Canadian Conservation Institute

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The Gentle Art of Applied Pressure

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by Robert Barclay, Carole Dignard, and Carl Schlichting

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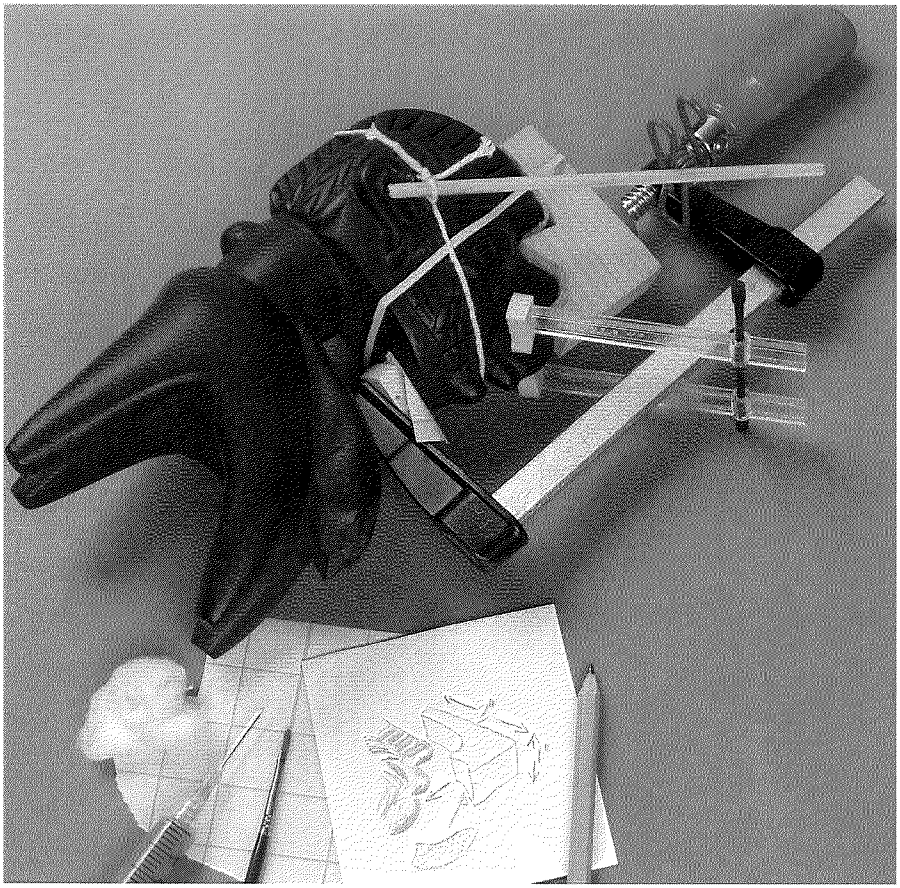

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Preface

The authors have worked in museum object conservation for many years — repairing, restoring, and preserving a wide range of cultural objects made of all kinds of materials. During this time we have encountered many challenges in holding things together while adhesive cures or sets, or while objects are restored to their original shapes. Some solutions have been variations on old established techniques; others have been completely new. After delving into our own experience and discussing the subject with many of our colleagues, we have discovered that a wealth of techniques have been developed. Yet very few publications deal with this critical requirement in the depth and detail it deserves. Perhaps the techniques are regarded by some of their practitioners as mere steps on the road to the successful treatment of a museum object, and thus they don't realize the benefits of discussing them in their own right. However, we feel (and think many practitioners will agree) that it is important to air this subject, providing information to others and encouraging feedback for the benefit of all of us. In addition, we feel the information we possess deserves a wider readership than museum workers alone. Model makers, hobbyists, and craftspeople from all walks of life come across the same kinds of problems on a regular basis. They also may benefit from our accumulated knowledge. Therefore, in this book we try to open up the world of gently applied pressure by examining this relatively unexplored topic as fully as possible.

R.L. Barclay
C. Dignard
C.D. Schlichting

Acknowledgements

Once we began preparing this book, it became clear that it would be limited in scope without the input and suggestions of many colleagues, both in the Canadian Conservation Institute and elsewhere. We acknowledge them all, while giving specific thanks to Ed Barclay, Malcolm Bilz, Gordon Fairbairn, John Grant, David Grattan, Fred Greene, Michael Harrington, James Hay, Hildegard Heine, Dale Kronkright, Janet Mason, Tom Stone, Jan Vuori, and Phil White. The ideas presented here arose over many years of work, and exact authorship is sometimes impossible to determine. We ask the forgiveness of any clamping device inventors who have not been fully credited. We would also like to acknowledge the photographic work of Carl Bigras and the publications staff of the Canadian Conservation Institute.

Dedication

We dedicate this book to the memory of Gordon Fairbairn, a furniture conservator who worked at the Canadian Conservation Institute for many years, and who never stinted in passing on his vast knowledge of techniques and approaches to his colleagues and students.

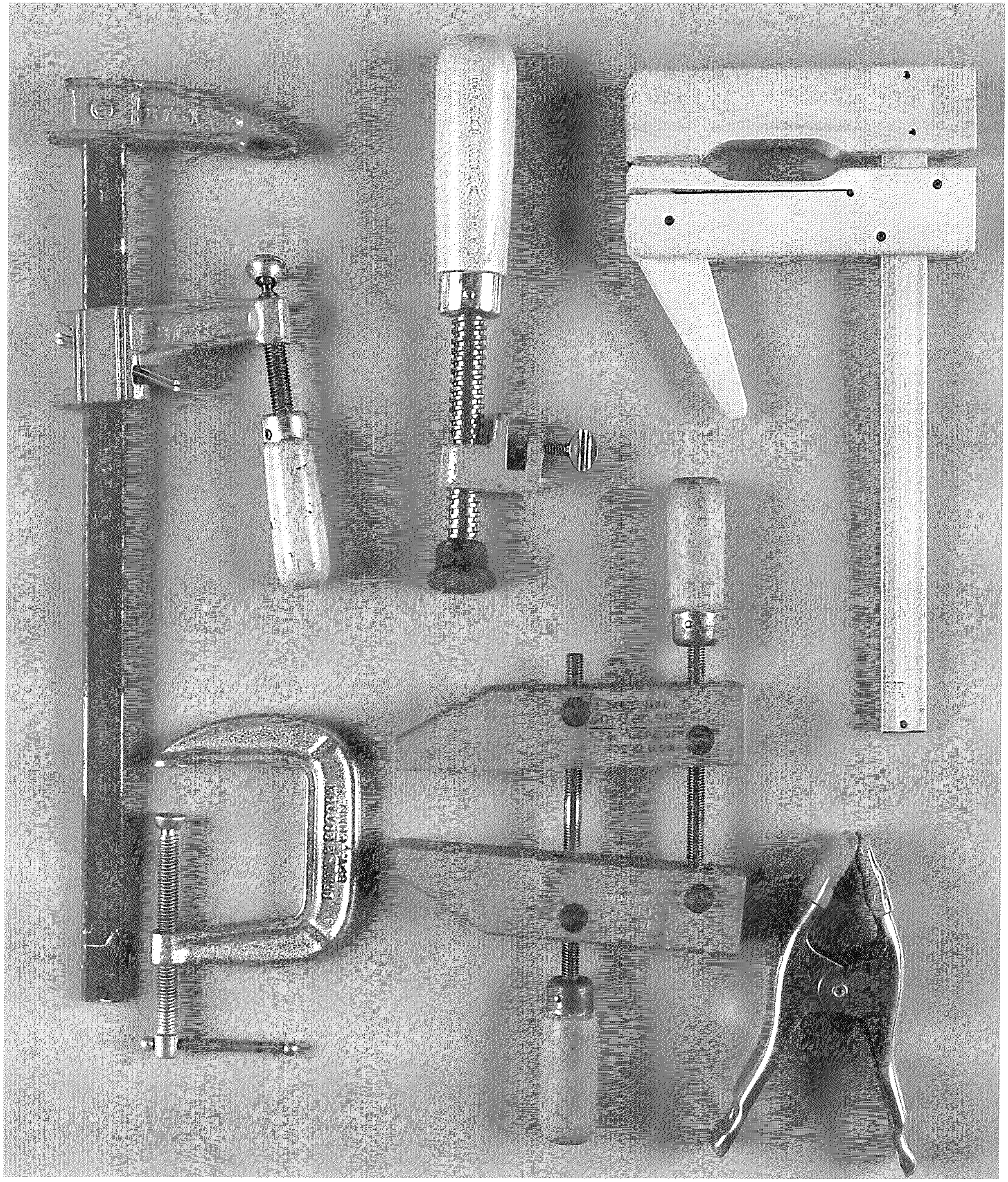
Introduction

The repair and restoration of museum objects frequently requires that broken or detached pieces be re-attached, usually with an adhesive. In fact, this is probably one of the most common remedial treatments carried out on museum collections. Setting parts in position while reshaping is an equally important function in conservation treatment. For example, distorted or shrunken components are often moistened to give them elasticity, and it is then essential to hold them in their proper shape by some means while they dry out.

Many craft magazines, books, newsletters, and other publications discuss and describe clamping techniques, particularly for wooden objects. The range of clamping solutions is as wide and diverse as the practitioners who have described them. A look at the index issues of *Fine Woodworking* magazine, for example, provides some idea of the enormous variety of innovative solutions to clamping problems in woodworking. We have included several basic descriptions and innovative solutions from that magazine in our Bibliography. However, it is not our intention to duplicate any of this material, or to indicate a bias toward any particular method(s) of gluing one piece of wood to another. Rather, we wish to highlight some simple, effective, and innovative methods for all manner of applications and materials where pressure needs to be applied in a gentle and controlled fashion. Having diverse examples and applications under one cover is our aim.

Hardware stores, craft shops, and specialist tool suppliers offer an enormous variety of clamping and holding systems, but sometimes even they do not have quite the right tool. Alternatively, the right tool may exist, but its method of application, advantages, and drawbacks may not be well understood. In this book we try to present as many solutions as possible, and to explore the application and features of a wide variety of systems. Even so, the information we present should be not be considered definitive. Rather, it is meant to stimulate new ideas and adaptations.

We refer in passing to some features of glue joins where they have a relation to the application of pressure, but the discussion of adhesives, their choice, and correct application, are outside the range of this publication.


TRADE MARK
Jorgensen

Multiplying human force

All clamps and other devices for applying pressure rely on some mechanism to maintain, control, and multiply the pressure applied by the user (i.e. gain a mechanical advantage). How much mechanical advantage is gained by a particular mechanism is determined by physical laws. One general concept is that by applying less pressure through a greater distance, one can gain more pressure at a specific point. Take, for example, loosening a bolt with a wrench. As the handle of a wrench gets longer, the force that must be applied to that handle to loosen the bolt decreases, but the distance the handle must travel increases. Using lower force and longer travel also makes it easier to control and fine-tune the application of pressure. A torque wrench is a perfect example of this; the accurate tightening of a bolt is assured by having a long handle, and thus more control.

There are three basic mechanisms for magnifying human force — the lever, the wedge, and the pulley — and all three can be used in mechanical clamps of one kind or another. Two additional mechanisms are air and fluid pressure, and these also work by varying the distance travelled. For example, achieving the same pressure from two air pumps with different-size diameters will require a longer stroke from the smaller-diameter pump than from the larger-diameter one.

Levers — Leverage is the principal way of multiplying force. All levers include a fulcrum, a load, and an applied force, and operate in three possible ways (the three classes of levers) depending on the order of the three elements (Figure 1). The mechanical advantage of levers is determined by the ratio of the distance from the force to the fulcrum divided by the distance from the fulcrum to the resistance.

Wedges — The second method of magnifying force is the wedge, or inclined plane. In simple terms, a tapered wedge driven between two pieces of wood will force them apart (Figure 2). The manner in which this happens depends on the angle of the wedge; a thinner wedge generates more force, but must travel a greater distance. All screw threads are wedges, although this may not be obvious at first sight. If we imagine that the thread of the screw is like a ramp, then we can see that the ramp winds around and up the shaft of the screw. The screw thread is therefore a wedge wrapped around a cylinder (Figure 3). This, of course, provides enormous multiplication of force because the rise is so gradual, and it consequently gives an equivalent degree of control. And unlike a simple wedge, the screw thread can also be used to pull things together.

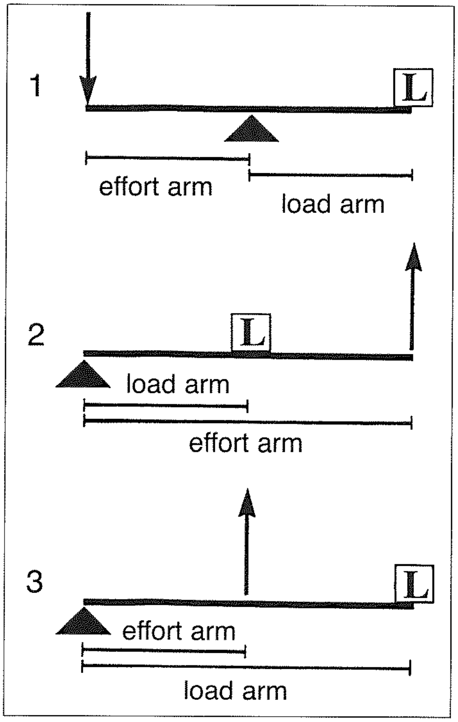


Figure 1. The three classes of levers. Each consists of a load (L), a fulcrum (triangle), and an applied force (arrow); the class is determined by the order of the three elements.

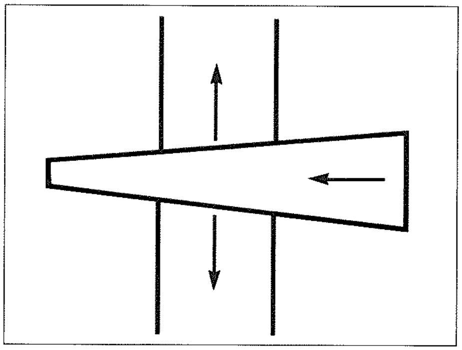


Figure 2. The wedge is a simple inclined plane. The amount of force applied depends on the angle of the wedge. In wood applications an angle between 5 and 10° will provide good force without slippage.

Pulleys — The third method of magnifying force is the pulley. The block and tackle is an arrangement of rope and pulleys found in hoists and "come-alongs" that allows the user to trade force for distance. A pulley is also a useful device for applying a force of a given magnitude in any desired direction.

We can see that many of the simple devices we use for applying pressure are actually combinations of these three basic mechanisms. They can be quite complicated to describe mechanically. For example, in the "c" clamp, the bar one grips to apply force is a lever, while the screw threads is an inclined plane. The band clamp combines the pulley's ability to apply force in any direction with leverage applied by the lever that turns the drum. Band clamps produce the greatest force when the band is almost completely pulled out of the winding drum (see Bands and Rings): the smaller the diameter of the coil, the greater will be the pressure applied by the band (Figure 4). Of course, the amount of pressure applied depends upon the leverage provided by the crank that turns the winding drum. A longer handle will compensate for a bigger drum.

