the neck. The ribs are protected with paper temporarily glued to their outer surfaces



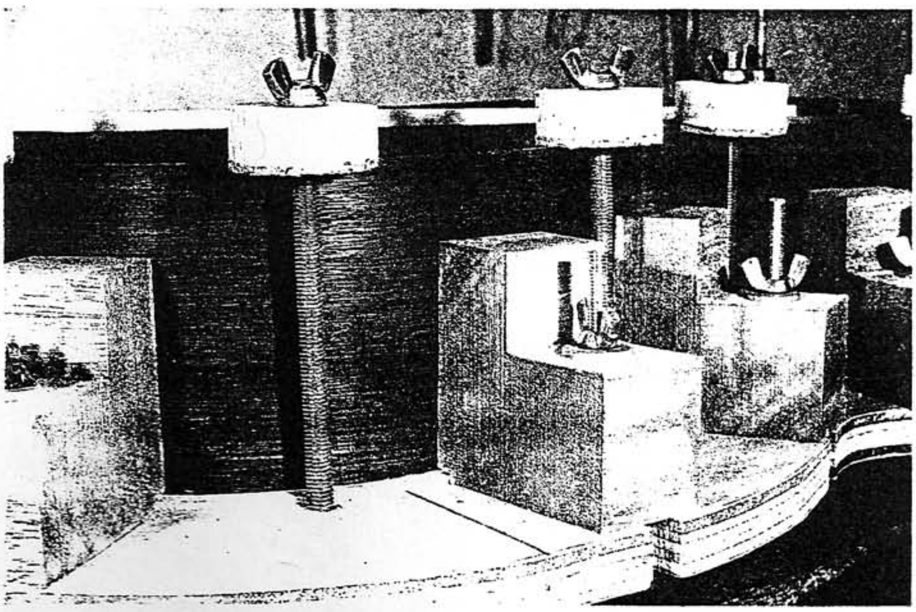
20-2 The harmonic bars are trimmed back by the thickness of the ribs (2 mm)



20-3 Fitting the rib to the neck and end-block



20-4 Gluing the rib to the soundboard – spool cramps exert downward pressure and the batten keeps the end-block vertical. G-cramps (not shown) are used to glue the end-block to the rib

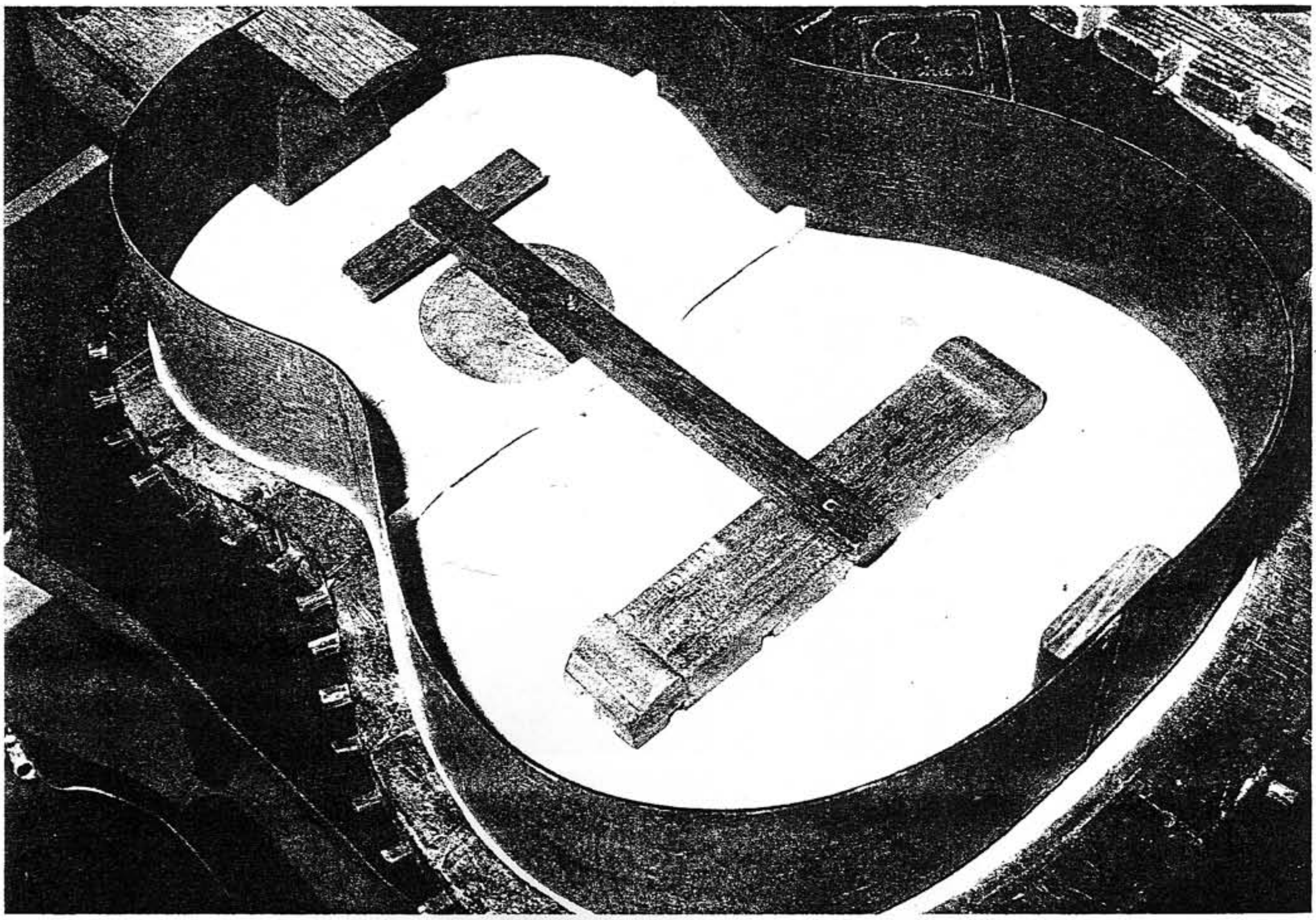


20-5 If necessary, additional support can be provided by the rib-supporting blocks

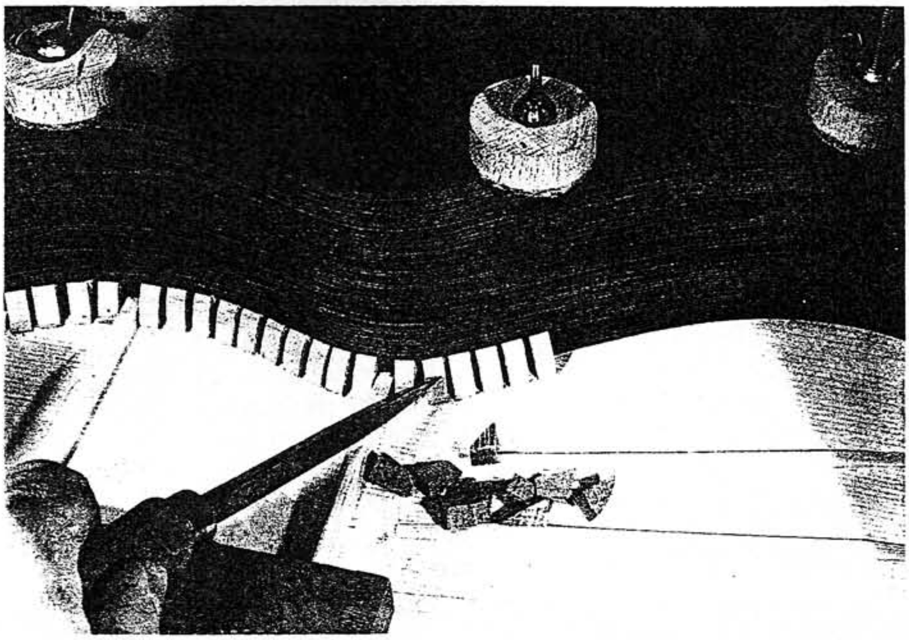
Method 2 – Continuous kerfed lining

Continuous strips of kerfed lining can be applied at the junction of soundboard and ribs, but in this case the linings must be glued to the ribs before the ribs are glued to the neck and end-block. The linings can be glued all the way along the edge of the rib, but must stop short of the area of rib that enters the neck slot and that glues to the end-block. The rib can then be dropped in place and the linings marked where they touch the harmonic bars on the soundboard. These areas must be trimmed out so that the ribs can make contact with the soundboard. Torres used a different, more accurate method – he fitted the ribs in place on the soundboard and marked the positions of the end of the harmonic bars onto the ribs. Because his bars usually became narrower towards the top, this meant that he obtained the exact cross-section of the bar drawn on the rib. The rib was then removed, and the linings glued on everywhere except the marked areas which the bar ends will occupy.

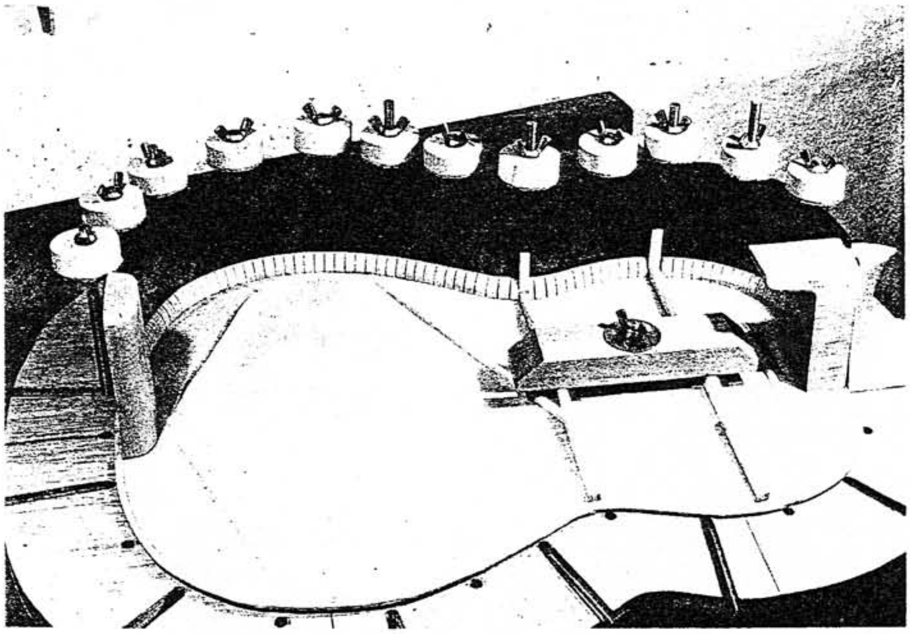
1 Trim back the harmonic bars 2 mm from the guitar outline (20-10).
2 Insert the ribs into the neck slots and cramp the lower ends to the end-block. It is now clear that the linings will have to stop short of the neck and the end-block, so mark these points on to the ribs.
3 Also mark on to the ribs wherever the harmonic bars or other struts butt up to the ribs (20-11).
4 The linings can be accurately prepared to length by placing them into the assembly and trimming to length. Their ends must be shaped to suit the surfaces to which they adjoin so that they can butt up closely to the bars and neck (20-12).
5 Once the linings have been cut to length and their positions marked on the ribs, the ribs can be removed and cramped against the guitar-shaped former so that they retain their correct profile. Glue the linings on to the edge of the rib. Stop the linings exactly at the various areas that have been marked for the neck, end-block, and harmonic bars. Clothes-pegs with elastic bands wrapped round will provide sufficient cramping strength. Ensure that the linings do not fall below the level of the ribs (20-13).
6 When the glue is dry, carefully plane and sand the surface of the lining level and smooth so that it will make contact with the soundboard. As the soundboard is flat around its periphery, the entire rib with lining attached should make contact with



20-9 A Robert Bouchet guitar ready to receive individual lining blocks which will join the soundboard to the ribs. Note his design of solera cramping-block which extends over the bridge bar



20-7 Gluing the individual blocks. Animal glue is best, as the blocks must be held in place until the glue sets



20-8 Small rib-blocks are glued in place to support the harmonic bars

the flat surface. It can be rubbed gently on a large sanding board if necessary.

7 Once the lining surface is flat, drop the ribs in place. They should come to rest on the soundboard surface (20-14). If any lining is in the way, trim until the ribs fit perfectly. Check that the ribs rise vertically off the solera. Remove the ribs.

8 Glue can now be applied to the linings, end-block and neck slots. The ribs can then be fitted in place with the aid of spool cramps and blocks, which will firmly hold them down to the soundboard while the glue dries (20-15).

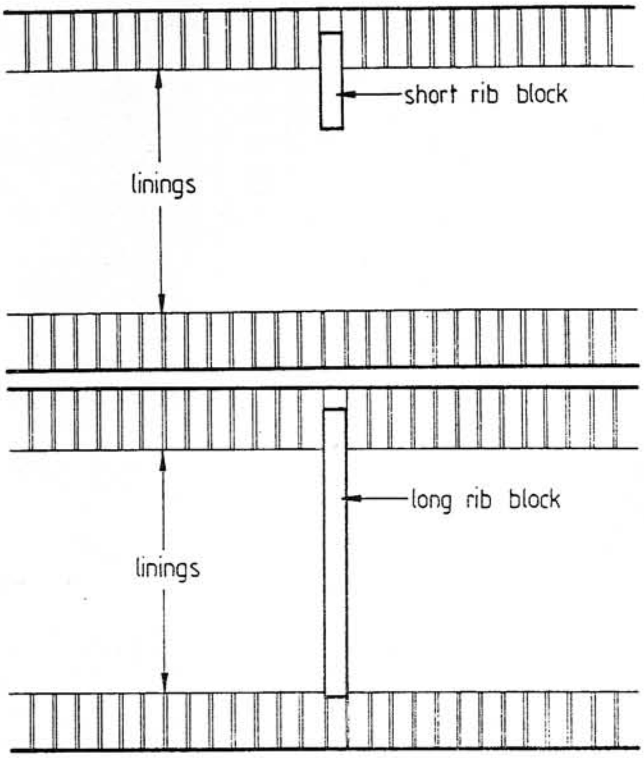
9 Now prepare and glue in small rib-blocks to support the harmonic bars (20-16) and (20-17).

Back linings

Before the linings that will receive the back can be attached, the upper surface of the ribs must be tapered down towards the neck.

1 Use a chisel and small plane to reduce the height of the ribs where they join the neck (20-18). The tapering should begin approximately at the waist position (20-19). Once the bulk of the waste is removed, use a large flat sanding board to level the surfaces.

2 The point where the tapering begins, at the waist, should be slightly rounded over with the sanding board so that the ribs form a smooth, gradual curve. The resulting shape, in combination with

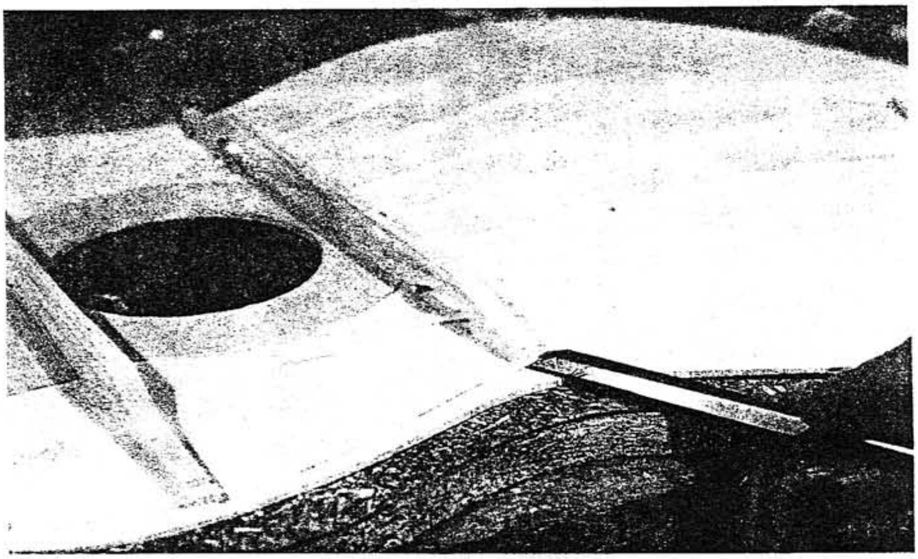


20-9 Top: most makers use short rib blocks to support the transverse bars, both for the soundboard and the back. Bottom: an alternative is to extend the blocks right across the rib and house them into both linings. This provides support for the rosewood ribs which have a tendency to split along the grain. Long blocks may also prevent the ribs from buckling

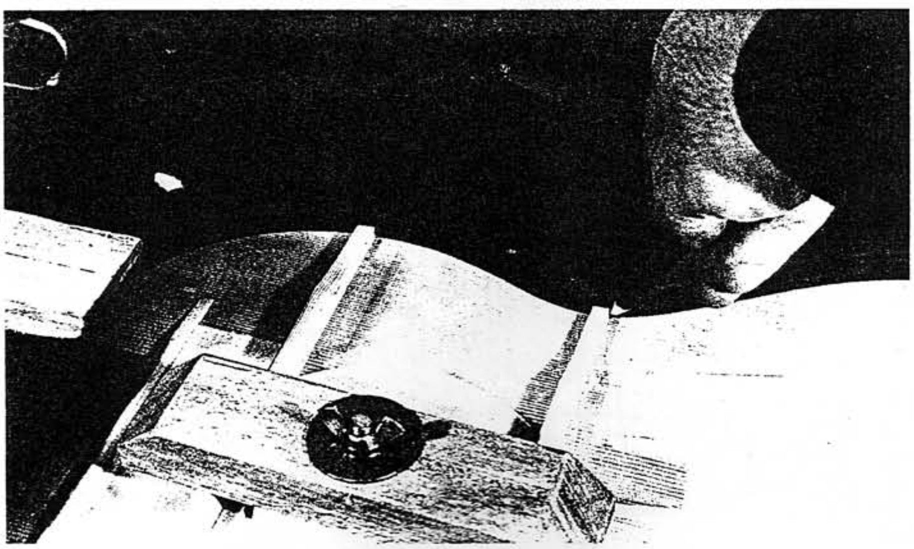
the arched back, will create a domed back that is arched both across its width and along its length.

3 Once the tapering is satisfactory, glue the continuous kerfed linings in place. (When the back is fitted, sections of lining will be removed to allow the transverse back bars to butt up against the ribs.) Some makers cut out small notches in the foot and end-block so that the ends of the linings can be securely housed into them.

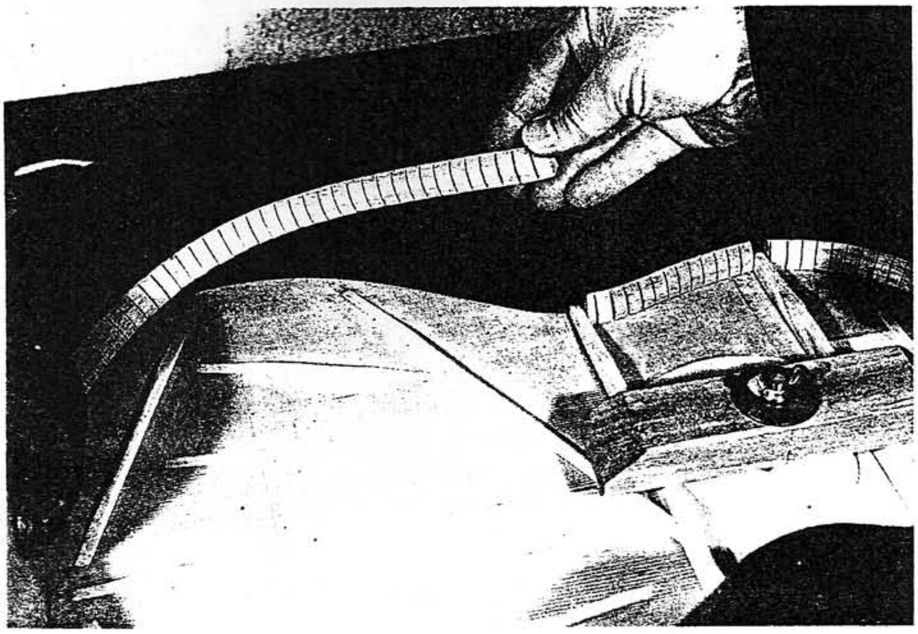
4 Clean away any excess glue that squeezes out on to the ribs. Leave to dry (20-20) and (20-21).



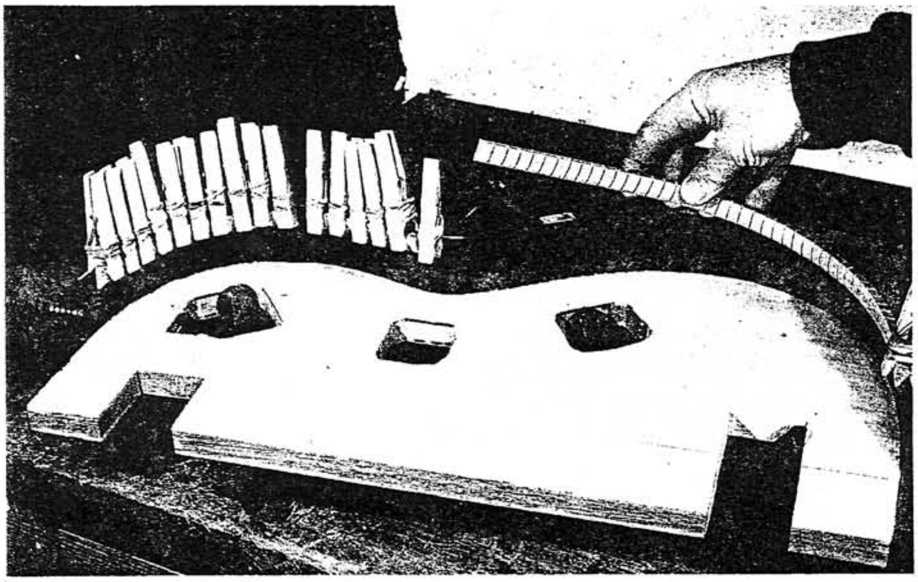
20-10 Trimming the harmonic bars back 2 mm from the outline of the guitar



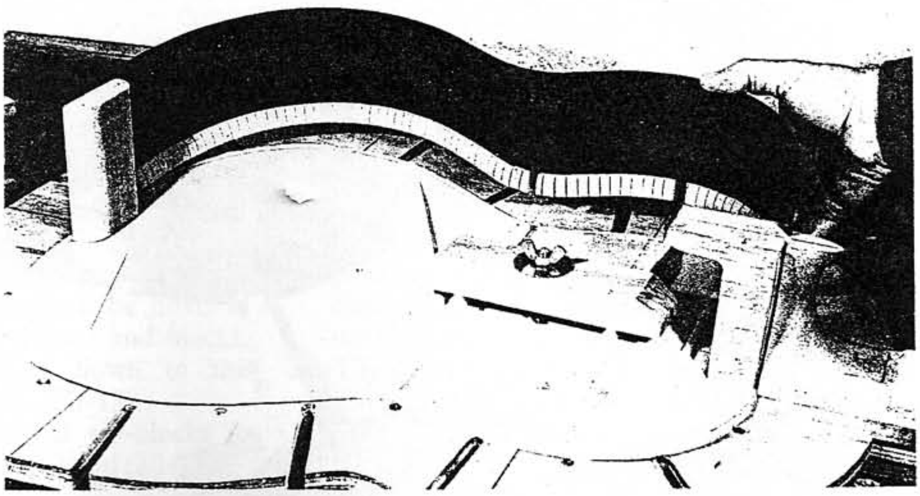
20-11 Marking the positions of the harmonic bars on to the ribs



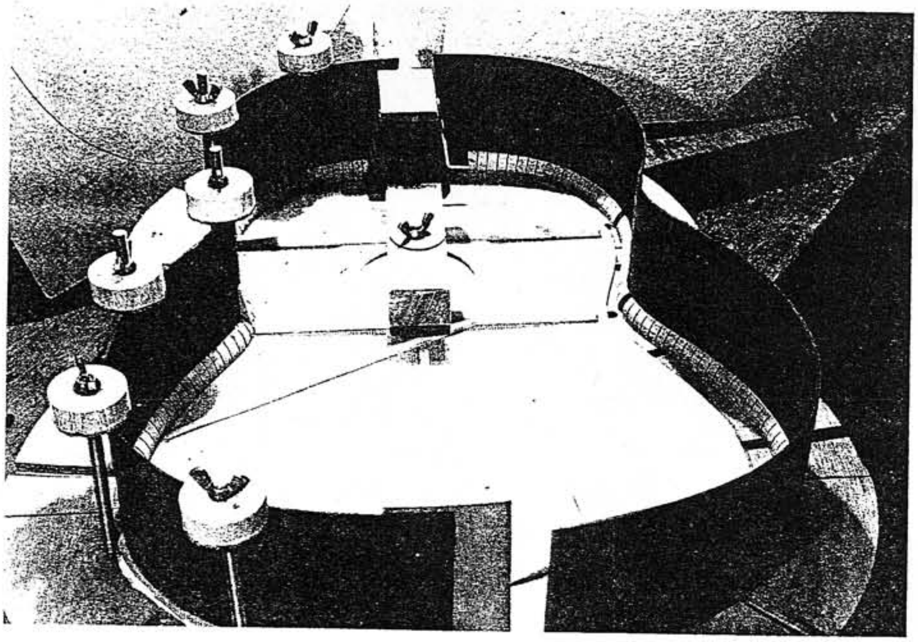
20-12 The kerfed lining is cut to length and fitted dry



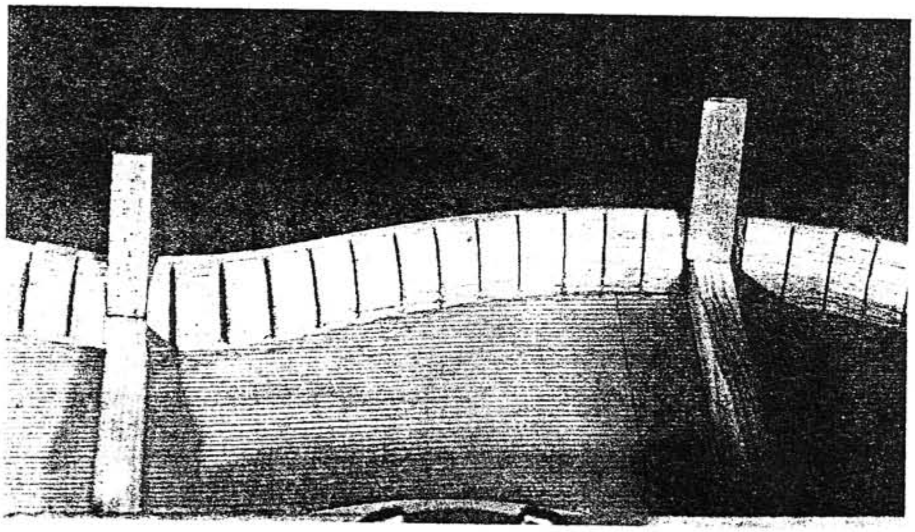
20-13 Gluing the lining to the rib – the rib has been cramped to a guitar-shaped former which retains the correct profile. Gaps will be left for the harmonic bars, neck and end-block



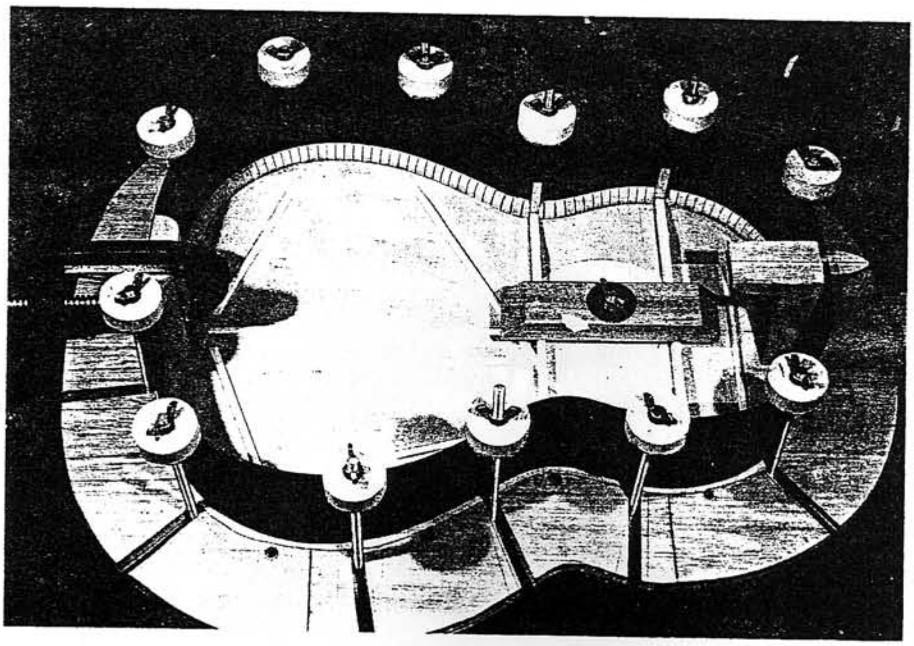
20-14 Fitting the lined rib to the assembly



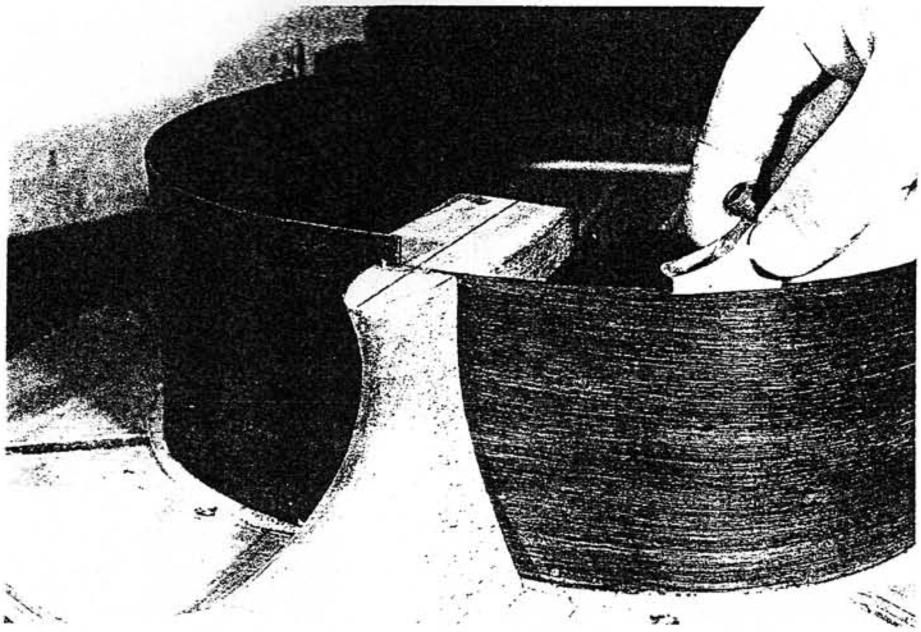
20-15 One rib has been glued and the other is ready for fitting



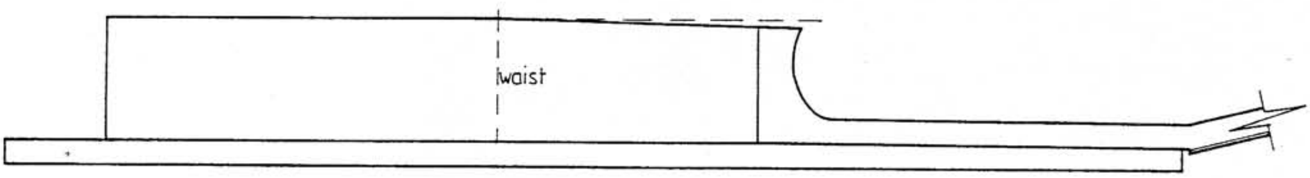
20-16 Rib-blocks are glued in the gaps in the lining. (They can be wedged in place while the glue dries with short battens placed between the solera cramping-block and the rib-blocks)



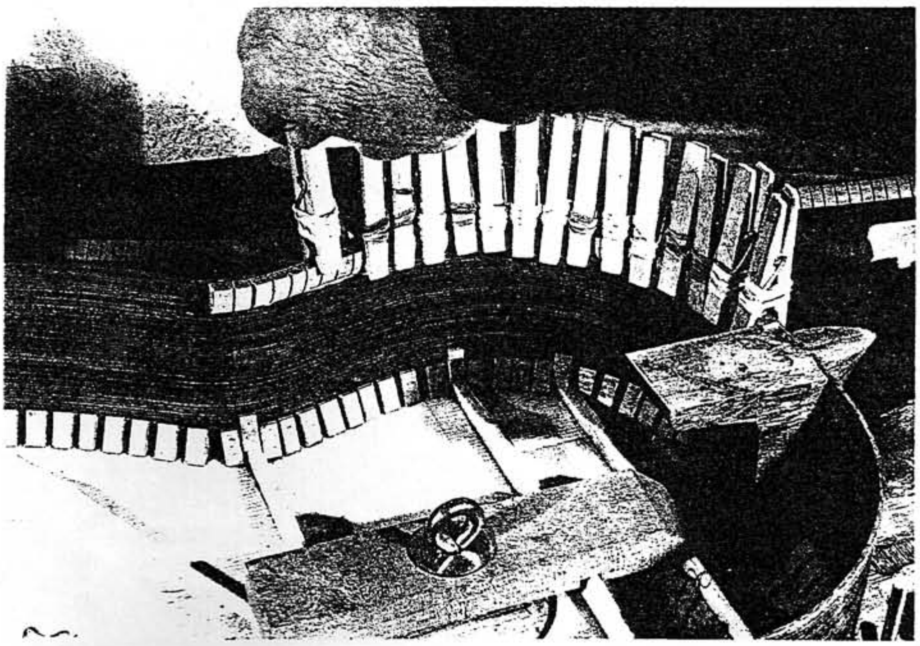
20-17 The second rib is glued in place



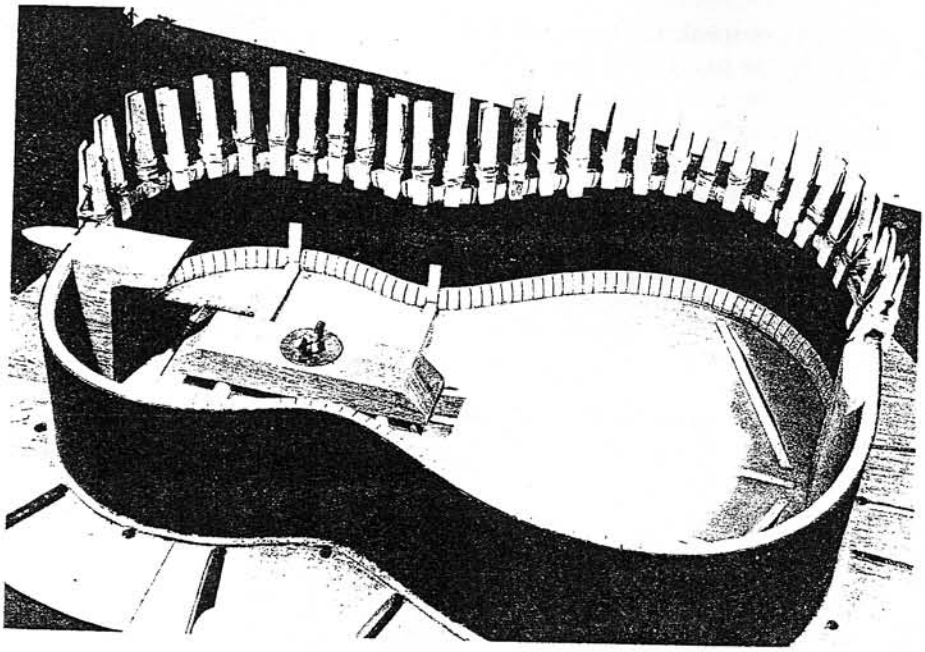
20-18 Before the back linings can be fitted, the ribs must be tapered from the waist to the neck



20-19 The angle of taper



20-20 Gluing the back lining



20-21 With all the linings in place, the back can now be fitted

21 Assembly: Back

21-1 Robert Bouchet fitting the back to a guitar

Once the back is glued to the ribs the guitar will become a stable structure. Although the ribs were tapered before the linings were glued in place, there is still some further shaping to be done before the back will fit. This is due to the domed structure of the back which results in the edges of the bouts being lower on the ribs than the waist. The back must fit accurately to the ribs and this requires careful adjusting of a number of different factors.

Tools

Block plane
Chisels
Dovetail saw
Straight-edge
Cramps
Rules

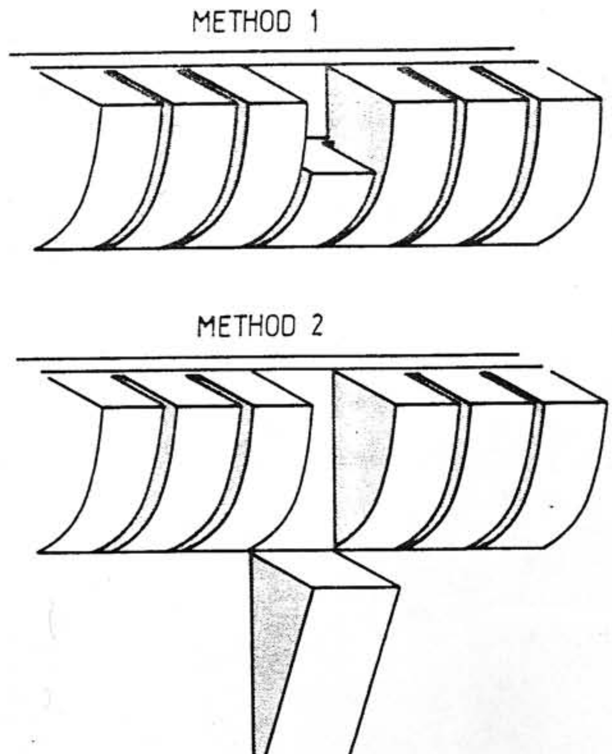
Materials

Prepared back, with transverse bars attached
Mahogany or cedar block for building up the foot of the neck
Mahogany off-cuts for rib blocks
Glue

Method

Shape the transverse back bars

There are two common methods of joining the back bars into the linings – the first involves scalloping the last 30 mm of bar down to a height of about 5 mm. A small notch is then cut out of the lining to allow this portion of the bar to fit into it. As the lining is 15 mm deep, and only 5 mm has been removed, there is still enough lining left to support the underside of the bar. With the second method, the bars can either be scalloped or they can be left to their full depth. A complete section of lining is then cut out and the bar fitted into this. In this case there is no support left beneath the bar, so a small rib-block or strut is glued in place on the rib before the back is glued. This block is similar to those used in the previous chapter to support the ends of the soundboard harmonic bars. Both methods require the same marking out procedure (21-2).



21-2 Two methods of fitting the back bars to the linings: (1) a small notch is cut out of the lining. Its depth is the same as the scalloped end of the back bar. The remaining lining below the notch provides support for the back bar; (2) a complete section of lining is cut out and a new supporting block is glued to the rib. The back bar then rests on this block

1 Place the back on a clean surface, and support the arched periphery with small wedges. Shape the bars as required, using a small plane, chisel and abrasive paper. They can be carved to a gable shape, or simply sanded smooth and left rectangular in section. Scallop the last 30 mm down to a height of 5 mm if required (21-3).
2 Place the back on top of the ribs, carefully aligning the centre seam (or back inlay) with the centres of the end-block and the heel. Place a few weights on the back, to ensure that it does not move, and then use a sharp pencil to mark on the ribs the positions where the back bars meet the ribs and linings. Also mark the bar along its underside, where it overhangs the rib (21-4).
3 Remove the back and place it on a clean surface. The pencil lines that are visible near the end of each bar must now be redrawn at the same angle, but 2 mm towards the centre. This ensures that the bars will fit to the inner edges of the ribs (2 mm being the thickness of the ribs). Saw down on these lines and clean up with a chisel (21-5).

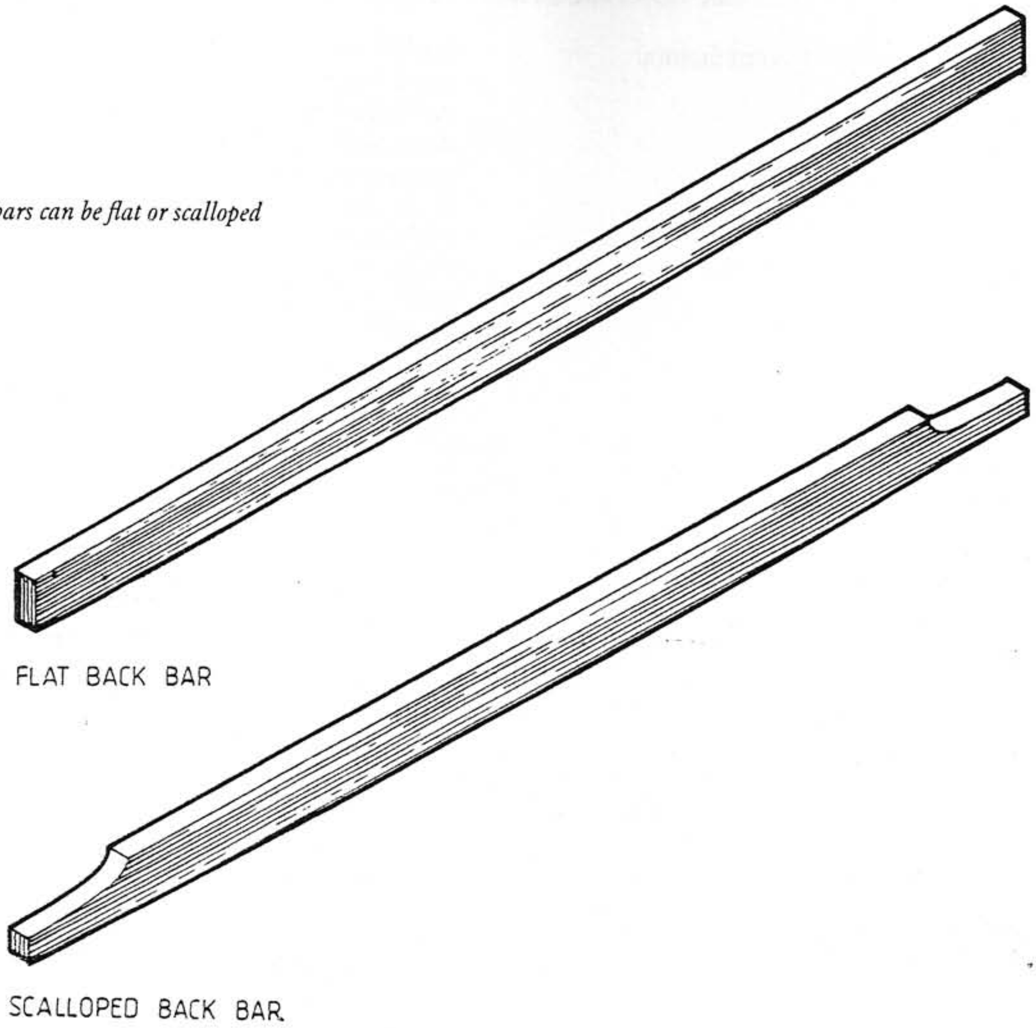
Prepare the linings

Now turn to the ribs – transfer the marks on the ribs that represent the positions of the back bars to the top of the linings, and join the relevant marks across the guitar with a straight-edge. Saw and chisel out the sections of lining between the marks so that the back bars can drop in place within the lining (21-6). If you have scalloped the ends of the bars to 5 mm, then you need only remove a small portion of lining to accommodate this depth of bar. If you are fitting the bars to almost their full depth, then cut out a complete section of lining (21-7).

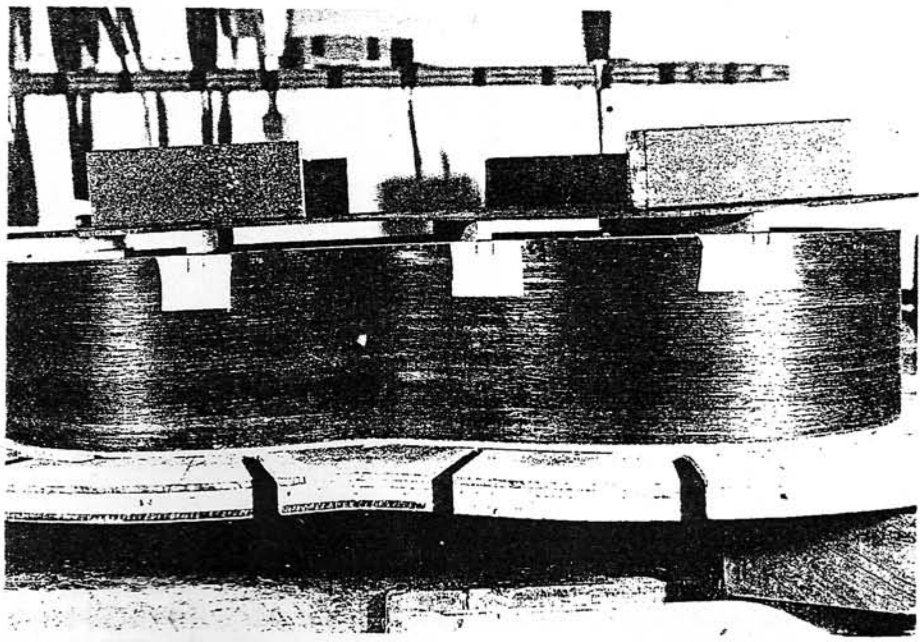
Fit the back

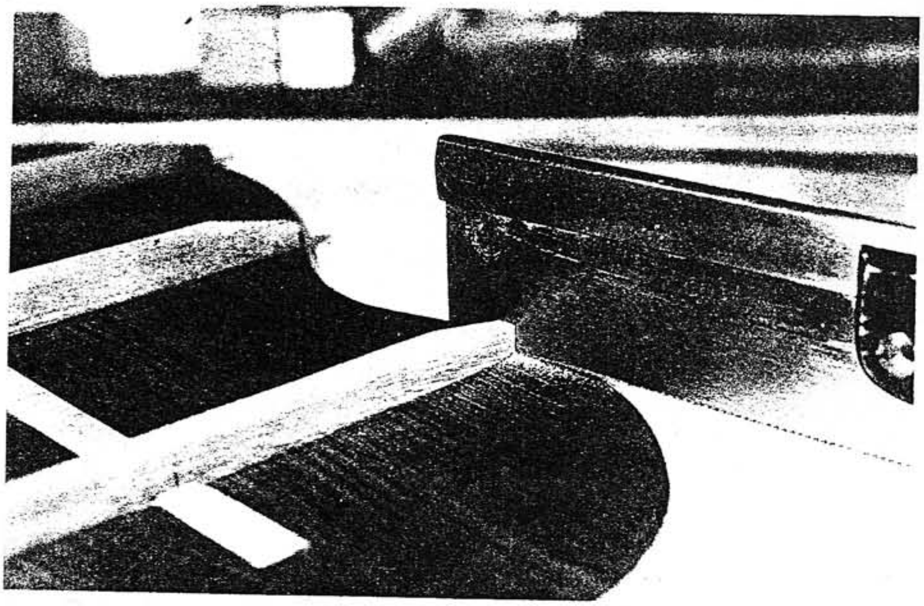
Try the back in place – if it does not fit, establish whether one or more bars are too long, or whether a gap in the lining is not wide enough. Make adjustments until the back fits in place without being forced. Check that the centre of the back aligns with the centres of the end-block and heel. The ends of

21-3 Back bars can be flat or scalloped

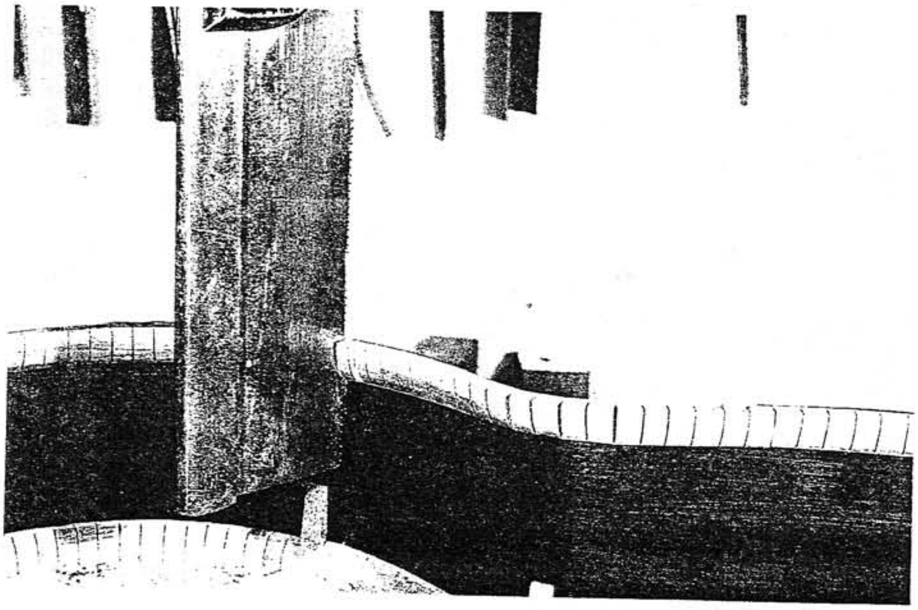


21-4 Marking the positions of the back bars on the ribs. The weights prevent the back from moving





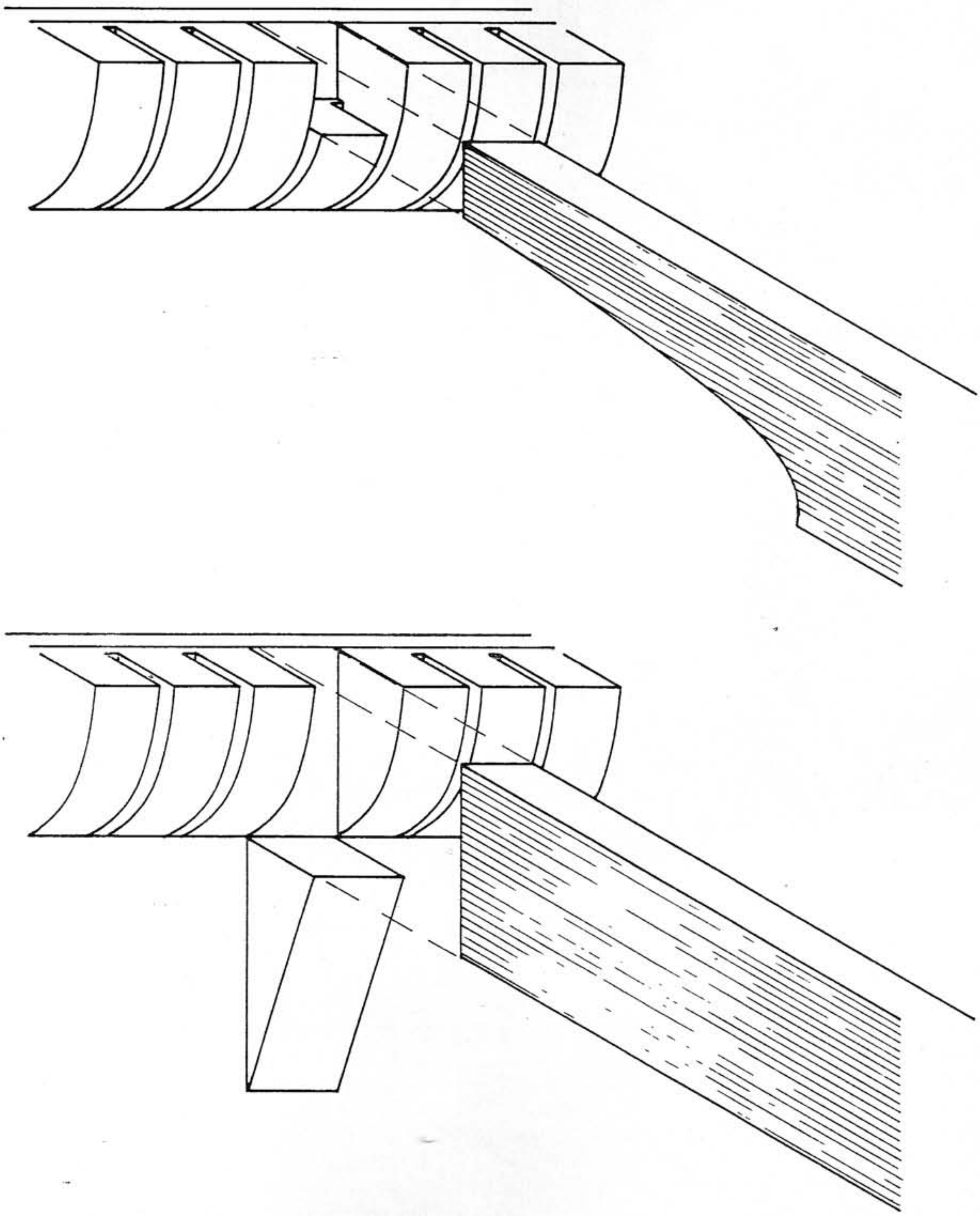
21-5 Sawing the back bars to length – they must stop 2 mm before the guitar outline as the ribs occupy that area



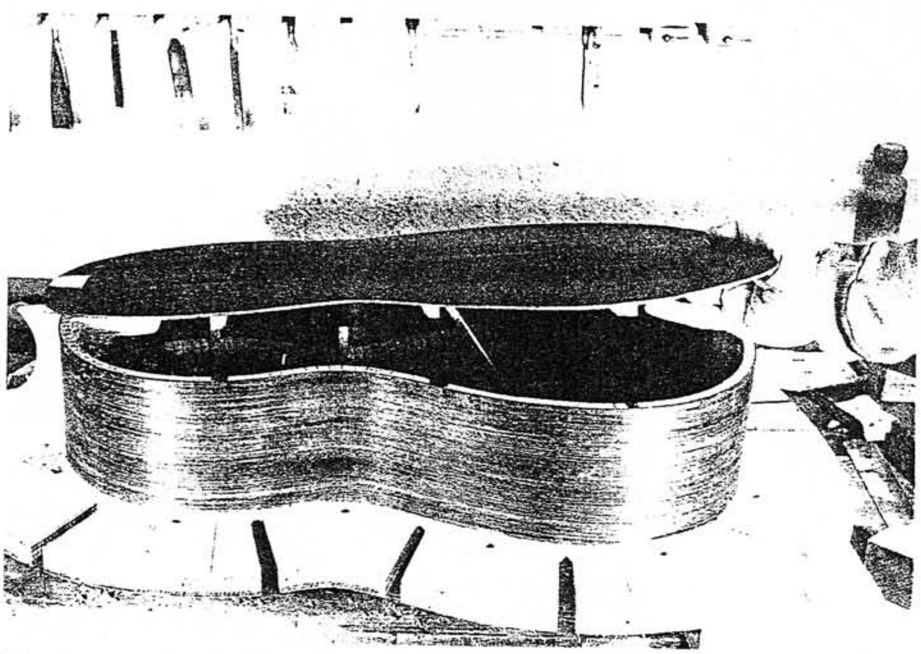
21-6 Sawing out a section of lining

the bars must not push the ribs apart. Check that the notch for a scalloped bar is deep enough to allow the back to make contact with the lining (21-8).

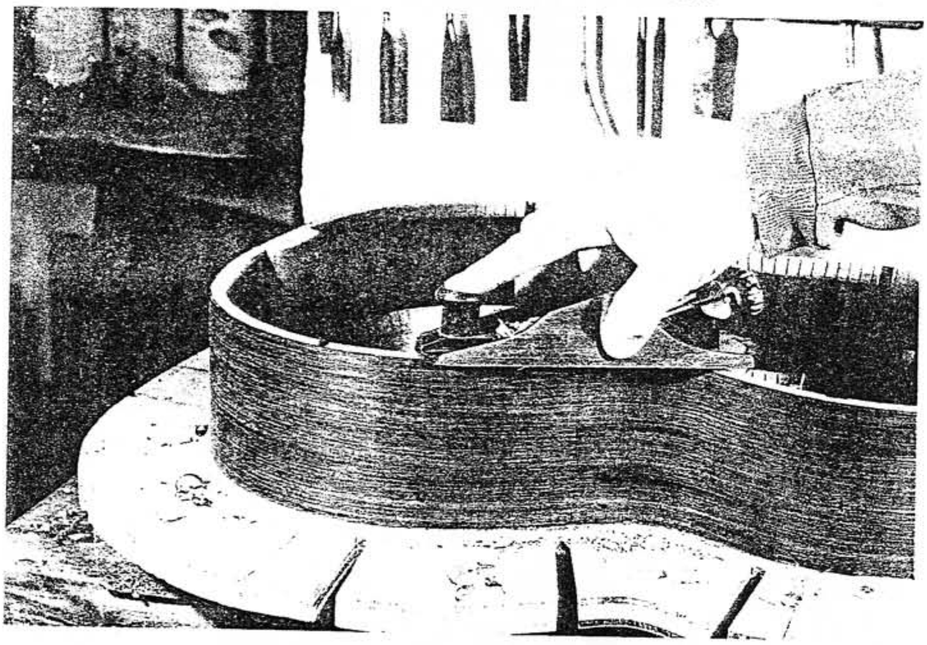
1 Mark the amount of back overhang at the end-block (on the underside of the back). Remove the back, and use dividers to mark the thickness of the end-block on to the back reinforcing, measuring from the overhang mark. Cut away the unwanted portion of reinforcing, so that the end-block will butt up against the remaining reinforcing.
2 Place the back on the ribs and draw a line on the heel, against the edge of the back. Remove the back. Set a pair of dividers to the distance from the line on the heel to the edge of the foot. Mark this on to the reinforcing, and remove the waste as before. The reinforcing should now butt closely at both ends of the guitar.
3 Fit the back in place. Because the back is arched, a slight adjustment to the height of the linings at the lower bout and upper bout is required. By sighting along the join of ribs to back, you will probably see a gap at the waist area. To close this gap, reduce the height of the lower bout and the upper bout with a block plane (21-9). Finish with a flat sanding board to ensure a smooth, gradual curve. The amount of height reduction needed will depend on the extent to which the back was arched. Continue adjusting until the back fits closely, with only minimal pressure. Do not reduce the height at the end-block, but do check with a straight-edge that the end-block is virtually on the same level as the ribs, or a bump will appear on the surface of the back. The end-block and the linings can slope up very slightly to meet the back, which, due to its arch, will not join the linings at a right angle.



21-7 Top: a scalloped bar fitting into a notched lining. Bottom: a flat bar fitting on to a rib-block



21-8 Fitting the back



21-9 Lowering the lining and rib in the area of the lower and upper bouts

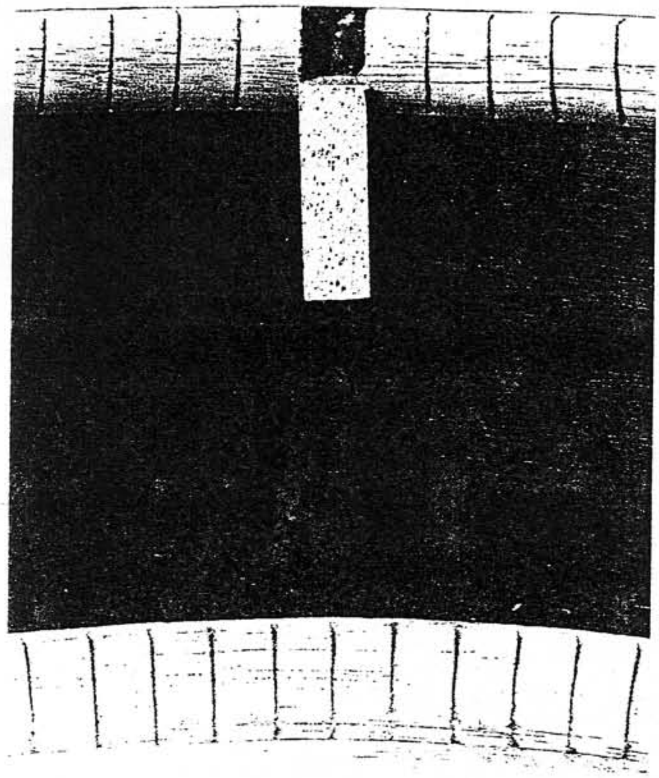
4 If complete sections of linings were removed and there is now no support below the ends of the back bars, prepare small rib-blocks, or longer struts, and glue them in place on the ribs. A gap must be left which is the same depth as the end of the back bar (21-10).

5 The final adjustment required is where the back meets the foot. Place the back on the workbench and use a straight-edge to observe the rise at the foot end of the reinforcing, probably about 3 mm (21-11). The height of the foot must now be built up with a thin off-cut of mahogany, so that a straight-edge placed across it will show a distance between the foot and the ribs equal to the arch of the back at this point. The simplest way to achieve this is to glue on a block of wood and then carve it down until the height is correct (21-12). Once the height at the end of the foot is correct, a gradual slope can be formed so that the front end of the foot is again flush with the ribs (21-13). It is important that the final shape of the foot matches the slope of the back – if it is too high, a visible hump will appear on the outside of the guitar. Once the block has been glued to the foot, carve it down gradually, checking frequently by placing a straight-edge across the foot, and at the same time measuring the gap between the linings and the straight-edge. This gap, equal on both sides, must be the same as the arch of the back (21-14).

Glue the back to the ribs

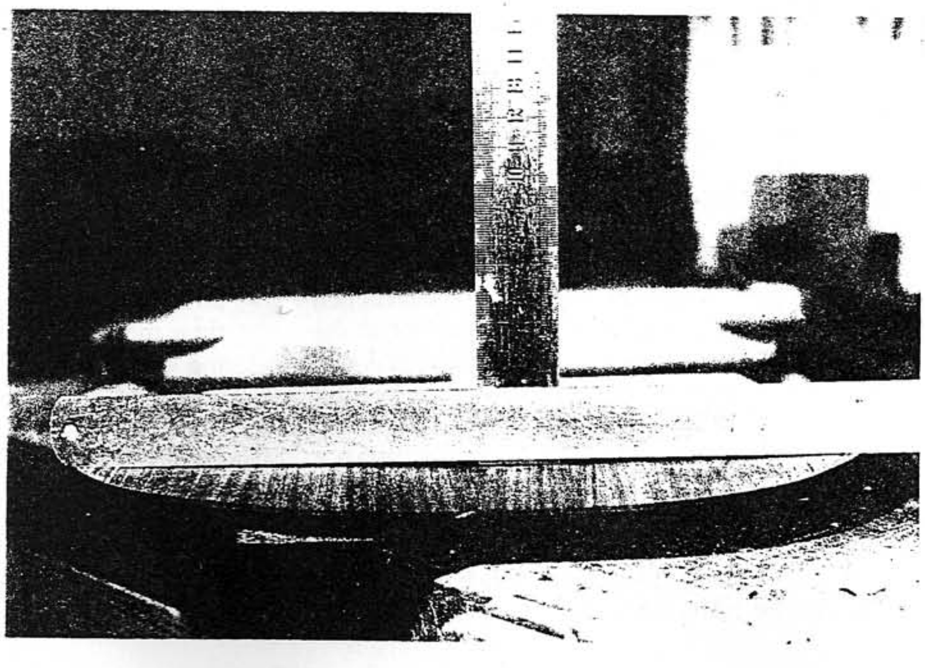
Various methods can be used to apply pressure around the edges of the back while the glue dries – some makers bind string or elastic bands over the back. Individual spool cramps are recommended as each one can be tightened separately to provide just the right amount of pressure.

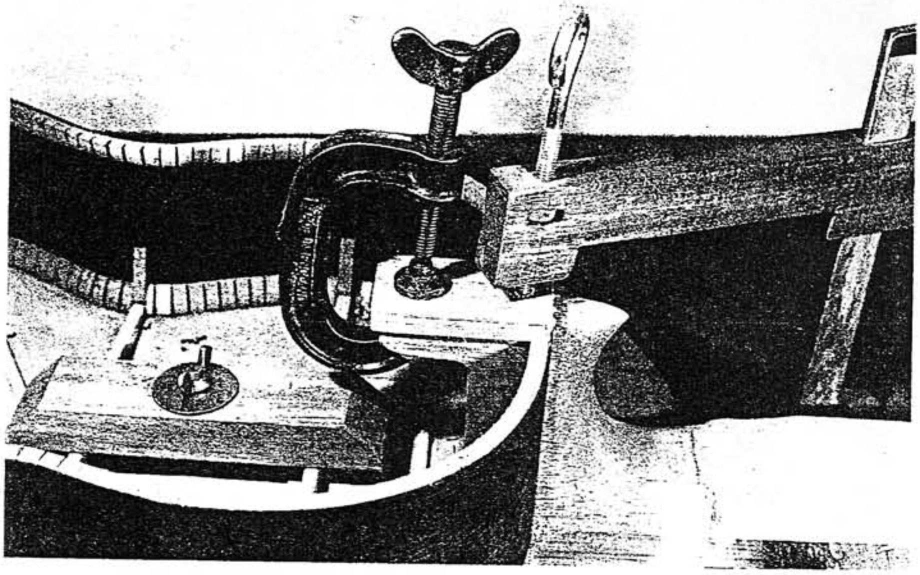
1 Place the back in position on the ribs and draw around the underside so that a clear line is visible showing the precise shape of the back. Cut the back accurately to this outline on a band saw. (If a coping saw is used, leave about 2 mm extra waste, as the wood may chip slightly. This is not too serious, as the purfling and binding will cover approximately 5 mm around the periphery of the back.)
2 Apply glue to the linings, end-block and foot. Place the back in position, ensuring that the ends of the transverse bars are in their notches. Tighten the spool cramps all the way round the back. Leave to dry (21-15) and (21-16).
3 Remove the cramps. Clean up the edges of the back with a sharp chisel, so that they finish flush with the ribs. Take care not to damage the ribs with the chisel.
4 The main structure of the guitar is now complete, so the bolt holding the internal cramping-block against the soundboard can be loosened and the guitar removed from the solera. Manoeuvre the cramping-block out gently, so that you do not damage the internal strutting and bars.



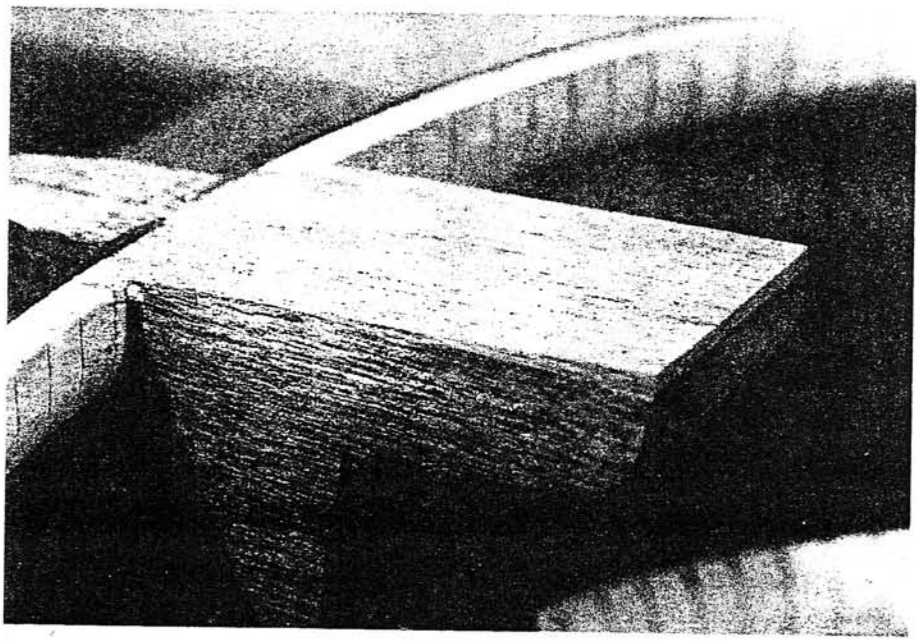
21-10 A rib-block glued in place

21-11 Measuring the arch of the back (neck-end)

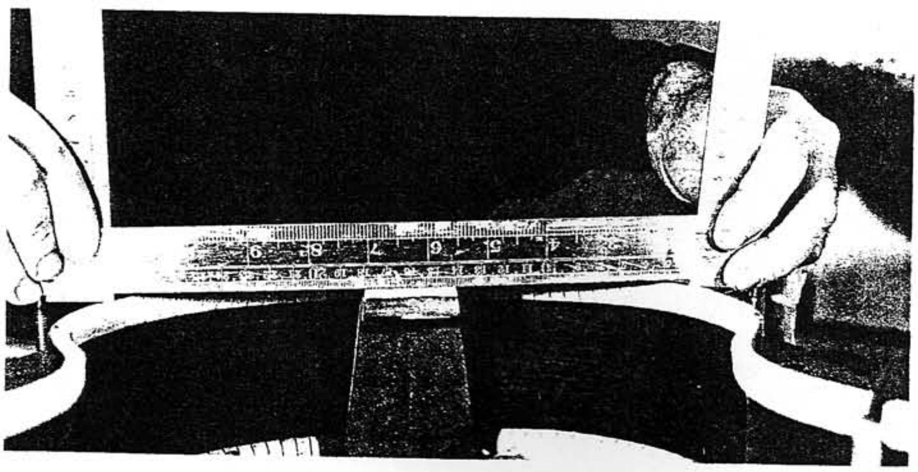




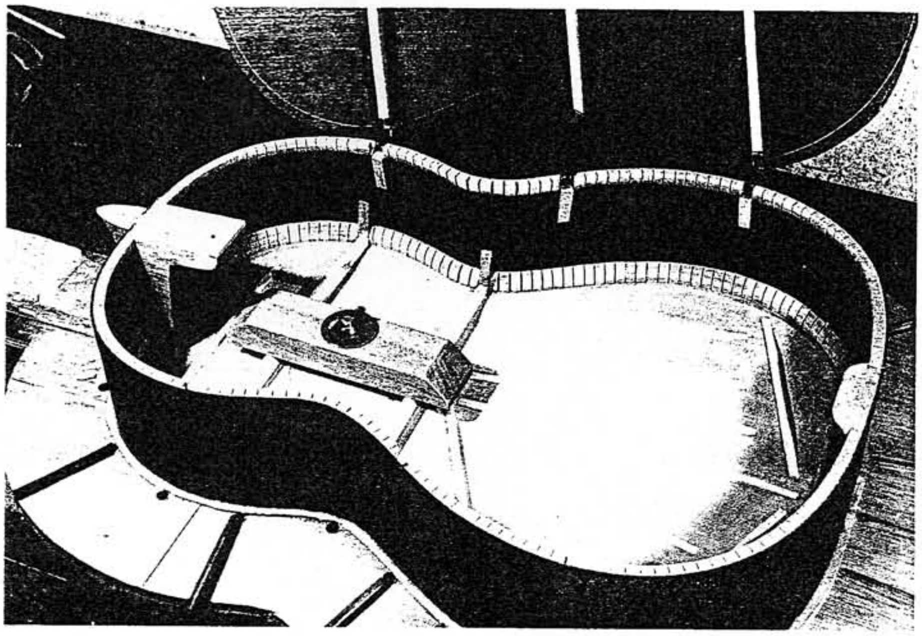
21-12 Gluing a block on to the foot



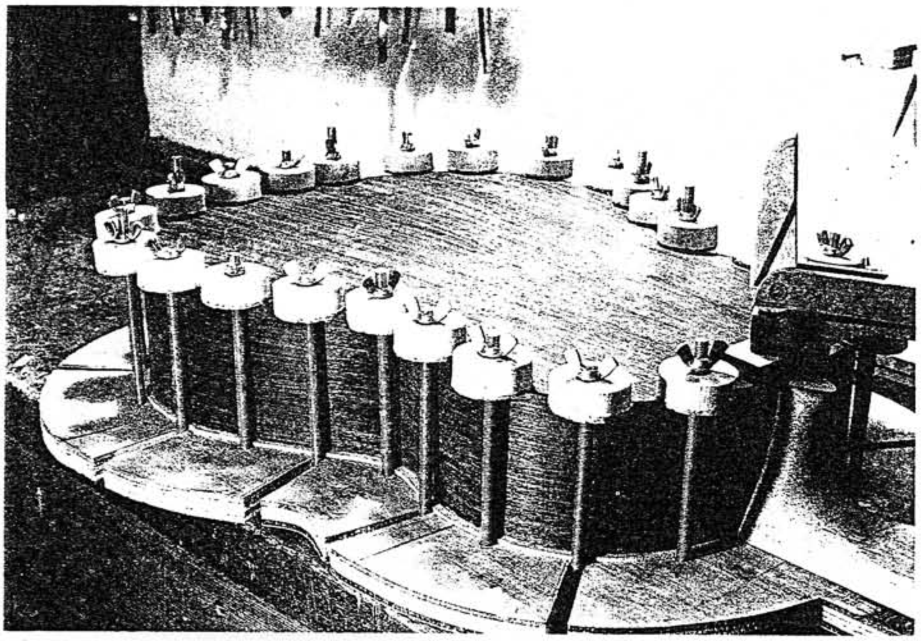
21-13 The foot shaped to receive the arched back



21-14 Measuring the difference in height between the top surface of the foot and the linings. The gaps must equal the measurement at (21-11)



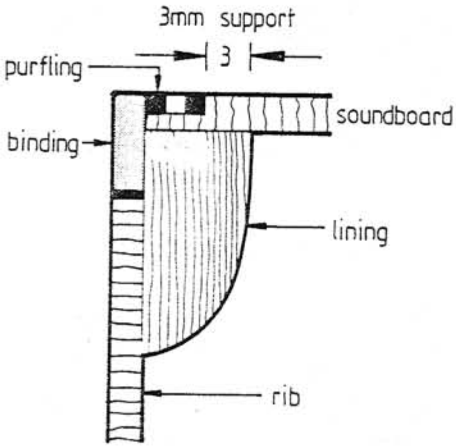
21-15 The back ready to be glued to the assembly

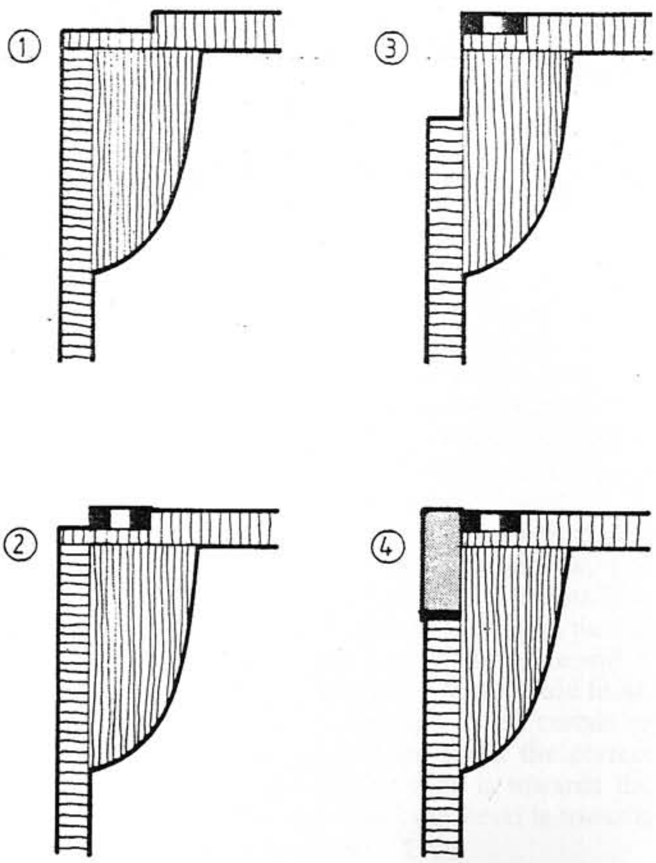


21-16 Gluing the back

22 Purfling and Binding

Now that the main structure of the guitar is complete, work can begin on binding all the exposed edges of the soundboard and the back. Although one purpose of applying binding around the guitar is for decoration, the most important function is to seal the exposed end-grain of the back and soundboard. This will prevent damage from chipping, and also slow down any absorption of moisture. The complete edging of the guitar consists of two components – purfling and binding. These are glued into a rebate that is first cut around the periphery of the soundboard and the back (22-1).





Purfling

Purfling describes the decorative lines that are set into the soundboard and the back. Their colour contrasts with that of the soundboard and back so that a line of visual definition is created all round the guitar. The simplest soundboard purfling consists of one thin strip of dark veneer. For a dark back, a light-coloured veneer strip would be used. More elaborate purfling can be made by gluing together alternating colours of veneer strips. Typical combinations would be black/white/black, or white/black/white. Some makers also incorporate herringbone or other designs taken from the rosette motif. Violin purfling can be purchased ready-made, or you can simply use veneer or 1 mm × 1 mm inlay strips.

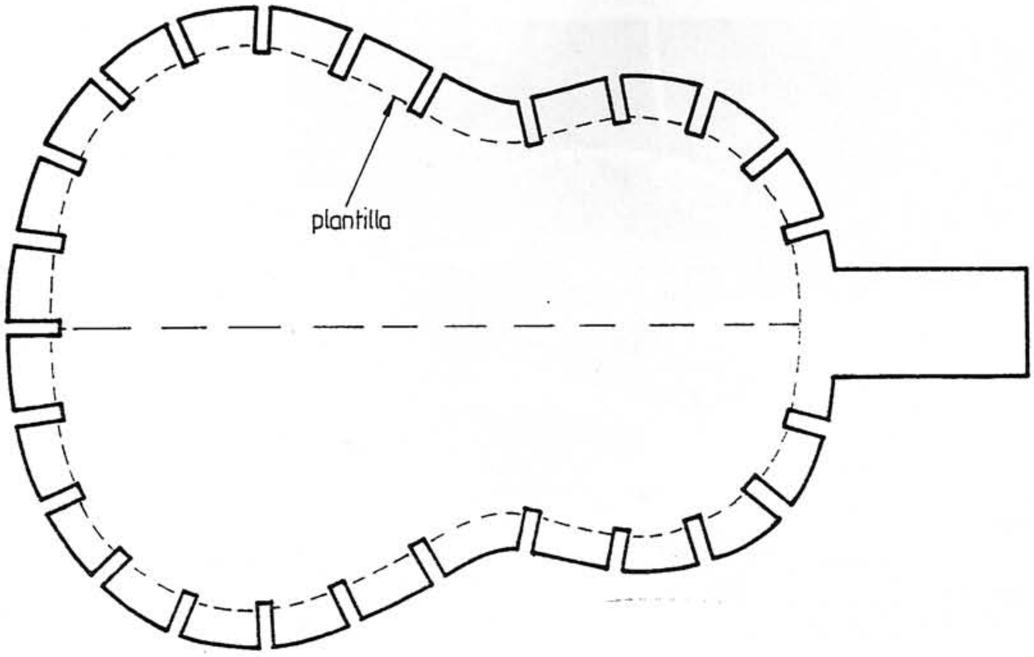
Binding

Binding describes the strip of wood that is glued into a rebate cut around the periphery of the guitar. It is usually the same thickness as the ribs (about 2 mm) and between 4 mm and 7 mm deep. The lower edge of the binding (visible on the rib) often has an additional strip of wood glued to it which may match the purfling.

Tools

Purfling groove cutter
Scalpel
Bending iron
Heavy-duty elastic bands
Large head pins
Chisels
Workboard

22-1 Top: typical design for the purfling and binding. Bottom: the four stages in binding the guitar: (1) a stepped rebate is formed which equals the width of the purfling and binding combined; (2) the purfling is glued against the edge of the rebate; (3) a portion of rib is removed so that its place can be taken by the binding; (4) the binding is glued into the rebate



22-2 The workboard used for gluing on the binding. Elastic bands are looped through the slots

Materials

Binding (four lengths, approximately 800 × 7 × 2)
Purfling (to suit the chosen design)
Glue
3 mm plywood for packing

Method

A guitar-shaped workboard is used for holding the guitar in place while the binding is fitted (22-2). Heavy-duty elastic bands are stretched over the guitar and anchored to the slots on the workboard. It is also useful to have a thin strip of packing which is cut to the outline shape of the guitar. This will be taped to the guitar and keep the arch of the back and soundboard from being damaged with the pressure of the elastic bands forces the guitar against the workboard.

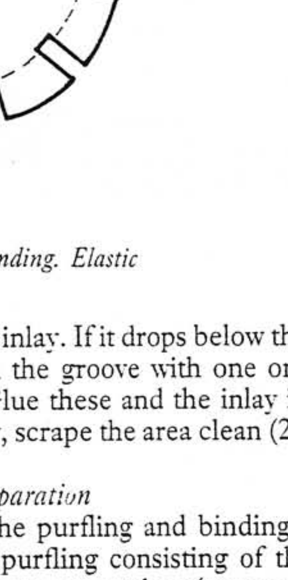
The end-block

The first step is to inlay the area where the two ribs meet over the end-block.

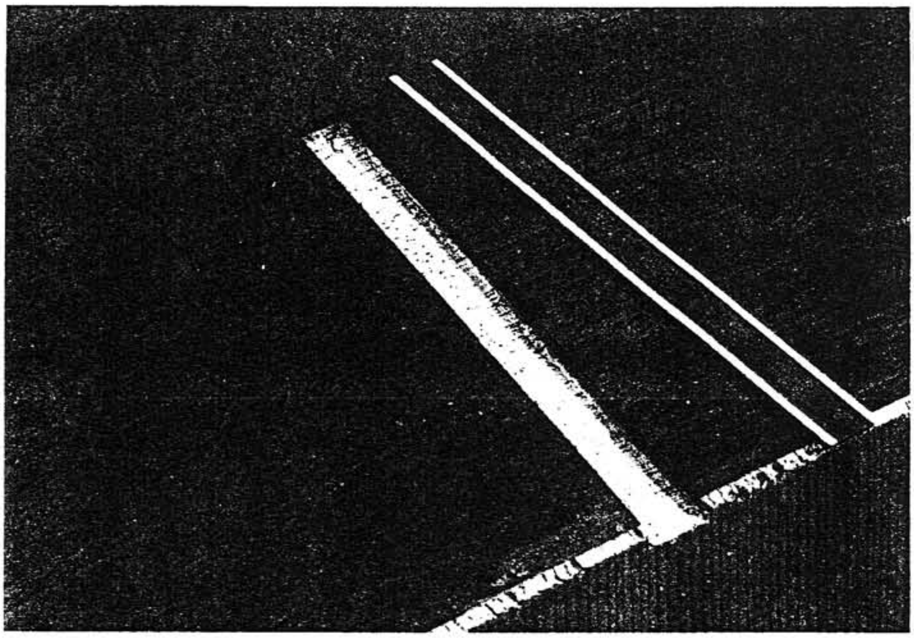
1 Cut a section of binding long enough to span the depth of the guitar at the end-block (approximately 100 mm. Glue on light-coloured veneer on both edges if required (22-3).
2 Hold the prepared inlay in position, ensuring that it is centrally placed in relation to the centre of the soundboard and the back. Mark along both sides with a sharp knife.
3 Remove the strip, and deepen the cuts with the knife. Remove the waste with a narrow chisel, until the end-block is revealed.
4 Insert the inlay. If it drops below the surface of the ribs, pack the groove with one or more strips of veneer. Glue these and the inlay into the groove. When dry, scrape the area clean (22-4).