For more information on levers, wedges, and pulleys, see the Center of Science and Industry (COSI) Web page on "Simple Machines" (http://www.cosi.org/onlineExhibits/simpMach/sm1.html).

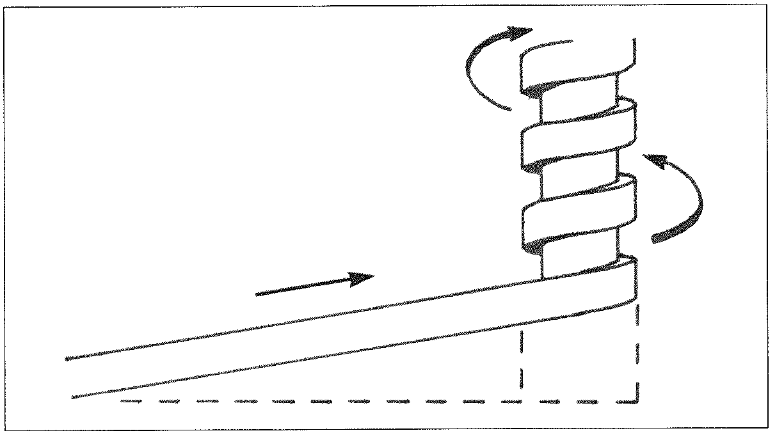


Figure 3. The screw thread is an inclined plane wrapped around a cylinder. Because the incline is very shallow, the force applied is comparatively large.

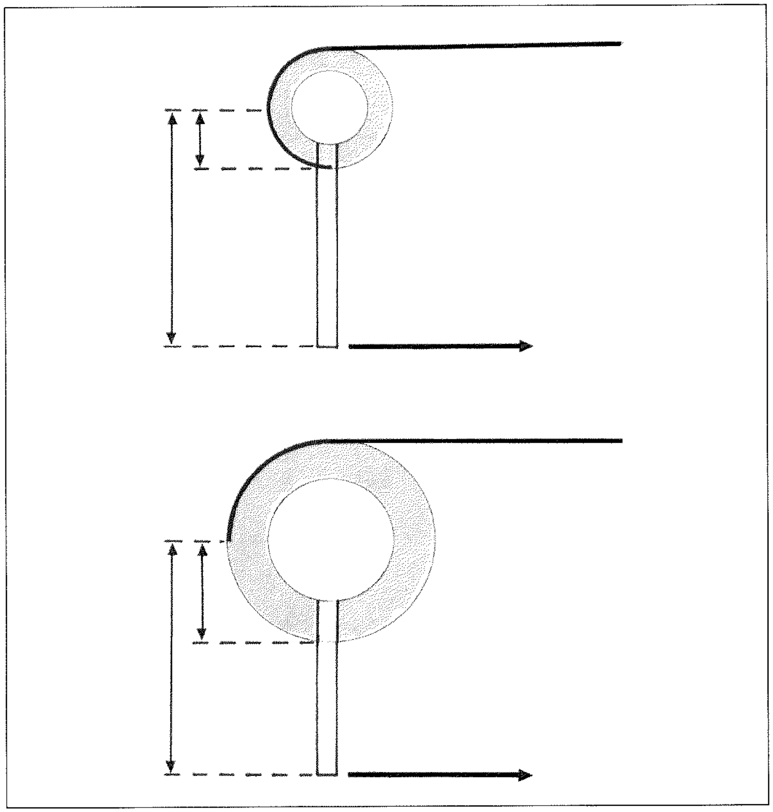


Figure 4. The smaller the coil, the better the lever ratio and the greater the resulting force.

Natural forces

Aside from the pressure applied by the human body to devices of various kinds, four natural forces are useful to us in holding things together: elasticity, gravity, air or fluid pressure, and magnetism.

Elasticity — Many materials are naturally elastic (stretchy), and this property can be used (in the form of metal springs, curved pieces of wood, or stretched rubber bands) to apply pressure.

Gravity — Applying a heavy weight to an object is the most common way to use gravity to exert pressure, and there are several useful expedients to increase the effectiveness of this strategy. Vacuum systems also use gravity (in the form of the weight of the Earth's atmosphere) to apply pressure.

Air or fluid pressure — Air and fluid pressure created by means of pumps can be the basis for some clamping devices. This is an another example of the benefit of elasticity, because it is the elastic properties of air that are being enlisted when applying pressure by means of compressed air. Although this approach is used more in industrial applications (where pneumatic and hydraulic clamping devices are almost universal), there are also some simple applications.

Magnetism — Magnetic attraction can be a very powerful clamping method for thin materials over comparatively small distances.

Distribution of pressure

Compressing materials to make effective glue joins or to give pieces new shapes often exposes them to forces they would not otherwise encounter. Also, because clamps are often placed at discrete locations, pressure may not be evenly distributed over the surface under treatment. This can result in several points of very high pressure surrounded by areas of lower pressure. Assessment of the force to be applied, and its effect on the materials, is essential if overcompression and potential damage are to be avoided. Whenever possible, a clamping method that has an inherently even distribution of clamping force should be chosen. Distribution of forces can be aided by increasing the surface area on which the clamps operate. This can be accomplished by using wide pads and resilient materials, such as softwood, dense rubbers, and plastics, to distribute pressure (Figure 5). Alternatively, shaped pieces known as cauls can be made to follow the contours of the object (Figure 6). Cauls will also help to prevent slippage by redirecting force and preventing shear stresses (Figure 7). Wooden cauls, carved to the shape of the pieces to be joined, are an old woodworkers' standby, as are sandbags, which are often heated to transfer warmth to the area to be formed or joined. Newer synthetic materials can be cast in situ.

Thin release materials, such as silicone-, wax-, or Teflon-coated papers, should be interleaved between all clamps or cauls and the piece being worked on, especially when adhesives are being used. In this way, there is no possibility of the clamping device sticking to the work.

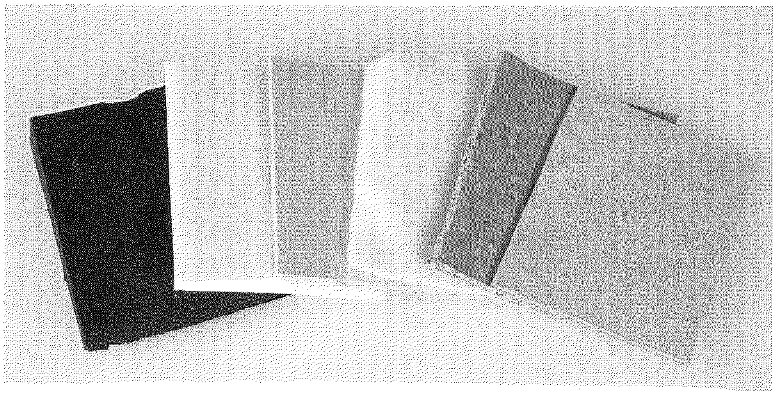


Figure 5. A range of padding materials can be used to prevent damage due to local pressure. Illustrated here are (left to right) rubber, foam plastic, balsa wood, felt, cork, and leather. Many other common materials are also suitable.

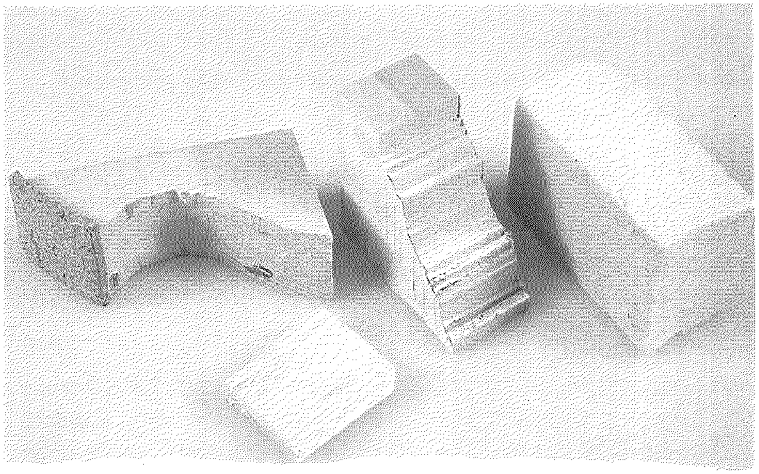


Figure 6. Specially shaped pieces (cauls) are sometimes necessary to ensure clamps conform to the object being joined and pressure is distributed evenly. Illustrated here are wood and foam plastic cauls of various shapes.

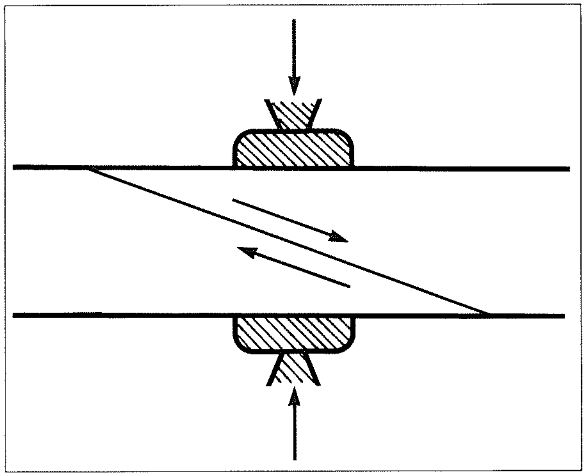


Figure 7. When pressure is applied at an angle, the two pieces tend to slide over each other (this phenomenon is known as shear). It is important to note that shear can operate in all directions, not just the left-to-right one shown here.

Join topography

The effectiveness of applying pressure to a join will depend on four factors:

- how closely the pieces fit
- the condition of the material being joined
- the extent of surface area in contact
- the shear forces

Closeness

Closeness of fit can be assured by careful re-alignment of existing breaks, or by good craftsmanship in making new joining surfaces. Not only does a thinner glue line result in a less obtrusive repair, but it also generally results in a stronger join.

Condition

The condition of the material being joined is an issue with old and decayed objects. It is pointless to make a strong glue join between two components that are so deteriorated that the glue line becomes the strongest part. Deteriorated objects must be assessed for the effectiveness of gluing before anything is done. In some cases, it is possible to consolidate the pieces before gluing to make them more durable, but that is an issue outside the scope of this book.

Surface area

The extent of surface area in contact is dictated by the nature of the object and the topography of the join. In cases where the materials to be joined offer only a very small surface area in comparison to the load they are expected to bear, it may be necessary to add dowels, pins, wires, or other strengthening devices. Again, this is a topic that goes beyond the subjects under discussion here.

Shear

Another important aspect of join topography is shear. It is very rare to be able to clamp a broken join exactly at right angles to the break. Often the only direction in which the clamps can be applied is far from the best angle to apply force. In this case, force is dissipated by shear. Instead of coming together evenly, there is slippage and the pieces move past each other like wedges (Figure 7). Also, the glue itself may act as a lubricant, causing the pieces to slip even more. This feature is often encountered when gluing two new pieces of wood together; once the clamps are applied, the pieces often slide in relation to each other until the excess glue is squeezed out. Countering shear may involve many strategies; one example is illustrated in Figure 8.

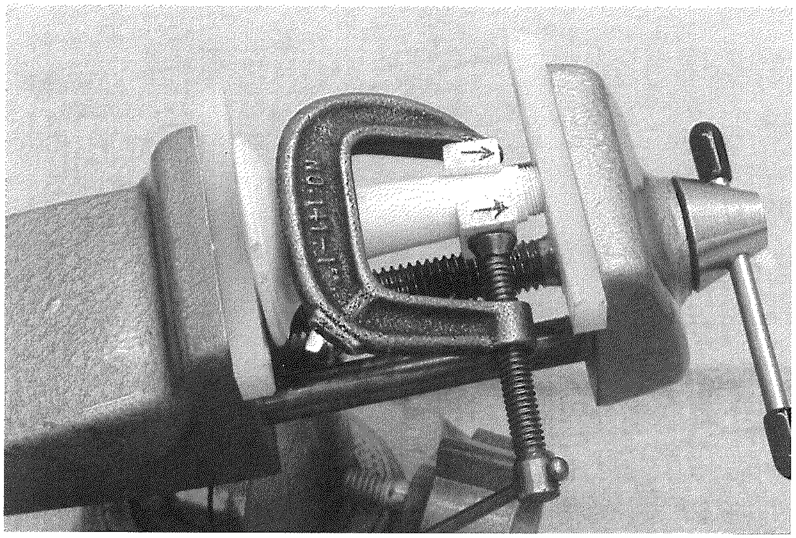


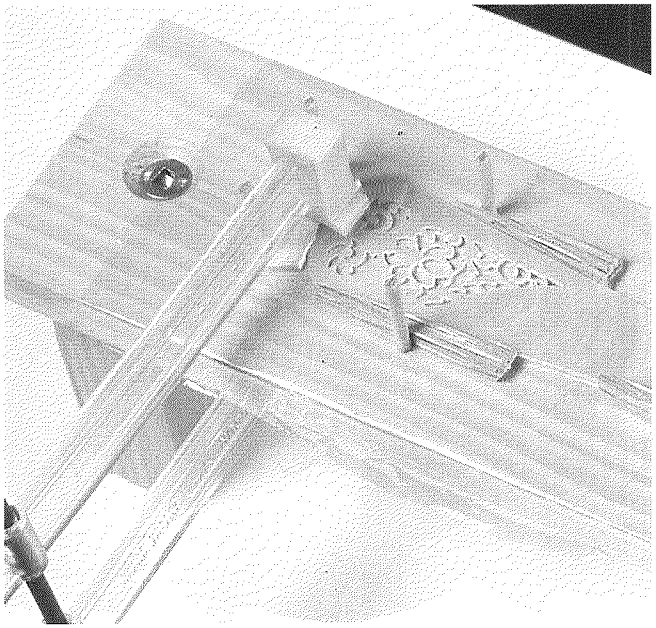
Figure 8. The crack in this ivory object is being compressed with a small "c" clamp and two shaped wooden blocks, which generate shear at right angles. To counteract these forces and prevent them from causing damage, the object is held in a vise.