The back – preparation

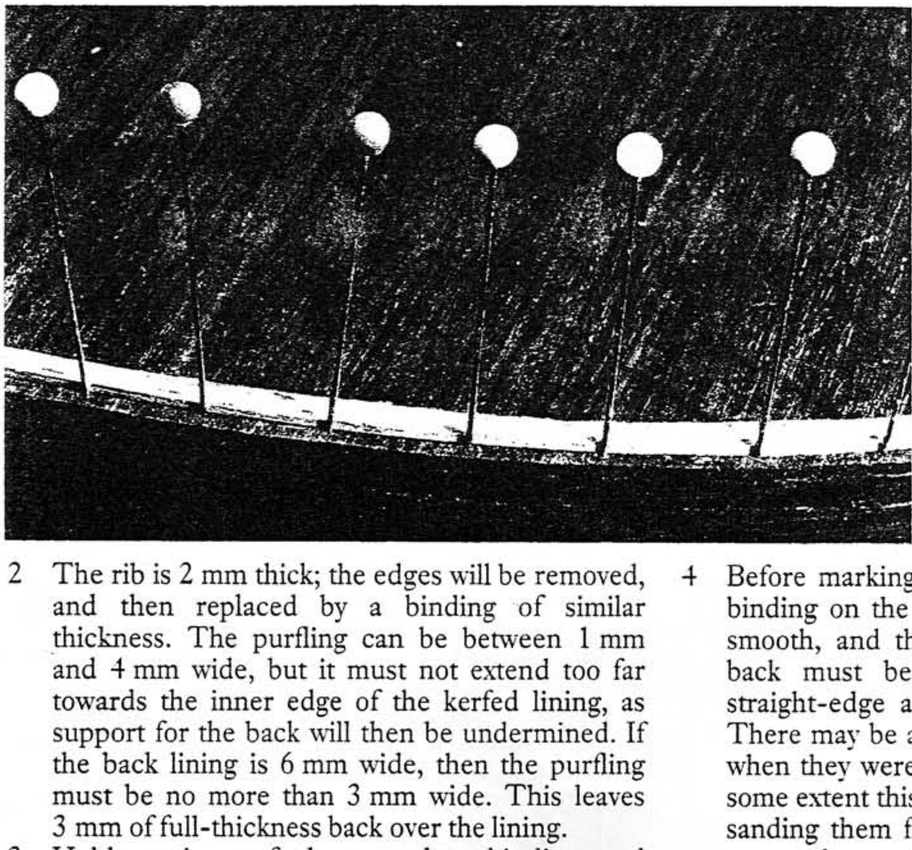
1 Prepare the purfling and binding required – for example, purfling consisting of three alternating strips of veneer; walnut/sycamore/walnut; and rosewood binding with a thin strip of light veneer (sycamore) glued to one edge.



22-3 Typical end-block inlay



22-4 The inlay ready to be glued



22-5 Gluing the back purfling into the rebate – the pins are pushed up against the purfling to keep it in close contact with the edge of the rebate

2 The rib is 2 mm thick; the edges will be removed, and then replaced by a binding of similar thickness. The purfling can be between 1 mm and 4 mm wide, but it must not extend too far towards the inner edge of the kerfed lining, as support for the back will then be undermined. If the back lining is 6 mm wide, then the purfling must be no more than 3 mm wide. This leaves 3 mm of full-thickness back over the lining.

3 Hold sections of the complete binding and purfling flush with the edge of an off-cut, and mark the total width with a knife. Set the purfling cutter to the mark, and cut a line. Deepen the cut with a scalpel, and then remove the waste with a chisel. Try the inlays in place – they should finish flush with the side of the off-cut. Be certain to have the blade of the purfling cutter the correct way round, so that the flat side is towards the inner edge of the wood (and the bevel is towards the waste side).

4 Before marking the position of the purfling and binding on the guitar, the ribs must be flat and smooth, and the edges of the soundboard and back must be flush with the ribs. Place a straight-edge across the ribs at various points. There may be areas where the ribs have buckled when they were shaped on the bending iron. To some extent this can be remedied by scraping and sanding them flat, but be careful not to remove too much material.

Cut the purfling rebate

1 Place the guitar soundboard down on a soft surface (an off-cut of carpet is useful). Hold the purfling groove cutter against the rib, and scribe a line all the way round the guitar. The tool must be kept vertical, or the distance from the edge of the guitar to the marked line will not be constant. The cleanest result is obtained if only one pass is made round the guitar. Repeatedly moving the

purfling groove cutter over the same mark will widen, rather than deepen it. Once a guide line has been scribed on the wood, deepen the cut with a sharp scalpel.

2 Remove the waste with a chisel, so that a step is formed from the cut to the edge of the guitar. The purfling should be set in to a depth of at least 1 mm, so make certain that the rebate is this depth. A safe-edge file can be used to clean up the rebate.

Glue in the Purfling

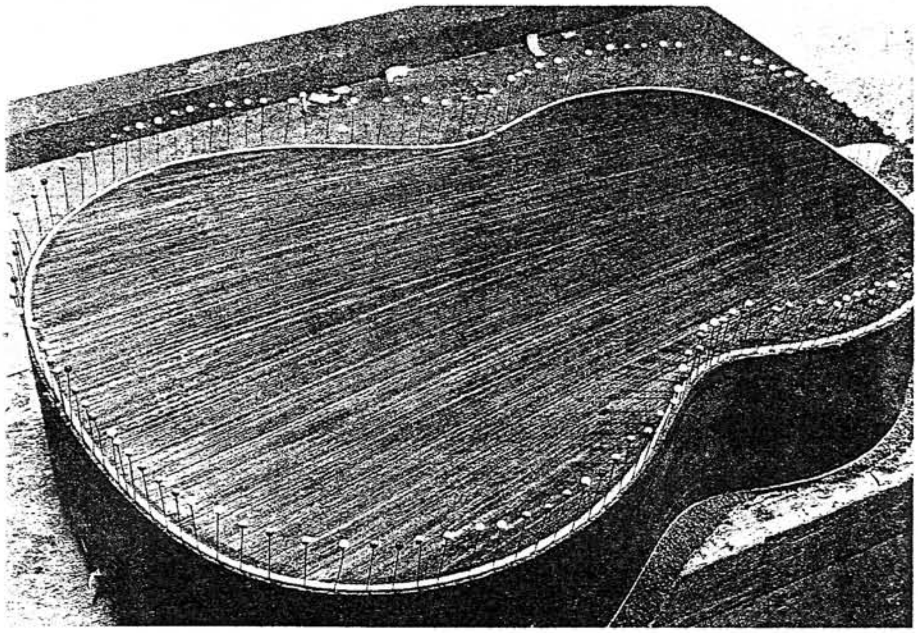
1 Most purfling is flexible and can be bent to the shape of the guitar while being glued. Thin strips of rosewood, however, will break very easily, and must first be shaped on the bending iron.

2 If the purfling is being made from several separate strips, they can all be glued in one operation.

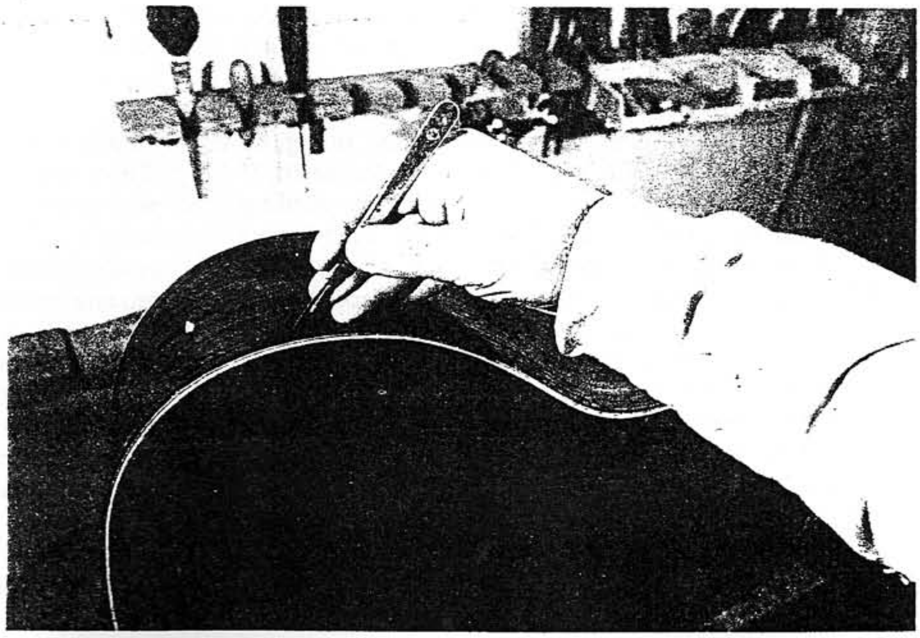
3 Spread glue along the rebate and place the purfling in position, starting at the centre of the end-block inlay. Insert large head pins tightly up against the purfling (22-5). These will hold the purfling against the edge of the rebate while the glue dries. The pins can be lightly tapped with a hammer as they may be difficult to push into the rosewood back. Continue inserting the purfling all the way round the back, and cut it so that it finishes at the centre of the heel.

4 Push the purfling down firmly with the end of a screwdriver or small file. It must be properly seated in the rebate, as the glue tends to make it rise up. Clean away the excess glue and allow to dry.

5 Repeat this procedure on the other half of the back (22-6).



22-6 The back purfling completed



22-7 Cutting the rib for the binding rebate

6 Clean up the surface with a cabinet scraper or abrasive paper so that the purfling is flush with the back.

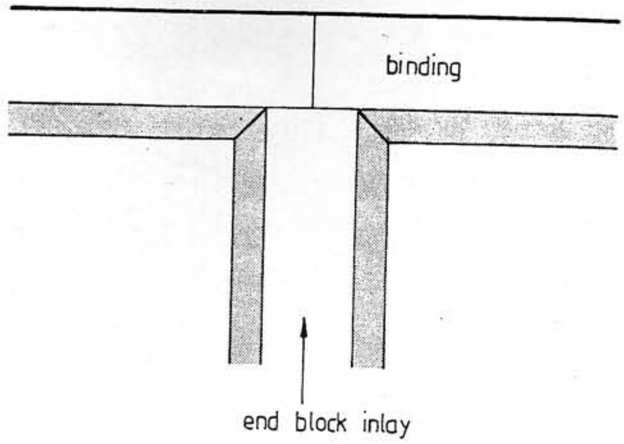
Cut the binding rebate

1 Set the purfling groove cutter to the depth of the binding. Scribe a line on to the ribs, but stop just before the cutter reaches the end-block inlay. Complete the line with a scalpel. If the binding has a thin veneer glued to its lower edge, this must be mitred to meet the similar veneer on the end-block inlay.

2 The guitar can be supported with the neck in a vice mounted on the workbench. Once the guideline has been deepened with a scalpel, begin cutting away the waste with a sharp chisel (22-7). The wood must be removed right up to the edge of the purfling, so that the binding can butt up to it. If the ribs and binding are the same thickness (2 mm) this will require cutting away the full depth of the rib until the lining is exposed. This provides a better gluing surface than if the binding is glued to a thin sliver of rib wood.

3 At the end-block inlay, the rebate must be slightly less deep because of the mitred join between the inlay and the binding (22-8).

4 At the neck end the binding must be carried through to the centre of the heel. The heel will later be capped with a piece of wood to match the back. This capping can either be a thin section about 2 mm thick, or it can be the full depth of the binding. This second option allows the decorative line of the binding to follow through on to the capping. If a deep capping is to be used, then reduce the height of the heel with a chisel until it is level with the lower edge of the binding rebate. For a thinner capping, chisel out a 2 mm wide slot so that the binding can be let in to the heel.



22-8 The end-block inlay and the binding are mitred to form a neat joint

5 The entire binding rebate must be clean and square. A flat safe-edge file may help.

Bend the binding

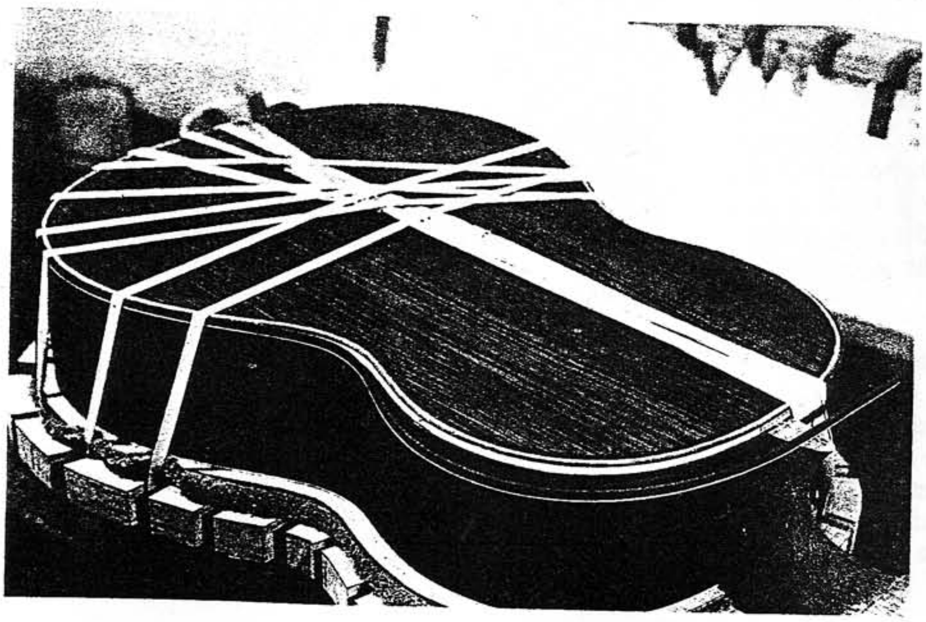
1 Cut a mitre at one end of the binding, and fit it to the centre of the end-block inlay.

2 Start shaping the binding on the bending iron. Begin at the mitred end and work round the lower bout, then the waist, and finally the upper bout. Place the binding in its rebate frequently to check progress. It can be held in place with strong elastic bands while the heel end is marked. Cut to length (22-9).

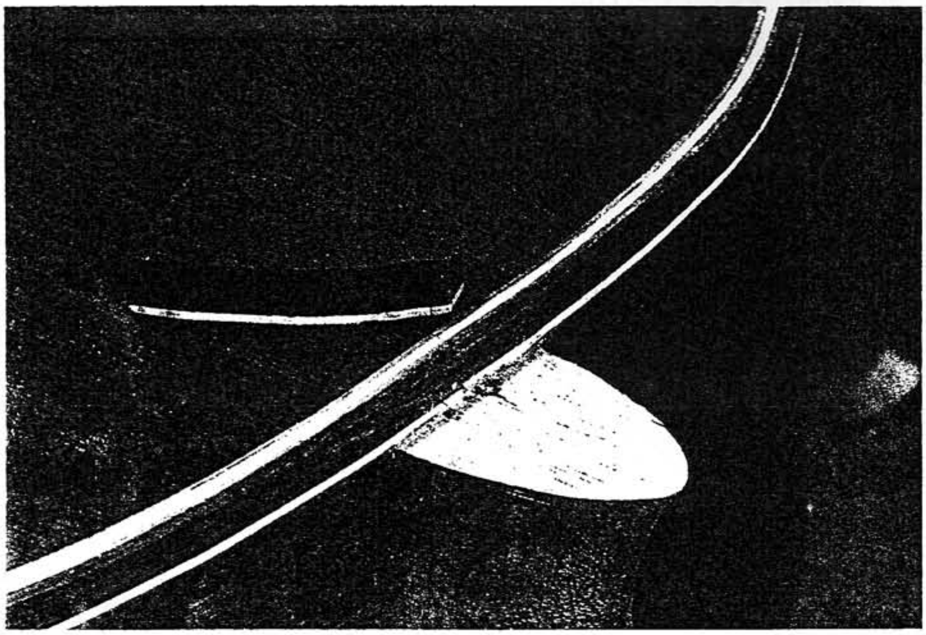
Glue the binding

1 Spread glue along the rebate and butt the mitred end of the binding up against the end-block inlay. Stretch elastic bands over the guitar and hook them on to the workboard. Work round the guitar, using as many elastic bands as necessary to ensure a close fit.

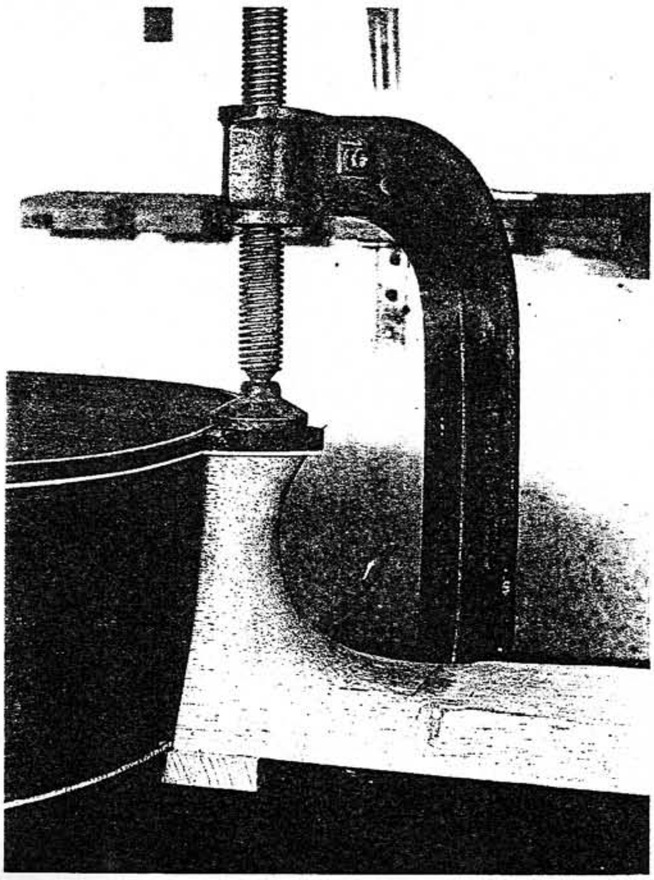
2 If the heel end has been slotted, then push the



22-9 Fitting the binding



22-10 The heel capping ready to be glued



22-11 Gluing the heel capping

binding into the slot. If the heel has been reduced to the depth of the binding, then simply push the binding in place and secure the end with a panel pin driven into the heel. Leave to dry.

3 Cut the rebate for the other binding and glue it in place in the same way.

Cap the heel

1 Prepare a 2 mm thick heel veneer, and glue it in place. When dry, trim the edges to the shape of the heel.

or:

2 Prepare a heel capping block the same thickness as the binding, and including a veneer line to match the binding. This can be cut from one or more thicknesses of veneer sheet, and glued to the capping block (22-10) and (22-11). Then glue the block to the heel and trim when dry.

The soundboard – preparation

Great care must be taken when cutting the purfling rebate on the soundboard – the soft spruce or cedar is easily damaged, and any cutting tool tends to follow the direction of the grain rather than the outline of the guitar. Many light cuts with the scalpel will give the best result.

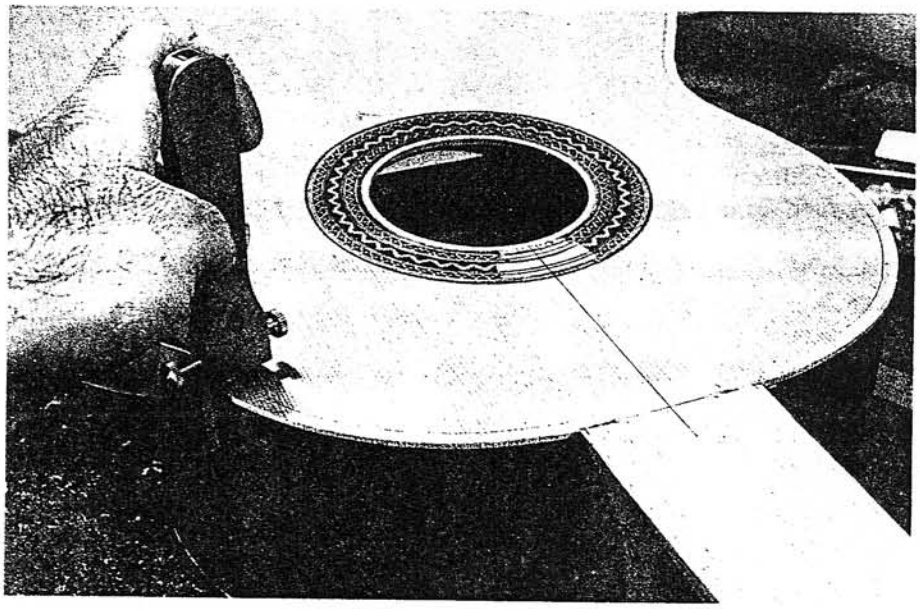
1 Before setting the purfling into the soundboard make certain that the entire surface is sanded smooth. Seal the soundboard with a coat of sanding sealer to prevent glue from the purfling getting into the grain of the soundboard.

2 Prepare the purfling and binding. Soundboard purfling is often more elaborate than the inlays on the back.

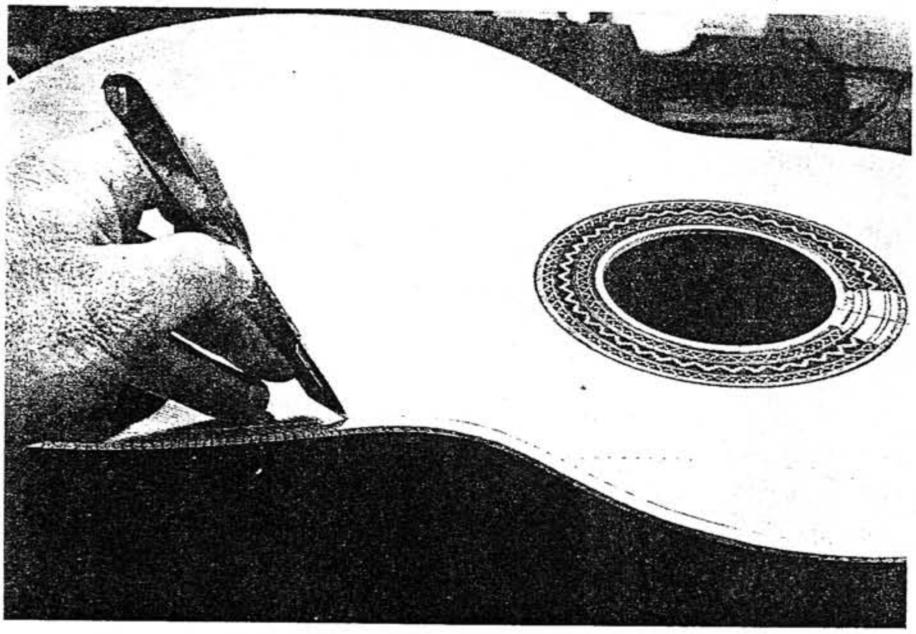
Cut the purfling rebate

1 Set the purfling groove cutter to the total width of all the purfling and the binding. Test it on an off-cut before marking the line on the soundboard (22-12). As with the back, deepen the cut with a scalpel (22-13). Carry the line at least 10 mm into the neck area, so that the fingerboard will cover the end of the purfling.

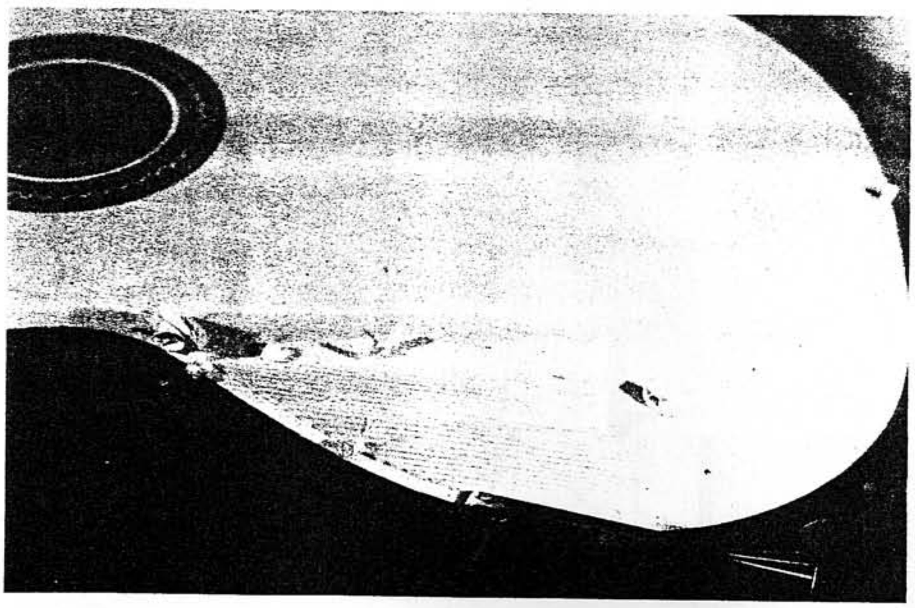
2 Pare away the waste with a chisel to form a flat rebate, at least 1 mm deep (22-14). A narrow



22-12 Marking the width of the purfling rebate with a purfling cutter



22-13 Deepening the cut with a scalpel



22-14 Forming the rebate for the purfling chisel is needed at the neck-end.

Glue in the purfling

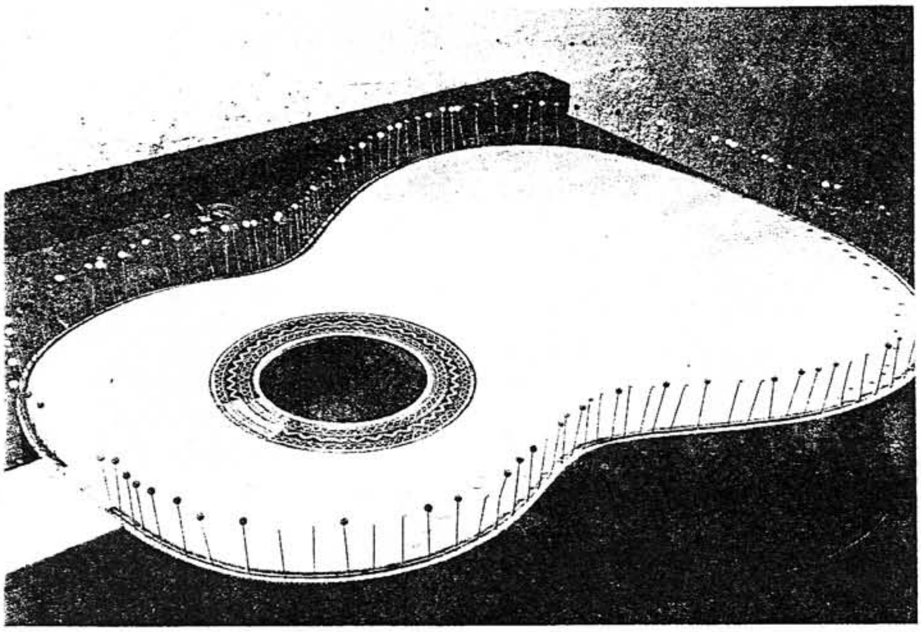
1 Spread glue along the rebate and then place the purfling in position, starting at the centre of the end-block. The pins can be pushed into the spruce soundboard with hand pressure.
2 The waist is the most awkward part, especially if you are gluing in several separate lines together. Be sure that they do not twist over as they follow the curve of the waist.
3 Push the purfling down with a small flat file so that it is well bedded into the rebate. Wipe away excess glue and leave to dry.
4 Repeat the procedure on the other half of the soundboard (22-15) and (22-16).

Cut the binding rebate

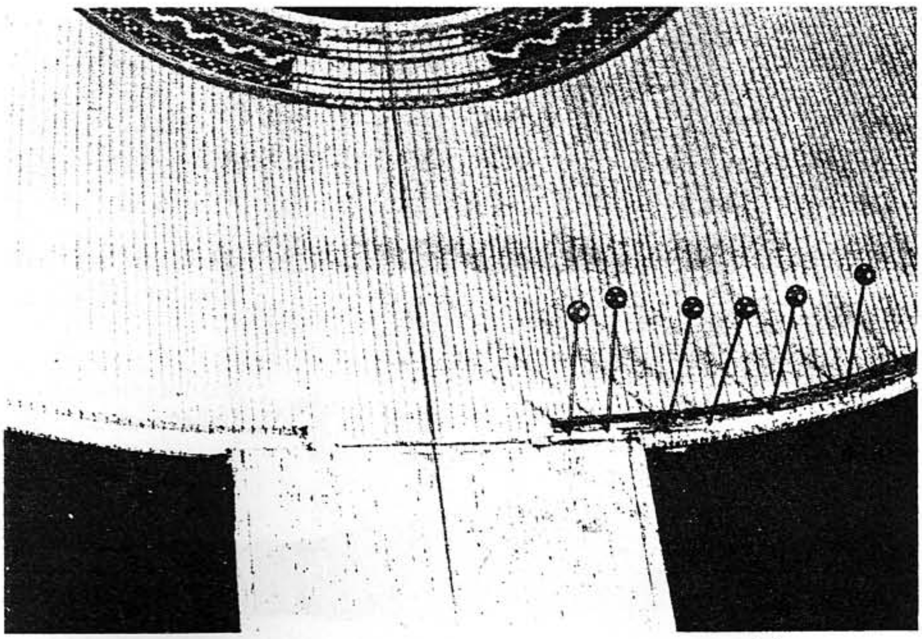
1 Mark and cut away the edge of the rib in the same way as you did for the back (22-17) and (22-18).
2 The end of the rib enters the slot cut in the neck. This must be chiselled out so that the binding can take its place.

Bend the binding

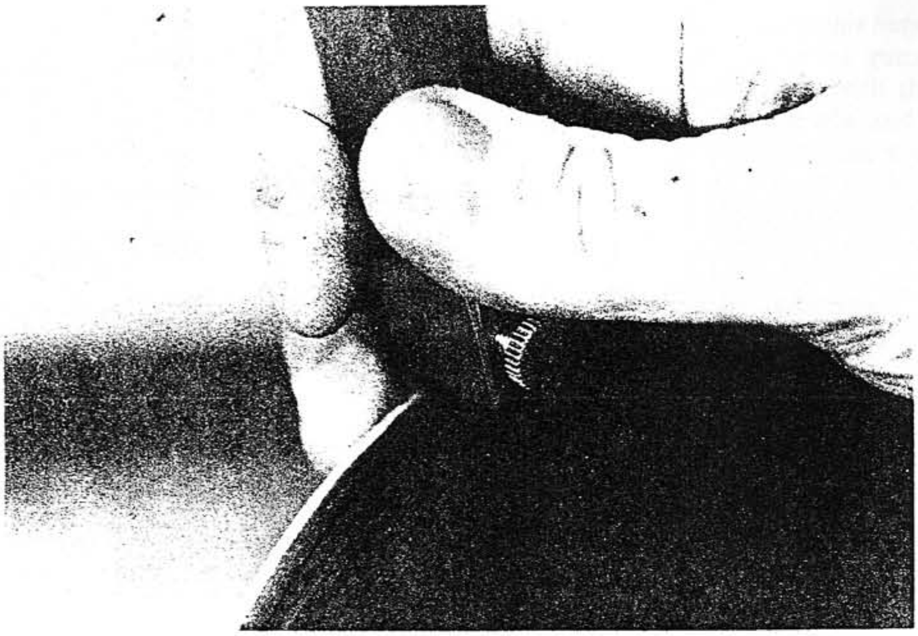
Shape the binding on the bending iron, then fit it in place and cut to length (22-19) and (22-20)



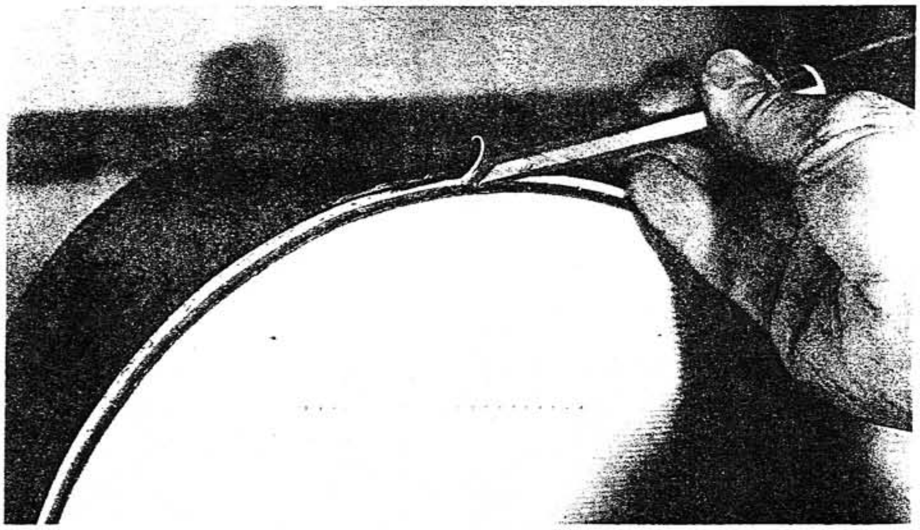
22-15 The purfling glued against the edge of the rebate



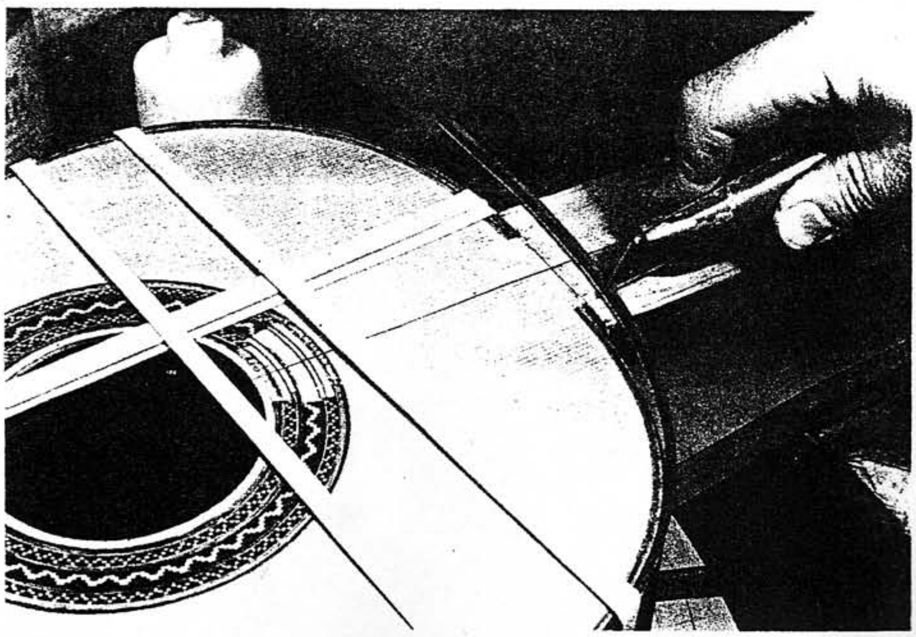
22-16 At the neck end the purfling is carried 10 mm to 20 mm past the outer edge of the neck so that the fingerboard will cover it



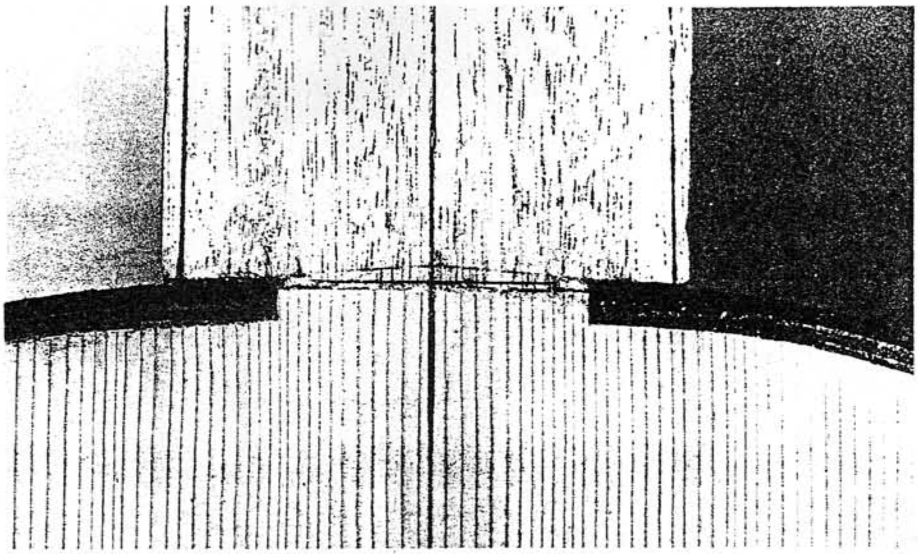
22-17 Marking the rebate for the binding



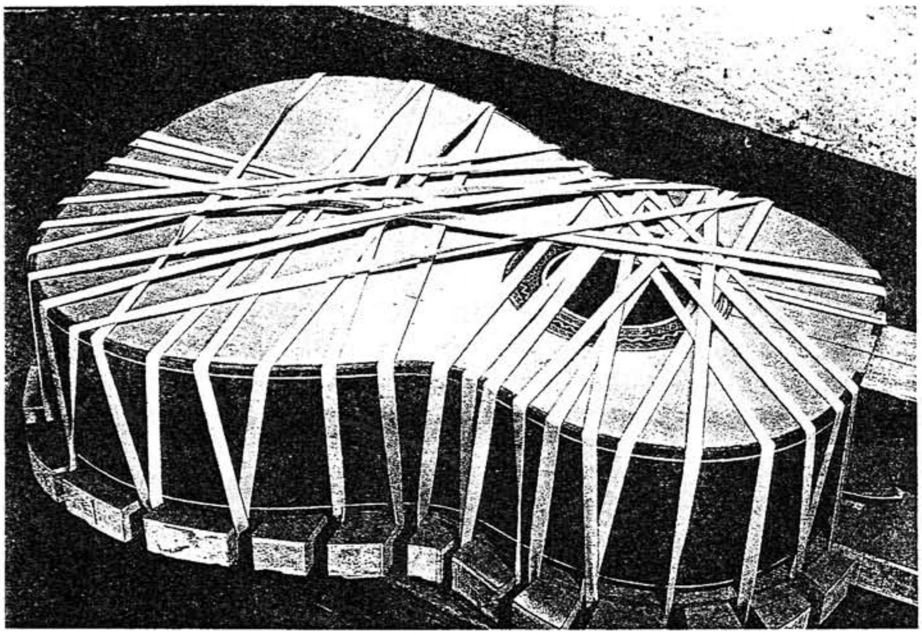
22-18 Forming the rebate for the binding



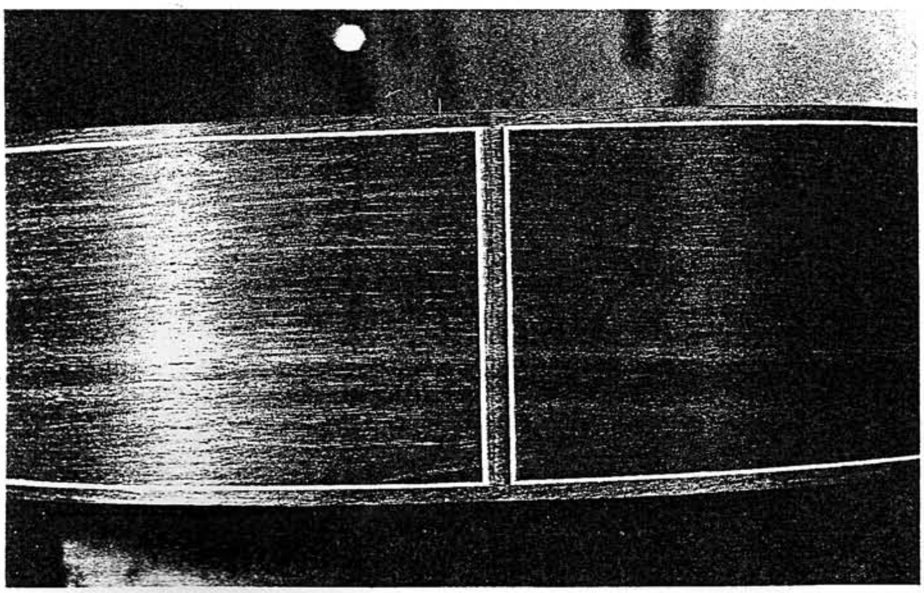
22-19 Fitting the binding



22-20 *The binding fitted*



22-21 *Gluing the binding*

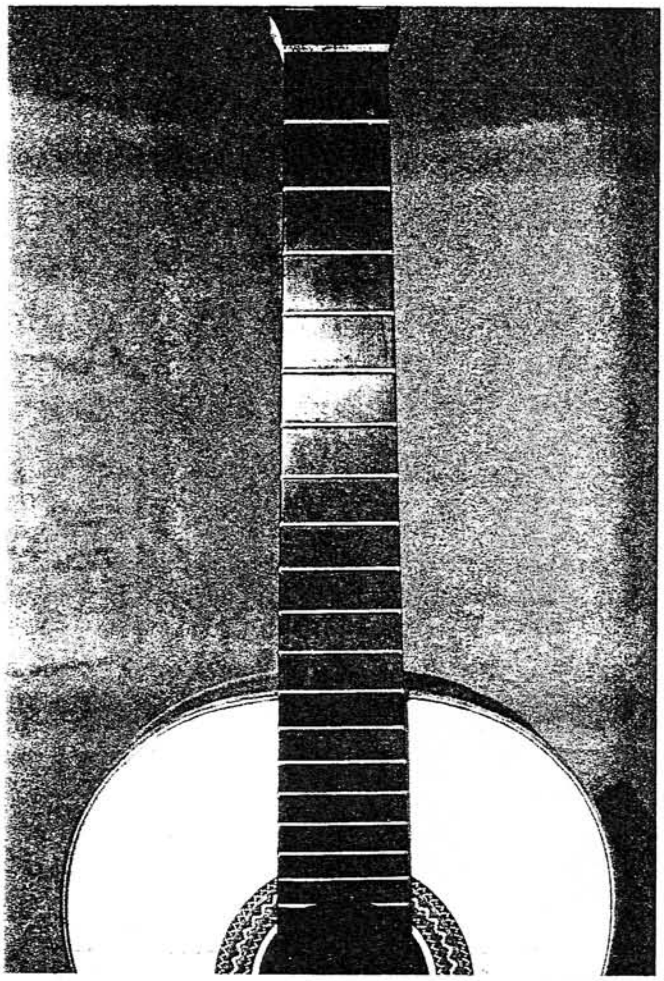


22-22 *The completed binding and end-block inlay*

Glue the binding
Tape the guitar-shaped packing strips to the back of the guitar so that the arched back is raised off the workboard. Glue the binding to the rebate, securing with elastic bands (22-21).

Clean up the guitar body
The body of the guitar is now complete. Scrape the binding flush with the ribs (22-22). Fill any gaps between the ribs and the binding with a mixture of rosewood sawdust and glue. When dry, this can be sanded flat and will be invisible.

23 Fingerboard



23-1 The completed fingerboard

The fingerboard is the part of the guitar that receives the most attention from the guitarist. It must be absolutely smooth so that the player's hand can move up and down with comfort. The fretwire must be accurately placed and the ends rounded over and smooth. The best guitars have fingerboards that are flat across their width, although some makers shape the bass side down slightly so that the bass strings have more space in which to vibrate without buzzing against the frets. (The same result can be obtained by making the bridge saddle slightly higher on the bass side than the treble.) The fingerboard is first prepared to its final thickness and shape, before being glued to the neck. Then the fret slots are cut and the fretwire installed.

Tools

Smoothing plane
Scraper plane
Cabinet scraper
Straight-edge
Rule
Dividers
Drill
Hammer (domed head)
Pliers
Cramps
File
Fret-slot saw
Fret file
Sharpening stone

Materials

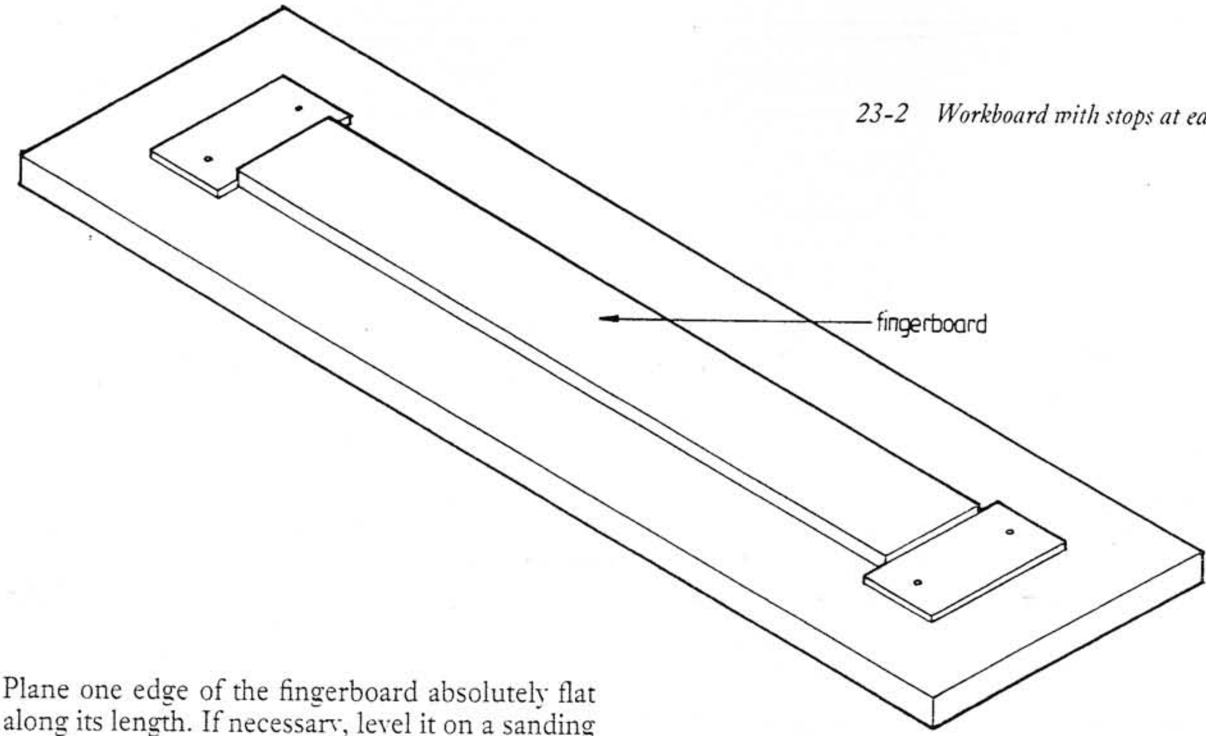
Ebony fingerboard (450 mm × 70 mm × 8 mm)
Dowel (3 mm diameter)
Glue
Fretwire (1.5 metres)
Epoxy glue

Method

The fingerboard must be tailor-made to fit the surface of the neck and the area of soundboard between the neck and the soundhole. If you place a short straight-edge from the soundhole to the neck, a gap of 1 mm to 2 mm will be evident where the two parts meet. This was caused by the shaped solera – the neck is raised up slightly due to the ramp. The underside of the fingerboard must therefore be shaped to this angle before being glued to the neck and soundboard.

Preparation

1 Secure the ebony fingerboard to the workbench with a thin stop at either end so that the smoothing plane can reach the complete length (23-2). Most ebony will work fairly well with a sharp plane, provided there are no areas of twisted grain or knots. Plane both surfaces and decide which will be the face side, to which the frets will be fitted.
2 Check the surfaces with a straight-edge. If the wood already has a slope at the end of one side, this can be selected as the gluing surface and placed over the soundboard as this is consistent with the shape required to fit this area. Although the fit will not be correct at this stage, at least you will not be fighting the natural shape of the fingerboard. Plane the fingerboard to an overall thickness of 6 mm or 7 mm.
3 Both sides of the fingerboard can be levelled and smoothed with a large, flat sanding block.



23-2 *Workboard with stops at each end*

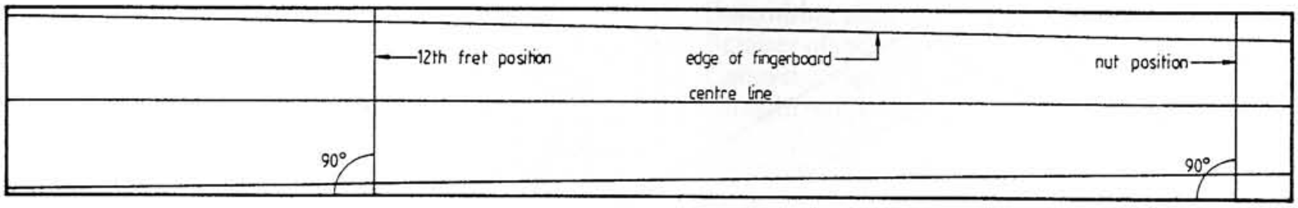
4 Plane one edge of the fingerboard absolutely flat along its length. If necessary, level it on a sanding board.

Set out the fingerboard shape (23-3)

1 Place a square against the flat edge, and mark a line across the wood to represent the nut end. Measure 325 mm from this line (half the scale length of 650 mm) and draw another line across the fingerboard to represent the position of the 12th fret.
2 Find the centre of the two lines (nut and 12th fret), measuring the same distance from the flat edge of the fingerboard, as the two edges may not be parallel. Draw a centre-line along the surface.
3 Use a pair of dividers to mark the width of the fingerboard at the nut and the 12th fret. Join up the lines to form the tapered shape of the fingerboard. These two outer lines are best scribed into the surface with a sharp marking knife.

Cut the fingerboard to shape

1 Plane the edges of the fingerboard down to the lines and use a straight-edge to make certain that the two edge surfaces are absolutely flat. This is important because the fret positions will be marked on to the surface using these flat edges as guides.
2 Place an adjustable bevel against one tapered edge, and set it so that it falls on the nut position line (23-4). Test the accuracy of the setting by turning the bevel over and placing it against the other edge. If necessary, redraw the line at the nut position so that it is truly square in relation to the centre-line of the fingerboard. Mark this final line quite deeply with a marking knife.
3 Chisel out a tiny ramp on the waste side of the mark, and saw off the excess wood, to form a straight end to the fingerboard. Check again with the adjustable bevel, which should now fit the angle perfectly from both edges of the fingerboard.
4 Carry the centre-line of the fingerboard over the edge at the nut end. Place the fingerboard on to the neck, and butt it up against the 5 mm wide nut, or a 5 mm piece of wood to represent the final nut, if the bone nut is not to hand. The nut butts up against the head veneer. Centre the fingerboard by referring to the centre-line on the neck. Look at the gap between the fingerboard and the neck at the position of the 12th fret. The lower (gluing) surface of the fingerboard must now be tapered slightly at the soundhole end so that this gap disappears and the fingerboard can be properly glued to the neck and soundboard (23-5).
5 Cramp the fingerboard face down and begin tapering about 50 mm from the end. Check progress by frequently placing the fingerboard in position on the neck. Gradually increase the length of the taper until it begins close to the position of the 12th fret. Check also that the fingerboard remains flat across its width. If the thickness at the end of the fingerboard becomes less than 4 mm to 5 mm, but the gap has not disappeared, try to trace the cause. It may be that the soundboard itself is not flat, or that the underside of the fingerboard is not flat. Eventually, the fingerboard should fit well with minimum pressure.



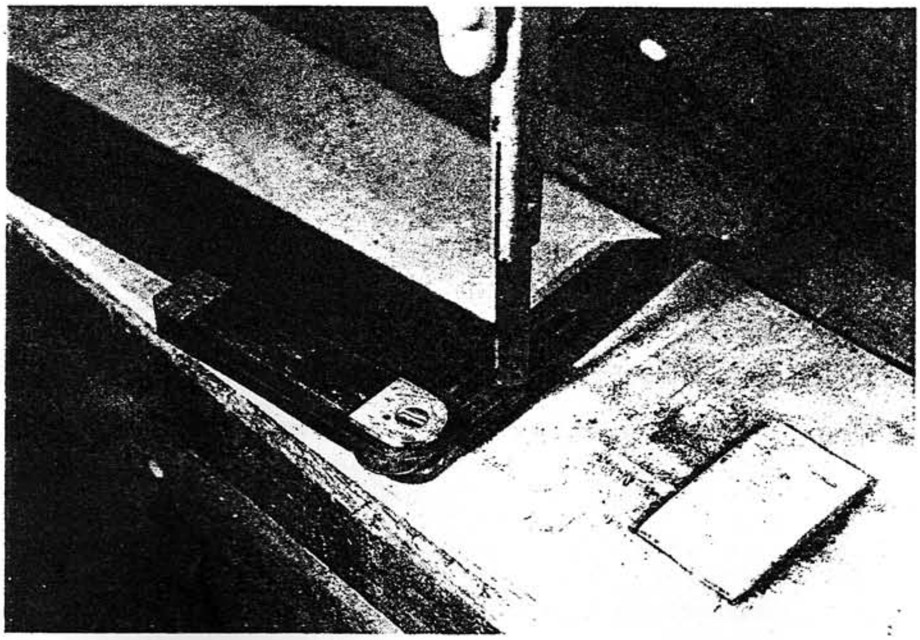
23-3 Setting out the fingerboard

6 Cramp the fingerboard in place dry, aligning the nut end with the centre-line on the neck. Various checks can be made to ensure that the soundhole end is correctly positioned; if you mark the last (19th) fret accurately on the fingerboard, using the adjustable bevel, and transfer the line on to the edges of the fingerboard, then these marks should fall symmetrically on to the soundhole rosette. They should also be equidistant from the edge of the soundhole itself (23-6). Another check can be made by placing a rule against the edge of the fingerboard at the 19th fret. The distance to the edge of the guitar should be the same on both sides. Finally, two straight edges can be placed along the edges of the fingerboard. The points at which they intersect the lower end of the guitar (at the end-block) should be equidistant from the centre of the soundboard (23-7). If there is any inconsistency between these measurements, most importance should be given to the position in relation to the soundhole. If this is not correct, then the two short 19th frets will not be of equal length.

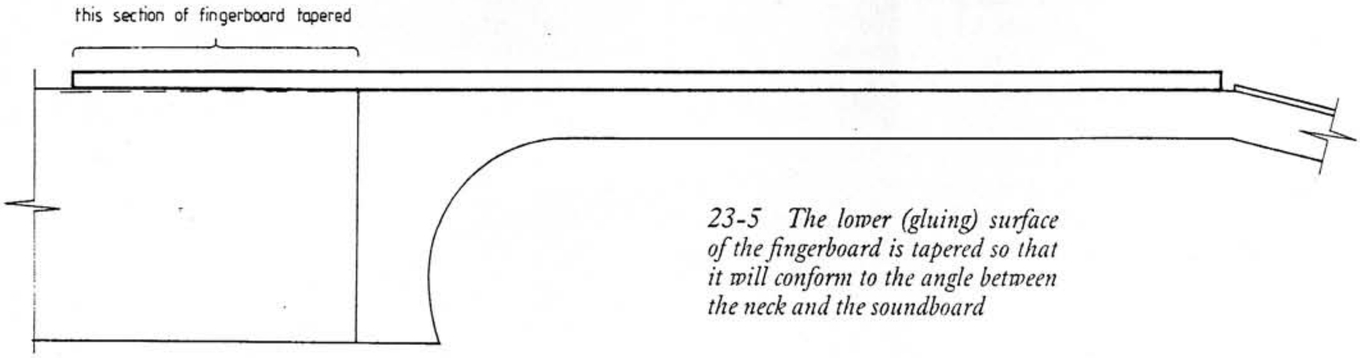
7 With the fingerboard correctly placed on the guitar, draw the shape of the soundhole on to its lower surface, using the soundhole as a guide for the pencil (23-8). Masking tape stuck to the lower surface of the fingerboard will make the line more visible. Remove the fingerboard. Draw the centre-line and the 19th fret on to the back of the fingerboard. The soundhole marking should be symmetrically placed in relation to these marks. Cut the circular shape at the end of the fingerboard with a fine fretsaw blade, slightly to the waste side of the line (23-9). There is no need to smooth this surface now, as the end of the ebony can best be shaped to the curve of the soundhole once the two have been glued together.

Glue the fingerboard

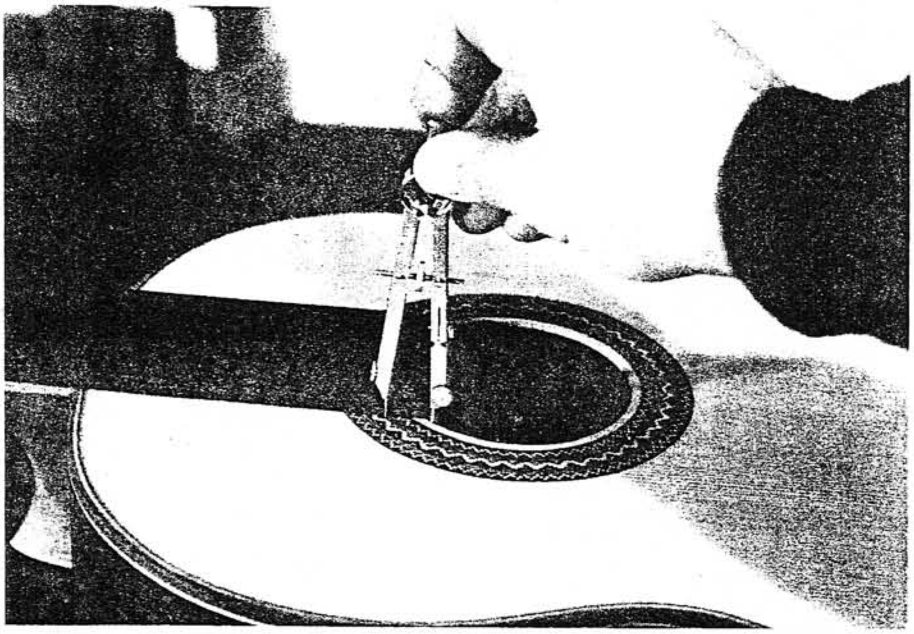
The wide surface area of the fingerboard makes it essential that some method be used to prevent it sliding out of position when the pressure of the cramps is applied. One method is to drill two small holes in the fingerboard through which panel pins can be temporarily driven into the neck. If the holes are made in the precise location of the fretwire for the 1st and 11th frets, they will not be visible in the completed instrument. A better method is to drill two or three small holes part way into the back of the fingerboard. Short dowels are inserted and these match up with holes drilled into the neck.



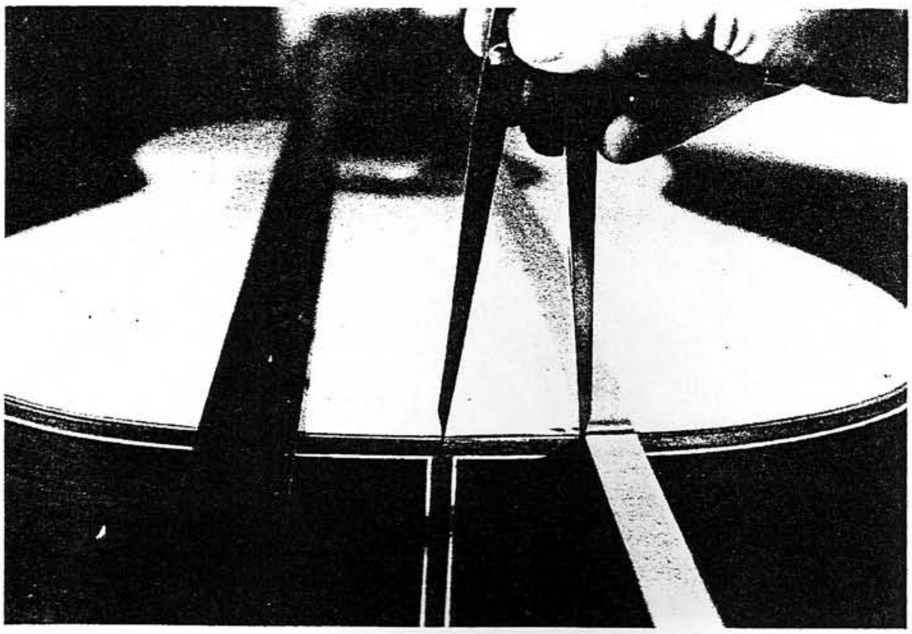
23-4 The adjustable bevel is set to mark a line that is at a right angle to the centre-line of the fingerboard



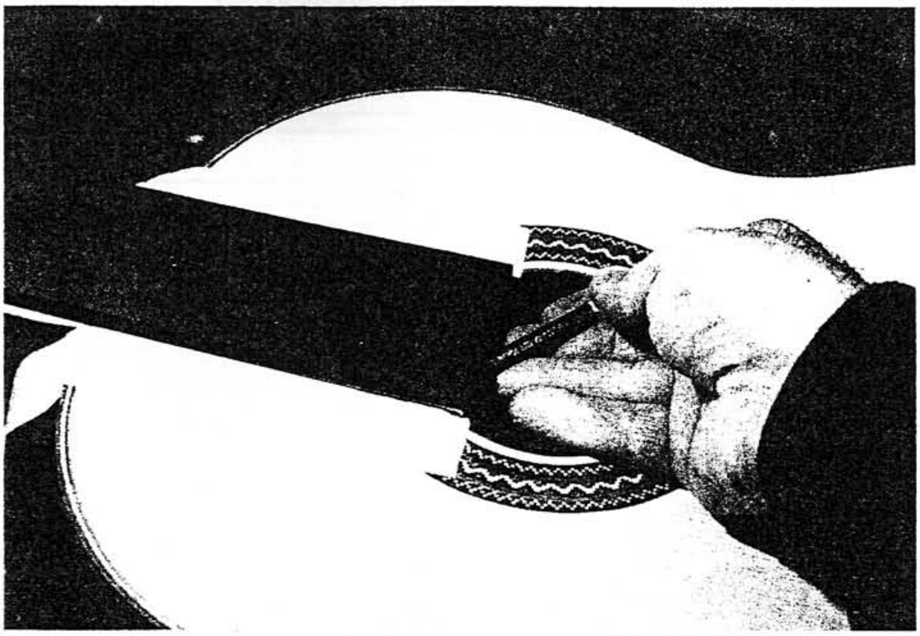
23-5 The lower (gluing) surface of the fingerboard is tapered so that it will conform to the angle between the neck and the soundboard



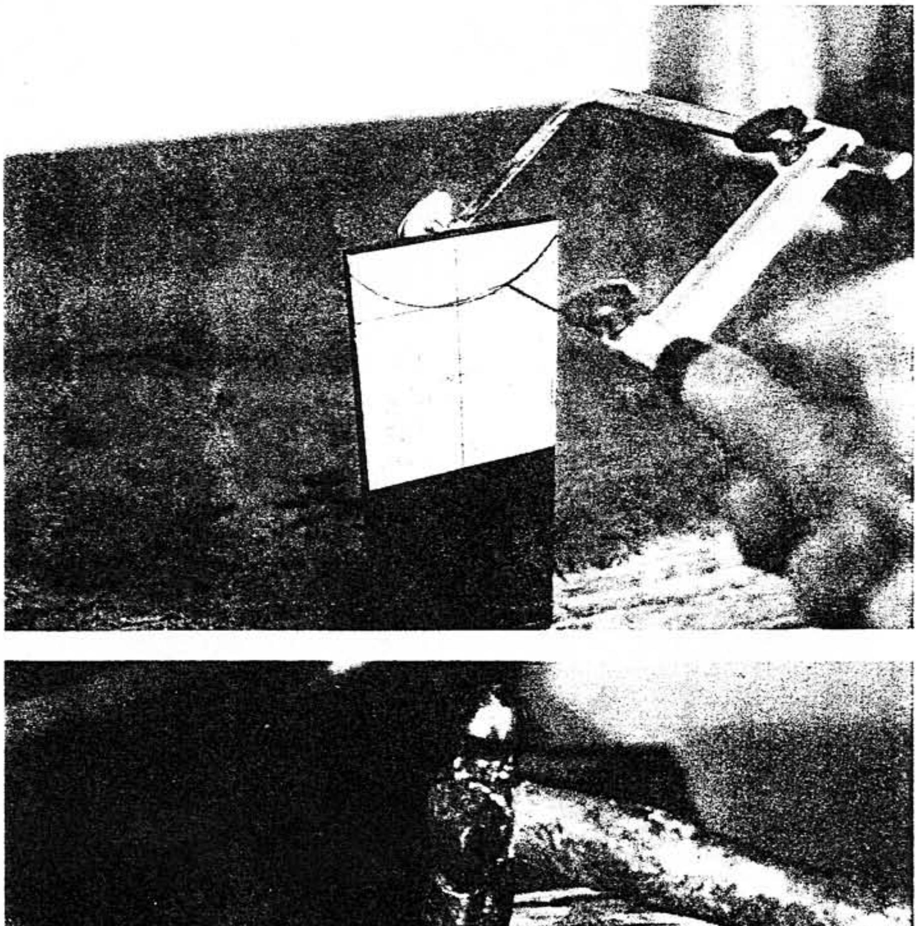
23-6 Measuring the distance from the edge of the soundhole to the 19th fret. This should be identical on both sides of the fingerboard



23-7 Measuring the distance from the centre of the soundboard to the (extended) edge of the fingerboard



23-8 Marking the shape of the soundhole on the underside of the fingerboard



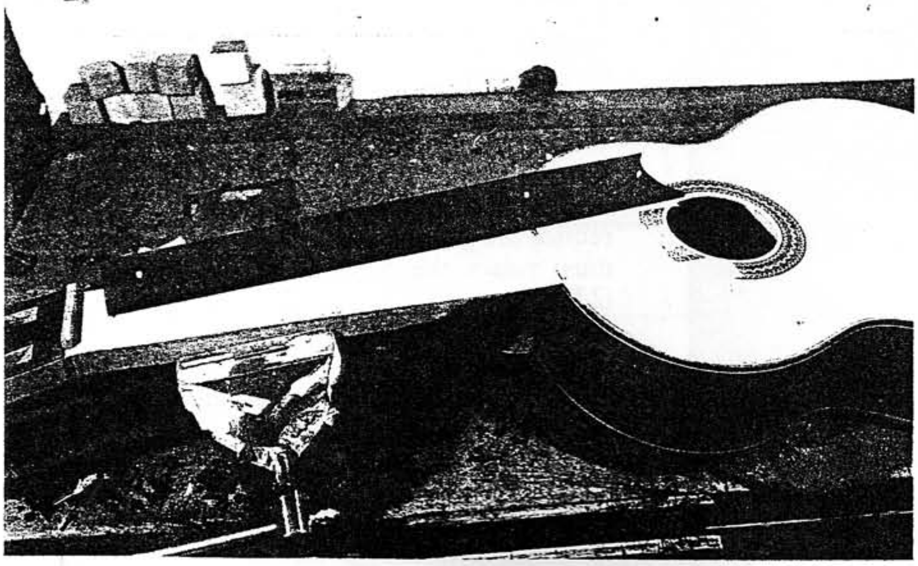
23-9 Cutting the end of the fingerboard to match the shape of the soundhole. The masking tape makes the pencil lines more visible

23-10 A method of making dowels of any diameter – the dowel is tapped through a series of holes of diminishing diameter until the required size is obtained

1 Cramp the fingerboard to the neck and mark its position on the soundboard with a strip of masking tape stuck each side. Its correct position can then be found again without having to remeasure.
2 Remove the fingerboard, turn it over, and carefully hammer in three dressmaker's pins; at the position of the 1st fret, the 11th fret, and the centre of the upper harmonic bar. Cut the pins off with a pair of pliers, leaving about 1 mm protruding. Place the fingerboard back in its position on the neck. Apply pressure first at the nut end, until the pin enters the neck. Then push down the other end of the fingerboard, so that it comes into contact with the soundboard between the two masking tape guidelines. Remove the fingerboard and extract the pin ends from it. Six tiny holes will now be visible; three on the back of the fingerboard, two on the surface of the neck, and one near the soundhole.
3 These holes are now taken as starting-points for drilling 3 mm diameter holes in which dowels will fit. The holes in the back of the fingerboard should be no more than half its depth. A drill press will ensure that the holes are at right angles to the surface. Set the depth stop to avoid the possibility of drilling right through the fingerboard. The holes in the neck and soundboard can be drilled with a hand-drill, and should be approximately 3 mm deep.
4 Prepare some small dowels of the correct diameter. A larger dowel can be reduced in size by hammering it through holes of diminishing diameter that have been drilled through a cabinet scraper (23-10). Glue the dowels into the fingerboard holes, ensuring that the amount left protruding is slightly less than the depth of the holes drilled in the neck and soundboard. The fingerboard should now fit in place on the guitar (23-11).
5 Prepare a cramping caul from a piece of plywood. Also needed will be the fingerboard cramping-block made in Chapter 15.
6 Spread glue thinly on both gluing surfaces. Locate the dowels, push the fingerboard down in contact with the guitar, and then place the caul on top. Apply cramps lightly at first, tightening them gradually once they are all in place. The cramping-block must be inserted through the soundhole so that three cramps can be introduced without damaging the bars below the fingerboard. One cramp can extend from the heel, but be careful not to tighten it over the arched foot as this may be damaged.
7 Remove the masking tape from the two edges of the fingerboard. Most of the excess glue will be on the tape. Use a wooden spatula and a damp cloth to clean away every trace of glue from the soundboard/fingerboard join, and from the nut end of the neck. (Remove the nut if it is still in place.) Clean away any glue at the edge of the soundhole. Leave to dry overnight (23-12).

Clean up the fingerboard

1 Support the guitar with its neck in a vice and use a chisel and round sanding stick to shape the soundhole area of the fingerboard (23-13).
2 Support the guitar in a bench-mounted vice so that the sides of the neck can be pared away until they are flush with the fingerboard. Work carefully right up to the head, and down to the ribs (23-14) and (23-15).
3 Now place a straight-edge on the fingerboard. It is unlikely to be perfectly level. Before the frets are installed the surface must be flat along its length. A scraper plane, followed by a long sanding block will accomplish this. Place a strong light behind the straight-edge and continue levelling the surface until no light is visible between the straight-edge and the fingerboard.

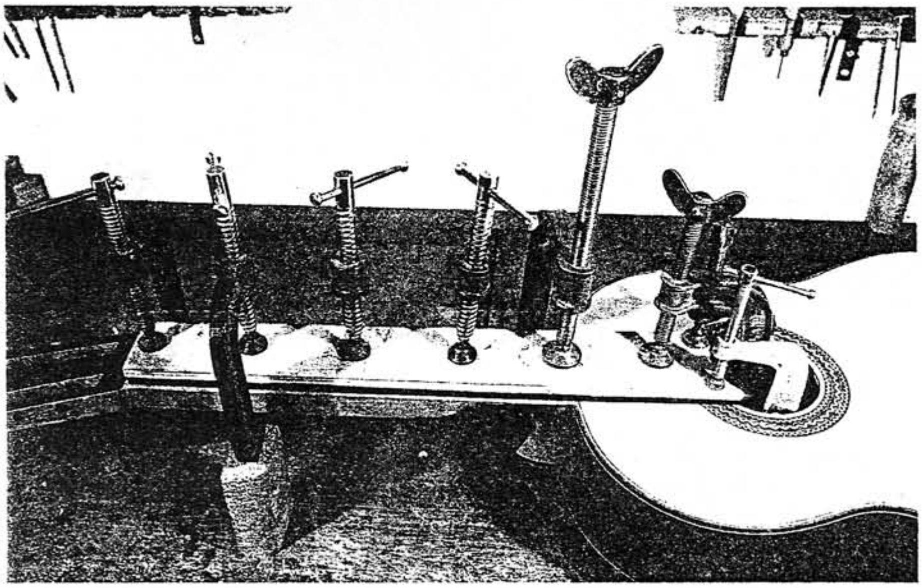


23-11 The fingerboard with locating dowels in place is now ready to be glued to the guitar

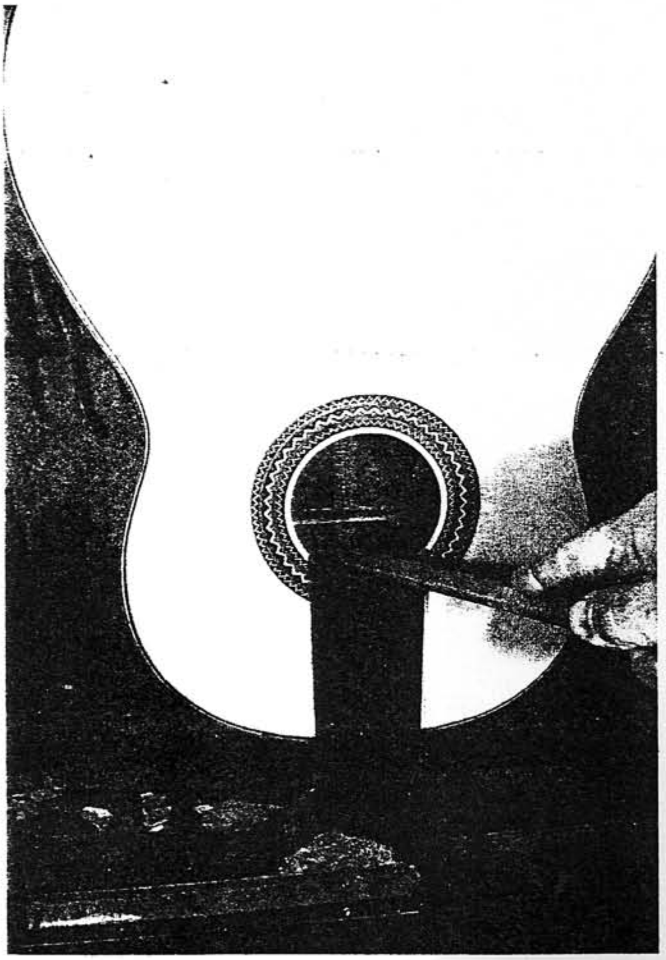
(Some makers create a slight hollow in the central area of the fingerboard, between the 4th and 9th frets. The idea is that this can help avoid the strings buzzing on the frets, even when the action is very low. Although this approach is essential in the case of steel-string guitars, it is not necessary for a classical guitar, where the action can be perfectly adjusted with a flat fingerboard.)

Check the action

The correct height of the strings above the soundboard (at the bridge), and above the 12th fret has been established by the angle of the neck to the soundboard. If, however, the neck angle is not absolutely correct, it may be necessary to taper the surface of the fingerboard slightly. This must be checked now, and any adjustments made before the frets are installed.



23-12 Gluing the fingerboard to the guitar



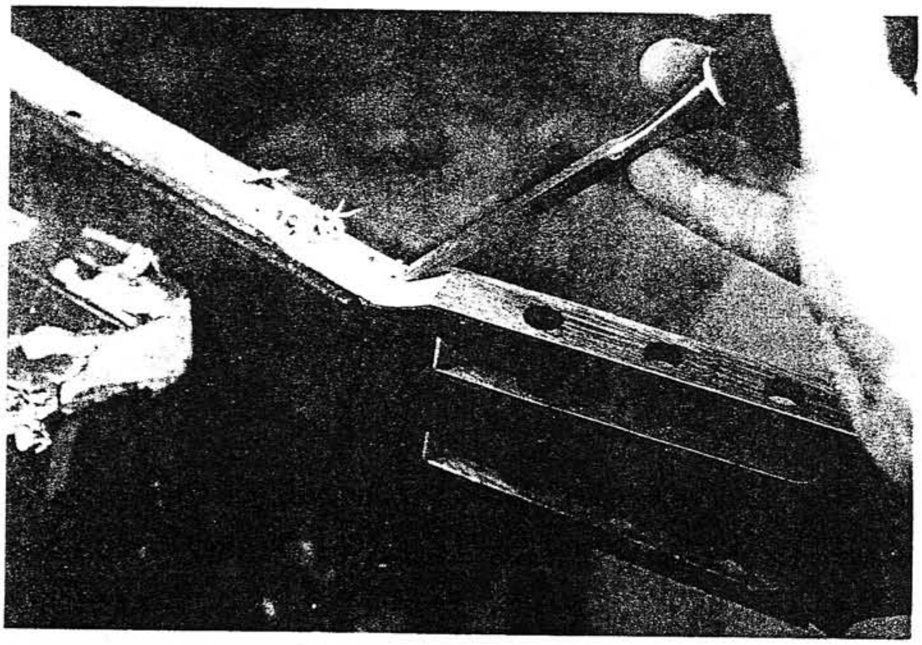
1 Place a block representing the saddle height (12 mm) on the soundboard at the bridge position. Make two pieces of packing from some veneer; one should be 1 mm thick and the other 2 mm thick. Place the 1 mm thick packing on the fingerboard at the 12th fret. Place the 2 mm thick packing at the 1st fret. The 1 mm thick packing represents the fretwire installed at the 12th fret. The 2 mm thick packing represents the fretwire plus 1 mm of string clearance above it, at the 1st fret. Place a long straight-edge from the bridge block to the packing at the 1st fret. Measure the gap between the straight-edge and the 1 mm packing at the 12th fret. This should be 3.5 mm – 4 mm. If it is much less, the fingerboard must be tapered down towards the soundhole end until this correct gap emerges. Although unlikely, if the gap is greater than 4 mm, the fingerboard could be tapered down towards the nut end. This would reduce the gap at the 12th fret. In either case, you must retain the overall flatness of the surface (23-16).

Set out the fret positions

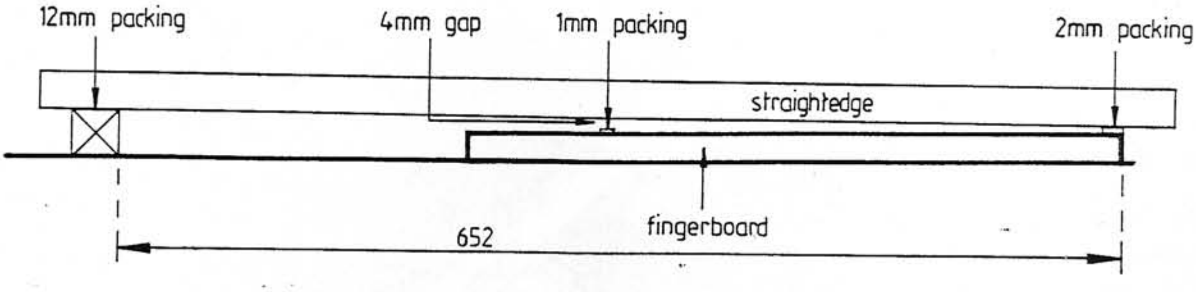
The distance between one fret and the next is calculated to produce intervals of a semitone. The precise distances, which diminish as the frets move

23-13 Smoothing the fingerboard to conform exactly to the shape of the soundhole

23-14 Removing the excess neck material so that it is flush with the fingerboard



23-15 Shaping the side of the neck at its junction with the head



23-16 Before installing the frets, a final check is carried out to ensure that the fingerboard has been correctly shaped to provide the required string heights at bridge, 12th fret and 1st fret. The straight-edge rests on a 12 mm high block at the bridge position and on some 2 mm thick packing placed near the nut. The 1 mm thick packing at the 12th fret represents the height of the fret wire. The gap between the straight-edge and the packing can then be measured down the fingerboard, are dependent upon a mathematical formula. This formula can be applied to any scale length, enabling you to make a guitar with either shorter or longer strings if required. (The scale length is the length of string between the nut and the saddle, which is free to vibrate.) However, there seems little to be gained by further experimentation in this area, as many makers have tried it in the past, and the conclusion is that the given size and structure of the guitar responds best with a scale length of 650 mm. There is a case for a shorter scale length if the guitarist has small hands, and finds it difficult to span the required distances along and across the frets. Increasing the string length beyond 650 mm does not appear to produce a louder instrument – this can be better achieved by the way in which the guitar is built, particularly with regard to the materials, plate thicknesses and method of strutting. (See Appendix 2 for alternative fret distance tables. Computer print-outs for any scale length are available – see Appendix 3.)

Most of the famous concert guitars featured in this book have a scale length of 650 mm. The fret distances are set out on each plan, and summarized in the table below. When transferring these measurements to the fingerboard, never do so directly from the plan, as paper can shrink. If you make a guitar with a different scale length, the fret positions can be calculated as follows.

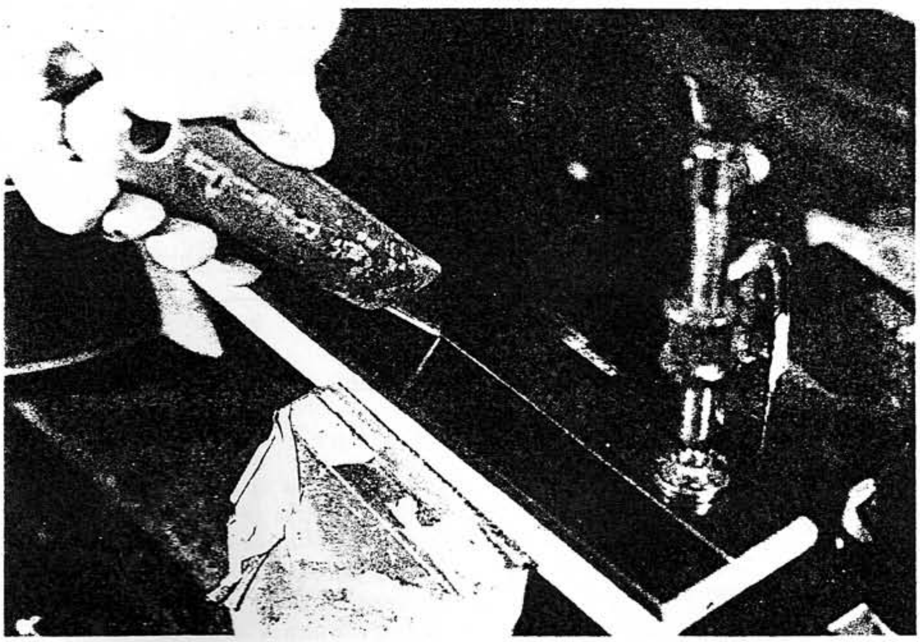
Divide the scale length by 17.817. This gives the distance from the nut to the 1st fret. Subtract this 1st fret distance from the scale length to establish the remaining length of string. Divide this remainder by 17.817. This gives the distance from the 1st fret to the 2nd fret. Add together the distances for the 1st and 2nd frets, and subtract the total from the full scale length. This gives the remaining length of string. Divide this remainder by 17.817 to give the distance between the 2nd and 3rd frets. Add together all three distances, and subtract the total from the full scale length. Carry on until nineteen fret distances have been calculated. The 12th fret should be exactly half the scale length.