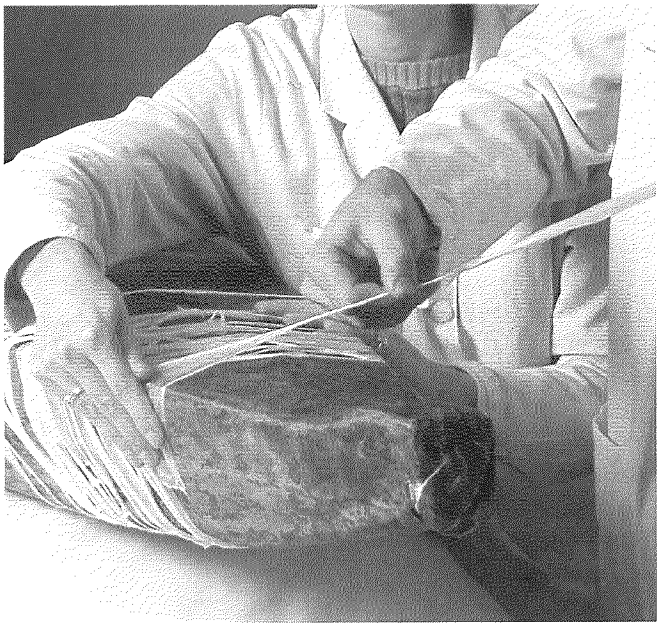
The dry run

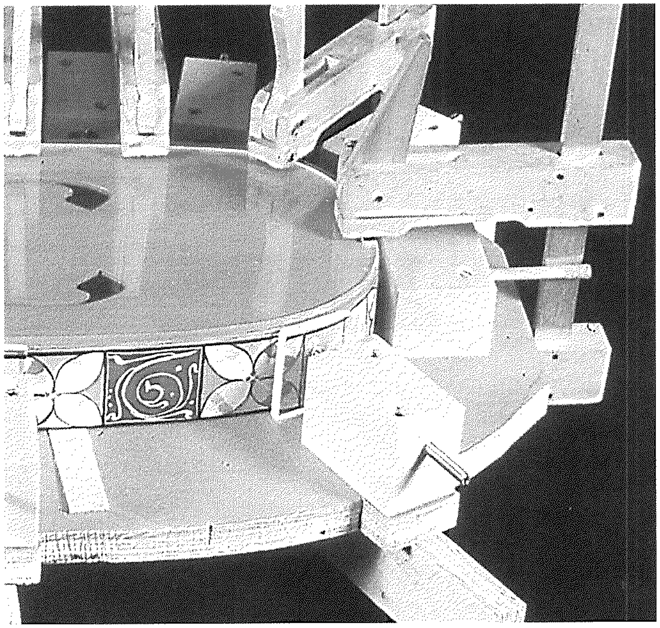
The importance of conducting a dry run before making a join cannot be emphasized enough. When things get really complicated (as will be seen in some of the following examples), it is necessary to establish control over all aspects of the job. The last thing one needs is to be juggling various components and making adjustments to the technique while the glue is in place and drying. All the idiosyncrasies of the technique must be understood and dealt with before any adhesive is introduced. Also, the dry run is exactly what it says it is. When the glue is applied, the dynamics of the situation change. Because fluid glue can provide a measure of lubrication, what appeared to be a secure clamping system when dry may show slippage and misalignment when the glue is in place.

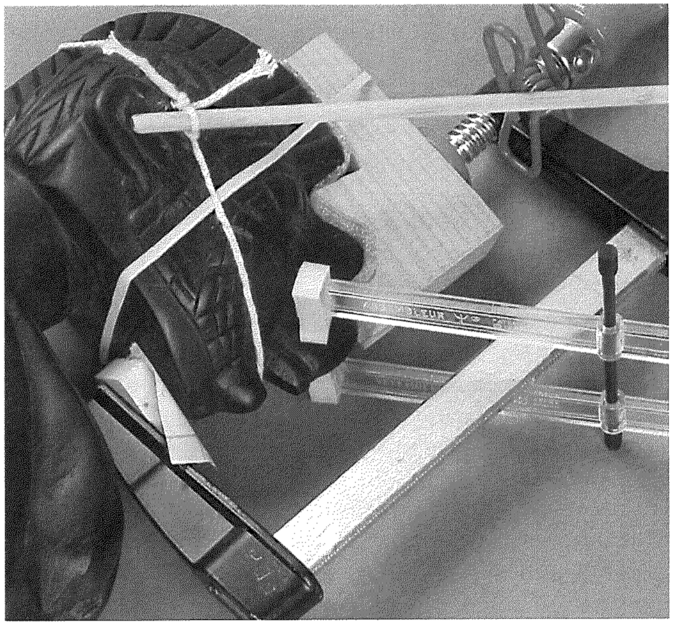
It is a good idea to start out with a variety of quick-adjusting clamps (cam, squeeze, spring, etc.), even if screw clamps will be used to complete the job. It is easier to set things in place with the quick-set clamps first, then apply the screws if and when more pressure is required. This also helps to counter slippage. As the glue begins to set, or as some of the moisture is absorbed by the wood, it tends to become less slippery and the joins are less inclined to slip under the relatively low pressure of the quick-set clamps. After the whole join is held together with however many clamps, then the lower pressure clamps can be exchanged for a more powerful type. This is usually done by applying the more powerful clamp next to the lesser, in situ. As a result, there may be several different types of clamp in place.

It is difficult to provide specific guidelines for complicated clamping situations, except to warn of these potential problems and to remind the operator to anticipate adjustments. Unless one is very familiar with the join problem at hand, and the adhesive used for the repair, it is safest to anticipate movement in directions at right angles to the applied pressure and to prepare methods of securing the join in both of these directions.









Hands

In many ways, hands are ideal clamping devices. Evolution has provided us with a sensitive, versatile, and powerful system for most tasks (Figure 9). However, while very flexible and adaptable, hands do lack the power of most mechanical devices and they do tire with sustained use. Even with these disadvantages, hand pressure may be all that is needed to make an effective join. Two factors must be considered: the pressure needed to make the join and the time required for the adhesive to set fully (or at least to meet the clamping time requirements for the chosen adhesive). If light pressure is all that is needed and setting time is quick enough, hands should be considered. A dry run is obviously called for in this situation. Estimate the time it will take for the glue to dry, and then hold the two pieces together with the required pressure for that time and beyond. The point at which it becomes too painful to continue should be well beyond the setting time of the glue. And bear in mind that it is not possible to change hands halfway through without compromising the strength of the join. Figure 10 shows the adhesion of quills using B-72 film activated with acetone; pressure is applied using a finger.

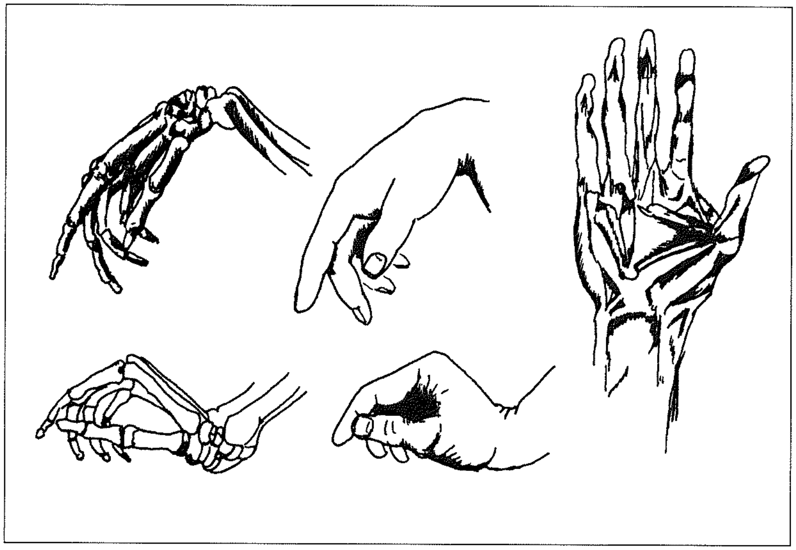


Figure 9. The hand is a marvellous natural clamping mechanism. (Drawing after J. Bracsay, Anatomy for the Artist.*)*

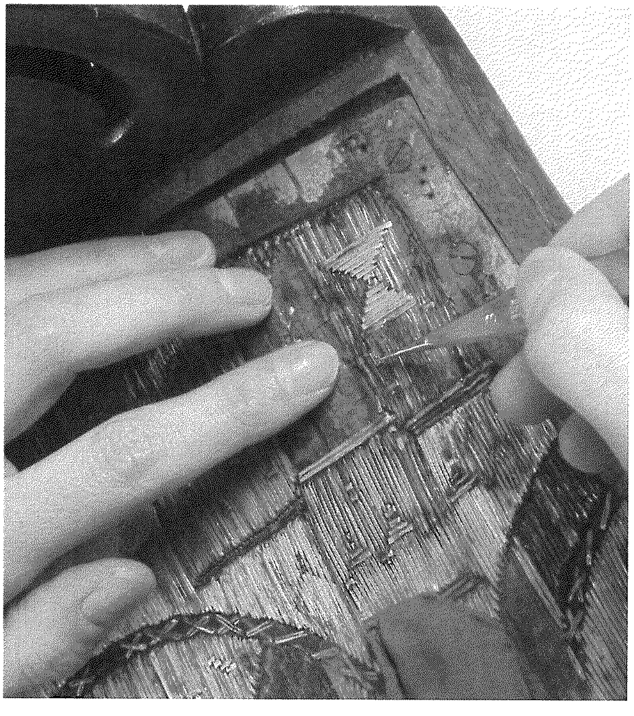


Figure 10. Adhering quills using finger pressure. A small slip of B-72 film is inserted under the loose quill, activated with acetone, and held under pressure until dried.

Screw threads

Clamps based on screw threads are undoubtedly the most well-established method of applying pressure, and the "c" clamp is the universal symbol for squeezing things together. Screw clamps are available for almost any application, but we can illustrate only a few here. However, the principle is the same for all of them (Figure 11). A screw thread is used to apply pressure to a small area, and the rotary motion of the screw is converted to linear motion by the use of a swivel head (Figure 12). Because of its power and weight, the screw clamp is the riskiest method of clamping — providing the greatest opportunity to damage a surface being repaired or a newly made piece. For this reason cauls and pressure pads are extremely important. For advice on a wide range of clamps and their applications, articles such as Maas (1994) are indispensable.

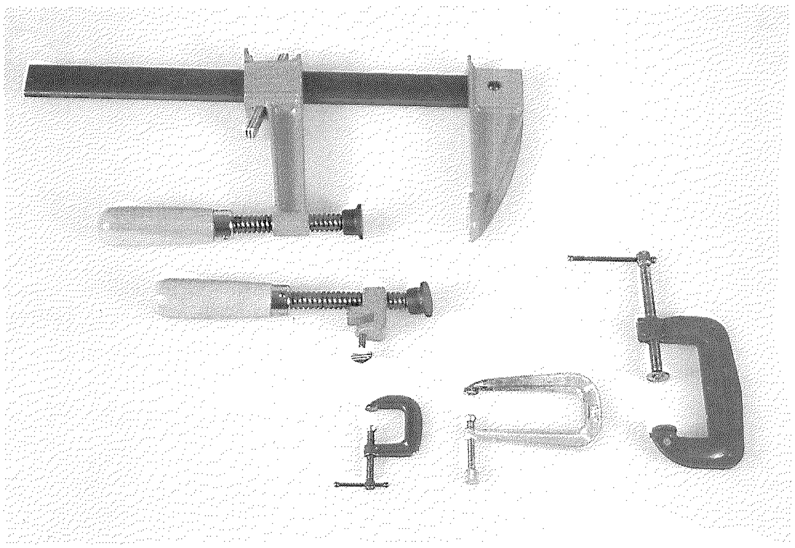


Figure 11. A small selection of the many variations of "c" clamps available today. Note the clamp head in the middle of the photo; this clamp can be attached in many different ways.

Figure 12. Close-up of the swivel head of a "c" clamp that converts the rotary motion into linear motion. These heads should be kept well lubricated with grease.

Figures 13–16 illustrate both the versatility of screw clamps and the creativity of their users. Figure 13 shows the application of individual clamp heads to a deteriorated log; Figures 14 and 15 show the repair of a very complicated break on a sculpture; and Figure 16 shows the use of threaded rod in custom-made clamps.

Clamp heads are also produced for screwing onto the ends of 1-in. black steel plumbing pipe. Their screw threads match the pipe threads used for joining sections in plumbing applications. Although driven by screw heads, these clamps also rely on the springiness of the steel for some of their effect: as the screw is tightened, the pipe bends out of a straight line. This is not a high-quality clamping system, but it is useful, cheap, and very versatile in its application to larger clamping problems.

Figure 13. Loose pieces of a fossilized log from Axel Heiberg Island in the Canadian High Arctic were re-attached using clamp heads adapted to apply pressure at adjustable angles.

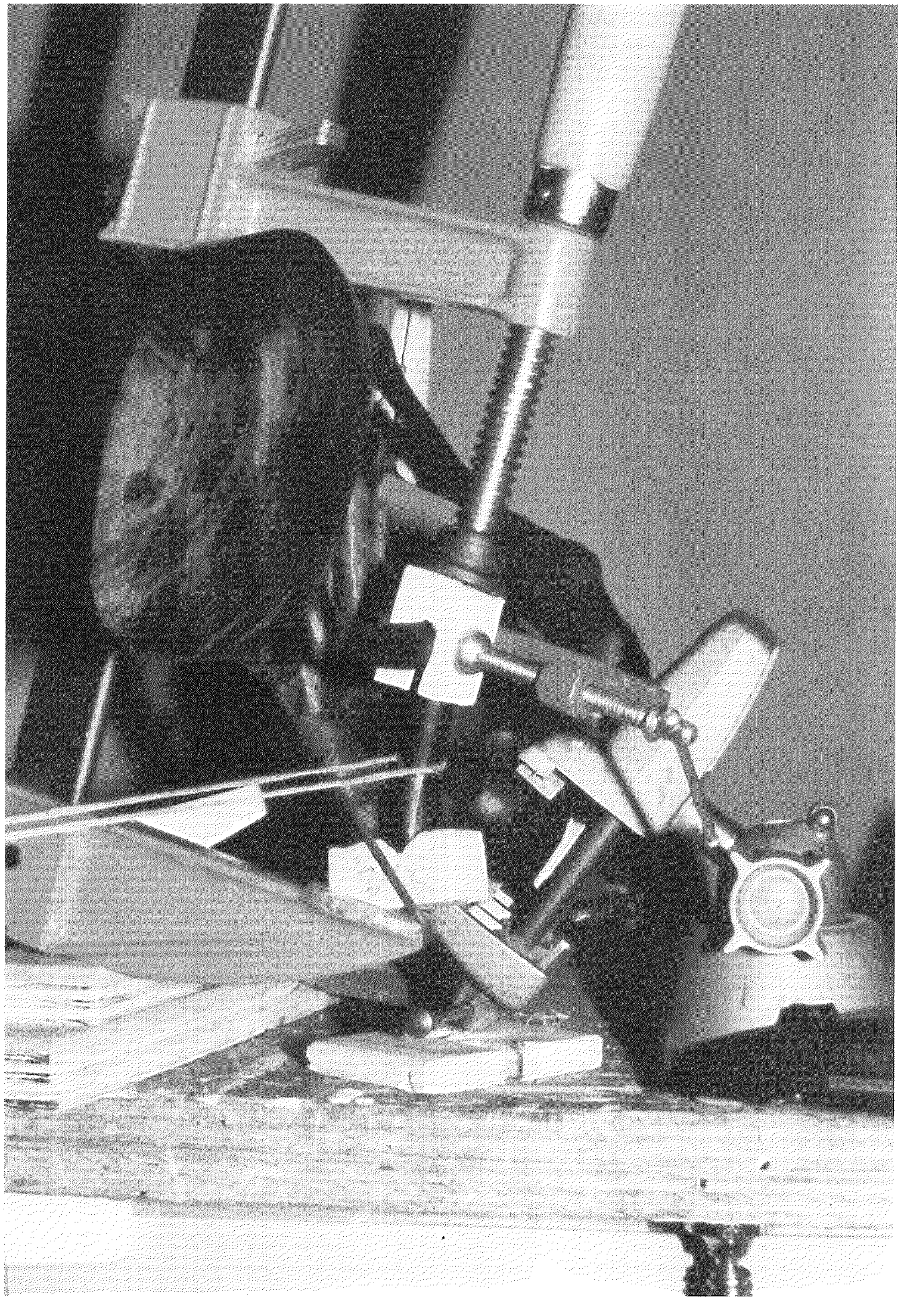


Figure 14. Re-attachment of the broken pieces of this African sculpture required a combination of clamps, a bench vise, string, and elastics. This example highlights the amount of time and ingenuity that are sometimes required for setting up a gluing job.