Fret positions for 650 mm scale length

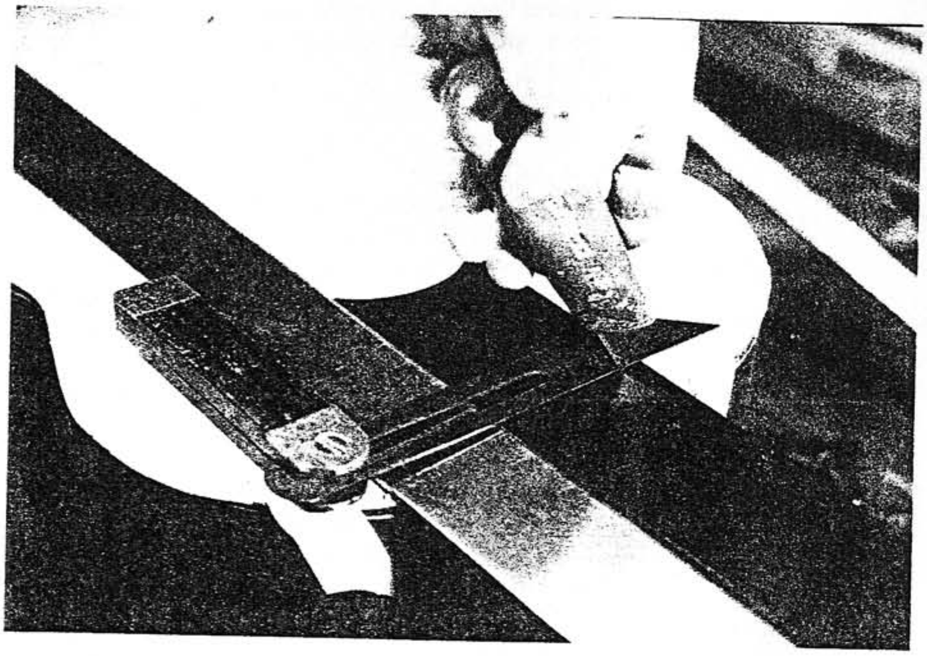
Distances from nut to:

Fret	Distance
1	36.5
2	70.9
3	103.4
4	134.1
5	163.0
6	190.4
7	216.2
8	240.5
9	263.5
10	285.2
11	305.7
12	325.0
13	343.2
14	360.4
15	376.7
16	392.0
17	406.5
18	420.2
19	433.1

1 Place the bone nut (or a wood blank of similar size) into its slot at the end of the fingerboard. Cramp a long steel rule along the centre line of the fingerboard, butting the end up against the nut.
2 Use the sharp point of a craft knife to mark the position of each fret on the centre-line (23-17). Check the measurements carefully, as correct spacing of the frets is essential if the guitar is to



23-17 Marking the fret positions on the centre-line of the fingerboard



23-18 Scribing the fret positions on the fingerboard (the hand holding the bevel has been removed for clarity)

have good intonation. Remove the steel rule.

3 Place the adjustable bevel against the edge of the fingerboard and set its movable arm so that it lies across the fingerboard, against the nut. Draw a series of pencil lines across the fingerboard and turn the bevel over to see if the lines register when measured from the other edge of the fingerboard. If not, adjust the setting on the bevel until the lines coincide with the bevel from both edges.

4 Place a straight-edge against the side of the fingerboard. (Place a protective sheet on the soundboard to avoid damaging it.) With the bevel held against the straight-edge, scribe the fret positions on to the fingerboard with a craft knife (23-18). The straight-edge extends well past the end of the fingerboard, and allows the bevel to continue its path while maintaining the same angle across the surface. Remove the straight-edge.

Cut the fret-slots and install the frets

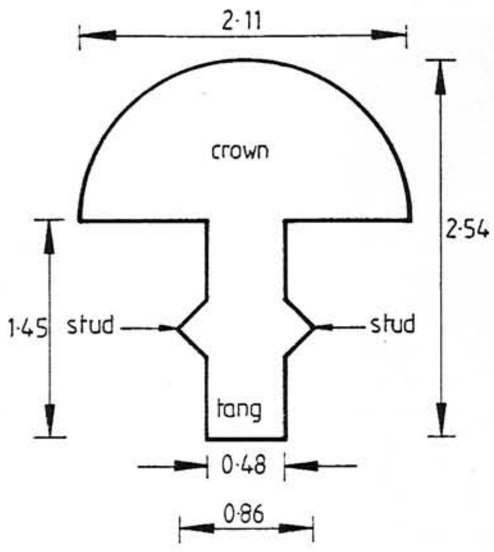
Fretwire is available in many sizes. Classical guitars usually have the medium gauge which is just over 2 mm wide. Use a dovetail saw to cut a slot in an offcut of ebony. Tap a piece of fretwire into it. If the slot is too narrow, the fretwire will be difficult to install, and in time it will distort the fingerboard. If the slot is too wide, the fretwire will not remain in place. Fretwire is manufactured with small studs on the tang. These studs help grip the sides of the slot and keep the fretwire in place (23-19). If the set on the saw is slightly too wide, place the edge of the blade on a flat surface, and gently tap the teeth with a hammer. This will reduce the width of the kerf. Try another test cut and tap some fretwire into it. (Purpose-made fret-slot saws can be purchased.)

1 A thin cabinet scraper can be marked to the depth of the fretwire tang with a strip of masking tape, and then used to check the depth of the saw-cuts. The fret slots must be cut with great care – not only must the saw remain at a right angle to the fingerboard's surface, but the depth of the cut must be correct; too shallow, and the fretwire will not bed down fully; too deep, and the fingerboard will be weakened. When cutting the last eight frets, the soundboard must be protected with a sheet of thick card or tin sheet (23-20).

2 Each slot must now be enlarged at the top with a triangular file. This will ensure that the fretwire beds down properly on to the fingerboard (23-21). Brush out all dust.

3 Cut lengths of fretwire with a 5 mm overhang at each side. If the wire was coiled, it must be straightened before cutting to length.

4 Some makers install the fretwire dry. Others apply some epoxy glue or P.V.A. glue to help fix it in place. Epoxy glue has the advantage of filling any gaps created by a saw cut that is too deep. Support the neck in a vice. Spread some epoxy glue along the bottom of the fretwire tang and place it over the first slot. Tap the fretwire down with a hammer that has a slightly domed head. Be careful not to dent the fingerboard itself. The first tap should be at one end of the fret. Work along to the centre and then the other end. Try not to bounce the hammer off the surface, but channel all the energy into the fretwire (23-22). Once the fretwire has been gripped by the walls of the slot, it is safest to complete the fitting by applying a small cramp to the neck. Place a steel rule adjacent to the fretwire so that the cramp can span the two and avoid damaging the fingerboard. This also keeps the cramp pressure horizontal



23-19 Typical dimensions of fretwire suitable for the classical guitar

(23-23). Clean away any excess glue and cut the fretwire off as close as possible to the edge of the fingerboard, taking care not to raise the fretwire up out of the slot as the wire cutter breaks through. This should be done while the glue is still wet.

5 Repeat this procedure until the 10th fret is in place. (The 10th fret can be cramped by placing a block against the heel.)

6 The remaining frets are more difficult to install because the flat neck surface is not available for securing the cramp. Frets 11 to 14 are best tapped in with the hammer only, although it may be possible to cramp against the foot and heel of the neck if a wide piece of packing it attached. Do not cramp tightly over the foot, though, as the back arch can be damaged.

7 The last five frets can be cramped against the block that was used when gluing the fingerboard, without being hammered. Leave overnight for the epoxy glue to thoroughly harden (23-24) and (23-25).

Clean up the frets

1 Carefully scrape away any dried glue from the fingerboard with a chisel.

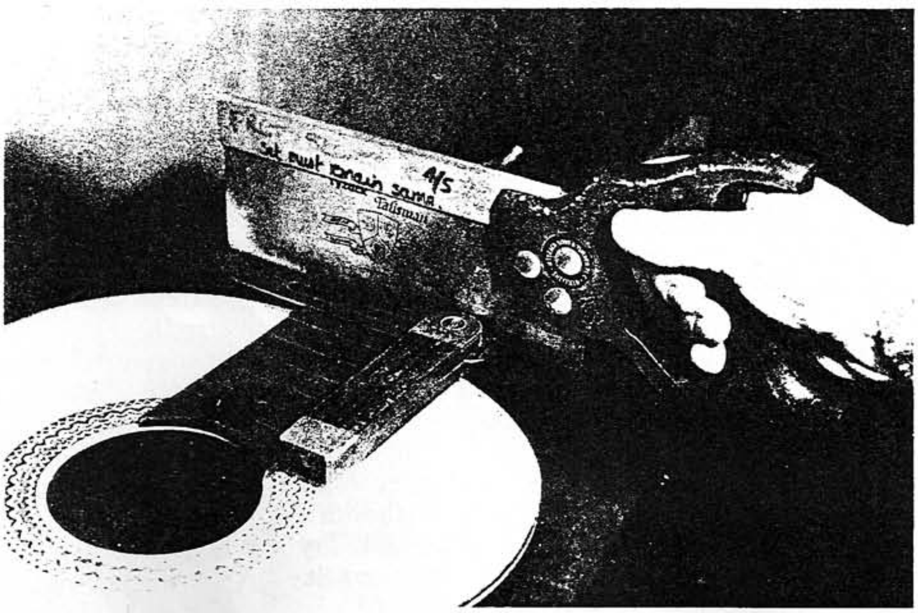
2 Place a straight-edge on the frets. If one or two are higher than the others the straight-edge will rock about. The surface of the frets can be levelled by rubbing a flat sharpening stone along them. Frets 1 to 12 should be flat, although if the idea of relieving the central part of the fingerboard appeals to you, you can allow a small gap between the straight-edge and frets 4 to 8. This 'dip' must be gradual, so that there are no sudden changes in height (23-26).

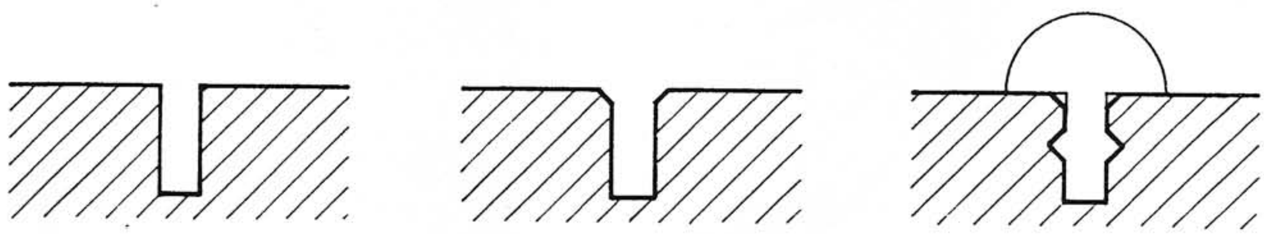
3 The curved surface of the frets will have been flattened by the levelling process, and there may also be small dents caused by the hammer blows. Each fret should now be shaped with a fret file to its original smooth curve. A fret file is specially shaped to follow the curve of the fretwire.

4 The two ends of each fret must now be bevelled, and all rough metal filed smooth. A long flat file can be used to bring the edges flush with the fingerboard (23-27). Then angle the file 45 degrees and bevel the ends of the fretwire (23-28).

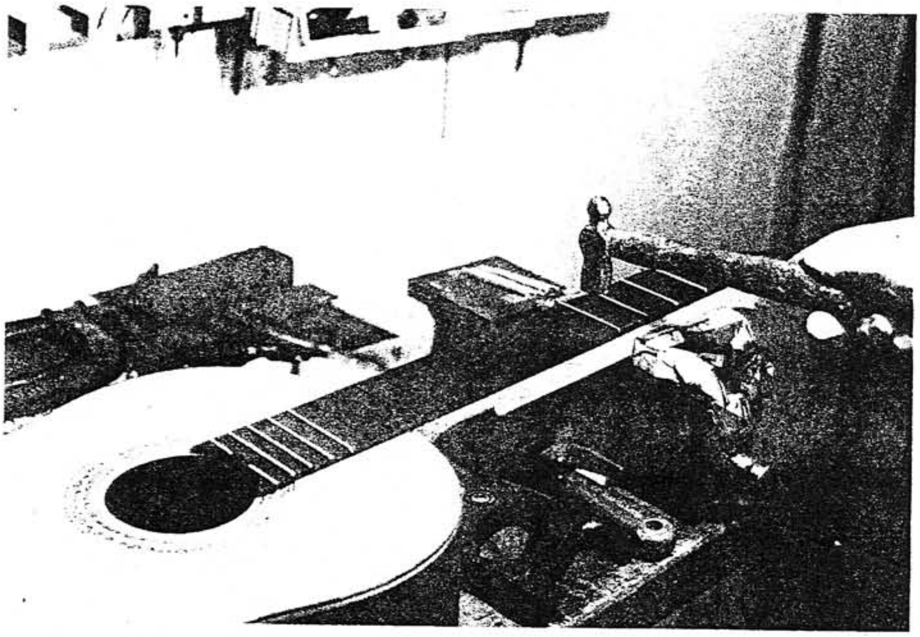
5 Stick a strip of masking tape along the edges of each length of fretwire. Use several grades of fine wet-or-dry paper, wrapped around a small hard wood block or pencil eraser, and smooth the surface of each fret to a shine (23-29). Remove the masking tape, and use the small sanding block to smooth the surface of the fingerboard between each fret. Finish with very fine steel wool, rubbed up and down the entire fingerboard.

23-20 Sawing the slots for the fretwire (the hand holding the bevel has been removed for clarity)

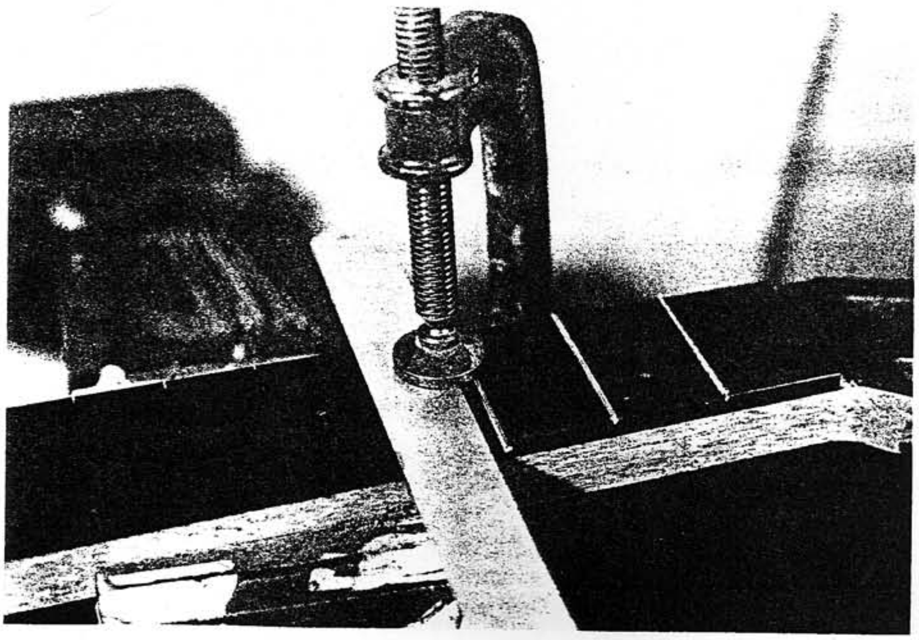




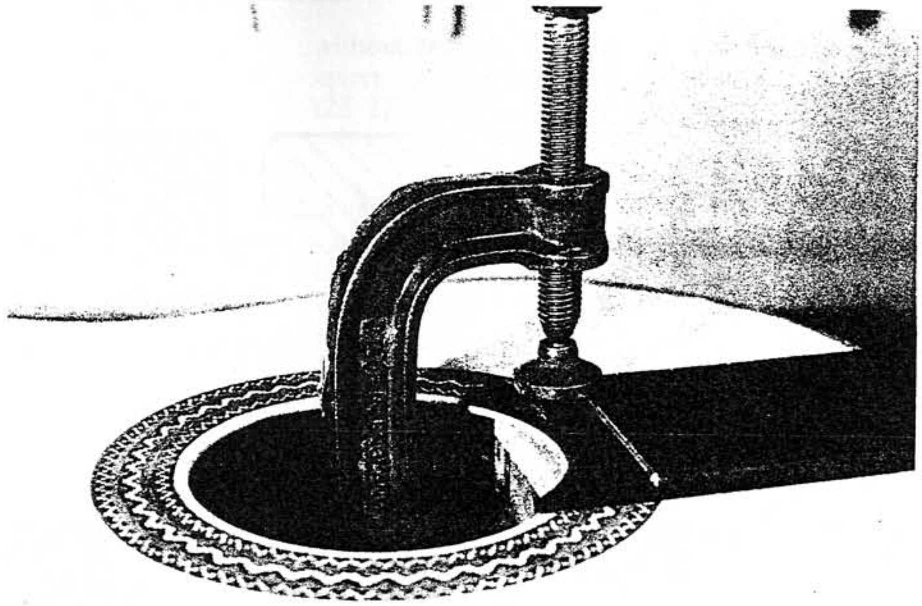
23-21 The top of the fret slots are bevelled with a triangular file. This helps the fretwire to seat well down on the fingerboard



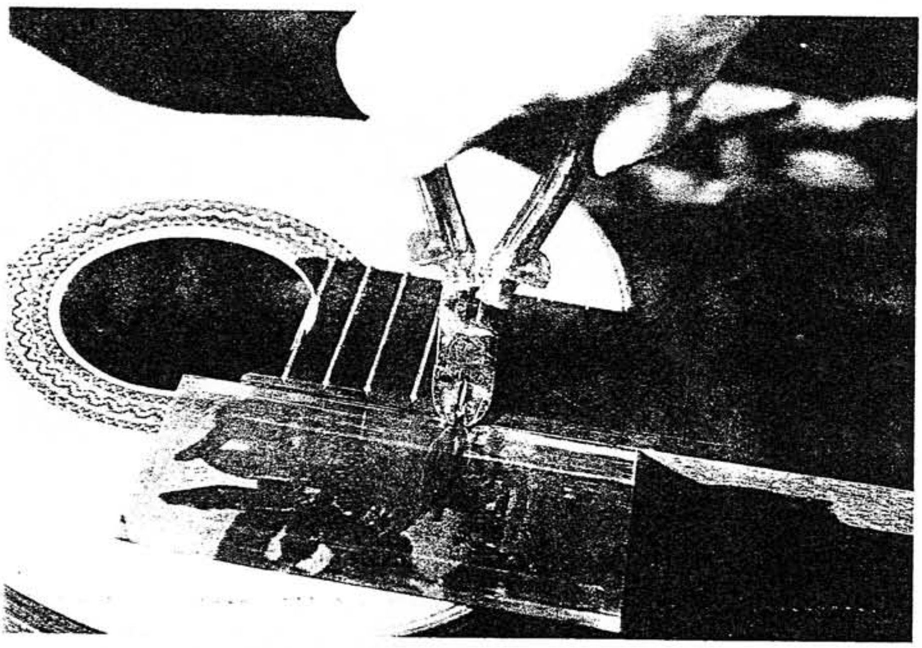
23-22 Hammering in the 4th fret



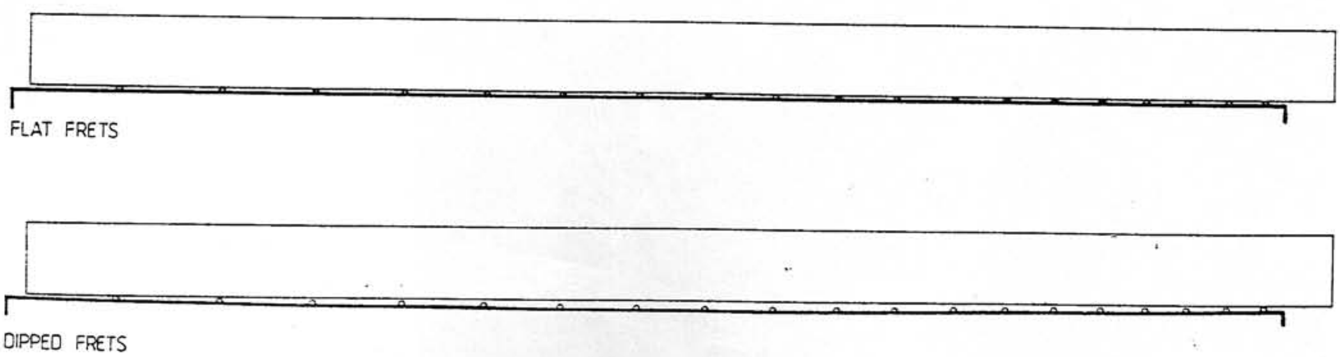
23-23 Applying even pressure on the fret by cramping against a rule



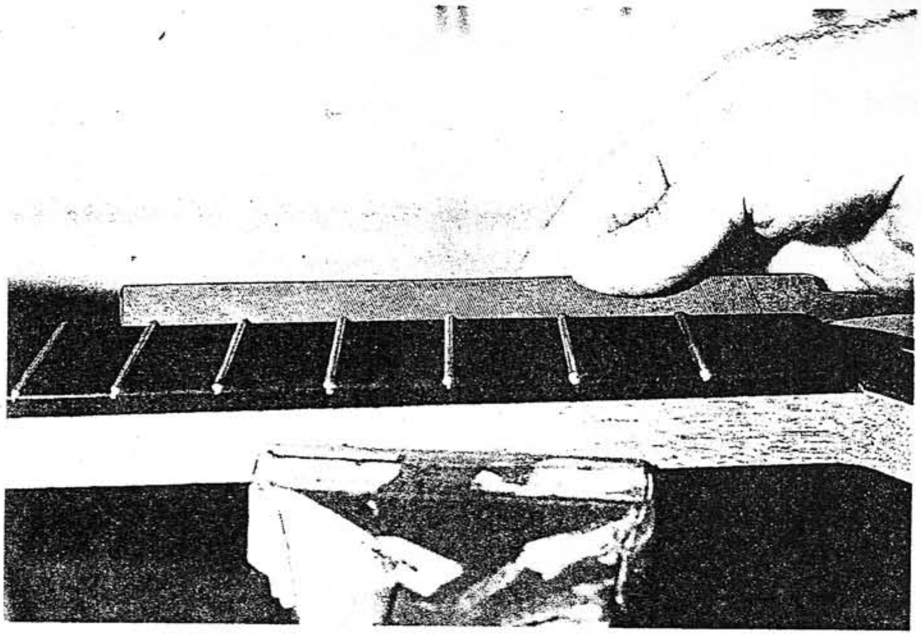
23-24 Cramping the short 19th fret and the 18th fret against the cramping block which is inserted inside the guitar



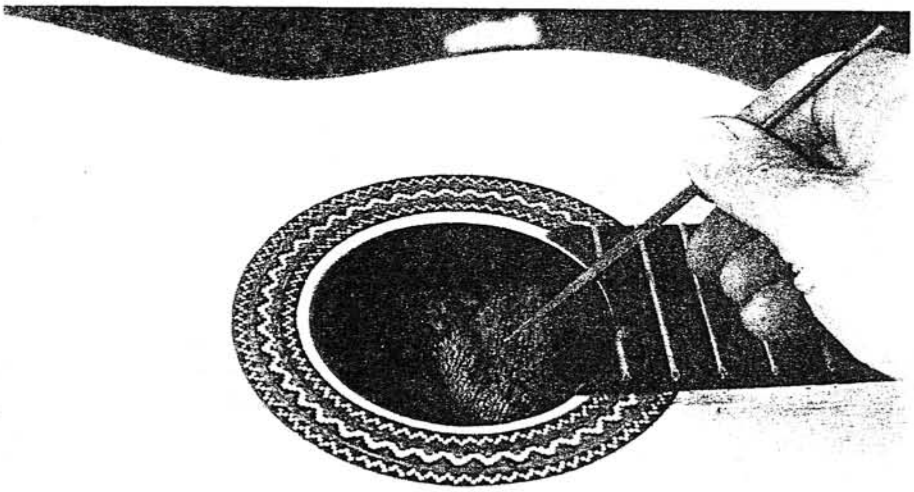
23-25 Cutting off the excess fretwire. The soundboard is protected with a sheet of thin steel



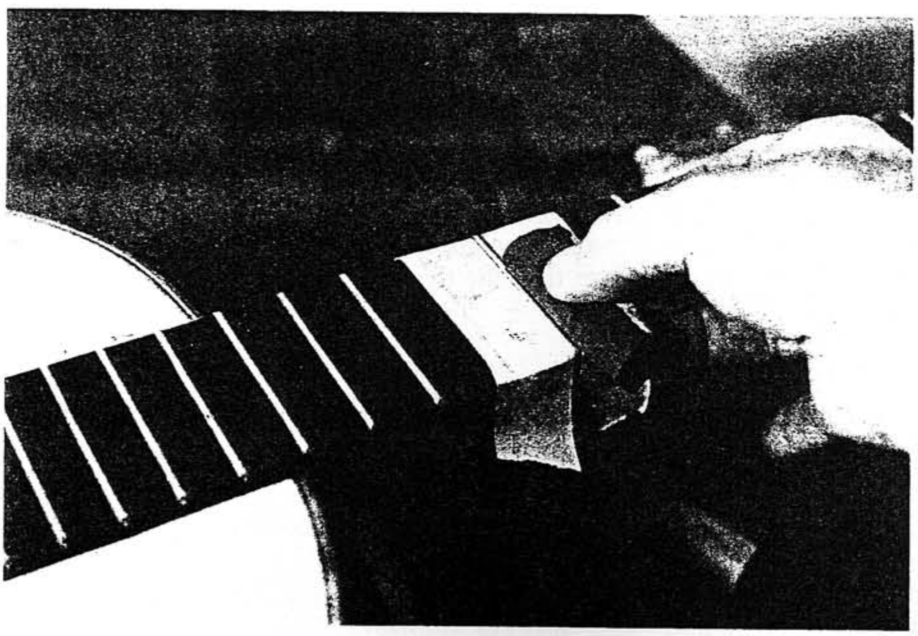
23-26 Top: a straight-edge placed over the frets should reveal no gaps. Bottom: some makers relieve the central area slightly so that the strings will have more free area in which to vibrate



23-27 Filing the edges of the fretwire flush with the fingerboard

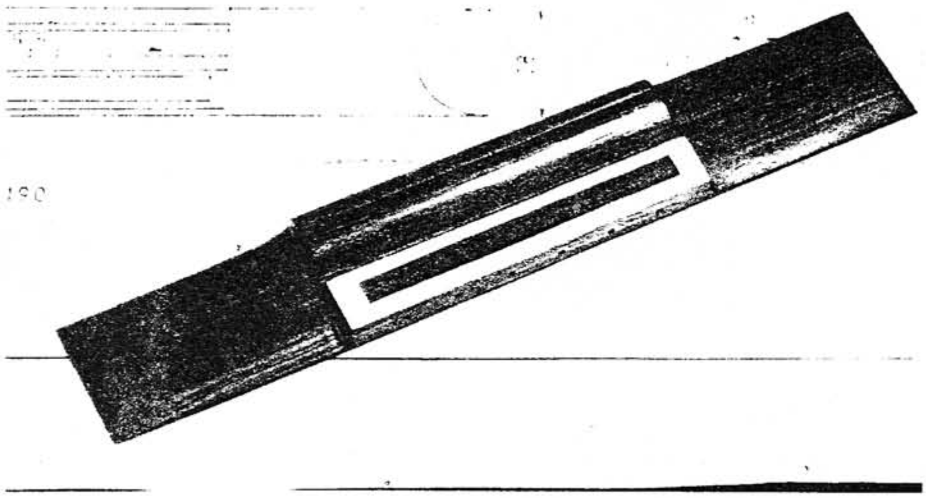


23-28 Shaping the inner ends of the two short 19th frets



23-29 Smoothing the fretwire with fine wet-or-dry paper

24 Bridge

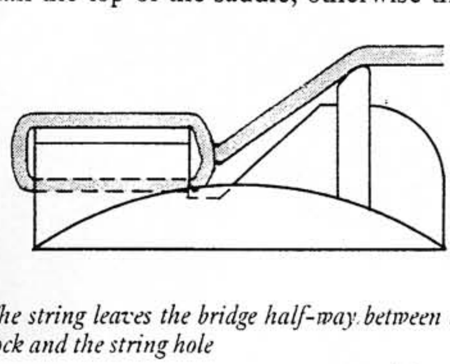


24-1 The completed bridge

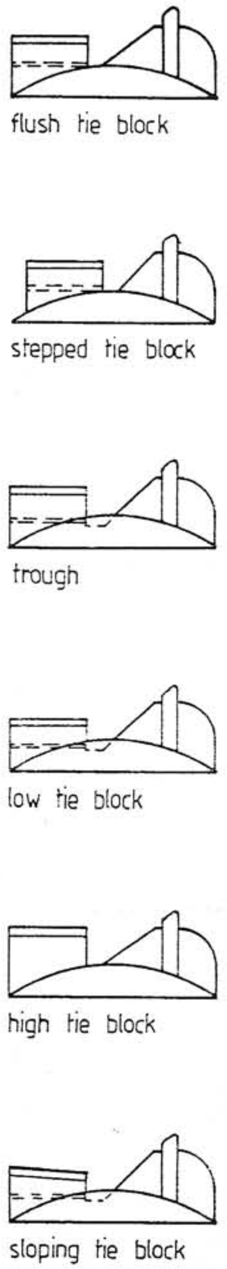
The bridge provides a means of securing the strings to the soundboard and it houses a bone saddle over which the strings pass. The height of the saddle determines the height of the strings above the soundboard. The strings are fastened to the rear of the bridge which is formed into a wide, flat tie-block, veneered with bone.

Although the design of the classical guitar bridge has evolved considerably from the more crude type of bridge found on early guitars and lutes, it nevertheless has several limitations; the position of the saddle determines the scale length of the instrument, and as it cannot be moved either forward or back, it is not possible to improve the intonation of one particular string once the bridge is glued to the soundboard. Although the saddle can be tapered down slightly towards the treble side, it is difficult to make fine adjustments to the height of any particular string above the soundboard. These restrictions make it essential that the bridge is glued at precisely the correct distance from the nut, and that the fingerboard surface is flat and correctly aligned to the soundboard.

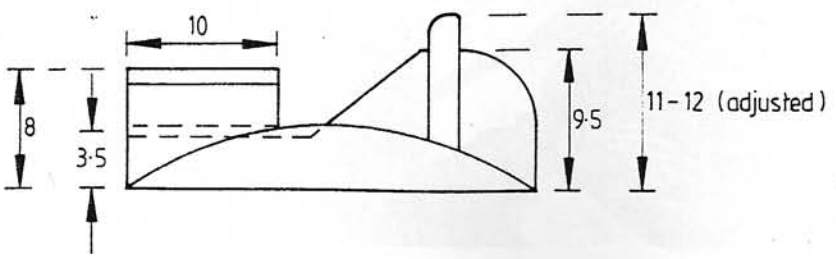
The most accurate way to make the bridge is to support the dimensioned bridge blank in a jig, and to cut the various slots with a router. If a router is not available, the slots can be cut with a dovetail saw and a narrow chisel. Bridge designs vary; some are longer and wider than others. Some have a 'trough' between the tie-block and the ramp leading to the saddle. This allows the string holes to be drilled very low, thus increasing the angle at which the strings leave the saddle (24-2). A definite change in angle is essential for clear tone production. It should be remembered that the string will not leave the hole quite as low as the hole itself – the string is wound over the top of the tie-block, and its height as it leaves the hole is about half-way between the hole and the top of the tie-block (24-3). Some bridges have a step behind the tie-block. The idea here is to move forward the area of bridge that is under stress from the pull of the strings. The upper surface of the tie-block should be lower than the top of the saddle, otherwise there will



24-3 The string leaves the bridge half-way between the top of the tie-block and the string hole not be sufficient change in the angle of the string as it leaves the saddle. Typical recommended measurements are shown in the drawing (24-4).



24-2 Various bridge designs



24-4 Recommended dimensions for the bridge

Tools

Router with flat-bottomed cutters; 2.0 mm, 3.5 mm and 10.0 mm
Smoothing plane
Chisels
Cabinet scraper
Needle files
1.5 mm drill
2.0 mm drill
Long-reach cramps
Jeweller's saw

Materials

Quarter-sawn Rio rosewood (200 mm × 32 mm × 12 mm)
Bone or ivory saddle (80 mm × 10 mm × 2 mm)
Bone or ivory tie-block veneer (80 mm × 10 mm × 1 mm)
2 mm diameter dowel
Plywood offcuts for router jig
Glue

Method

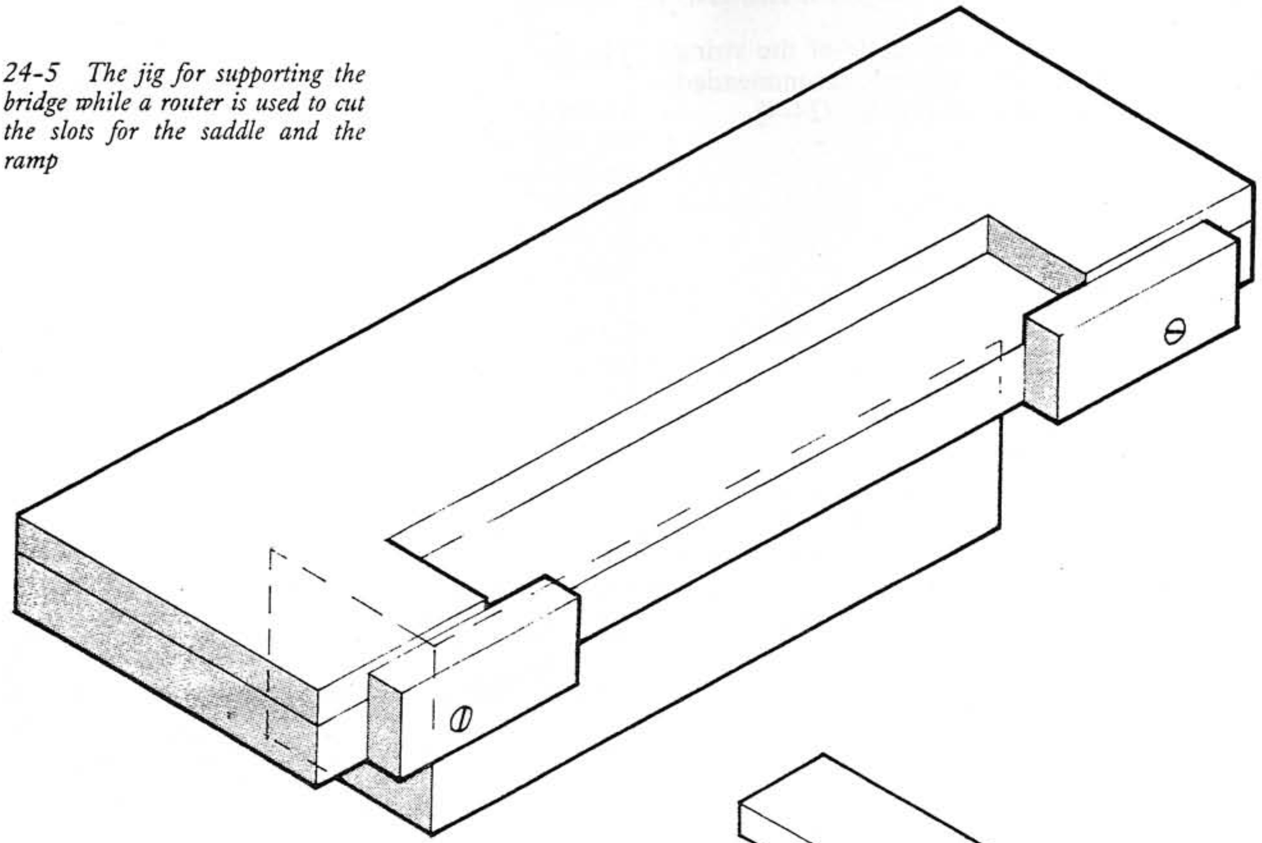
Make the jig (24-5)

1 The dimensions of the jig will depend on the available router and the chosen bridge design. Prepare two pieces of 9 mm thick plywood to the required dimensions, for example 280 mm × 90 mm. Glue some veneer to the surface of one piece to bring its total thickness to 10 mm. (This is the maximum thickness of the bridge.)
2 On the 10 mm thick piece cut out the shape of the bridge (185 mm × 29 mm in the case of Hernández y Aguado).
3 Glue the two pieces together.
4 Attach a batten to the underside. This allows the jig to be securely held in a vice.
5 Screw on two movable gates. These can be tightened to hold the bridge blank in place.

Mark out the bridge (24-6)

1 Prepare the rosewood blank to the length and width required but do not thickness it yet, as the lower surface must first be shaped to the arched profile of the soundboard. The surfaces must be flat and square all round. It should fit tightly into the jig.

24-5 The jig for supporting the bridge while a router is used to cut the slots for the saddle and the ramp

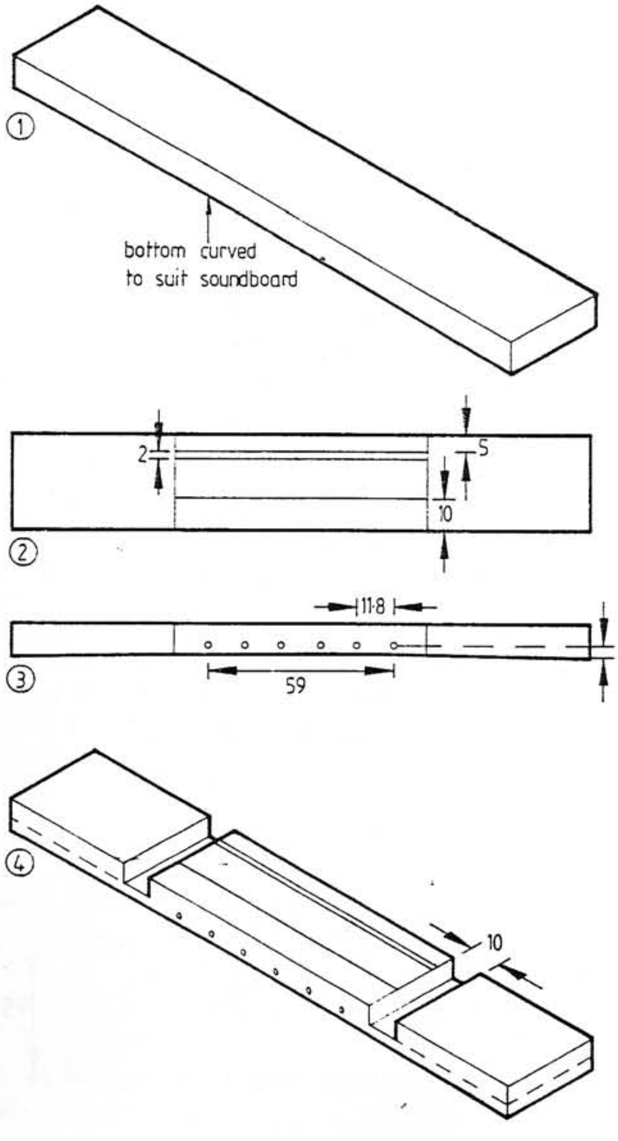


2 Mark the position of the bridge on the soundboard. The gluing surface of the bridge can now be hollowed slightly at its centre with a cabinet scraper. The gentle curve produced must match that on the soundboard so that the bridge can make contact without much pressure. Be particularly careful to see that the two ends of the bridge are in contact with the soundboard. Test the curve by holding a straight-edge along the bridge. Check also that the surface is flat across its width.

3 Once the bridge fits the soundboard, set a marking gauge to 10 mm and scribe a line along the bridge to define its thickness. Plane the top surface down to the line. The bridge should now fit into the jig and lie flush with its upper surface.

4 Mark out the position of the tie-block, the wings, and the saddle (24-6).

5 Use a pair of dividers to mark the string holes accurately. They must be equally spaced, and should be 3.5 mm above the base of the bridge (24-7).



24-6 Setting out and preparing the bridge for routing: (1) the lower surface is curved to match the arch of the soundboard; (2) the position of the saddle slot and the tie-block are marked; (3) the string holes are marked (4) if a router is to be used, then two rebates are formed to assist entry of the cutter into the wood

Drill the string holes

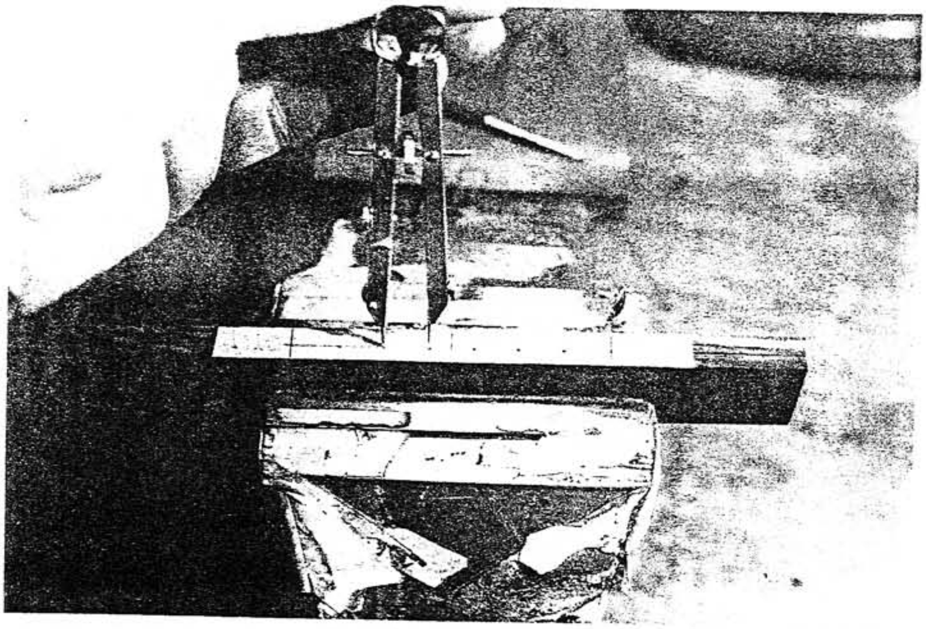
Drill the string holes with a 1.5 mm drill. Deepen each hole gradually, as the hard rosewood tends to stick to the drill and prevent it from cutting. A drop of oil on the drill may help, but do not get it on the gluing surface of the bridge. Set the depth stop so that the holes are bored only to the start of the tie-block (24-8).

Cut the router slots

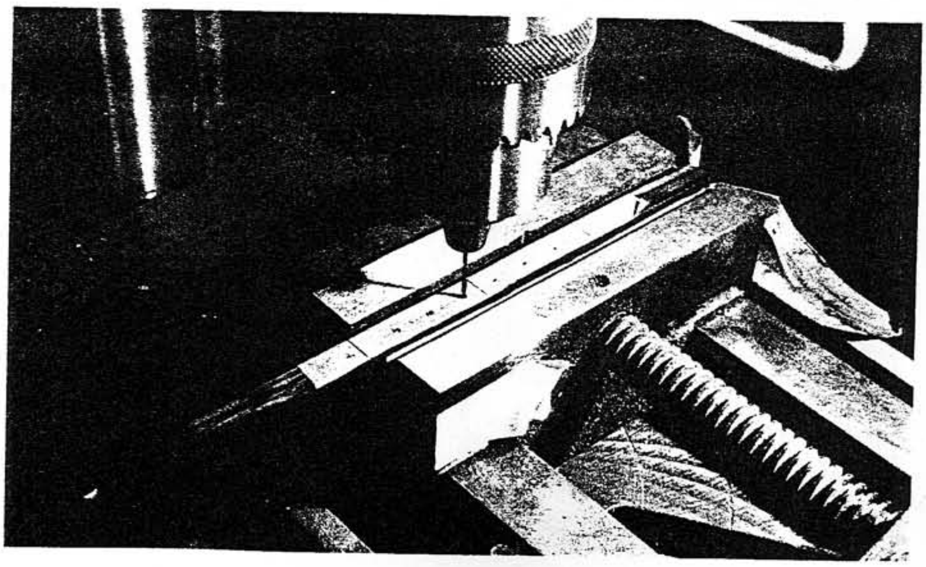
1 Saw and chisel out a 10 mm wide rebate at each side of the tie-block. This allows access for the router (24-6).
2 Place the bridge into the jig. Cut the 2 mm wide saddle slot first. Lower the cutter with each pass until the slot is 5 mm deep. (At this depth it will be level with the wings.)
3 Use the 10 mm wide router cutter to reduce the tie-block area to 7 mm (24-9).
4 Use the 3.5 mm wide router cutter to form the gap between the tie-block and the ramp leading up to the saddle. Lower the cutter gradually, until the string holes emerge. The bottom of this slot can be lower than the wings, creating a 'trough' (24-10).

Shape the bridge

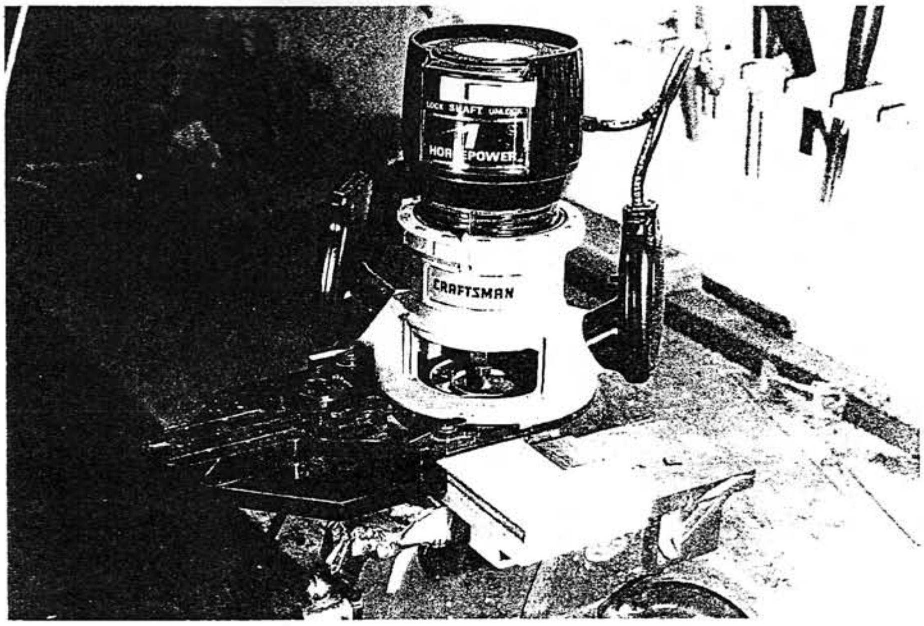
1 Cut away the remaining wood above the wings and smooth them to 4 mm thick (24-11).
2 Shape the ramp and the front of the saddle slot with a chisel (24-12).
3 Shape the wings, taking care not to produce a feather-edge. Leave the edges about 0.5 mm thick (24-13) and (24-14).



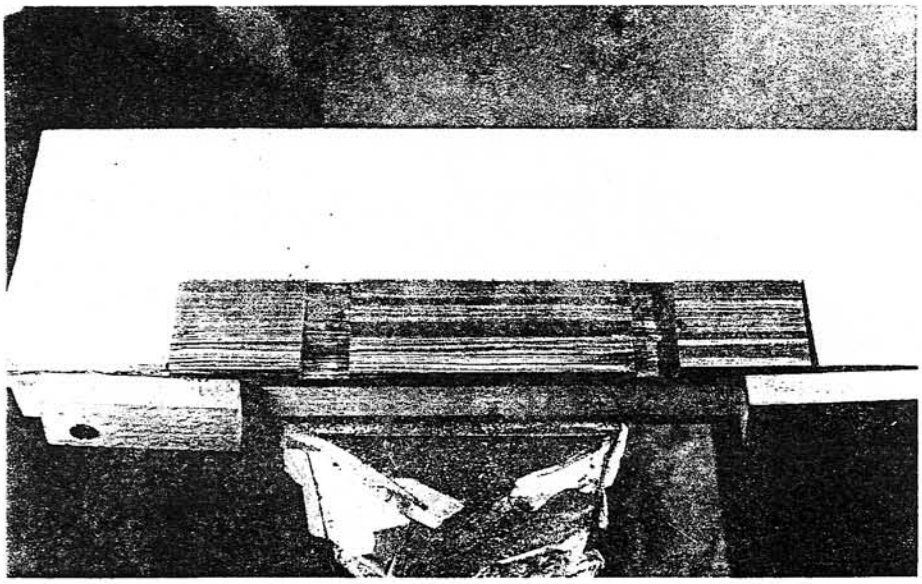
24-7 Setting out the string holes with dividers



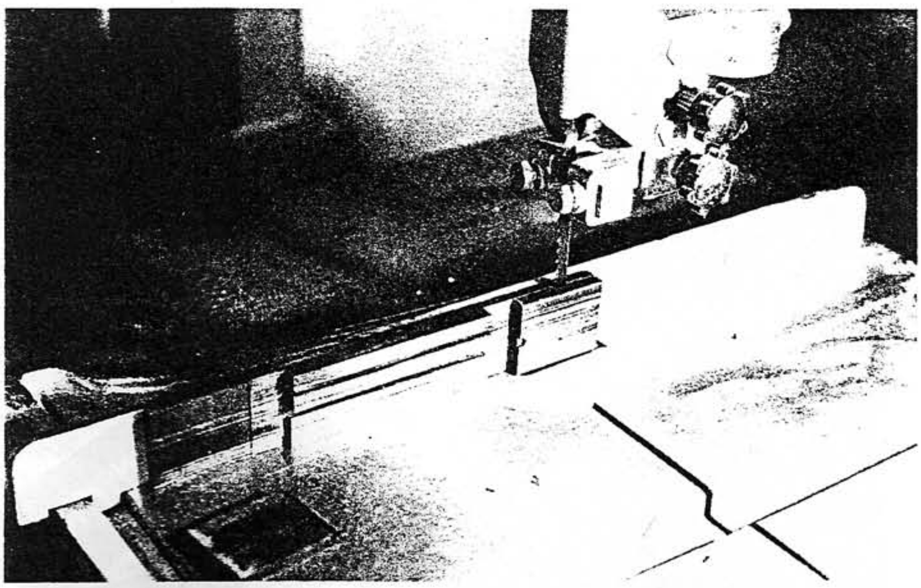
24-8 Drilling the string holes



24-9 The router in position on the jig



24-10 The routing complete – the saddle slot and the slot between the tie-block and the ramp have been cut. The surface of the tie-block has also been reduced in height



24-11 Removing the waste from the wings

Make the bridge veneer

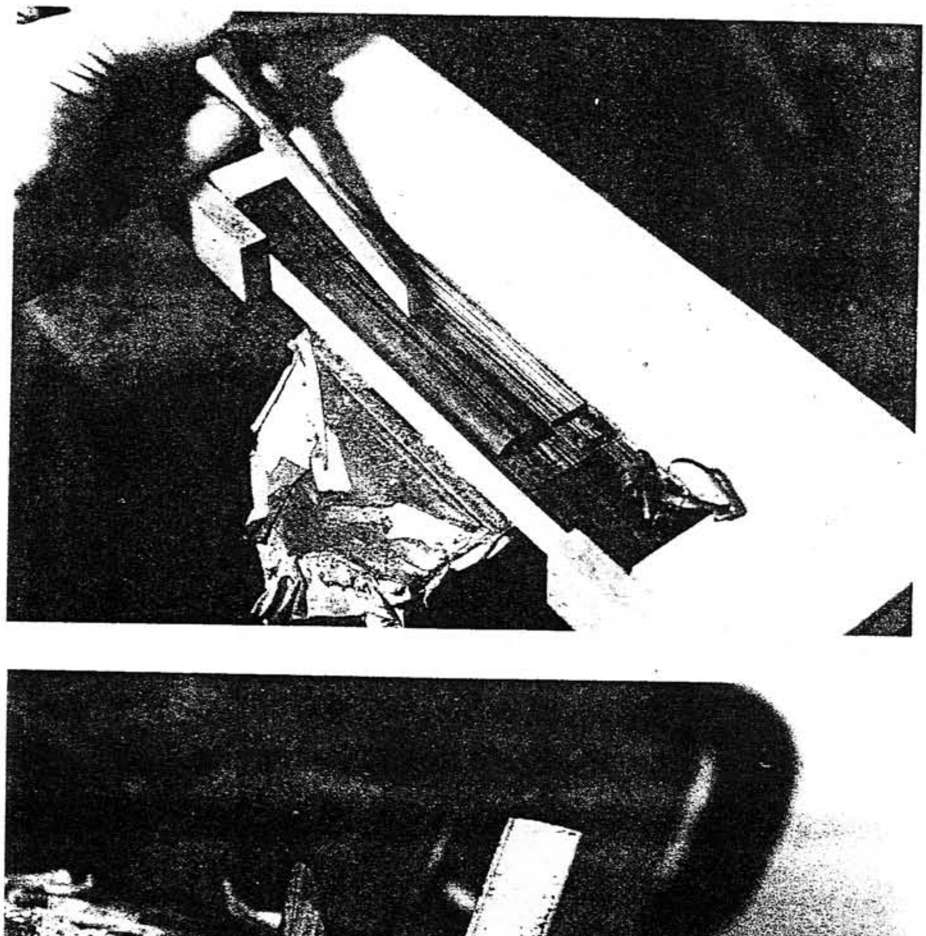
1 Prepare a piece of bone veneer to the same size as the tie-block. If you wish to inlay the central part of the bone, this can be cut out with a fine jeweller's saw, and a wood inlay inserted. This gives a neater result than mitring together four thin strips (24-15), (24-16), (24-17) and (24-18).

2 Glue the veneer to the tie-block. Smooth the entire bridge with fine abrasive paper and fine steel wool.

3 The rosewood bridge will bleed colour on to the surrounding spruce soundboard unless both surfaces are first sealed with a coat of sanding sealer. (Do not seal the lower (gluing) surface of the bridge, which can be protected with masking tape.) Ensure that the soundboard is absolutely smooth and then coat it with sealer.

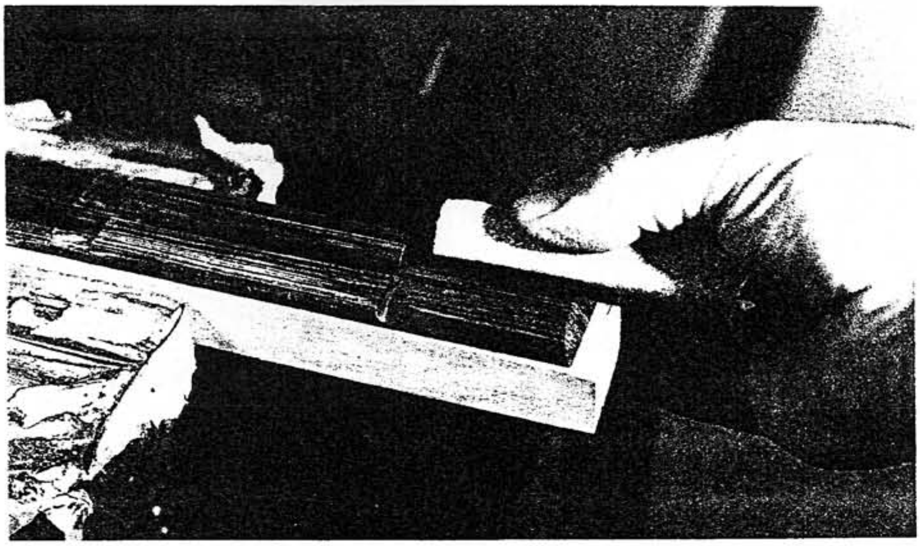
Compensation (24-19)

1 Place the bridge (with saddle inserted) in position on the soundboard. Measure the distance from the saddle to the nut. If the scale length is 650 mm, then the actual length of vibrating string must be 652 mm (24-20). This extra 2 mm of compensation is necessary because the action of the fingers pushing down on the strings creates a distortion in pitch. The strings are suspended above the frets and they are stretched slightly when pressed down. If the actual string length were the same as the theoretical scale length that was used for calculating the fret distances, then each note on the guitar will be slightly higher in pitch than it should be. This becomes particularly noticeable at the octave (12th fret), where the difference between the open (unfretted) string

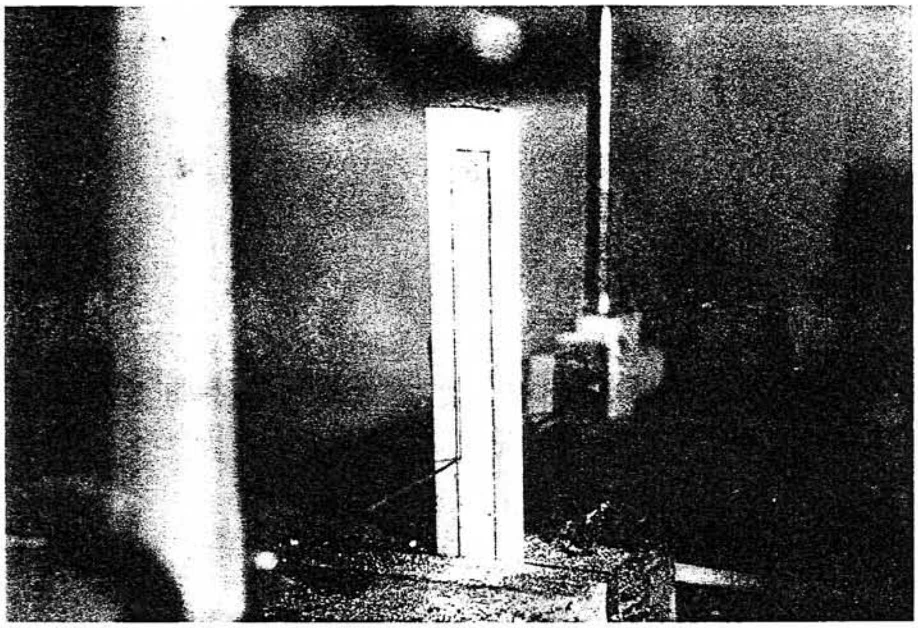


24-13 Filing the wings

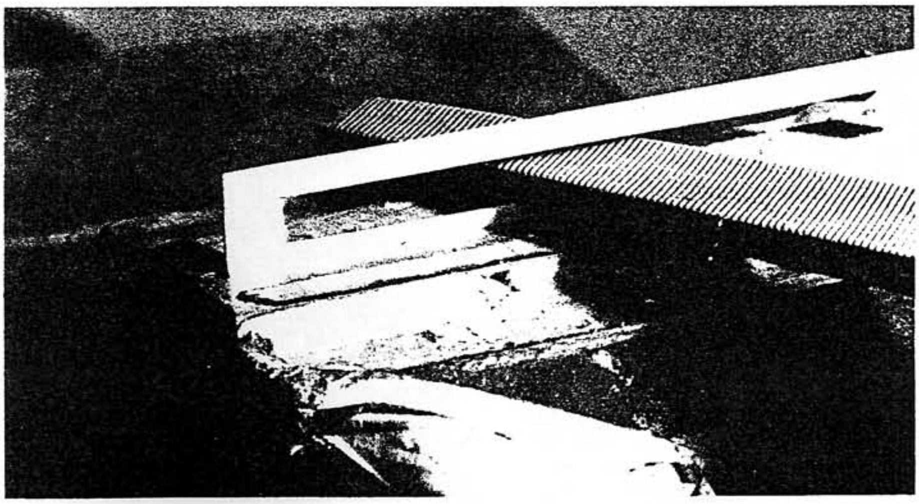
24-12 Shaping the ramp and the front of the saddle slot



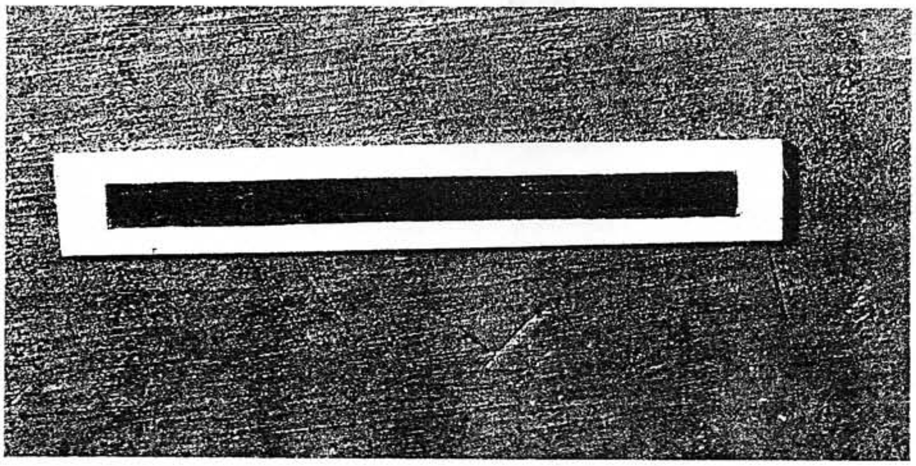
24-14 Final smoothing of the wings



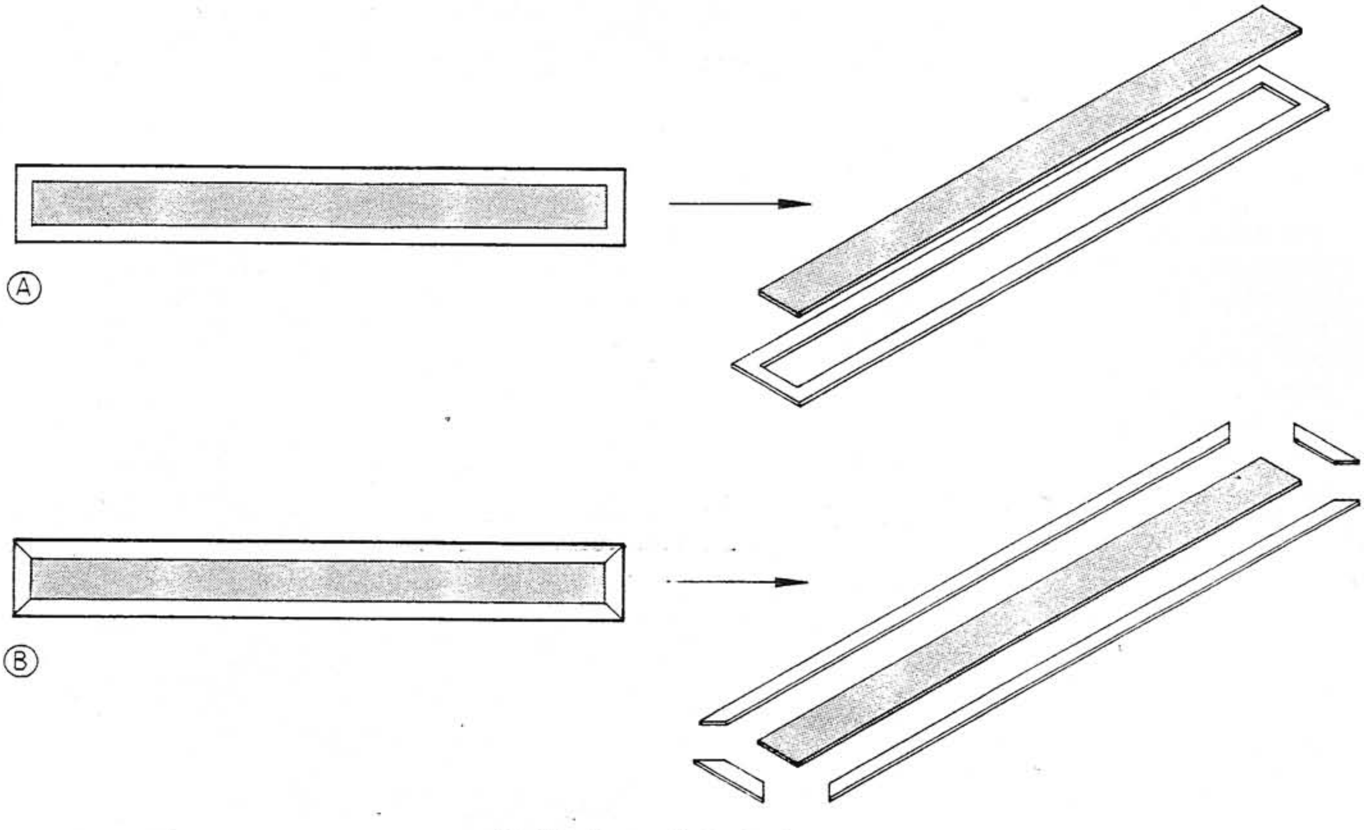
24-15 Cutting out the centre of the bone bridge veneer



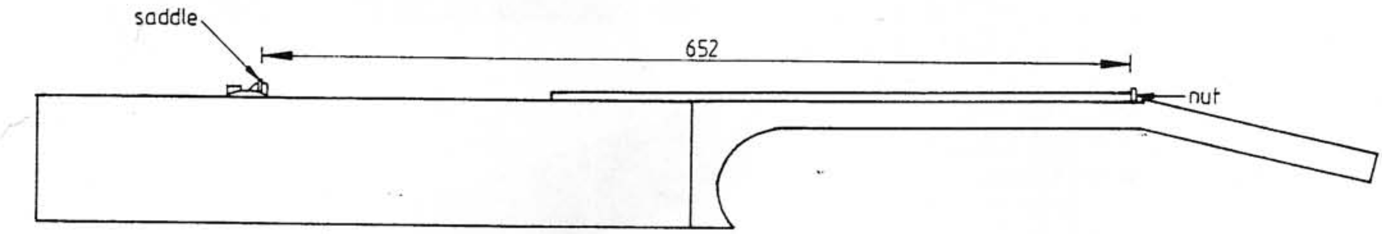
24-16 Smoothing and levelling the cut-out area to receive the inlay



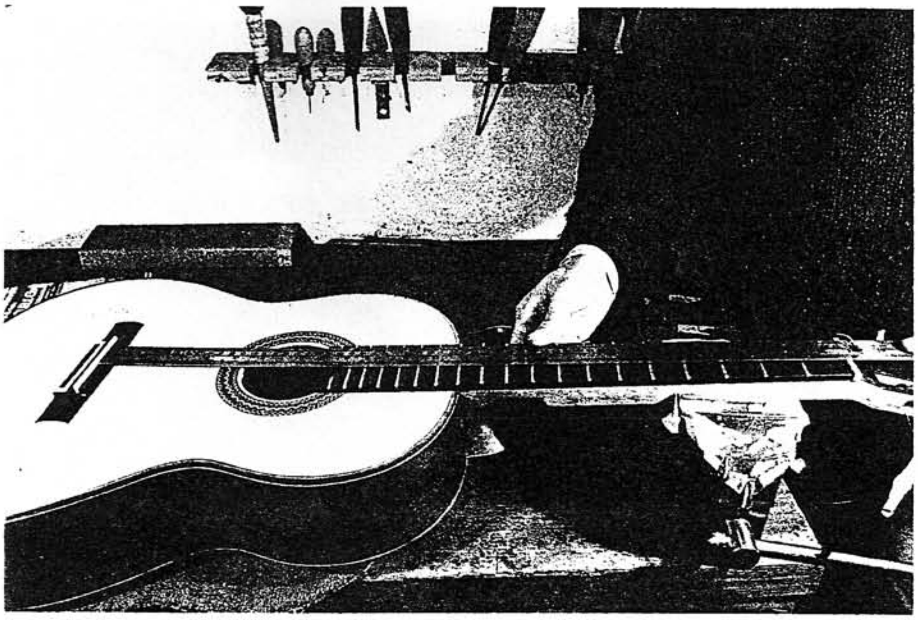
24-17 The veneer ready to be glued to the tie-block



24-18 Two methods of making the veneer



24-19 Compensation – the scale length of 650 mm requires a vibrating string length of 652 mm

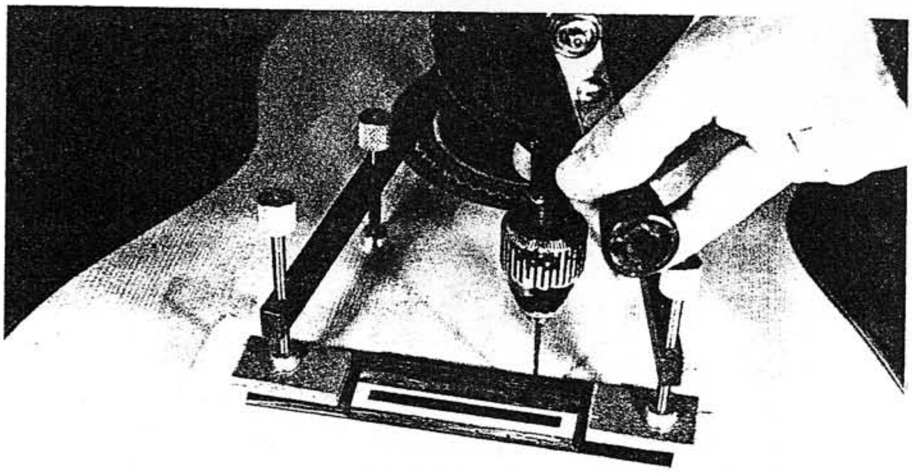


24-20 Measuring the distance of the vibrating string – 652 mm from the soundhole-side of the saddle to the fingerboard-side of the nut

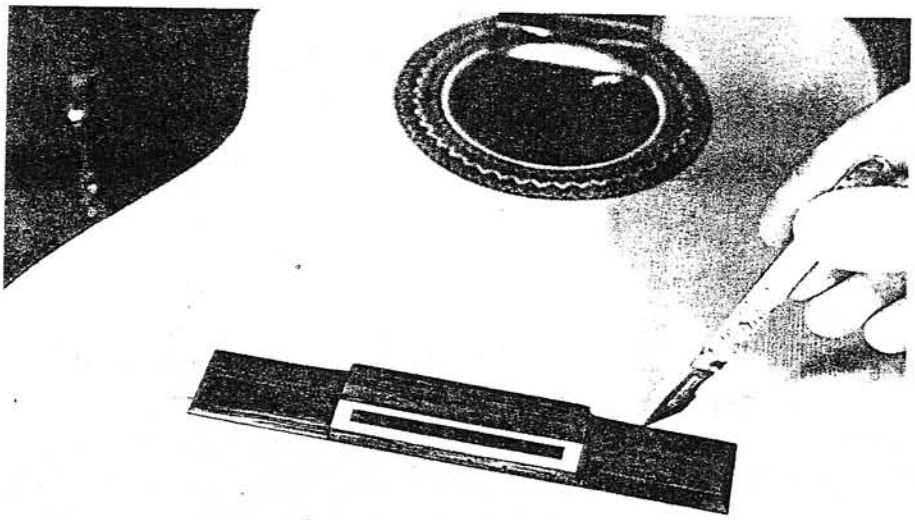
and the same string stopped at the 12th fret can be quite pronounced. Many different methods of perfecting compensation have been tried over the history of fretted instrument making, and the one described here is the most effective. Some makers cut the saddle slot at an angle so that the bass strings have more compensation than the treble, but this is very rarely done now. A guitar with a much shorter scale length will require more compensation, whereas an instrument with a longer scale length requires less.

2 If the guitar was constructed with careful reference to the central axis then the centre of the bridge will fall exactly on the centre join of the soundboard. However, it is possible that some small inaccuracy has occurred, so the bridge position must be checked. Make a dummy nut to fit tightly in place at the gap between the fingerboard and the head veneer. File two small grooves which must be the correct distance between the 1st and 6th strings. Insert a spare 6th and 1st string through the two machine-head barrel holes nearest to the fingerboard. Pull them tight and align them over the outer two holes in the bridge. Adjust the bridge position until the strings are symmetrically placed in relation to the fingerboard – the gap between the string and the edge of the fingerboard must be equal at both sides (24-21). Secure the bridge with a strip of masking tape at each end. Check that the distance from nut to saddle is 652 mm.

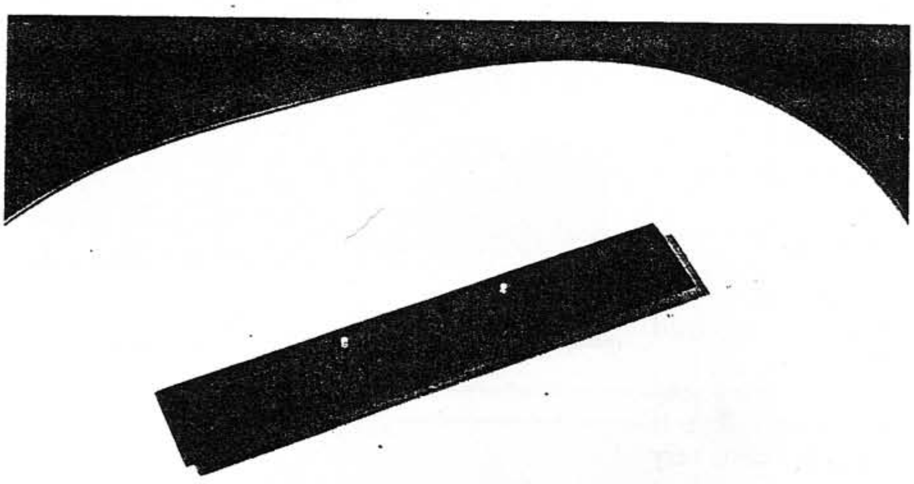
24-21 Aligning the bridge transversely



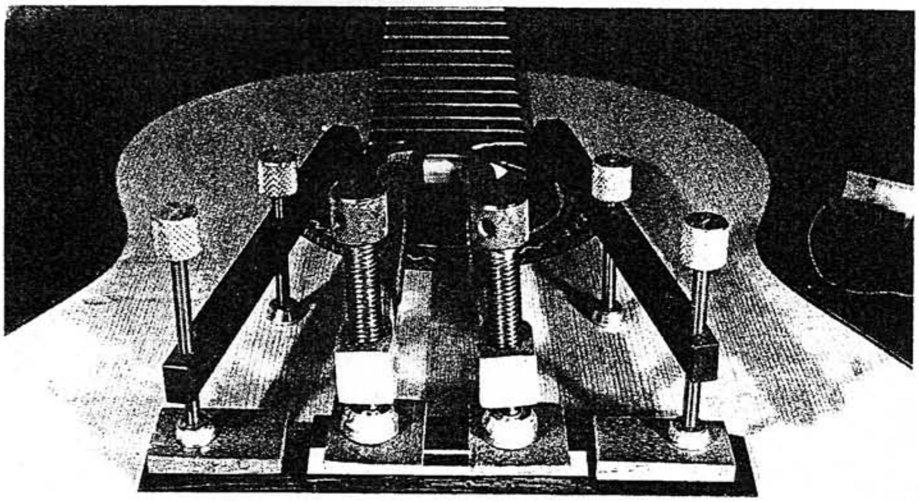
24-22 Drilling 2 mm diameter holes through the saddle slot and the soundboard



24-23 Scribing the position of the bridge on the soundboard



24-24 The bridge, with locating dowels, is ready to be glued to the soundboard



24-25 Gluing the bridge

Glue the bridge

1 Once you are certain that the bridge is correctly positioned, insert two long-reach cramps through the soundhole so that the bridge wings can be held secure. Make some small cramping blocks that are shaped to the curve of the wings. (The bridge cramping block made in Chapter 15 must be in place inside the guitar.)

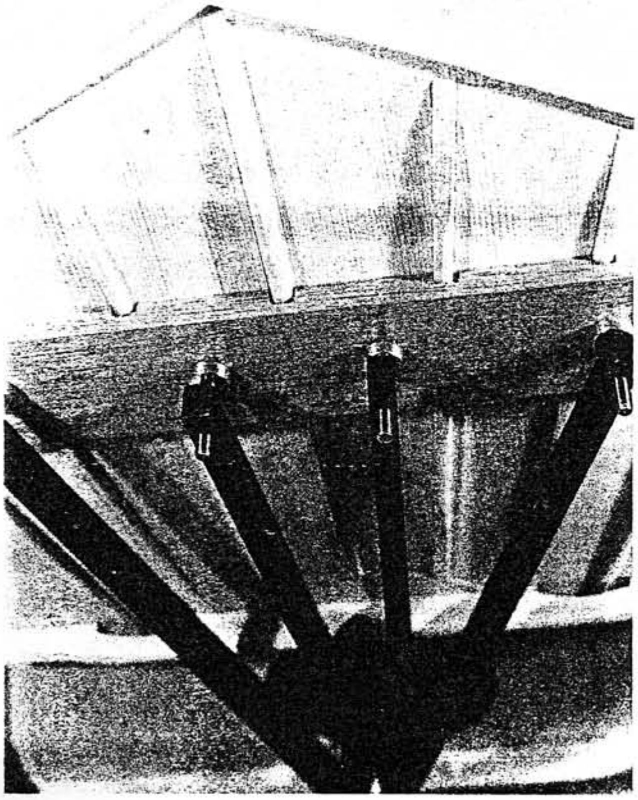
2 Drill two, 2 mm diameter holes through the base of the saddle slot and the soundboard, one at each end, but do not drill through a fan strut (24-22). Remove the bridge.

3 Prepare some 2 mm diameter dowel, using the method described in Chapter 23, and glue in short sections to the bottom of the bridge, which should now fit securely in place on the soundboard; the dowels will prevent the bridge sliding out of position when it is glued.

4 With the bridge in place carefully mark around the edges with a sharp scalpel blade (24-23). The two short ends will be easier to see if they are marked with strips of masking tape. Remove the bridge and scrape away any sanding sealer from the gluing area. Sand the surface smooth with a small, flat sanding block and brush away the dust. Clean the gluing surface of the bridge with the sanding block (24-24).

5 Spread glue onto the soundboard and the base of the bridge. Locate the dowels and push the bridge down. The long-reach cramps can now be inserted through the soundhole and tightened (24-25) and (24-26).

6 It is important that all excess glue be cleaned away with a wooden spatula and then a damp cloth. If any glue dries on the soundboard, it will be very difficult to remove. Leave the cramps in place overnight.



24-26 Gluing the bridge (internal view) – the bridge cramping-block distributes the pressure of the cramps evenly

25 Final Shaping of the Neck

The final shaping of the neck must be carried out with care – a neck that is over thick or too round in section will make the guitar awkward to play and cause the player's hand unnecessary stress. The thickness of the neck usually increases slightly towards the body of the guitar although there is quite a variation from one instrument to another. The best way of determining the final shape is to try it out in the playing position and make adjustments until it feels right. Several templates can be made to represent the shape at the 1st, 6th and 9th frets, although it is not difficult to judge the shape by eye and feel. A semicircular shape creates too much thickness, but the back of the neck should not be flat. The most satisfactory shape is somewhere between these two.

Tools

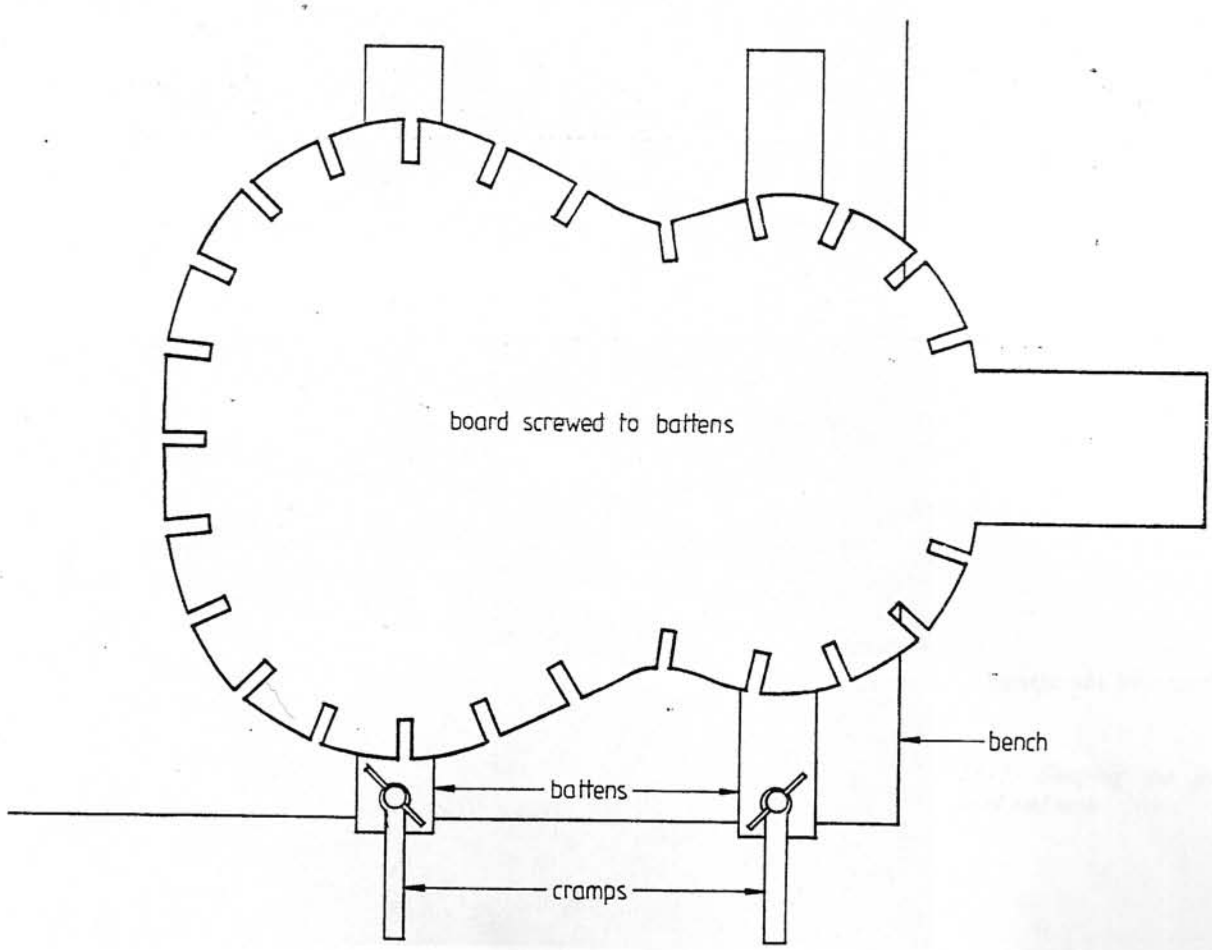
Spokeshave
Cabinet scraper
Chisels

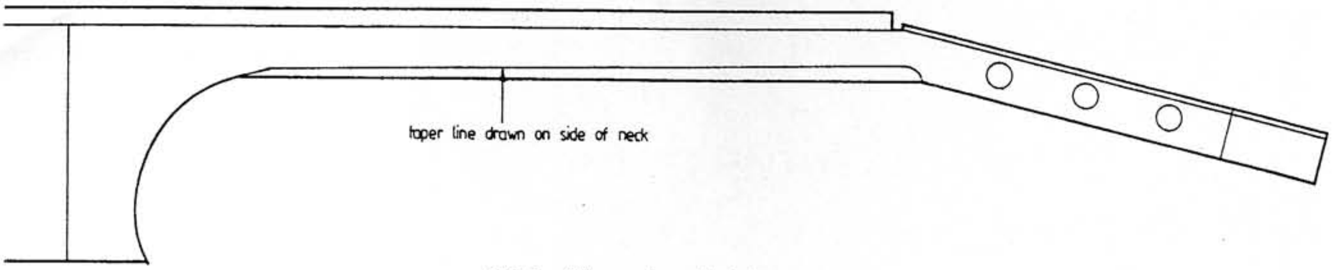
Method

1 Place the guitar with the soundboard down on to the workboard used for gluing on the binding. Two battens can be screwed under the board to assist cramping it to the workbench (25-1). Protect the soundboard with a guitar-shaped carpet off-cut. Fasten elastic bands over the guitar to keep it secure.