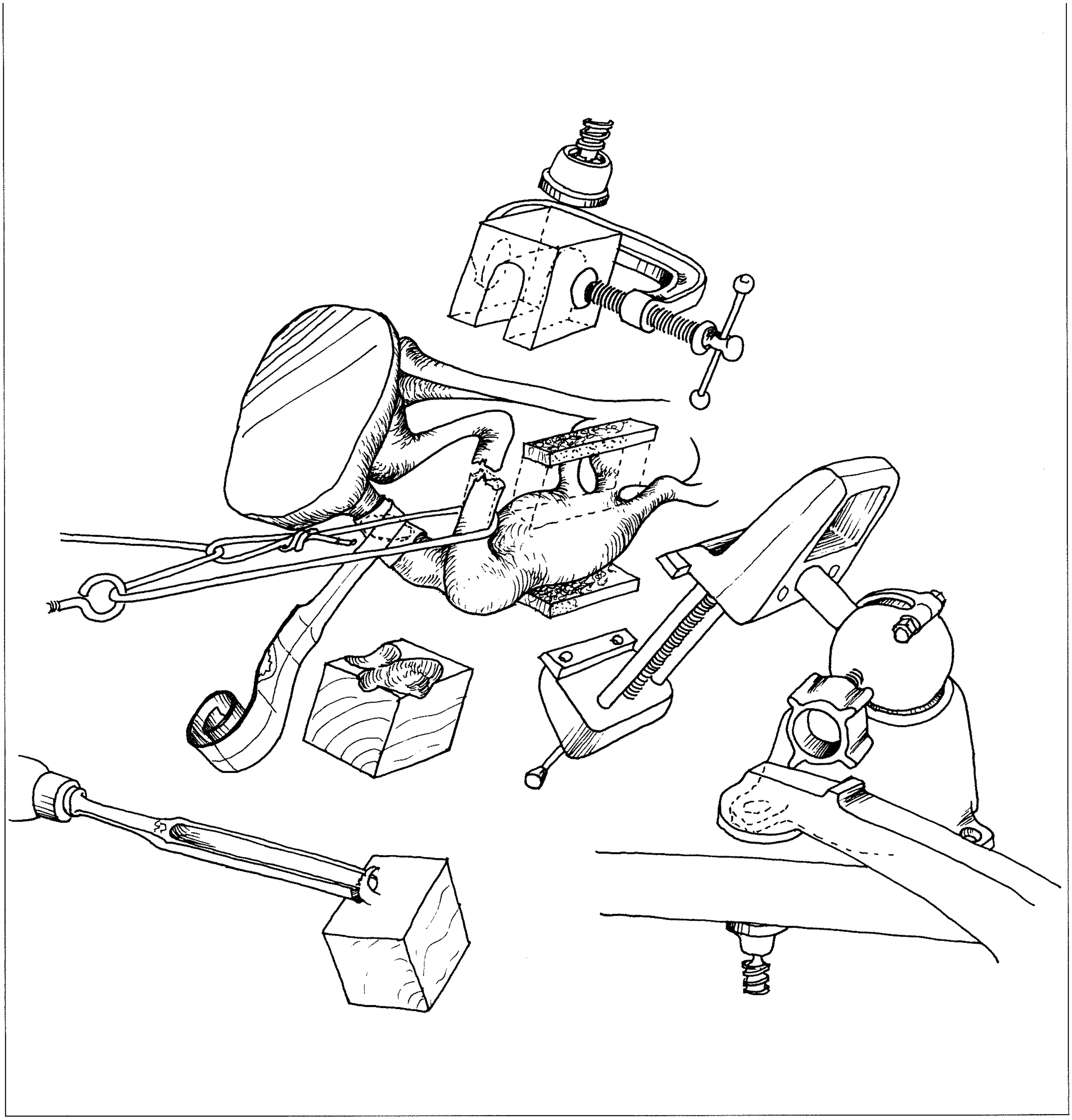


Figure 15. Schematic drawing of Figure 14. Note the intricacy of the carved wooden cauls.

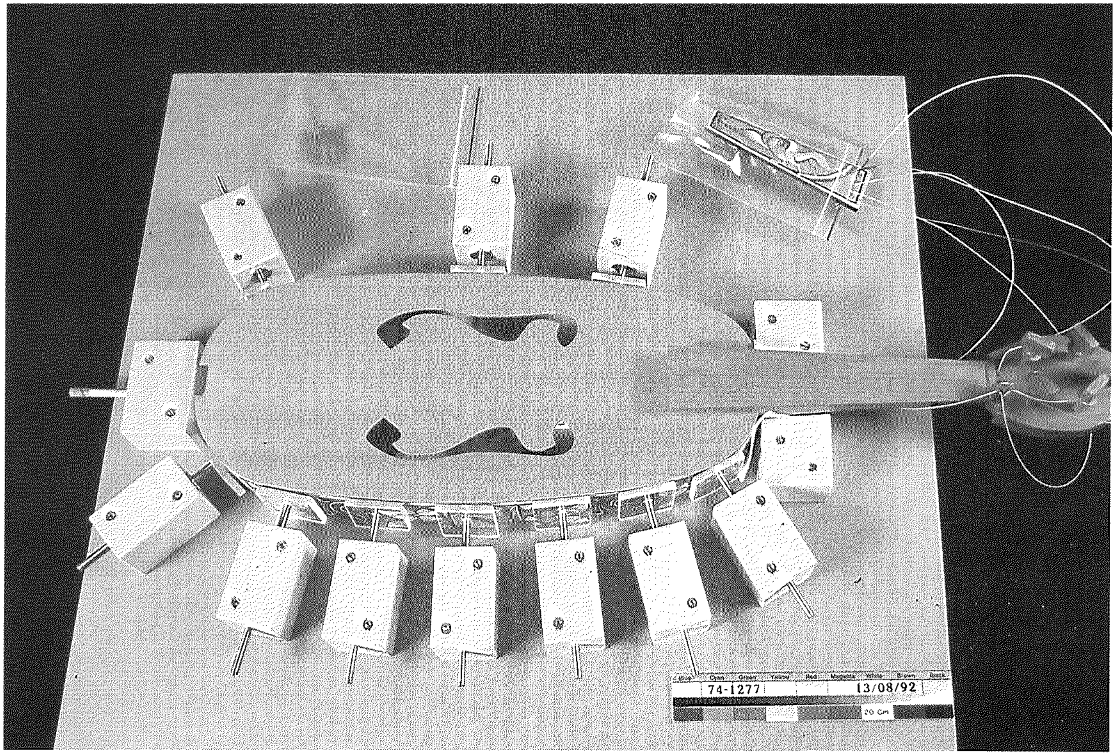


Figure 16. Threaded rod was used to make these clamps to apply pressure during the construction of a reproduction medieval fiddle. (Courtesy of the Canadian Museum of Civilization, #74-1277.)

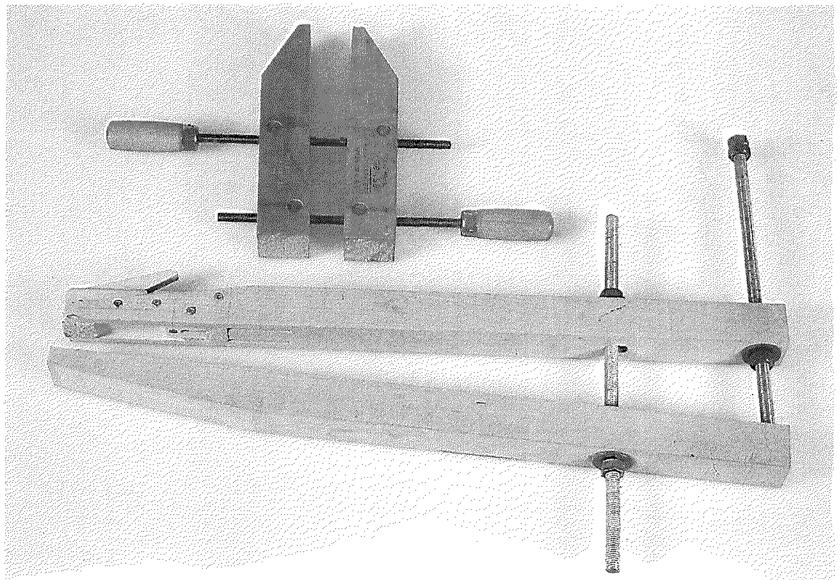


Figure 17. The handscrew at the top is typical of those used for woodworking applications. The one at the bottom is a homemade variation that includes a cam clamp; this was made to reach into a tight corner.

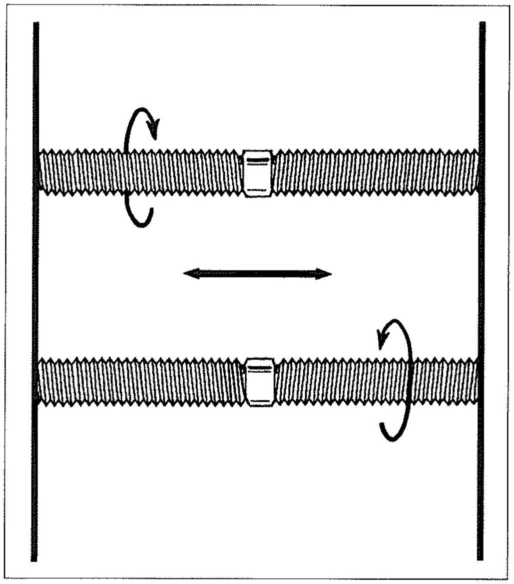


Figure 18. Handscrews use left- and right-handed threads on each spindle.

A variation on the standard screw clamp is the wooden handscrew (Figure 17). This type is characterized by its two screw shafts, each having left- and right-hand threads. When the handles are turned, the jaws move away from, or toward, each other relative to the centre of the screw (Figure 18). The jaws can therefore be moved twice as fast, which is convenient for hurried hot glue joins. The jaws can also be made to meet at an angle, rather than just parallel to each other, which is very useful in some applications.

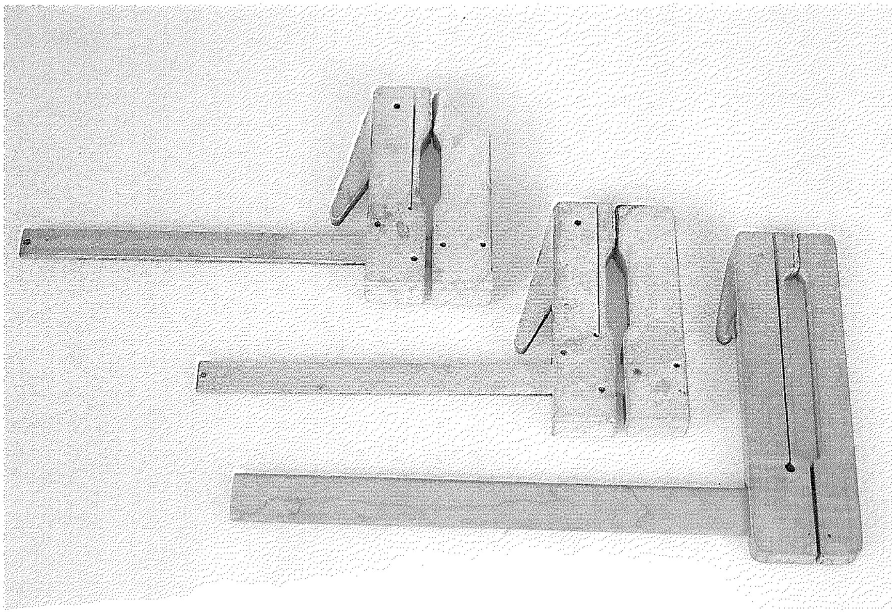


Figure 19. Cam clamps. The one in the middle is typical of the clamps available from various manufacturers. The one at the top has had its jaw cut away for better access. A small pad of foam plastic can be inserted to cover the metal bar on the inside to prevent scratching if it touches the piece being clamped. The lower clamp is handmade entirely from wood; it is suitable for lighter applications.

Cams

Cam clamps arose from the German woodworking tradition, and have now become the preferred tools of many cabinetmakers and restorers (Figure 19). Mechanically, the cam is an inclined plane wrapped around a circle (Figure 20). Cam clamps have the advantage of comparative power, but within a set limit because they cannot be overtightened. Eventually one reaches the end of travel of the cam, usually within 120° or so of rotation. Cam clamps can be applied and removed very quickly (often with one hand) and, because most of them are made of wood padded with cork, they are less damaging to delicate surfaces than many other types of clamps. However, caution is necessary when using a cam clamp because the pad upon which the cam acts increases its angle of contact as the cam rotates and pressure is applied. This concentrates pressure on the front edge of the pad and can cause damage if not anticipated. The principle on which these wooden clamps are based has now been applied to metal clamps as well, which have the advantage of greater durability. Figure 21 shows the application of cam clamps to the fiddle seen in Figure 16.

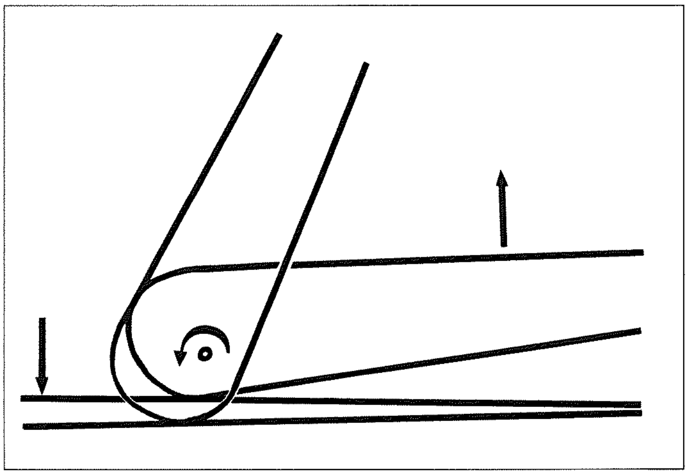


Figure 20. Cam clamps use the principle of the inclined plane, but wrapped around a circle. The amount of pressure that can be applied is self-limiting as the lever runs out of cam after turning about 120°.