2 Mark the final thickness of the neck on its sides, for example, 22.5 mm at the nut and 25.0 mm at the 9th fret (25-2). Join these marks up and carve away the waste with a chisel and spokeshave until the back of the neck is absolutely flat and tapered

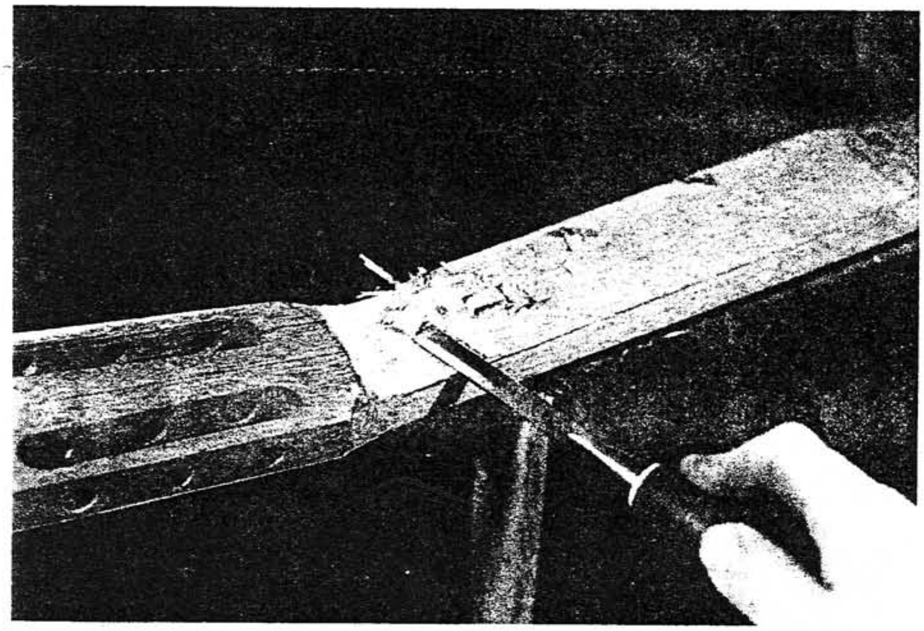
25-1 A method of securing the guitar while the neck is shaped



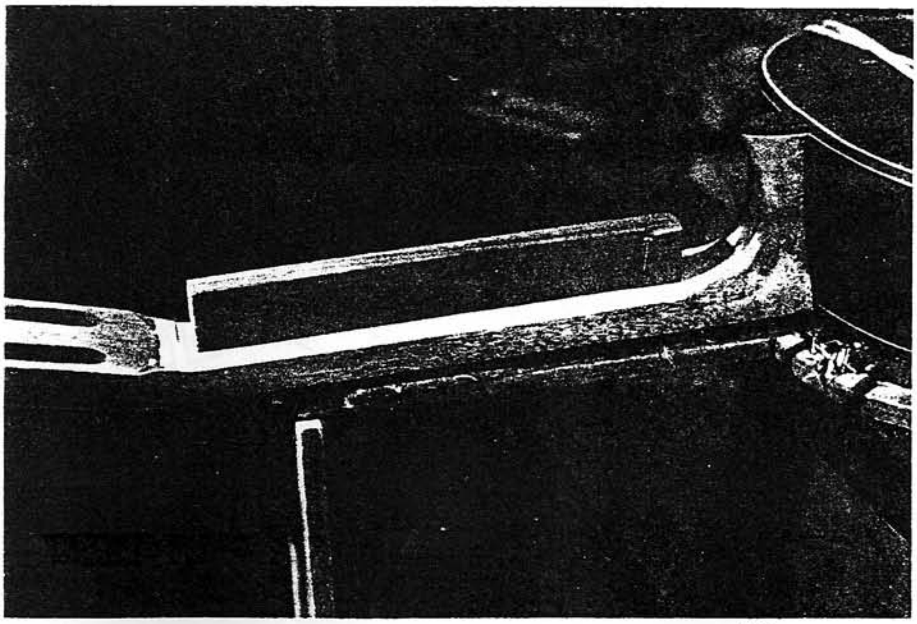


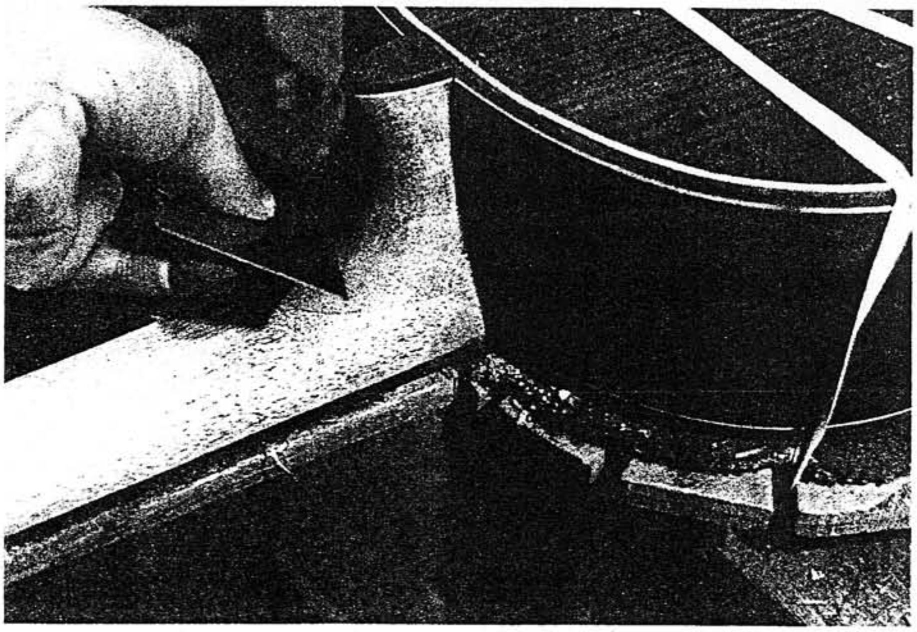
25-2 The neck marked for tapering

25-3 Reducing the neck thickness at the head-end

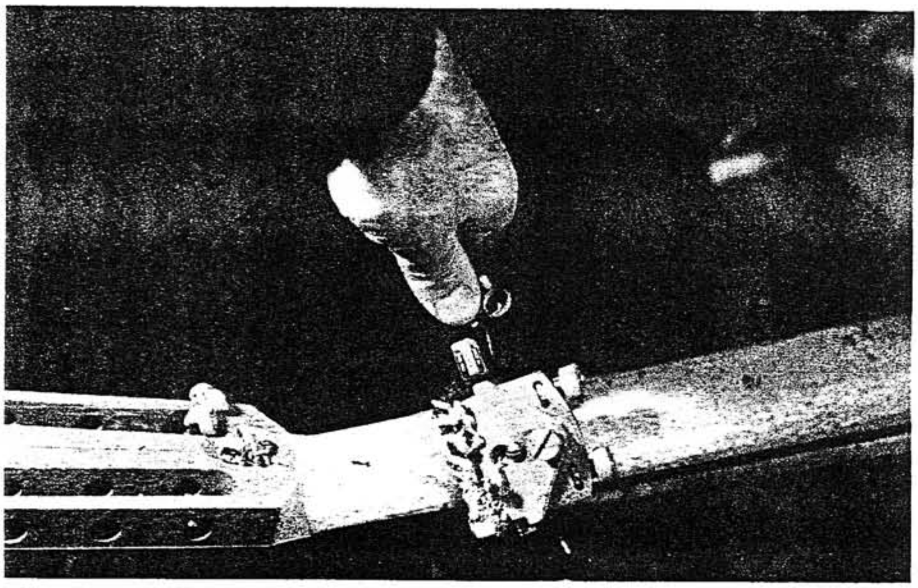


25-4 Checking that the tapered surface is flat

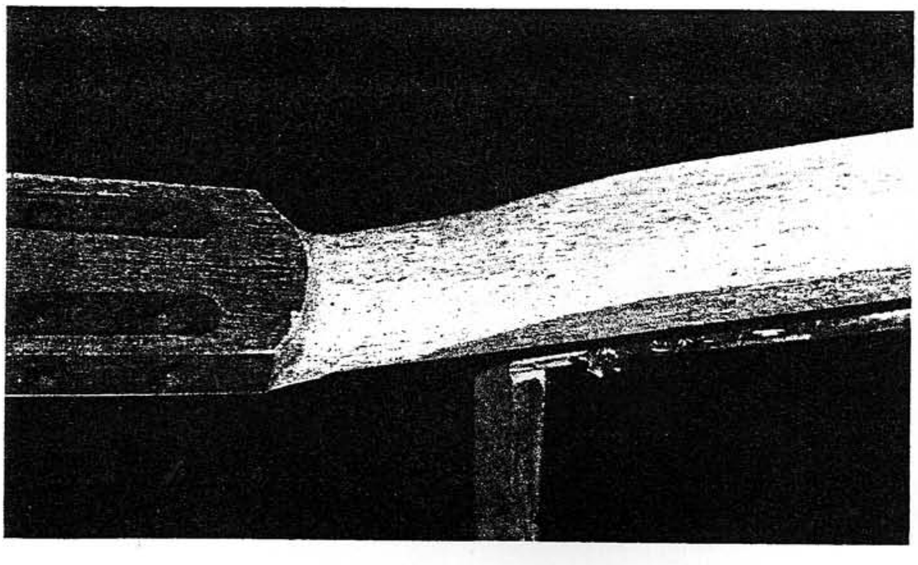




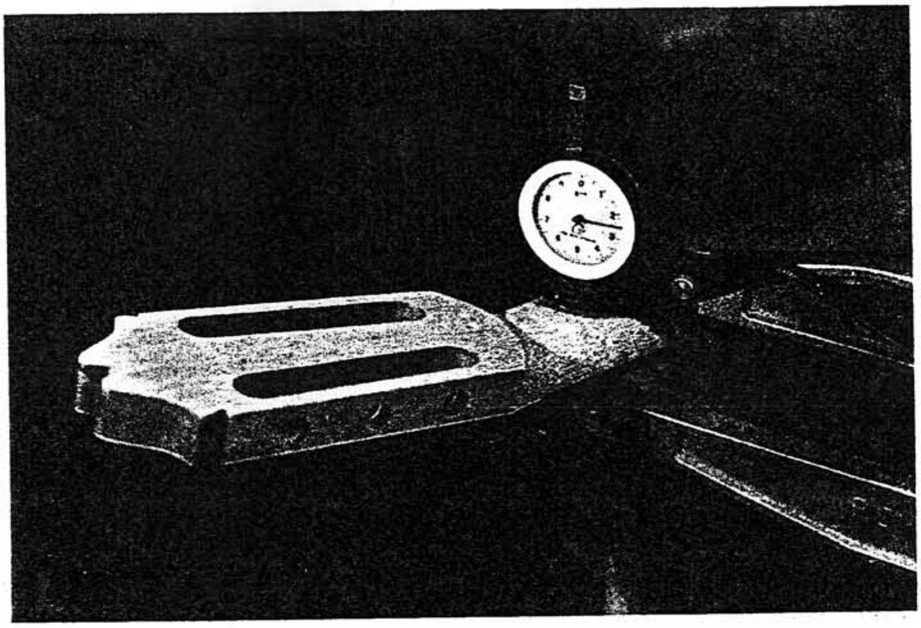
25-5 Shaping the junction of heel and neck with a cabinet scraper



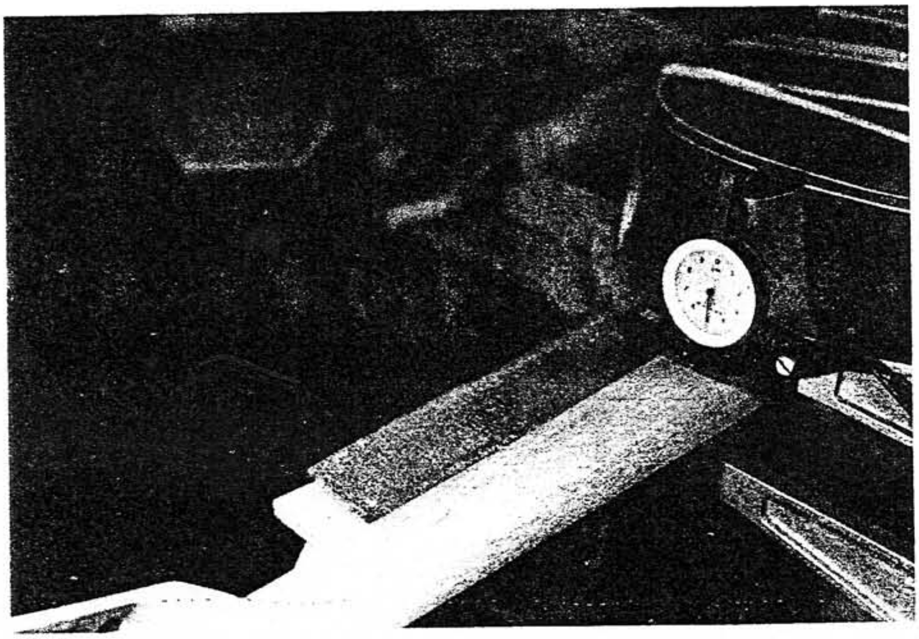
25-6 Rounding the neck with a spokeshave



25-7 Shaping the junction of head and neck



25-8 Measuring the neck thickness at the 1st fret



25-9 Measuring the neck thickness at the 9th fret

to these measurements (25-3) and (25-4). Do not begin rounding the edges of the neck until the surface has been tapered to the correct thickness.

3 Now begin shaping the sides of the neck into a curve but do not remove any wood from the edge of the fingerboard.

4 A cabinet scraper is the best tool for working right up to the body of the guitar, and for merging the heel gently into the neck (25-5).

5 Sand the back of the head and use a chisel to define the lower end of the head, which is curved. The end of the curve should fall on the glue line between the neck and head. The change of angle at this point, as the head slopes down to meet the neck, will result in this glue line remaining unnoticed (25-6) and (25-7). The transition from the back of the head to the neck is a gentle radius, not a step.

6 Once the basic shape has been formed, use a sheet of coarse garnet paper to sand over the entire neck. The pressure of your hands pulling the paper down will help create a smooth, even shape. Check the thickness at the 1st and 9th frets (25-8) and (25-9).

7 Final smoothing around the neck to body join is best done with abrasive paper wrapped around a small eraser.

8 Brush on a coat of sanding sealer. When it is dry, the neck can be sanded to a high degree of smoothness. The sealer will reveal any remaining rough spots or scratches. Continue smoothing the surface until all the sealer has been removed.

26 Action and Stringing Up

Now is the ideal time to make the bone nut and saddle, and to adjust their heights until the strings are the correct distance above the frets (26-1). The final sanding and polishing of the guitar can then be carried out in the knowledge that the instrument is ready to be strung up as soon as the varnish has dried. In guitar making, the word 'action' is used to refer to the distance between the strings and the fingerboard. 'High' and 'low' action refer to the strings being either high above the frets or very close to them. The strings should be as close as possible to the frets, but not so close that a vibrating string touches a fret, or buzzing will occur when the strings are plucked. In practice, the string height need only be measured at two places; the 1st fret and the 12th fret. If the gaps between the tops of these frets and the underneath of the strings passing over them are correct, then the remaining fingerboard will also be correct. Adjusting the action is accomplished by altering the height of the nut and the saddle. This requires inserting and removing these components numerous times, and also tightening and loosening the strings so that accurate measurements can be made.

Tools

File
Needle files
Jeweller's saw

Materials

Bone nut (54 mm × 10 mm × 5 mm)
Bone saddle (80 mm × 9 mm × 2 mm)
Machine heads
Set of strings

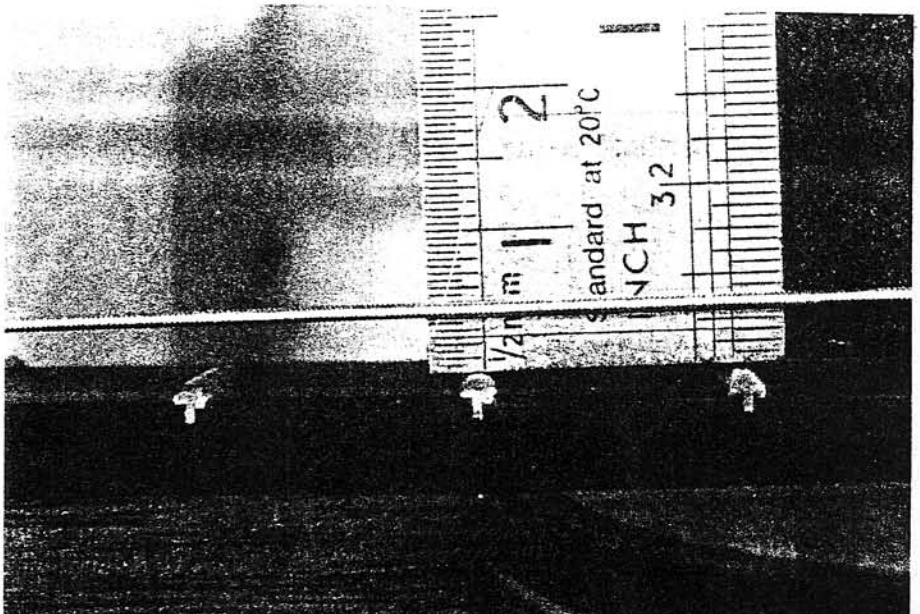
Method

Make the nut

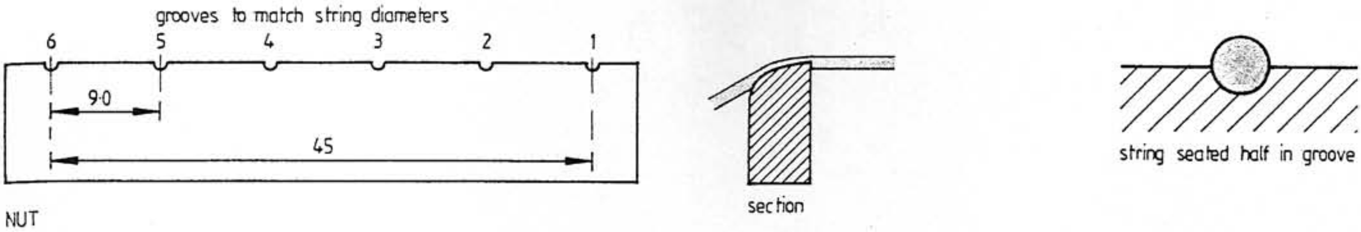
1 Cut and file a piece of bone to the overall dimensions required (26-2). At this stage the nut should be left longer than the actual width of the neck. Reduce its thickness gradually until it fits snugly into the gap between the fingerboard and the head veneers. The top surface must be shaped to slope down towards the head.

2 Mark the centre of the nut and set a pair of dividers to the distance between the strings. (This varies slightly according to which plan you are following.) Having marked all six strings, check that the total distance from the 1st to the 6th string is correct. Square the marks across the top of the nut.

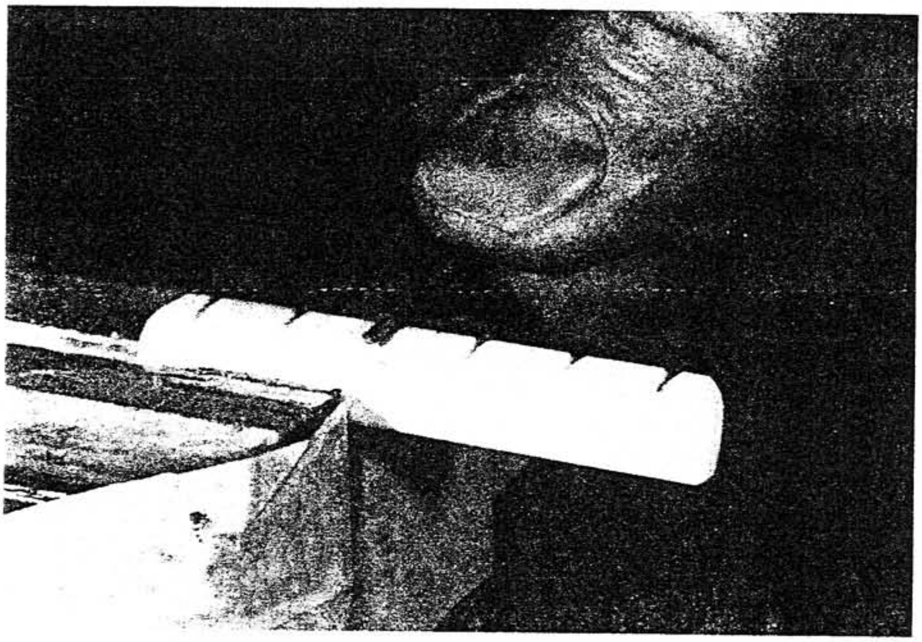
3 Use a triangular needle file to scribe the positions of the strings across the top of the nut. Now change to a rat-tail needle file (which is circular, and tapers to a point), and shape each notch until it is the correct size for the string that will pass over it (26-3). The string should rest to half its thickness in the groove (26-2). Use the actual guitar strings to test the size of the groove – the



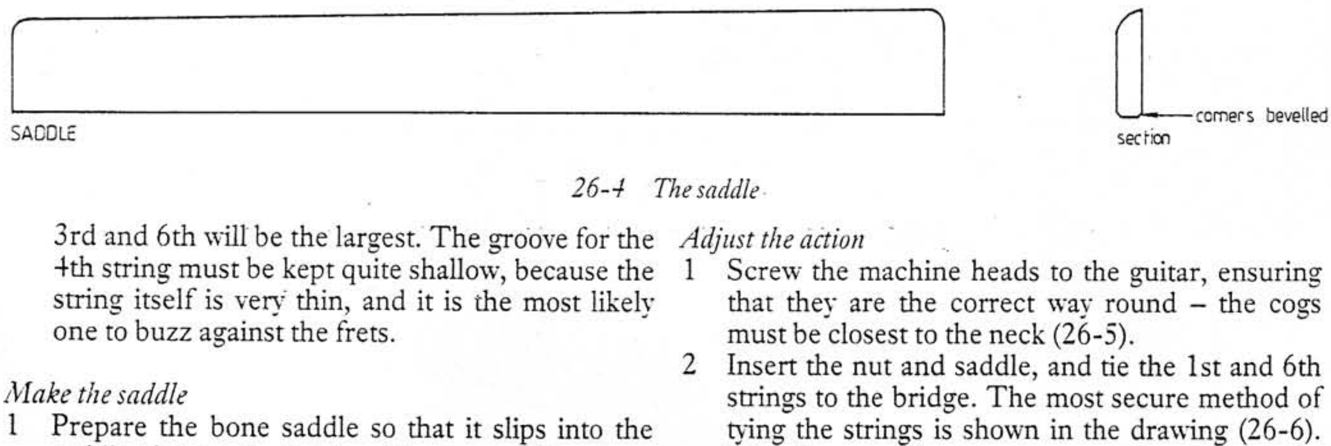
26-1 Measuring the gap between the top of the 12th fret and the underside of the 6th string



26-2 Left: setting out the nut. Centre: the top surface of the nut slopes down towards the head. Right: the string is seated to half its diameter in the groove



26-3 Shaping the string grooves



26-4 The saddle

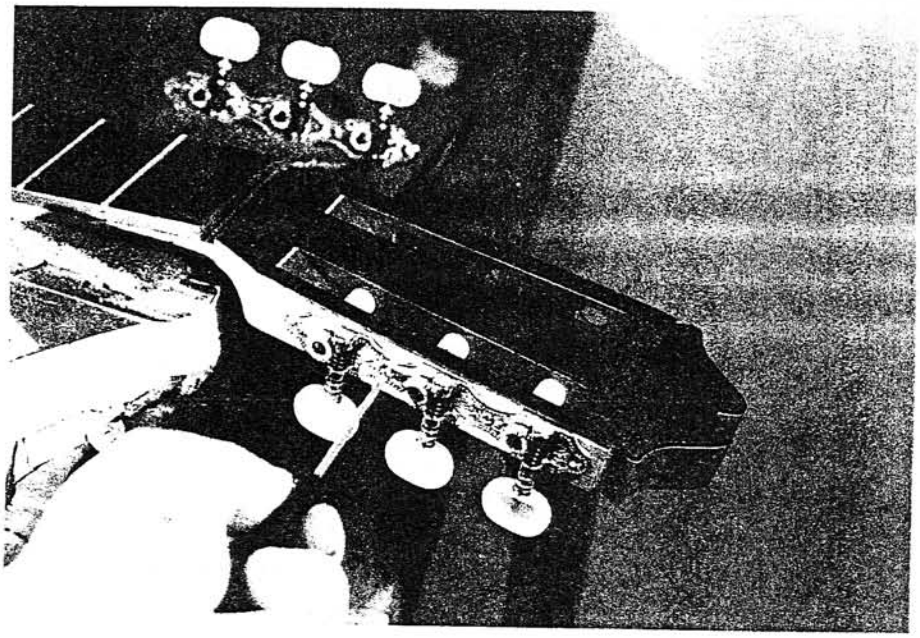
3rd and 6th will be the largest. The groove for the 4th string must be kept quite shallow, because the string itself is very thin, and it is the most likely one to buzz against the frets.

Make the saddle

1 Prepare the bone saddle so that it slips into the saddle slot on the bridge. The top surface must slope down slightly towards the tie-block so that the strings have a definite change of angle as they leave the front edge of the saddle (26-4).
2 Wrap some abrasive paper round a cabinet scraper and clean out the bottom of the saddle slot. It should be flat. The base of the bone saddle must also be flat so that it makes contact with the bridge. When a string is plucked, the vibrations are transmitted through the bone saddle to the bridge and then to the soundboard. It is essential that all these surfaces are in good contact.

Adjust the action

1 Screw the machine heads to the guitar, ensuring that they are the correct way round – the cogs must be closest to the neck (26-5).
2 Insert the nut and saddle, and tie the 1st and 6th strings to the bridge. The most secure method of tying the strings is shown in the drawing (26-6). The three trebles require more loops than the basses. Thread them through the holes in the machine head barrels and tighten the strings until they are reasonably taut. The precise position of the nut can now be found – the gap between the strings and the edge of the fingerboard must be the same on both sides. If the nut is still too long and protrudes over the edge of the neck it can now be filed down.
3 Place a steel rule on the 1st fret and measure the distance to the underside of the 1st string. Repeat with the 6th string. If the gap is well over 1.0 mm,



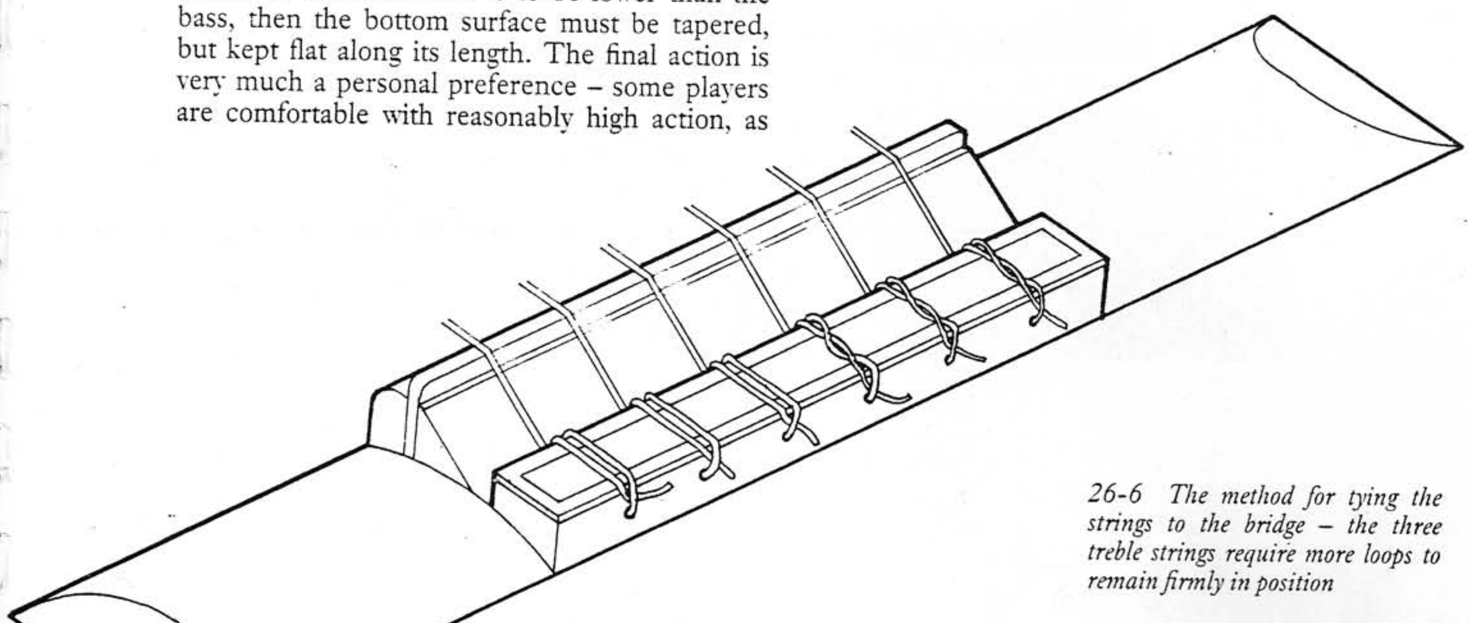
26-5 Fitting the machine heads

remove the nut and carefully rub its lower surface on a flat sanding board to reduce its height. Be sure to keep the lower surface both square and flat. At this stage do not reduce the gap to less than 1.0 mm (26-7).

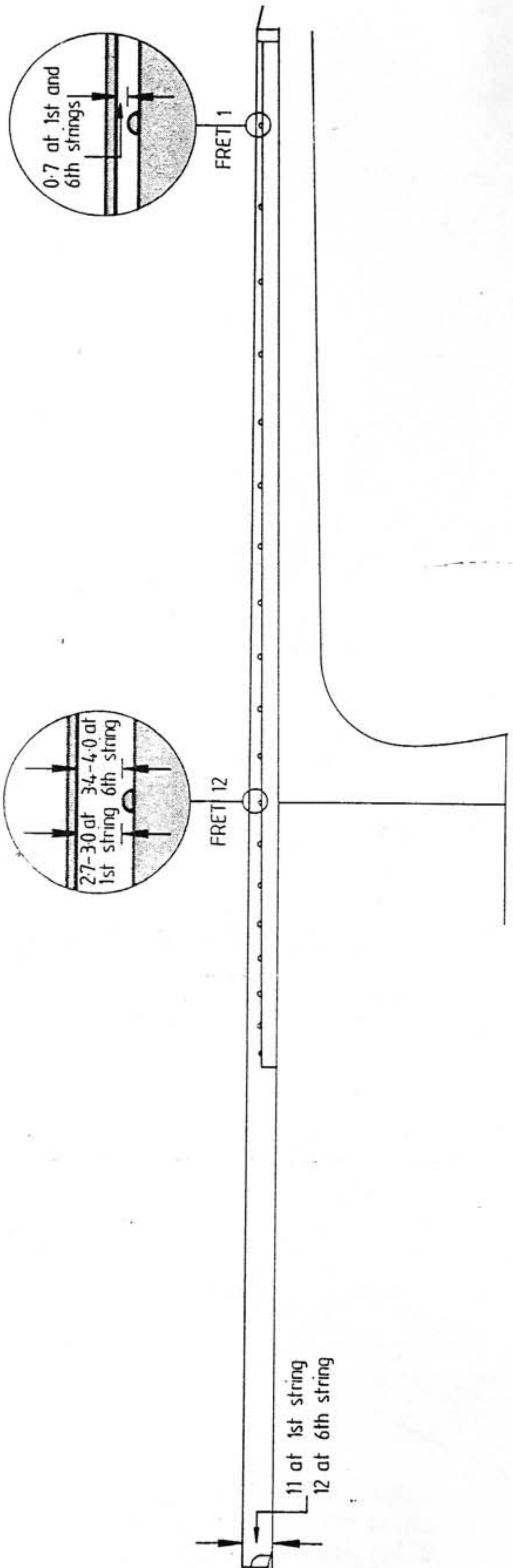
4 Now place the rule on the 12th fret and measure the gap between the top of the fret and the underside of the strings (26-7). The 6th string must be left slightly higher than the first. The final gap should be between 3.5 mm and 4.0 mm. The 1st string is less likely to touch a fret when it vibrates, so the final gap here can be 2.5 mm to 3.0 mm. The saddle must be removed so that its bottom surface can be rubbed down to lower the action. If the treble side is to be lower than the bass, then the bottom surface must be tapered, but kept flat along its length. The final action is very much a personal preference – some players are comfortable with reasonably high action, as this allows a stronger playing style. Each time that the saddle is rubbed down you must check that it is still flat and that it fits right to the bottom of the saddle slot. It helps if a small bevel is formed on each side of the saddle so that it seats firmly at the base of the saddle slot.

5 As the height at the 12th fret approaches its final dimension, check the gap at the 1st fret again. If necessary, reduce it further until the gap is just under 1.0 mm.

6 Tighten up the strings to pitch and measure again. (The more taut the strings, the greater the gap becomes.) Once the 1st and 6th strings are correct, and notes can be played all the way up



26-6 The method for tying the strings to the bridge – the three treble strings require more loops to remain firmly in position

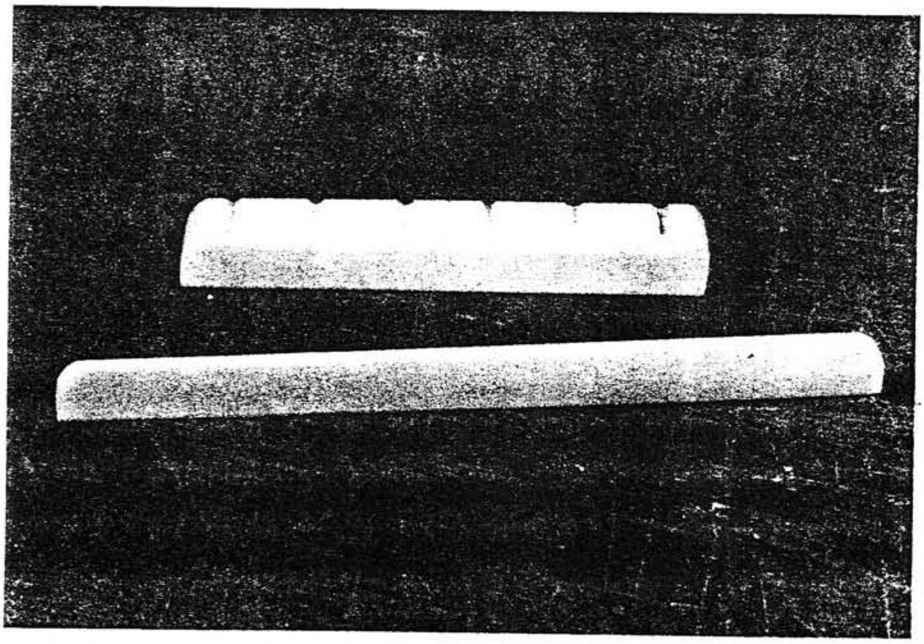


26-7 Adjusting the action – the heights of the saddle and nut are altered until the required gaps are obtained at the 1st and 12th frets and down the fingerboard without any buzzing, it is safe to assume that the action will be satisfactory for all the other strings. It can be interesting to compare the quality of sound produced before and after varnishing – the polished surface does produce a brighter sound, so do not judge the instrument's tone at this stage. The guitar can now be tuned up to pitch. (The tuning is E (6th string); A (5th string); D (4th string); G (3rd string); B (2nd string); E (1st string).) Make any final adjustments to the nut and saddle, then remove the strings, nut and saddle so that the guitar can be varnished. The nut and saddle are not glued to the guitar – the tension of the strings will keep them in place, and they must be removable so that adjustments can be made in the future (26-8).

Buzzing

If the gaps have been correctly adjusted and yet buzzing occurs on one or more strings, there could be a number of different causes. This should be remedied now rather than leaving it until the guitar has been varnished. Place a straight-edge from the 1st to the 12th frets to check that they are flat. If one fret is slightly high, the straight-edge will rock. Use a fret file or sharpening stone to level it if necessary and then reshape it as described in Chapter 23. If you are certain that the frets are all level and that the gaps are correct, and yet there is still buzzing, then the cause could be something very simple, such as the end of a string resting on the soundboard. Determine if the buzz is over the frets, or on the soundboard. A loose strut inside the guitar can cause the soundboard to buzz. In this case, glue will have to be smeared along the strut. Give the guitar to a proficient guitarist, if you are not one yourself, as the buzz may simply be caused by a bad playing style.

When stringing up the guitar, especially after varnishing, protect the soundboard around the bridge with a piece of card with a bridge-shaped window cut out. It is easy for a string to slip and damage the polished surface.



26-8 The nut and saddle are removed before the guitar is varnished

27 Varnishing and Polishing

Now that the construction of the guitar is complete, the final process of applying a surface finish to the instrument must be carried out. A guitar requires only the minimum thickness of varnish to seal and protect the wood. Any further building up of finishing material will only inhibit the soundboard from vibrating freely. The surface coating also helps prevent moisture from being absorbed and it allows the full beauty of the wood to be revealed.

The choice of a matt, satin or high gloss finish is really a matter of personal preference. The tradition is for a glossy finish, but a close look at a row of mass-produced factory guitars will reveal that they have been indiscriminately sprayed with thick layers of lacquer. The gloss on a hand-made instrument should be far more subtle and gentle. Varnishing is a process that requires a great deal of care and patience. It should be carried out over a period of weeks rather than days, if a good result is expected.

Many of the makers referred to in this book used the traditional finish of french polish. Many still favour this today, but more recent developments by the manufacturers of finishing materials mean that there are also other choices. The words 'varnish', 'polish', and 'lacquer' are often used interchangeably. In this context, 'varnish' describes any finish that is applied by brush or spray, while 'polish' refers to the shellac-based finish that is applied during french polishing. This chapter describes how to apply a surface coating by brush (varnishing), and also the traditional method of french polishing.

Varnishing

The aim of varnishing is to achieve a perfectly flat, smooth surface coating on the wood. In practice it is not possible to accomplish this with a brush, no matter how soft the hairs. The brush will leave ridges in the varnish, and the varnish itself will not lie flat and level. The method of obtaining the desired surface is to build up successive layers of varnish, sanding down each coat when dry so that all imperfections are removed, until there is a thick enough coating to work to a smooth, level surface. This final rubbing down is followed by polishing and burnishing the surface in order to obtain the degree of gloss required.

Types of Varnish

Many types of varnish are available for brush application:

Oil varnish
Spirit varnish
Modern lacquers

The following method is basically similar, whether you are using a modern lacquer, an oil varnish or a spirit varnish. Of these, an acid catalyst lacquer is recommended, as it is durable and fairly quick-drying. It can be applied extremely thinly so that the final thickness will not have any adverse effect on the tone of the guitar. It is a two-part lacquer, specially formulated for brush application. The two parts are mixed together just before use, and one to two coats can be applied per day. Do not use a lacquer intended for spray application as it will set too quickly, making brushing impossible. It is essential to use a good varnishing brush, which can only be obtained from a specialist supplier. The best brushes used to be made from otter or badger hair, but wildlife conservation policies mean that these brushes are no longer available. Some suppliers stock squirrel hair brushes, which are the best quality now produced. Good synthetic fibre brushes are also manufactured – refer to the suppliers' catalogues in Appendix 3 for current availability.

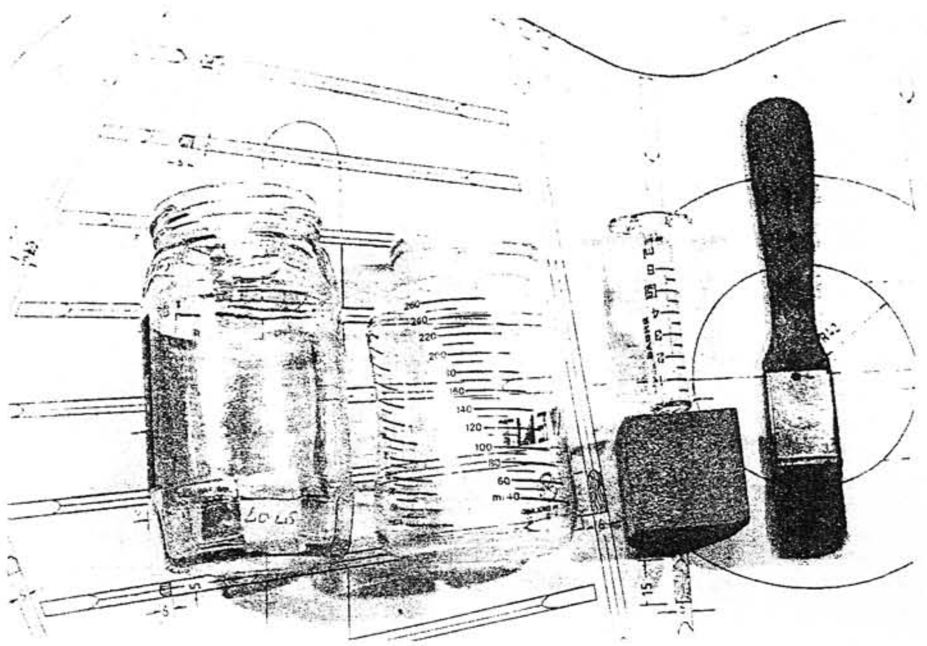
Materials (27-1)

Thixotropic grain filler (rosewood colour)
Old paint brush
AC lacquer (brushing)
Glass mixing jars
Disposable measuring syringe
25 mm wide brush (squirrel hair flat lacquer brush)
Garnet paper (various grades)
220 and 320 lubrisil paper
1200 wet or dry paper
Cork sanding block
Eraser for use as a small sanding block
Cutting compound
Burnishing cream
Rags
Soft duster

Equipment

A few simple supports are useful as they allow your concentration to be on the varnishing rather than trying to hold up the guitar (27-2 A, B and C).