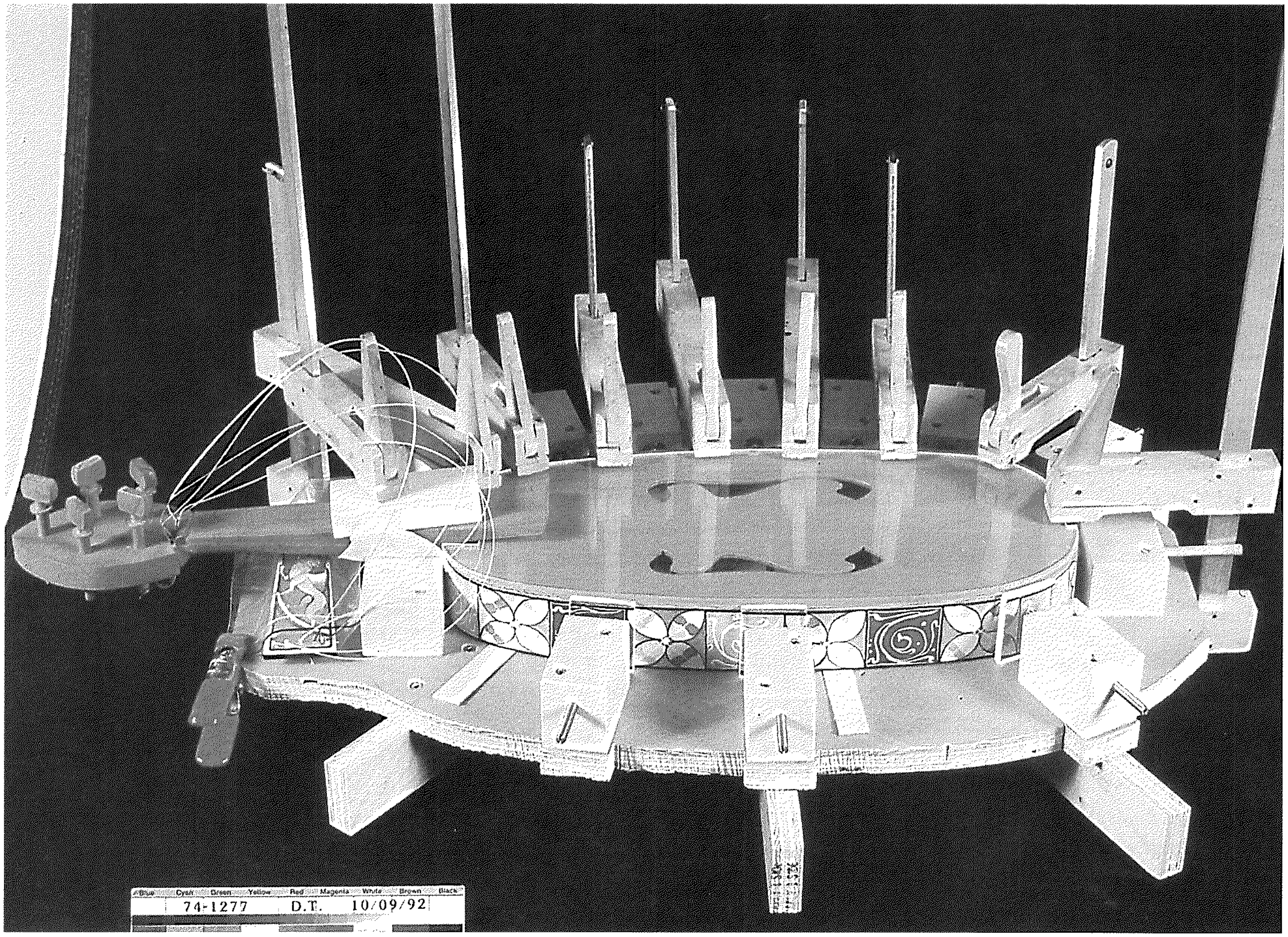


Figure 21. The application of cam clamps to the fiddle described in Figure 16.
(Courtesy of the Canadian Museum of Civilization, #74-1277.)

Squeeze and lock

This class of device covers a wide range of clamps where the screw principle has been replaced by some form of locking lever. The idea is to apply pressure by multiplying the force of the hand, and then prevent the pressure from being lost once the hand is released. One squeezes to apply pressure, then the jaws are prevented from slipping back. The advantage of this kind of clamp is the one-hand application — which is very useful when juggling several components (Figure 22).

Visegrip pliers are one form of squeeze and lock clamp. They are available with a range of specially shaped heads but are mostly used where great power is needed, particularly when working with metals. The leverage provided by the handles multiplies the grip of the hand considerably, and, coupled with the hard jaws, these devices can

Figure 22. Many clamps make use of the squeeze and lock principle. Shown here is one of the more popular kinds.

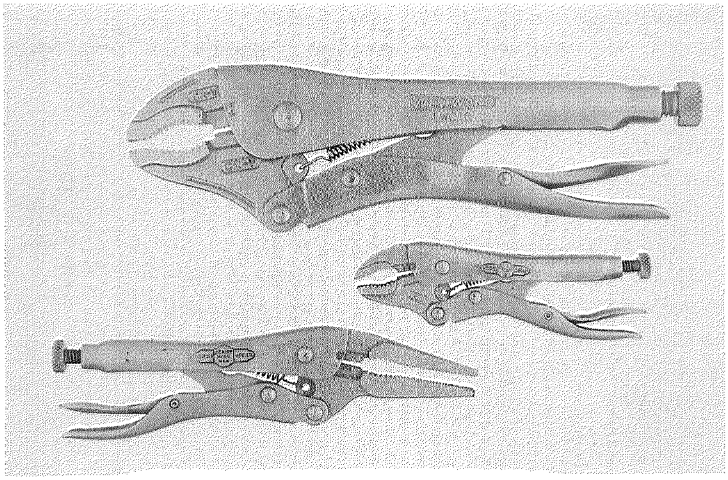


Figure 23. Visegrip pliers come in a wide range of sizes and many different shapes. [Note: Visegrip is a trade name that has become a generic description.]

easily cause damage (Figure 23). Surgical haemostats use the squeeze and lock principle, but because of their small surface area, even they can damage delicate surfaces.

Another variation on this type of clamp is the so-called toggle clamp. As with the Visegrip application, the initial clamping width is set by an adjustable screw and then a lever is thrown to apply the full force. Hoffman (1992) illustrates a wide range of commercial clamps that use this principle.

Springy materials

Clamping systems based on springs use the natural elastic memory of materials to apply pressure. Although some materials that can be deformed easily do not return to their original shape, others spring back readily to the shape they had before deformation. Materials in the latter class are useful in many spring applications.

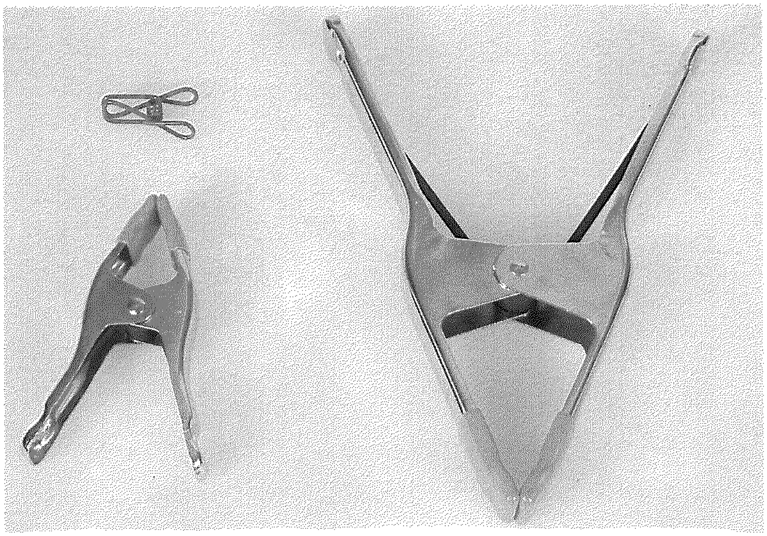


Figure 24. Spring clamps were traditionally used by welders, but with soft jaws, they are suitable for a wide range of applications. Also shown (top left) is a small clamp made of wire that is coated in plastic.

Metal springs are found in typical welders' clamps, which come in a wide range of sizes and shapes (Figure 24). A coil spring is wrapped around the pivot pin and sprung between the inside of the jaws (Figure 25). These clamps often have resilient plastic tips that minimize damage to sensitive surfaces. Alligator clips for electrical work use the same principle (Figure 26). A variation on this theme uses two alligator clips on adjustable arms. This devise is used primarily for fine soldering jewellery and electronics; it is good for positioning components, but not necessarily for applying pressure (Figure 27).

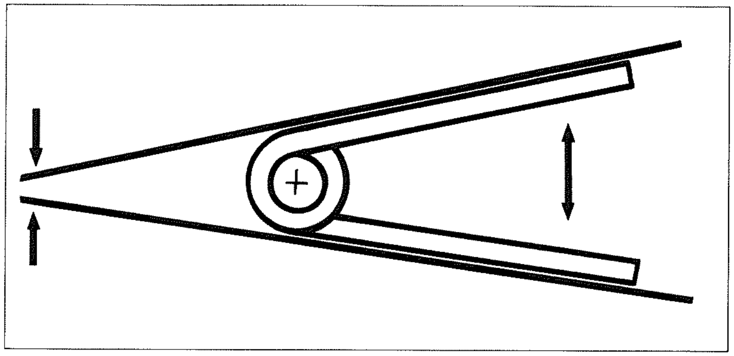


Figure 25. The spring in this typical welders' clamp is coiled around the fulcrum and bears upon the inside of the handles.

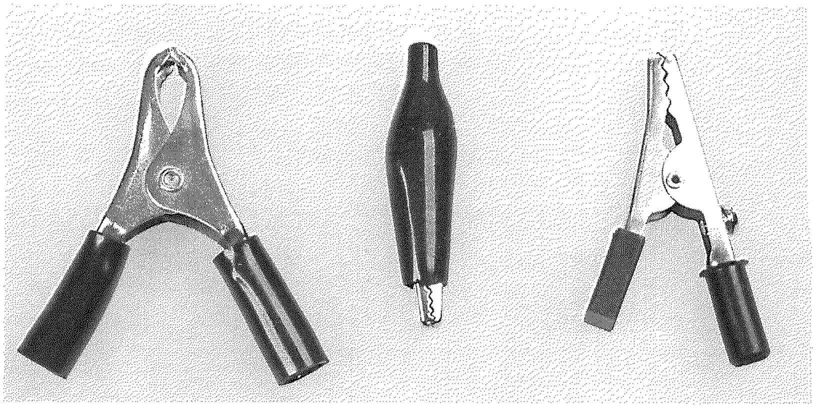


Figure 26. A range of alligator clips. These are made for electrical and electronic applications, but can be useful for holding many different things together.

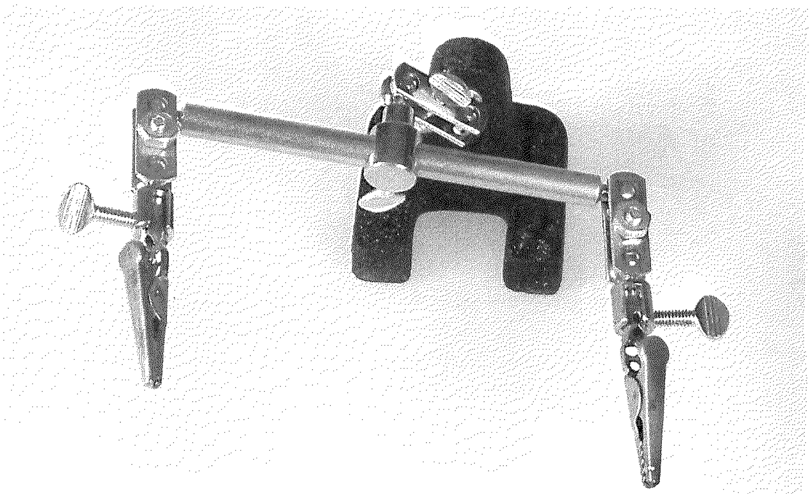


Figure 27. This device is used for positioning components during assembly. It is not suitable for applying sustained pressure.

Spring wire corner clamps (manufactured by Ulmia) are useful for holding mitre joins together while gluing. Squeezing the handles of the applicator opens the clamp, which is then placed on the corner and released (Figure 28). Various thicknesses of wire spring are available.

Spring clamps based on the same principle as alligator clips, but made entirely of spring wire, come in a variety of sizes. Given a supply of spring steel wire and a little ingenuity, small clamps can be made to suit specific tasks (Figure 29). Spring clamps applied to an Egyptian cartonnage are shown in Figures 30 and 31, and in Figure 32 the same principle is applied to a deteriorated bark basket. Figure 33 shows bent pieces of thin, stainless steel spring wire holding a glue join on a felt hat.

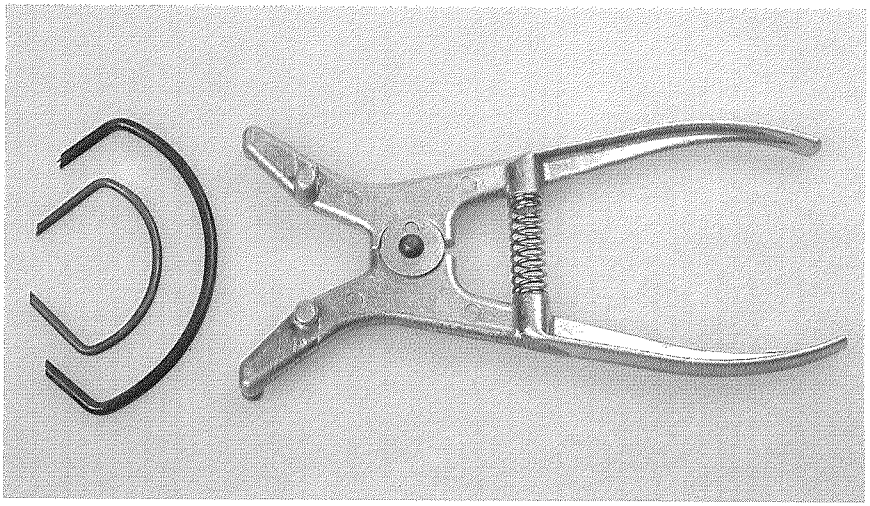


Figure 28. Spring steel corner clamps with the tool used to set them in place.

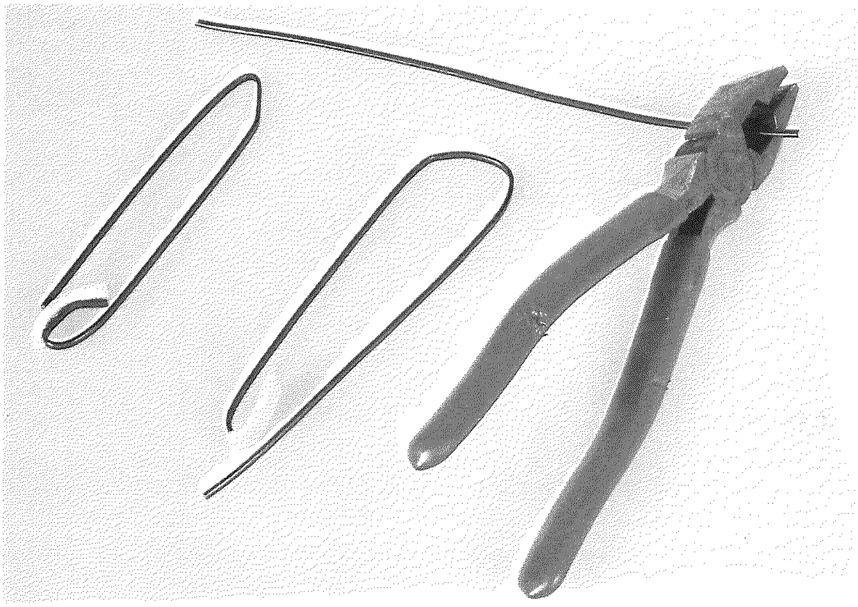
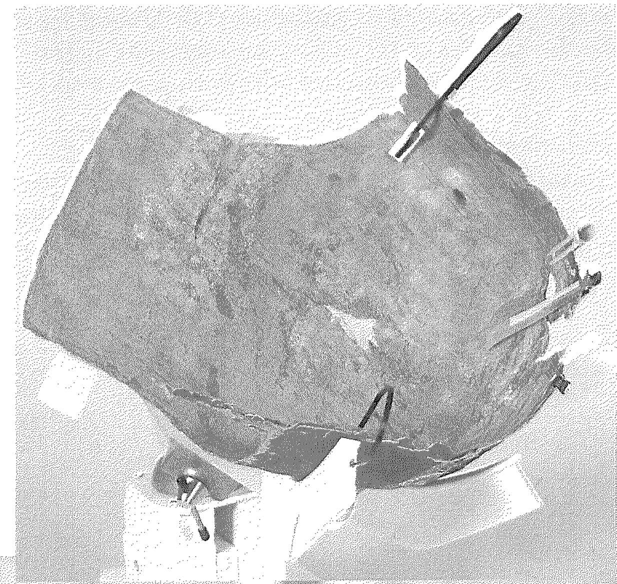


Figure 29. Spring wire comes in many forms, including piano wire. In this case, the wire has been bent and soft foam pads have been attached to the ends with hot glue.

Figure 30. Interior view of the cartonnage shown in Figure 31.



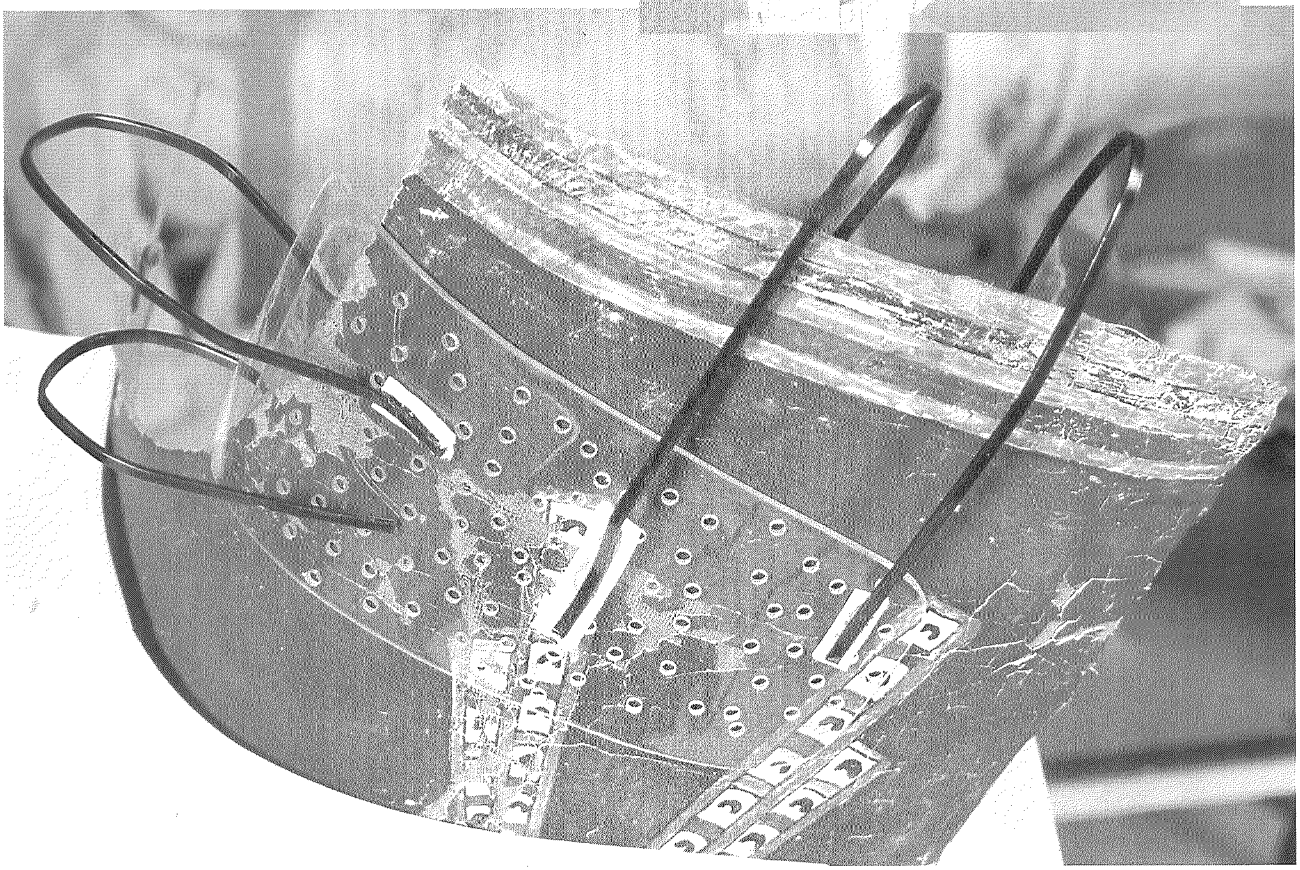


Figure 31. Spring wire is used here to apply gentle, even pressure to a Plexiglas caul used in reforming the cartonnage from the head of an Egyptian mummy.

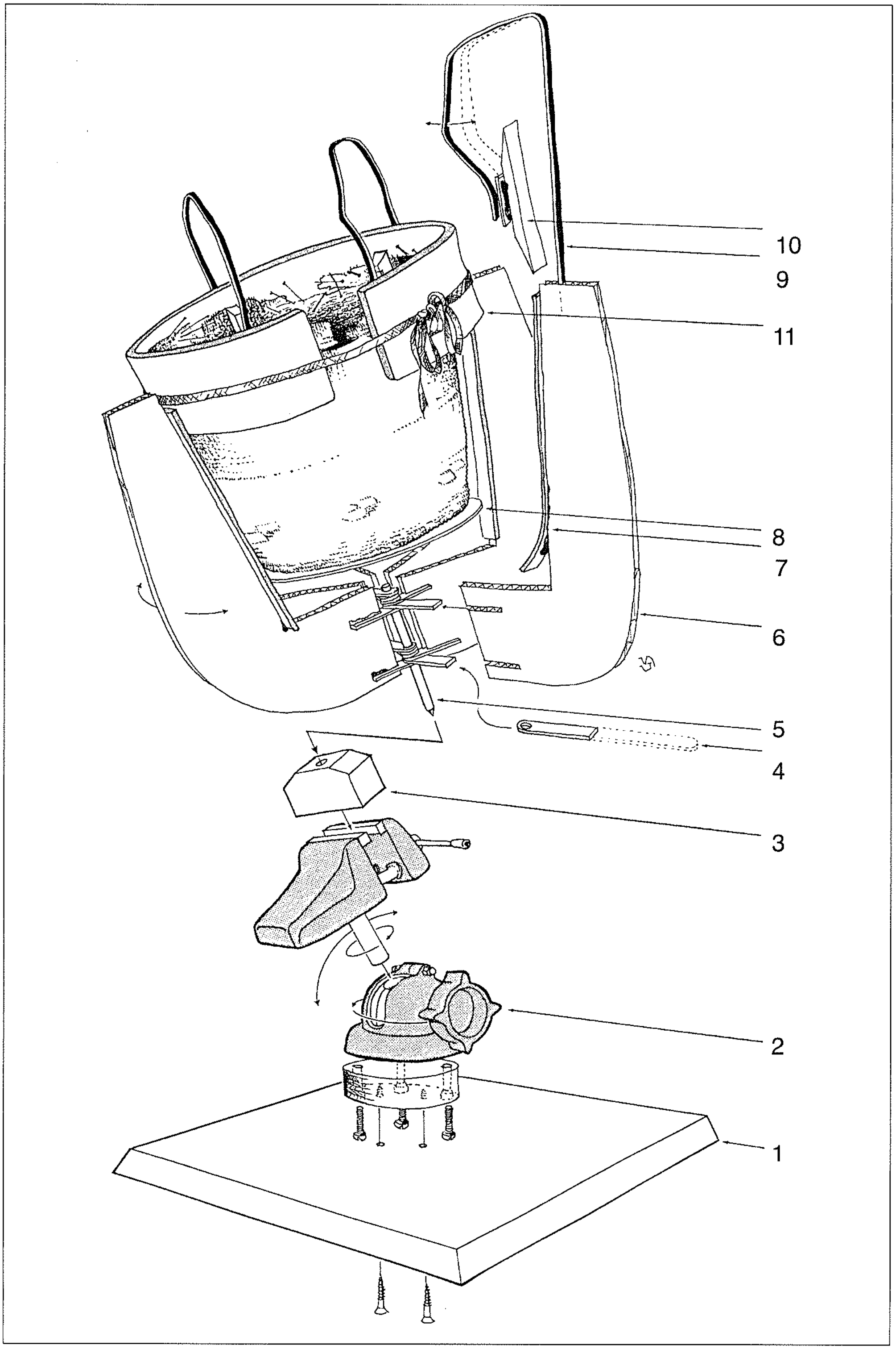


Figure 32. Detailed drawing of a clamping assembly using the same type of spring wire clamp as in Figures 30 and 31. Note how a basket is attached to the mount and spring clamps are used to apply pressure: 1, wood base; 2, universal vise; 3, wood block; 4, wood dowel; 5, flat wood stick (tongue depressor); 6, fluted plastic sheet; 7 and 8, polyethylene foam padding attached with hot-melt glue; 9, spring steel strip; 10, styrene foam pressure pad; 11, polyethylene foam padding attached with linen twill tape. (Courtesy of the Canadian Association for Conservation.)

Other spring-loaded items that can be used as gluing clamps include bobby pins, clothespins, and paper clips (Figures 34–37). Dooley (2002) describes some interesting methods of adapting clothespins.

Spring-loaded tweezers used by jewellers for picking up small items have applications for light clamping situations. Similar devices are available from grocery and hardware stores for picking pickles out of jars (Figure 38).

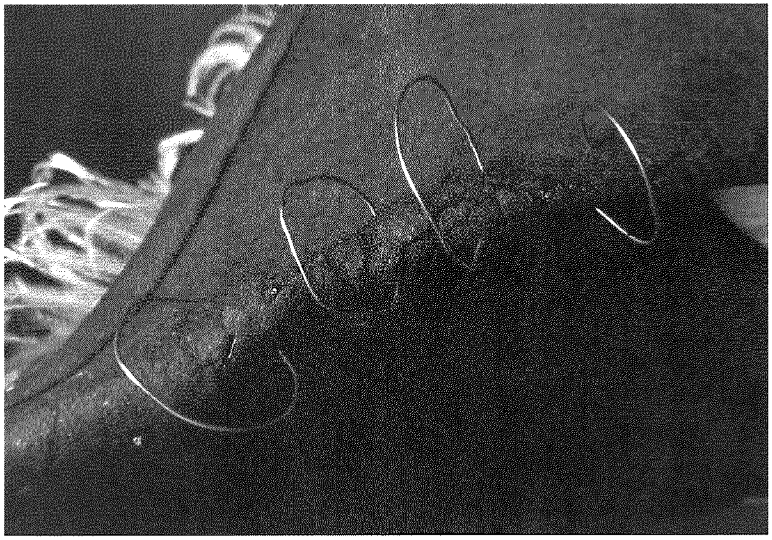


Figure 33. Thin spring wire is used here to apply pressure to a glue join in the felt of a military hat.

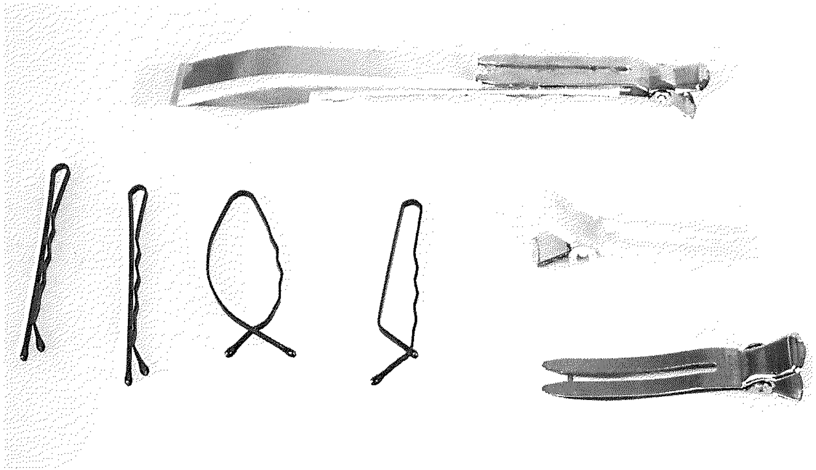


Figure 34. A selection of hairpins. The one at the top has been adapted for a long reach and reduced pressure (remember that by the laws of the lever, as the extension gets longer the force that can be applied is reduced).