(A) A flat-topped stool of convenient height, on which the guitar is placed while varnishing the soundboard (1), head veneer (2), head sides (3) and bridge (4).
(B) Two supports for varnishing the back (5) and the



27-1 Left to right: varnish jar with the required volume marked on the side; graduated measuring vessel; syringe embedded in a wood block; varnishing brush

back of the head (6). The taller support consists of a convenient length of 16 mm dowel, one end of which is embedded into a stable base. The other end has a 50 mm disc of wood attached. This disc is inserted through the soundhole and rests on the inside of the back. A section on the top of the disc can be cut away to allow it to straddle the back reinforcing strip. A similar support is made to prop up the neck of the guitar and is about 100 mm shorter (the depth of the guitar body), so that the instrument remains horizontal when supported.

(C) A hook screwed to the ceiling allows the guitar to be suspended while the ribs (7) and neck (8) are varnished.

Method

Preparation

1 Read the instructions supplied with the AC lacquer. Some are toxic, and the fumes should not be inhaled. Wear a vapour mask.

2 It is now necessary to prepare some glass jars. They must be clean and each one marked on the side to the required level. If, for example, the proportions of the mixture are 9 units of lacquer to 1 unit of catalyst, then pour water into a measuring vessel to the 40 ml mark. Now transfer this to one of the glass jars, stick some masking tape on the side, and mark a line at the water level. Empty into the next jar and repeat. The catalyst will be measured by pouring it into an upturned syringe, as only 4.5 ml will be required to go with the 40 ml in the jar. (40:4.5 will give the 9:1 mixture required). This is an economical way of using the lacquer as it provides just enough for one coat. It also ensures that each coat will be a similar ratio of mixture which is important. If the syringe-pull is removed, the lower spout of the syringe can be put into a matching size hole drilled into a small wood block (27-1). The catalyst can then be poured in. Do not use the syringe to suck up the catalyst, as the action of forcing it out under pressure can introduce air bubbles into the mixture which are likely to remain on the guitar surface and be visible as tiny areas of 'pitting'.

Sand the guitar

1 Sand the entire guitar with garnet paper, starting with 100G, and progressing to 150G, 180G and 220G. Work systematically, starting with all the rosewood areas. Brush away dust frequently, or it can become caught up in the paper, and scratch the surface. Sand with the grain, using a cork sanding block at first. As you get to the finer papers, wrap small pieces around a firm pencil eraser, about 30 mm × 30 mm. Once all the rosewood is smooth and the dust brushed away, move on to the mahogany, and finally, the spruce or cedar.

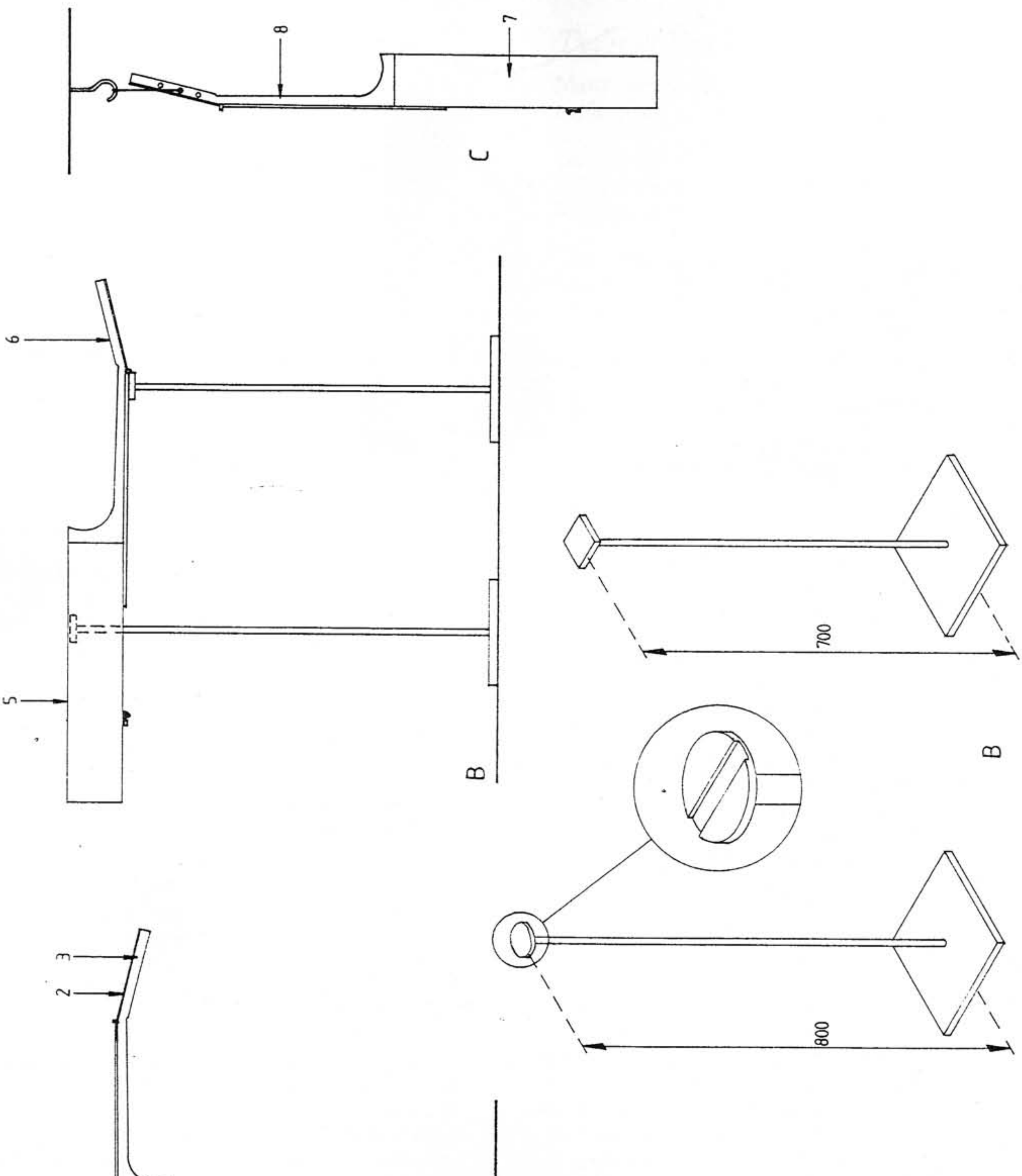
2 Ensure that all dust is removed. Place the guitar soundboard uppermost on the stool. All varnishing should be carried out in a warm, dust-free environment with natural lighting.

Mix the varnish

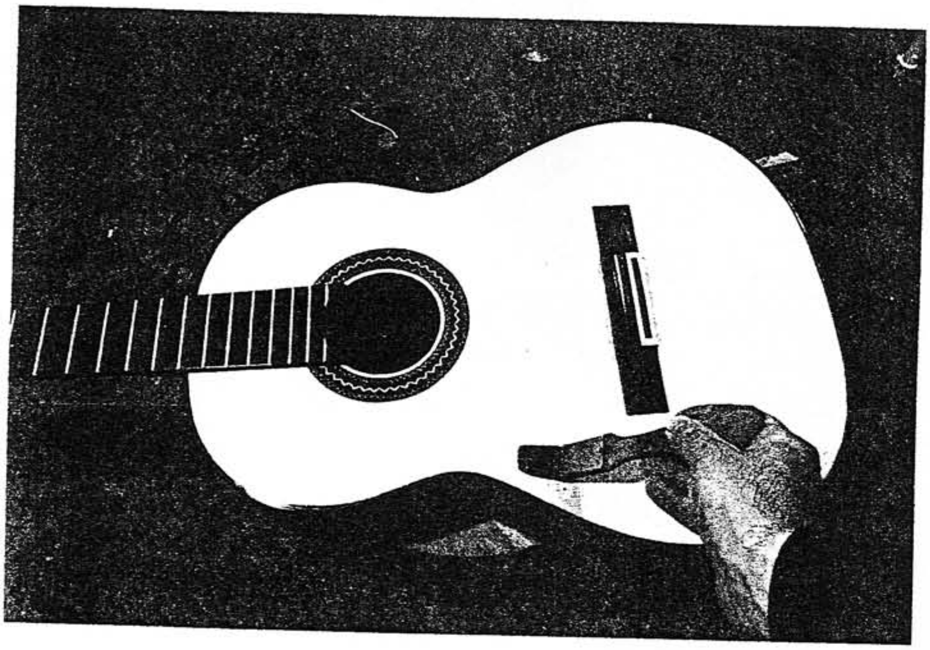
Mix some varnish: pour the lacquer into a jar to the marked level. Pour the catalyst into the syringe to the required level. Now add the catalyst to the lacquer in the jar and mix carefully with a clean stick. Try not to introduce air into the mixture.

Varnish the soundboard, head veneer and bridge

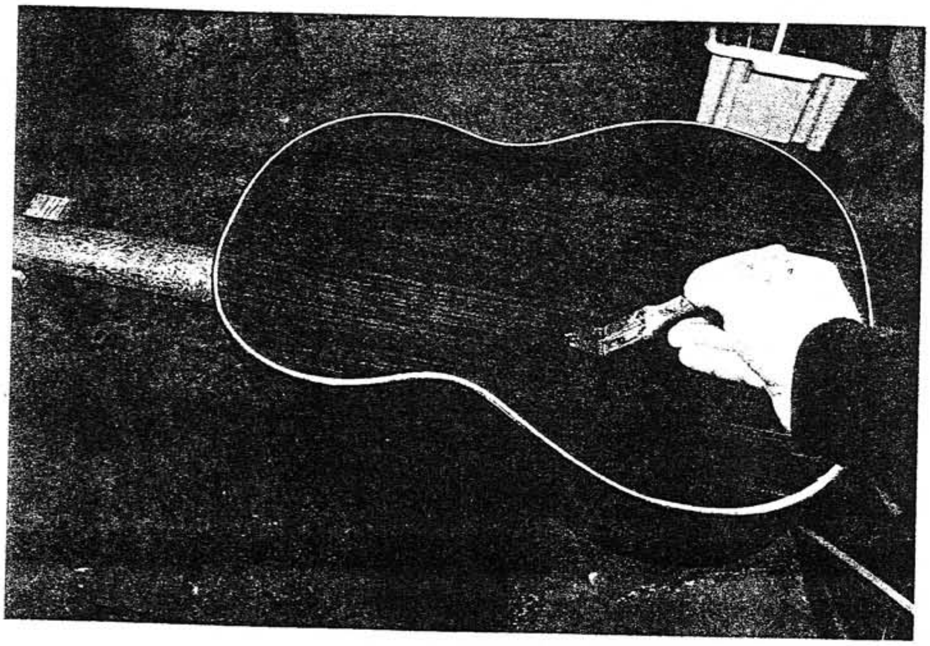
1 Place the brush in the mixture, having first twirled it in your fingers to remove any loose hairs. Let it soak up the varnish, then begin brushing it on to



27-2 Varnishing sequence



27-3 Varnishing the soundboard



27-4 Varnishing the back

the soundboard (27-3). Start at one edge, on the lower bout side, and let the brush follow the outer shape of the guitar. This way, you will avoid the problem of varnish dripping down on to the ribs in the waist area. Varnish must be applied neither too thinly nor too thickly. Excessive 'brushing out' may appear to have covered the surface because it will change colour and look wet, but when sanded down you will discover that there is virtually nothing there. On the other hand, if it is left too thick, large ridges and runs will occur which are difficult to sand out without the danger of rubbing through back to the wood. Brush with long, even strokes – the varnish begins to set very quickly and if you do notice any ridges or runs, leave them alone or you will simply 'drag' the coating. It is better to deal with them when sanding down prior to the following coat. Continue applying varnish, working towards the bridge and right up to the fingerboard. Before reaching the other edge of the guitar, move round and complete it from the other side so that once again you can keep the guitar rib in view, to ensure that there are no drips.

2 Now that the soundboard is completely covered, move round to the head and varnish the top, sides, slots and ramps.
3 Next, varnish the bridge, taking care to avoid touching the soundboard.

Varnish the back and the back of the head

1 Wait a couple of minutes for the varnish to set sufficiently not to run when the guitar is turned over and placed on the wooden supports. Pick it

27-5 *The guitar is suspended so that the ribs can be varnished*

up by the neck and place the soundhole over the disc of the support with the other support under the fingerboard. Now varnish the back, again taking care to avoid any runs down onto the ribs (27-4).

2 Varnish the back of the head.

Varnish the ribs and neck

1 Wait a few minutes, keeping the guitar in this horizontal position, then remove it from the supports and hang it up on the ceiling hook. (A section of wire coat-hanger can be used.) Varnish the ribs, taking care to cover the bindings right up to the edges, and making certain that no ridges or runs are left, especially in the waist area, as these will be the most difficult to remove later (27-5).

2 Varnish the neck. (Do not apply any varnish to the fingerboard. Lemon oil can be rubbed into this just before stringing up.)

3 Wash the brush out well, using the recommended solvent and leave the guitar hanging up until the next day.

Fill the grain

The first coat of varnish acts as a sealer – the wood will now be kept clean and the next stage of filling the grain of the open pored woods will give cleaner results than if the sealer coat was omitted. Some woods have a very open grain structure which shows as small holes or grooves on the surface. These will absorb the varnish and make it difficult to obtain a completely smooth surface. Although some varnishes will eventually build up enough thickness to fill the wood, it is more satisfactory to apply a grain filler. The most likely wood to require filling is rosewood. Some mahogany needs filling, but do not apply any filler to the spruce or cedar soundboard. Thixotropic grain filler is available in different colours to match the wood. The one needed here is a dark brown 'rosewood' filler.

1 Open the tin, stir the contents, and brush the filler on to the back first, using an old, fairly stiff paintbrush. Brush across the grain, then with the grain. Leave for five minutes, and then rub a coarse rag across the grain, forcing the filler into the pores of the wood. Change to a clean rag frequently, and try to remove all the filler that is on the surface of the wood. The aim is to leave filler only in the pores.

2 Fill the ribs of the guitar and the head veneer (if this is rosewood). The guitar must now be left for at least 24 hours so that the filler can dry completely. If varnish is applied over undried filler it is in danger of either not setting properly, or of cracking later as the moisture level in the filler alters.

3 When dry, sand the filled areas with 220G lubrisil or a similar abrasive. The surfaces should now appear very smooth. Lightly sand the soundboard with 320G lubrisil. The first sealer coat may have revealed tiny scratches or dents and now is the time to obtain an absolutely clean and smooth surface, using fine abrasive papers.

Apply three to six coats of varnish

More coats of varnish can now be applied. Each one must be left to harden for 24 hours (unless the manufacturer recommends otherwise). Between coats, smooth the varnish with 320G lubrisil, or 400G wet or dry paper. Try to avoid handling the guitar with your bare hands, as it is possible for the oils in the skin to leave fingerprints on the surface. These may then be sealed in by the following coat of varnish, and later be revealed when the guitar is polished. Handle the instrument with a clean soft duster during sanding. The aim in smoothing the varnish is to obtain as level and blemish free a surface as possible, before applying the following coat. The danger is that too much rubbing down will remove the varnish and expose the wood. The edges and corners of the guitar are especially susceptible to this problem and should only be sanded very lightly. The number of coats of varnish required will depend entirely on how carefully this rubbing down is carried out. Provided that the varnish is neatly and smoothly

27-6 *Final polishing*

applied, with a minimum of ridges and runs, then only light sanding will be needed, and three coats will be enough. If while sanding down ridges or runs, you reveal the wood, then several more coats are needed. Once you feel that sufficient thickness has been applied all over the guitar, do not sand down the final coat but leave the instrument hanging up for at least one week or longer. It is important for the varnish to harden completely before being rubbed down and burnished. Cutting back and burnishing a 'soft' varnish will not produce a shine.

Final smoothing and polishing

1 Now that the varnish is hard, it must be smoothed with fine wet or dry paper, dipped in water. Start with 800G and then change to 1200G. The water produces a fine slurry which must be wiped away periodically to reveal the surface. Deal with a small area at a time and continue smoothing it until all signs of glossiness have disappeared. The surface will now be smooth and matt all over.
2 Dry off the surfaces and use a fine cutting compound such as 'T-Cut' to further smooth the surface.
3 Now a burnishing cream can be applied and the instrument buffed up to create as shiny a surface as required (27-6).

French Polishing

French polishing is a method of applying a shellac-based liquid to a wood surface. Rather than using a brush, the polish is applied with a 'rubber'. This is a soft pad made from cotton wadding wrapped in a piece of lint-free cotton cloth. The cotton wadding is first soaked in the polish before being wrapped in the cloth. The resulting pad or 'rubber', is then moved over the surface, depositing the polish which is squeezed through the cloth.

Shellac is a natural material produced by the lac insect. This is collected, purified, and mixed with industrial alcohol to produce a wide variety of french polishes. Many colours are available but the guitar maker is likely to prefer the lighter shades, as these will not unduly darken the light coloured soundboard and inlays. (There has been a fashion for darkly stained soundboards – Fleta guitars are finished with a deep orange-yellow polish, but nowadays many makers feel that the natural beauty of the wood should not be hidden.)

The advantage of french polish is that a very thin coating can be applied, and this will not adversely affect the guitar's tone. Unfortunately, shellac is not very hard wearing. The constant friction caused by the player's clothing rubbing against the guitar will eventually wear the polish away. Neither is shellac resistant to alcohol. Nevertheless, the 'natural' characteristics of french polish mean that it still appeals to many makers.

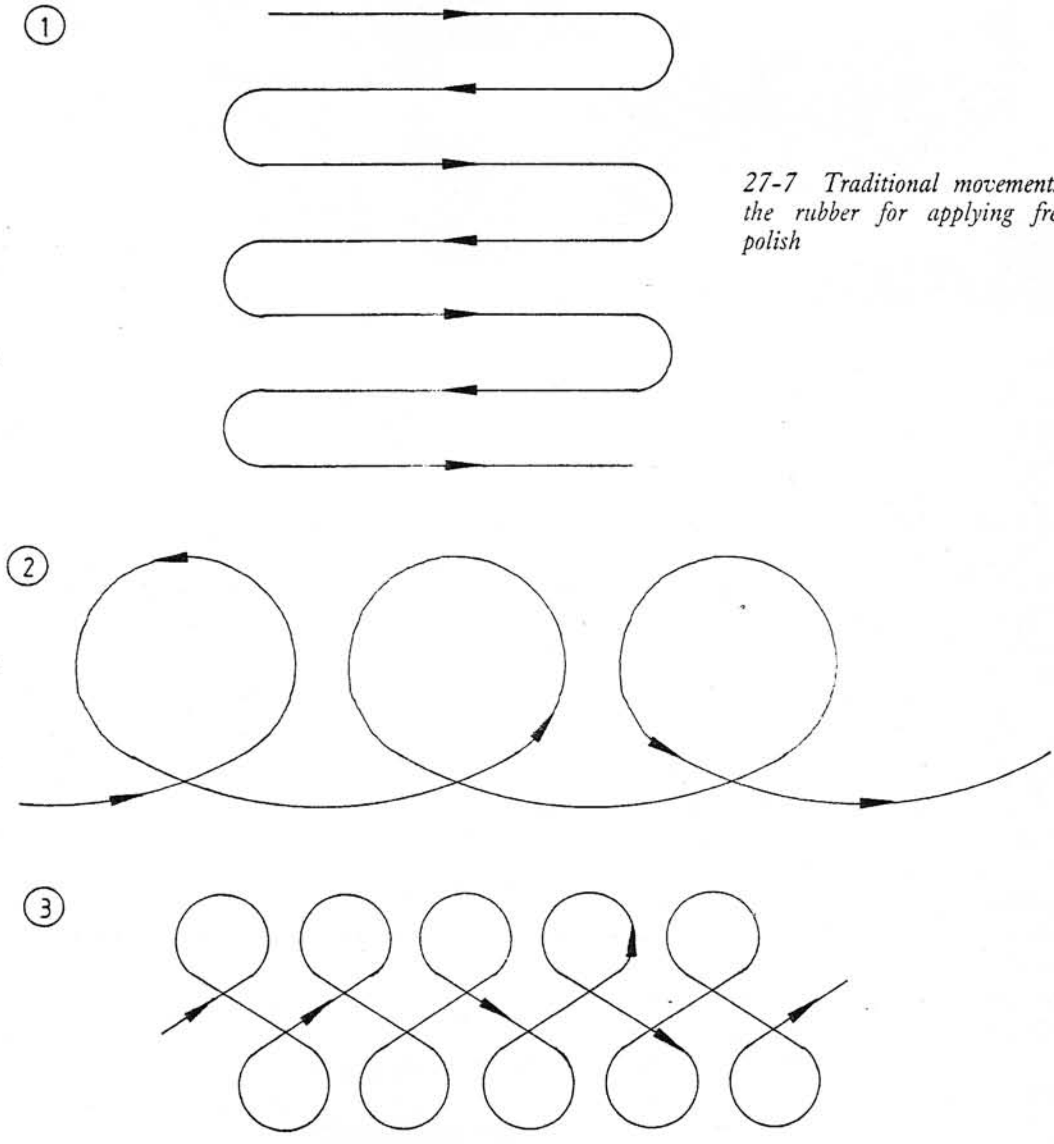
Materials

French polish (pale or transparent)
Methylated spirits
Cotton wadding
Cotton cloth or linen (lint free)
Glass storage jars
Fine abrasive paper

Method

The guitar must be prepared for french polishing in the same way as for varnishing – use varying grades of abrasive paper to bring the surfaces to absolute smoothness. Fill any holes or gaps with a woodfiller. (Rosewood dust mixed with glue makes a good filler for rosewood, but repairing light coloured wood is much more difficult). Brush on one coat of the polish to act as a sealer. When dry, apply a grainfiller. This must be sanded smooth, and then the french polishing can begin. Use only one brand of polish on the guitar, as different types may not be compatible. Any sanding sealer that was used earlier to protect the instrument should be removed during the final sanding, prior to beginning polishing.

polish. Squeeze it out, and then replace it in the cloth. Each time the rubber needs recharging, this process must be repeated. It is best not to add polish directly to the cloth surface as any impurities will be deposited on the face of the rubber and be liable to scratch the polished surface. The cloth acts as a strainer for the polish. After use, the rubber must be stored in a clean, airtight glass jar, otherwise it will harden and become useless.



27-7 Traditional movements of the rubber for applying french polish

Make the rubber

Cut a piece of clean cotton cloth into a rectangle about 175 mm × 125 mm. Cut a piece of cotton wadding to the same size, and then fold it in half. Fold it in half again. Fold the corners underneath so that a pear shape results. The bottom surface should be flat. Place the cloth over the wadding and fold it over and underneath. Twist the loose cloth round a number of times until the flat surface is quite firm and taut. When you are ready to begin polishing, remove the wadding from the rubber and soak it in

Polishing

There are a number of traditional hand movements which are used to spread the polish evenly over the surface – long, straight movements are used first (27-7). You can work over the same area a couple of times until a dull shine appears. The surface must then be left to harden for about ten minutes, after which a further coat can be applied. This time move the rubber in circles, making sure that all areas of the surface are covered. Once again leave the polish to dry, then apply another coat, moving the rubber in long, figure-of-eight patterns. The most important point to remember is that the rubber must be kept constantly moving while in contact with the surface. This means that a sweeping movement of your hand must start before the rubber touches the surface and when you want to remove the rubber, lift it off the surface while your hand is still in motion. If the end of a polishing sequence is done with long, straight movements, there will be less chance of small circular track marks appearing at the edges of the work. When several coats have been applied to the entire guitar, hang it up and leave until the next day.

Although the alcohol in the mixture evaporates quite fast, the polish is in fact slow to harden. As more coats are applied, the drying process becomes even slower. Each time that a new coat is applied, the alcohol in it will begin to dissolve the underlying coats. This is why french polishing must be carried out in many short steps, over a period of time. The raw wood will also allow the first coats to sink in to the grain, and the following day the surface may appear quite dull. The method is to gradually build up many coats until the surface has sufficient body to be left to harden completely prior to burnishing. It may be necessary to add a few tiny drops of linseed oil to the surface of the rubber. This will help lubricate the surface. Use as little oil as possible, as it will result in smears appearing on the surface, and in any case, it will have to be burnished away at the end.

Once the polishing is complete, hang the guitar up in a warm atmosphere for as long as possible, and certainly no less than seven days. The final process involves making a new rubber which is charged only with methylated spirits. It should be fairly dry, or the spirits will start to dissolve the surface, rather than burnish it. The rubber is moved over the surface quite rapidly until a high gloss emerges. There are many variations in the method of french polishing. sometimes the polish is gradually diluted with alcohol as work proceeds. This makes a separate burnishing stage unnecessary. A burnishing cream can also be used once the surface has hardened. Fine abrasive paper can be used between coats if necessary, although if the rubber and the work surface are kept clean, this is not essential. Other variations include the use of extra fine steel wool for cutting back the coats. (Make certain that it is oilfree.)

The awkward shape of the guitar means that polishing may be easiest if done in stages – the soundboard and head can be completed first, then the back and ribs, and finally the neck. This slows down the process even more, and some makers improvise a variety of hooks and props to facilitate the work. The most difficult area to polish well is the soundboard, because the fingerboard and bridge are constantly preventing the rubber from depositing polish right up to the corners. The answer is to make sure that the rubber is shaped with a small, sharp point at one end and to keep this well charged with polish. Some makers, including Daniel Friederich, delay gluing the bridge to the soundboard until the polishing is complete. The gluing area is then scraped clean of polish, and the bridge glued in place. French polish takes a long time to harden – once all the polishing and burnishing is complete, the instrument should be left hanging up in a dry, warm atmosphere for between one and two weeks. This will ensure that the polish is hard, and avoid the possibility of pressure marks appearing on the surface when the guitar is played – soft polish will readily take the impression of clothing as the player's body presses against the instrument.

27-8 The completed guitar

Appendix 1 Conversion Tables

Fractions Reduced to Decimals

1/2's	1/4's	8ths	16ths	32nds	64ths	mm	inch
					1	0.397	0.015625
				1	2	0.794	0.03125
					3	1.191	0.046875
			1	2	4	1.588	0.0625
					5	1.984	0.078125
				3	6	2.381	0.09375
					7	2.778	0.109375
		1	2	4	8	3.175	0.125
					9	3.572	0.140625
				5	10	3.969	0.15625
					11	4.366	0.171875
			3	6	12	4.763	0.1875
					13	5.159	0.203125
				7	14	5.556	0.21875
					15	5.953	0.234375
	1	2	4	8	16	6.35	0.25
					17	6.747	0.265625
				9	18	7.144	0.28125
					19	7.541	0.296875
			5	10	20	7.938	0.3125
					21	8.334	0.328125
				11	22	8.731	0.34375
					23	9.128	0.359375
		3	6	12	24	9.525	0.375
					25	9.922	0.390625
				13	26	10.319	0.40625
					27	10.716	0.421875
			7	14	28	11.113	0.4375
					29	11.509	0.453125
				15	30	11.906	0.46875
					31	12.303	0.484375
1	2	4	8	16	32	12.7	0.50
					33	13.097	0.515625
				17	34	13.494	0.53125
					35	13.891	0.546875
			9	18	36	14.288	0.5625
					37	14.684	0.578125
				19	38	15.081	0.59375
					39	15.478	0.609375
		5	10	20	40	15.875	0.625
					41	16.272	0.640625
				21	42	16.669	0.65625
					43	17.066	0.671875
			11	22	44	17.463	0.6875
					45	17.859	0.703125
				23	46	18.256	0.71875
					47	18.653	0.734375
	3	6	12	24	48	19.050	0.75
					49	19.447	0.765625
				25	50	19.844	0.78125
					51	20.241	0.796875
			13	26	52	20.638	0.8125
					53	21.034	0.828125
				27	54	21.431	0.84375
					55	21.828	0.859375
		7	14	28	56	22.225	0.875
					57	22.622	0.890625
				29	58	23.019	0.90625
					59	23.416	0.921875
			15	30	60	23.813	0.9375
					61	24.209	0.953125
				31	62	24.606	0.96875
					63	25.003	0.984375
2	4	8	16	32	64	25.400	1

Millimeters to Inches

mm	inches	mm	inches	mm	inches	mm	inches
.1	0.00394	6.5	0.25591	12.9	0.50787	19.3	0.75984
.2	0.00787	6.6	0.25984	13.0	0.51181	19.4	0.76378
.3	0.01181	6.7	0.26378	13.1	0.51575	19.5	0.76772
.4	0.01575	6.8	0.26772	13.2	0.51968	19.6	0.77165
.5	0.01969	6.9	0.27165	13.3	0.52362	19.7	0.77559
.6	0.02362	7.0	0.27559	13.4	0.52756	19.8	0.77953
.7	0.02756	7.1	0.27953	13.5	0.53149	19.9	0.78346
.8	*0.0315*	*7.2*	*0.28346*	*13.6*	*0.53543*	*20.0*	*0.7874*
.9	0.03543	7.3	0.2874	13.7	0.53937	20.1	0.79134
1.0	0.03937	7.4	0.29134	13.8	0.54331	20.2	0.79527
1.1	0.04331	7.5	0.29528	13.9	0.54724	20.3	0.79921
1.2	0.04724	7.6	0.29921	14.0	0.55118	20.4	0.80315
1.3	0.05118	7.7	0.30315	14.1	0.55512	20.5	0.80709
1.4	0.05512	7.8	0.30709	14.2	0.55905	20.6	0.81102
1.5	0.05906	7.9	0.31102	14.3	0.56299	20.7	0.81496
1.6	0.06299	8.0	0.31496	14.4	0.56693	20.8	0.8189
1.7	0.06693	8.1	0.3189	14.5	0.57086	20.9	0.82283
1.8	0.07087	8.2	0.32283	14.6	0.5748	21.0	0.82677
1.9	0.0748	8.3	0.32677	14.7	0.57874	21.1	0.83071
2.0	0.07874	8.4	0.33071	14.8	0.58268	21.2	0.83464
2.1	0.08268	8.5	0.33464	14.9	0.58661	21.3	0.83858
2.2	0.08661	8.6	0.33858	15.0	0.59055	21.4	0.84252
2.3	0.09055	8.7	0.34252	15.1	0.59449	21.5	0.84646
2.4	0.09449	8.8	0.34646	15.2	0.59842	21.6	0.85039
2.5	0.09843	8.9	0.35039	15.3	0.60236	21.7	0.85433
2.6	0.10236	9.0	0.35433	15.4	0.6063	21.8	0.85827
2.7	0.1063	9.1	0.35827	15.5	0.61023	21.9	0.8622
2.8	0.11024	9.2	0.3622	15.6	0.61417	22.0	0.86614
2.9	0.11417	9.3	0.36614	15.7	0.61811	22.1	0.87008
3.0	0.11811	9.4	0.37008	15.8	0.62205	22.2	0.87401
3.1	0.12205	9.5	0.37401	15.9	0.62598	22.3	0.87795
3.2	0.12598	9.6	0.37795	16.0	0.62992	22.4	0.88189
3.3	0.12992	9.7	0.38189	16.1	0.63386	22.5	0.88583
3.4	0.13386	9.8	0.38583	16.2	0.63779	22.6	0.88976
3.5	0.1378	9.9	0.38976	16.3	0.64173	22.7	0.8937
3.6	0.14173	10.0	0.3937	16.4	0.64567	22.8	0.89764
3.7	0.14567	10.1	0.39764	16.5	0.6496	22.9	0.90157
3.8	0.14961	10.2	0.40157	16.6	0.65354	23.0	0.90551
3.9	0.15354	10.3	0.40551	16.7	0.65748	23.1	0.90945
4.0	0.15748	10.4	0.40945	16.8	0.66142	23.2	0.91338
4.1	0.16142	10.5	0.41338	16.9	0.66535	23.3	0.91732
4.2	0.16535	10.6	0.41732	17.0	0.66929	23.4	0.92126
4.3	0.16929	10.7	0.42126	17.1	0.67323	23.5	0.9252
4.4	0.17323	10.8	0.4252	17.2	0.67716	23.6	0.92913
4.5	0.17717	10.9	0.42913	17.3	0.6811	23.7	0.93307
4.6	0.1811	11.0	0.43307	17.4	0.68504	23.8	0.93701
4.7	0.18504	11.1	0.43701	17.5	0.68897	23.9	0.94094
4.8	0.18898	11.2	0.44094	17.6	0.69291	24.0	0.94488
4.9	0.19291	11.3	0.44488	17.7	0.69685	24.1	0.94882
5.0	0.19685	11.4	0.44882	17.8	0.70079	24.2	0.95275
5.1	0.20079	11.5	0.45275	17.9	0.70472	24.3	0.95669
5.2	0.20472	11.6	0.45669	18.0	0.70866	24.4	0.96063
5.3	0.20866	11.7	0.46063	18.1	0.7126	24.5	0.96457
5.4	0.2126	11.8	0.46457	18.2	0.71653	24.6	0.9685
5.5	0.21654	11.9	0.4685	18.3	0.72047	25.7	0.97244
5.6	0.22047	12.0	0.47244	18.4	0.72441	24.8	0.97638
5.7	0.22441	12.1	0.47638	18.5	0.72835	24.9	0.98031
5.8	0.22835	12.2	0.48031	18.6	0.73228	25.0	0.98425
5.9	0.23228	12.3	0.48425	18.7	0.73622	25.1	0.98819
6.0	0.23622	12.4	0.48819	18.8	0.74016	25.2	0.99212
6.1	0.24016	12.5	0.49212	18.9	0.74409	25.3	0.99606
6.2	0.24409	12.6	0.49606	19.0	0.74803	25.4	1.0
6.3	0.24803	12.7	0.50	19.1	0.75197	25.5	1.00394
6.4	0.25197	12.8	0.50394	19.2	0.7559		

Inches to Millimetres

inches	to mm	inches	to mm	inches	to mm	inches	to mm
.005	.127	.325	8.255	.645	16.383	.965	24.511
.010	.254	.330	8.382	.650	16.510	.970	24.638
.015	.381	.335	8.509	.655	16.637	.975	24.765
.020	.508	.340	8.636	.660	16.764	.980	24.892
.025	.635	.345	8.763	.665	16.891	.985	25.019
.030	.762	.350	8.890	.670	17.018	.990	25.146
.035	.889	.355	9.017	.675	17.145	.995	25.273
.040	1.016	.360	9.144	.680	17.272	1.0	25.40
.045	1.143	.365	9.271	.685	17.399	1.005	25.527
.050	1.270	.370	9.398	.690	17.526	1.010	25.654
.055	1.397	.375	9.525	.695	17.653	1.015	25.781
.060	1.524	.380	9.652	.70	17.780	1.020	25.908
.065	1.651	.385	9.779	.705	17.907	1.025	26.035
.070	1.778	.390	9.906	.710	18.034	1.030	26.162
.075	1.905	.395	10.033	.715	18.161	1.035	26.289
.080	2.032	.40	10.160	.720	18.288	1.040	26.416
.085	2.159	.405	10.287	.725	18.415	1.045	26.543
.090	2.286	.410	10.414	.730	18.542	1.050	26.670
.095	2.413	.415	10.541	.735	18.669	1.055	26.797
.10	2.540	.420	10.668	.740	18.796	1.060	26.924
.105	2.667	.425	10.795	.745	18.923	1.065	27.051
.110	2.794	.430	10.922	.750	19.050	1.070	27.178
.115	2.921	.435	11.049	.755	19.177	1.075	27.305
.120	3.048	.440	11.176	.760	19.304	1.080	27.432
.125	3.175	.445	11.303	.765	19.431	1.085	27.559
.130	3.302	.450	11.430	.770	19.558	1.090	27.686
.135	3.429	.455	11.557	.775	19.685	1.095	27.813
.140	3.556	.460	11.684	.780	19.812	1.10	27.940
.145	3.683	.465	11.811	.785	19.939	1.105	28.067
.150	3.810	.470	11.938	.790	20.066	1.110	28.194
.155	3.937	.475	12.065	.795	20.193	1.115	28.321
.160	4.064	.480	12.192	.80	20.320	1.120	28.448
.165	4.191	.485	12.319	.805	20.447	1.125	28.575
.170	4.318	.490	12.446	.810	20.574	1.130	28.702
.175	4.445	.495	12.573	.815	20.701	1.135	28.829
.180	4.572	.50	12.70	.820	20.828	1.140	28.956
.185	4.699	.505	12.827	.825	20.955	1.145	29.083
.190	4.826	.510	12.954	.830	21.082	1.150	29.210
.195	4.953	.515	13.081	.835	21.209	1.155	29.337
.20	5.080	.520	13.208	.840	21.336	1.160	29.464
.205	5.207	.525	13.335	.845	21.463	1.165	29.591
.210	5.334	.530	13.462	.850	21.590	1.170	29.718
.215	5.461	.535	13.589	.855	21.717	1.175	29.845
.220	5.588	.540	13.716	.860	21.844	1.180	29.972
.225	5.715	.545	13.843	.865	21.971	1.185	30.099
.230	5.842	.550	13.970	.870	22.098	1.190	30.226
.235	5.969	.555	14.097	.875	22.225	1.195	30.353
.240	6.096	.560	14.224	.880	22.352	1.20	30.480
.245	6.223	.565	14.351	.885	22.479	1.205	30.607
.250	6.350	.570	14.478	.890	22.606	1.210	30.734
.255	6.477	.575	14.605	.895	22.733	1.215	30.861
.260	6.604	.580	14.732	.90	22.860	1.220	30.988
.265	6.731	.585	14.859	.905	22.987	1.225	31.115
.270	6.858	.590	14.986	.910	23.114	1.230	31.242
.275	6.985	.595	15.113	.915	23.241	1.235	31.369
.280	7.112	.60	15.240	.920	23.368	1.240	31.496
.285	7.239	.605	15.367	.925	23.495	1.245	31.623
.290	7.366	.610	15.494	.930	23.622	1.250	31.750
.295	7.493	.615	15.621	.935	23.749	1.255	31.877
.30	7.620	.620	15.748	.940	23.876	1.260	32.004
.305	7.747	.625	15.875	.945	24.003	1.265	32.131
.310	7.874	.630	16.002	.950	24.130	1.270	32.258
.315	8.001	.635	16.129	.955	24.257	1.275	32.385
.320	8.128	.640	16.256	.960	24.384		

Appendix 2 Fret Distance Tables

Scale Length 604 mm

distances from nut to:

fret 1	33.9
fret 2	65.9
fret 3	96.1
fret 4	124.6
fret 5	151.5
fret 6	176.9
fret 7	200.9
fret 8	223.5
fret 9	244.9
fret 10	265.0
fret 11	284.0
fret 12	302.0
fret 13	318.9
fret 14	334.9
fret 15	350.0
fret 16	364.3
fret 17	377.7
fret 18	390.4
fret 19	402.4

Scale Length 630 mm

distances from nut to:

fret 1	35.4
fret 2	68.7
fret 3	100.2
fret 4	130.0
fret 5	158.0
fret 6	184.5
fret 7	209.5
fret 8	233.1
fret 9	255.4
fret 10	276.4
fret 11	296.3
fret 12	315.0
fret 13	332.7
fret 14	349.4
fret 15	365.1
fret 16	380.0
fret 17	394.0
fret 18	407.2
fret 19	419.8

Scale Length 640 mm

distances from nut to:

fret 1	35.9
fret 2	69.8
fret 3	101.8
fret 4	132.0
fret 5	160.5
fret 6	187.4
fret 7	212.8
fret 8	236.8
fret 9	259.4
fret 10	280.8
fret 11	301.0
fret 12	320.0
fret 13	337.9
fret 14	354.9
fret 15	370.9
fret 16	386.0
fret 17	400.3
fret 18	413.7
fret 19	426.4

Scale Length 645 mm

distances from nut to:

fret 1	36.2
fret 2	70.4
fret 3	102.6
fret 4	133.1
fret 5	161.8
fret 6	188.9
fret 7	214.5
fret 8	238.7
fret 9	261.5
fret 10	283.0
fret 11	303.3
fret 12	322.5
fret 13	340.6
fret 14	357.7
fret 15	373.8
fret 16	389.0
fret 17	403.4
fret 18	416.9
fret 19	429.7

Scale Length 648 mm

distances from nut to:

fret 1	36.4
fret 2	70.7
fret 3	103.1
fret 4	133.7
fret 5	162.5
fret 6	189.8
fret 7	215.5
fret 8	239.8
fret 9	262.7
fret 10	284.3
fret 11	304.7
fret 12	324.0
fret 13	342.2
fret 14	359.3
fret 15	375.7
fret 16	390.8
fret 17	405.3
fret 18	418.9
fret 19	431.7

Scale Length 650 mm

distances from nut to:

fret 1	36.5
fret 2	70.9
fret 3	103.4
fret 4	134.1
fret 5	163.0
fret 6	190.4
fret 7	216.2
fret 8	240.5
fret 9	263.5
fret 10	285.2
fret 11	305.7
fret 12	325.0
fret 13	343.2
fret 14	360.4
fret 15	376.7
fret 16	392.0
fret 17	406.5
fret 18	420.2
fret 19	433.1