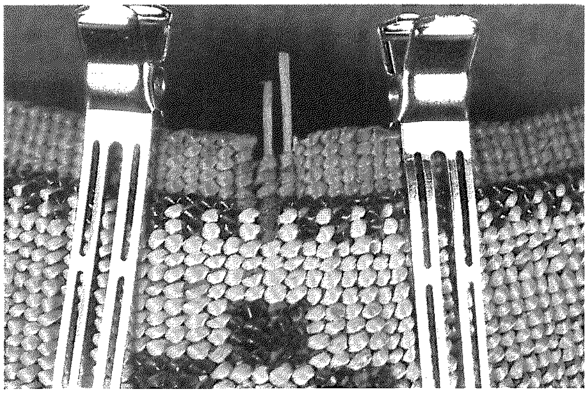


Figure 35. Spring-loaded hairpins are used to align the edges of a basket under treatment.

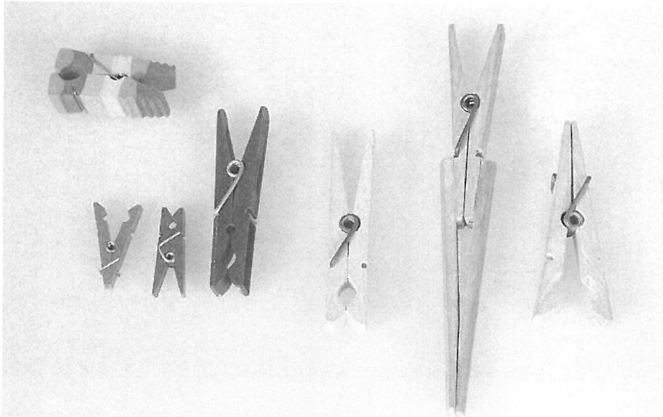


Figure 36. A selection of readily available clothespins. The jaws of the one on the right have been reversed, and the one beside it has been adapted by gluing on longer jaws.

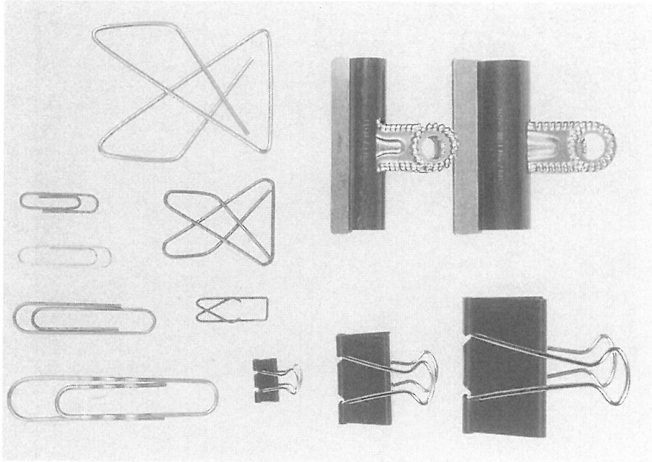


Figure 37. A selection of readily available paper clips. Note the variety of sizes.

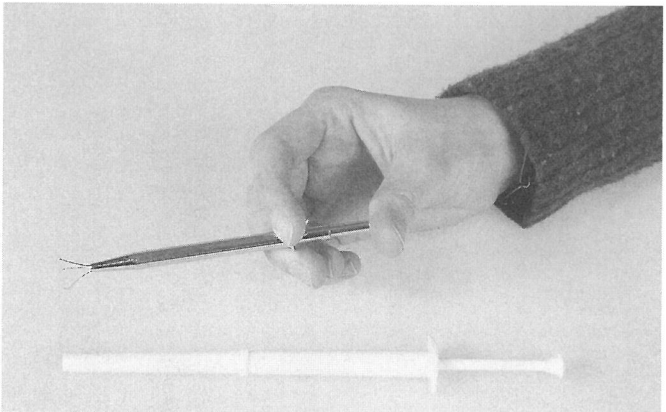


Figure 38. Tweezers used by jewellers (top) and devices for removing pickles from jars have many applications as light-pressure clamps.

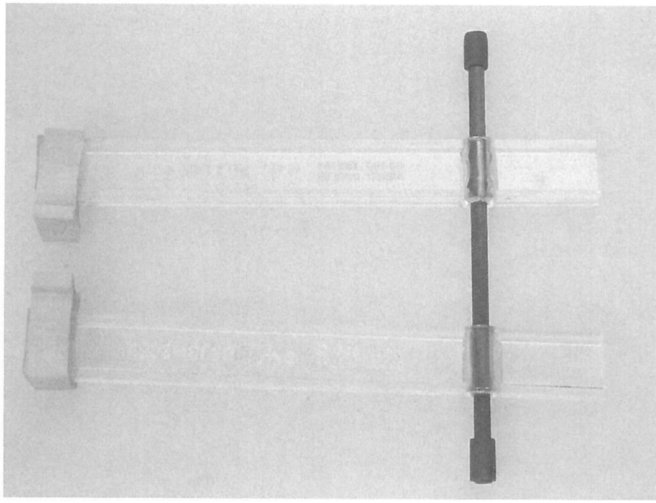
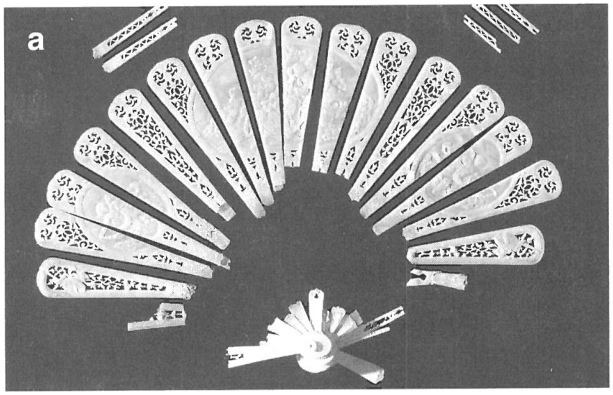
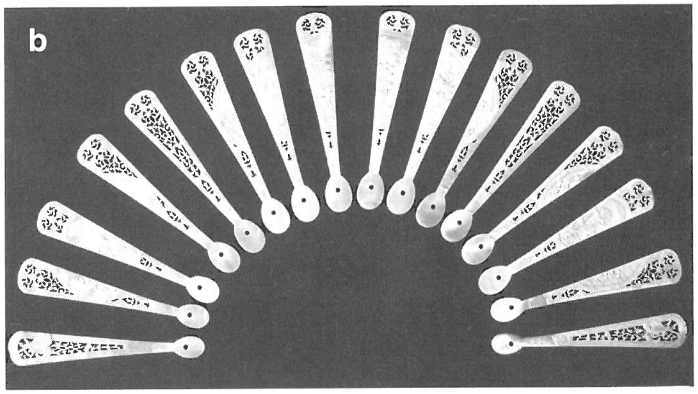


Figure 39. The Berna "Assembleur" clamp uses the springy quality of a carbon fibre rod to provide gentle pressure. Plastic pads help to distribute the pressure evenly.

One unique form of lightweight clamp uses the springiness of carbon fibre rods to provide force. The jaws of the clamp are placed on the object and then tension is applied to the back of the clamp with the fingers, thus bending the carbon fibre rod (Figure 39). (This is a refined miniature of the plumbing pipe clamp described on p. 9.) A fan being clamped with this method is shown in Figure 40. Note the use of small wooden wedges to apply lateral force, and the before and after views of the pieces of the fan. This principle can be used to make similar clamps from spring wire, wood, or a variety of flexible plastics.





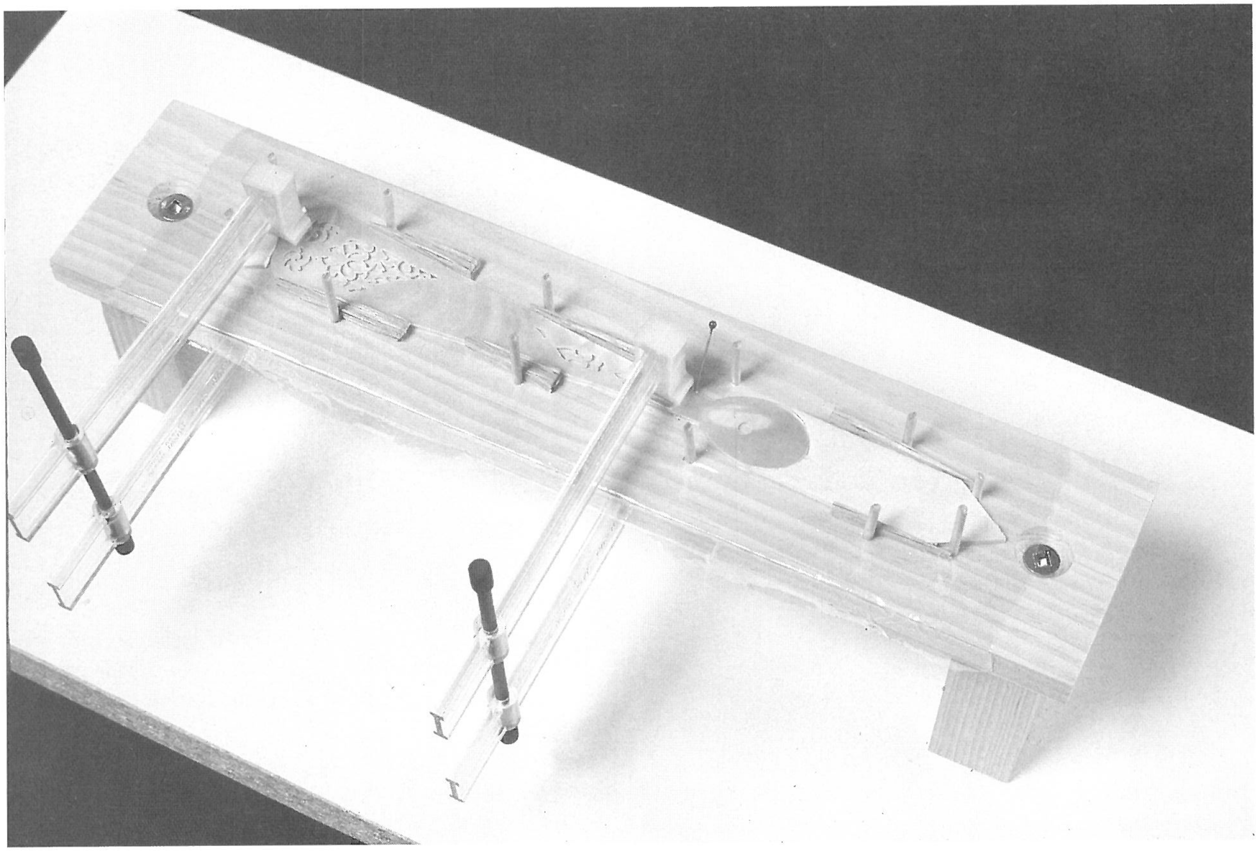


Figure 40. Carbon fibre spring clamps hold the glue joins of the delicate mother-of-pearl arms of this fan in position vertically, while small wooden wedges working against the upright dowels set into the wood base apply pressure from the sides. (a) The fan sticks before treatment. Each one was broken off at its base and some had sections missing. (b) The fan sticks after treatment and prior to reinserting the pivot pin.

Wood and other materials with natural springiness can be used to apply pressure directly. For example, a wooden dowel can be sprung between the ceiling of a workshop and the loose veneer of a table under treatment. Figure 41 demonstrates how this method can be used to apply pressure to a variety of surfaces. The length, diameter, degree of bend, and species of wood all provide a measure of control over the pressure applied. In some cases a telescoping post with a screw thread adjuster may provide the control and consistent pressure needed. It should be remembered that wood creeps while under pressure, so the force applied can be expected to decrease as the wood accommodates itself. This is not much of an issue with large pieces of dowelling, but when using small wooden applicator sticks, their springiness can be lost in a matter of hours. Figure 42 shows the adhesion of the lacquer on a percussion instrument using thin wood sticks to exert pressure.

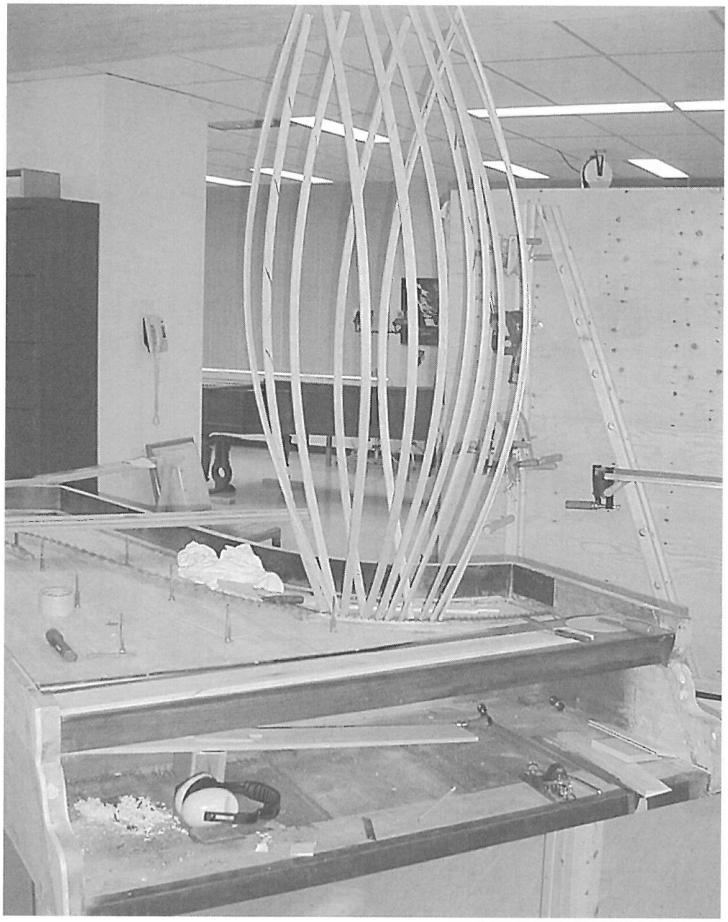


Figure 41. The springiness of thin wooden slats is employed to apply pressure to a glue join on a keyboard instrument. The plywood sheet above is firmly attached to the roof beams above the dropped ceiling. (Courtesy of Cantos Music Foundation.)

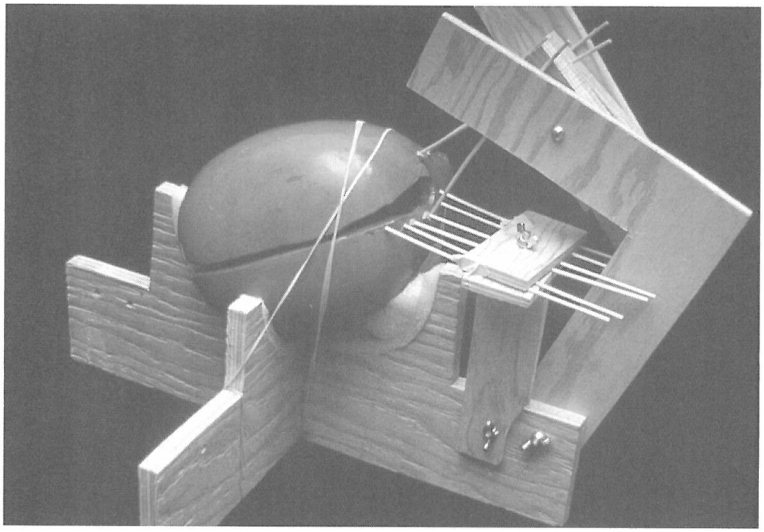


Figure 42. Re-adhering the lacquer on a Mu-yu, a Japanese percussion instrument. As the adhesive is run under the lacquer, the wood applicator sticks are pushed forward and secured in place with wing nuts. Each applicator stick has a cork pad glued to its end. The slight springiness of the sticks is helpful in applying pressure.

Elastic materials

Elastic materials are a subcategory of the springy materials dealt with above. They also use the natural flexibility of materials in applying pressure, but they act under tension instead of compression. Materials with a good degree of reversible extension, such as natural and synthetic rubbers, are preferred, but metal can also be coiled in the form of long tension springs.

Rubber tubing, bungee cords, elastic bands, Velcro, and other items can all be co-opted as suitable pressure appliers (Figure 43). However, because these do not have the same degree of control as screw- or cam-operated devices, it is necessary to select the pressure required by judging the amount of extension, the kind of material used, and its thickness. When applying continuous elastic bands to relatively fragile objects, it is often difficult to set them in place. Spreading them out between the fingers of two hands sometimes helps, but it is often necessary to have another person's help (Figure 44). It is also important to avoid surface contamination from release agents in films and some kinds of tubing.

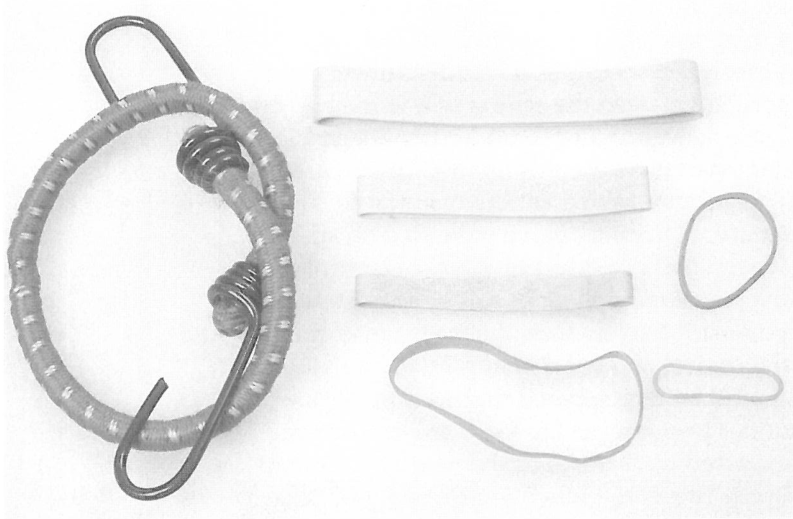


Figure 43. A selection of readily available elastic materials, including a variety of elastic bands and a bungee cord. Although made for other uses, these can all be used as clamps in certain circumstances. Bicycle inner tubes also provide a good supply of elastic rubber, and by cutting them on the diagonal, rings of various lengths can be produced.

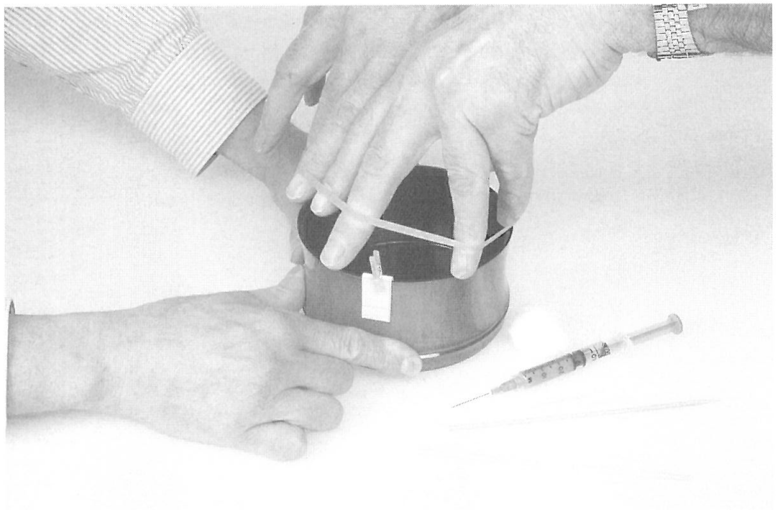


Figure 44. Applying an elastic band to a cracked bowl is a two-person job; one person holds the object while the other stretches the elastic band and sets it in place. A miniature clothespin (from a supplier of dolls' accoutrements) holds the release paper in place over the glue join.

Parafilm is very useful for applying slight pressure to objects for short periods of time. It is a thin paraffin wax film that has a certain amount of stretch and is also somewhat tacky (Figures 45 and 46). Plastic wraps such as Stretch-n-Seal and Saran Wrap have similar properties. Figures 47 and 48 show Parafilm being applied to the damaged prow of a kayak. Figure 49 shows its application to a basket.

Adhesive tapes have some applications in holding small pieces together under light loads and for limited amounts of time, but they should be used with caution. Tapes should not be left in contact with delicate surfaces for long because their adhesives can be transferred. Also, it is necessary to avoid contact between the adhesive being used to make the join and the adhesive in the tape.

Figure 45. A roll of Parafilm with backing paper. Parafilm is useful for providing very weak pressure.

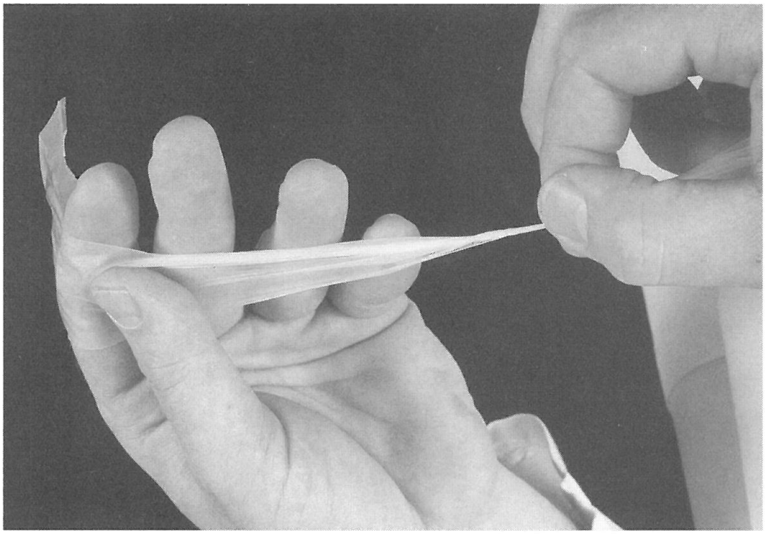


Figure 46. Parafilm can be stretched slightly before application.

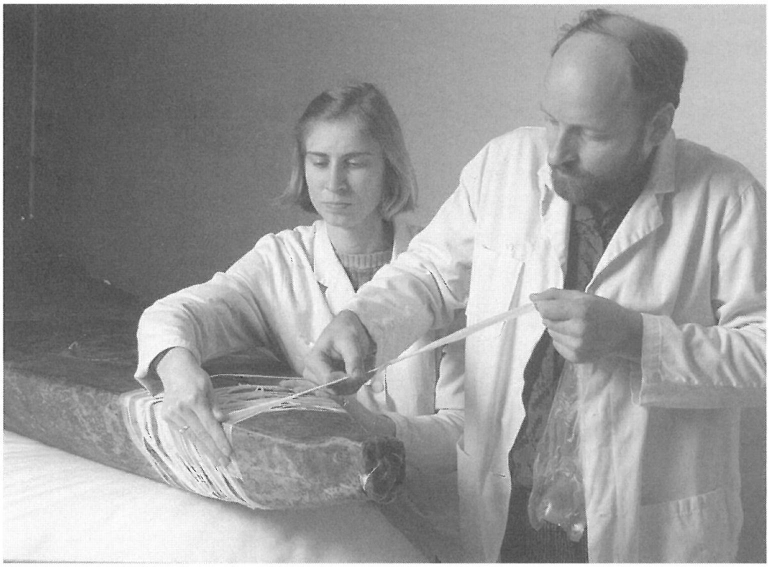


Figure 47. Parafilm wrapped around the prow of a kayak.

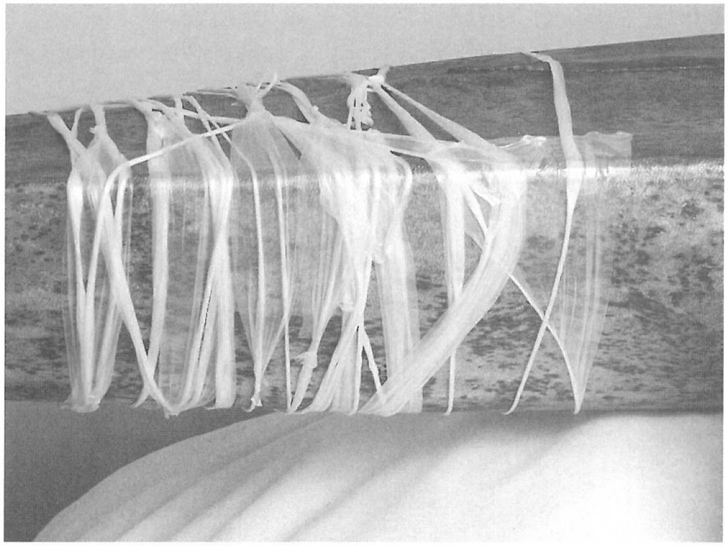


Figure 48. The skin covering on the prow of this kayak was held together with Parafilm while backings and adhesive were applied.

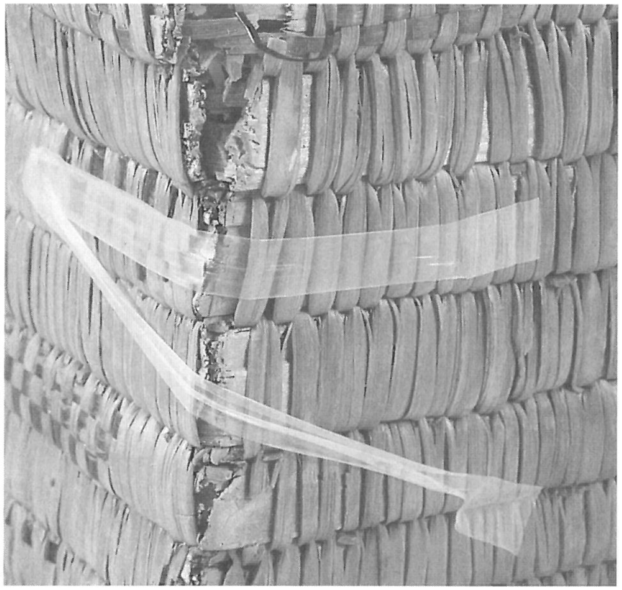


Figure 49. The edges of a fragile basket are drawn together gently with Parafilm prior to applying reinforcements and adhesive from the inside.

Bands and rings

Band clamps use the properties of pulleys and levers. The band is pulled around a drum with the aid of a wrench or lever. The drum has a ratchet attached to it, so it will rotate in only one direction (Figure 50). Band clamps are ideal for applying force to many odd-shaped objects that would otherwise be very difficult to hold together. One disadvantage is that there is likely to be more pressure in the region of the winding drum than elsewhere along the band, due to the friction of the band on the object being clamped. This can be minimized by inserting a slick-surfaced material between the band and the object, or it can be used to advantage by positioning the winding drum close to the place where the most force is required. Figures 51–53 illustrate some examples of band clamps. Figure 51 shows the application of band clamps; Figure 52 shows how fabric strips and Velcro were used to apply pressure in the repair of a Chinese drum; and Figure 53 shows a tiny band clamp made from tinplate and a nut and bolt.

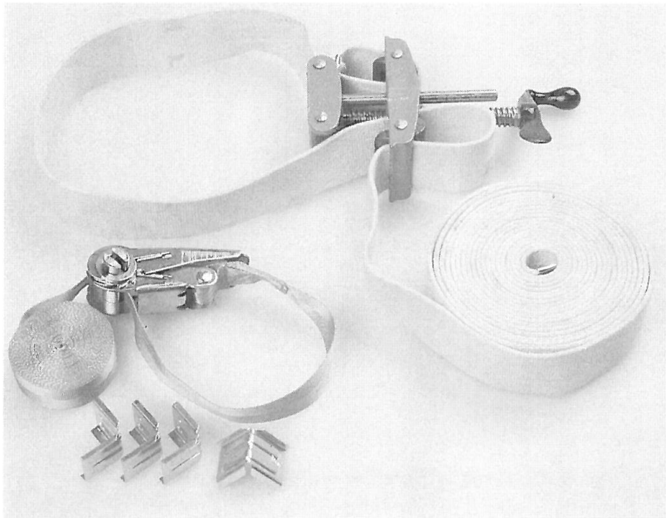


Figure 50. Two sizes of band clamp showing the ratchet mechanisms and turn screws. The smaller band clamp comes with four corner pieces so that it can be wrapped around rectangular objects such as picture frames or boxes.

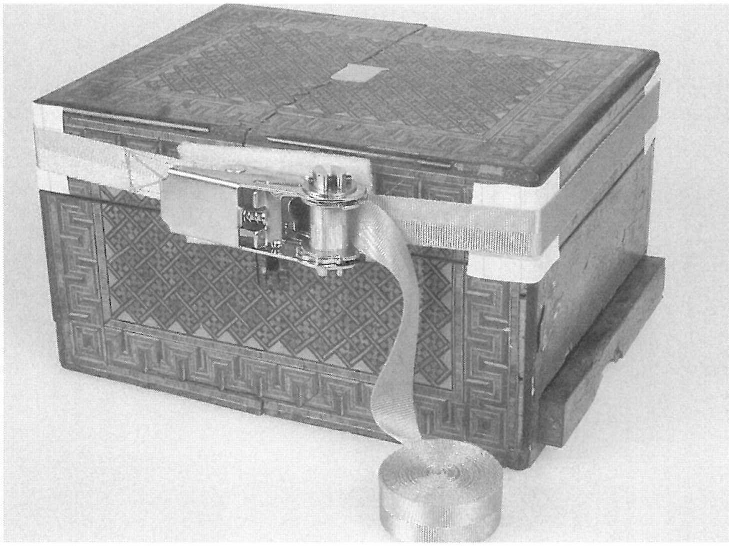


Figure 51. A band clamp applied to a wooden box. Note the release paper on the corners to promote sliding, and the soft padding below the ratchet mechanism.

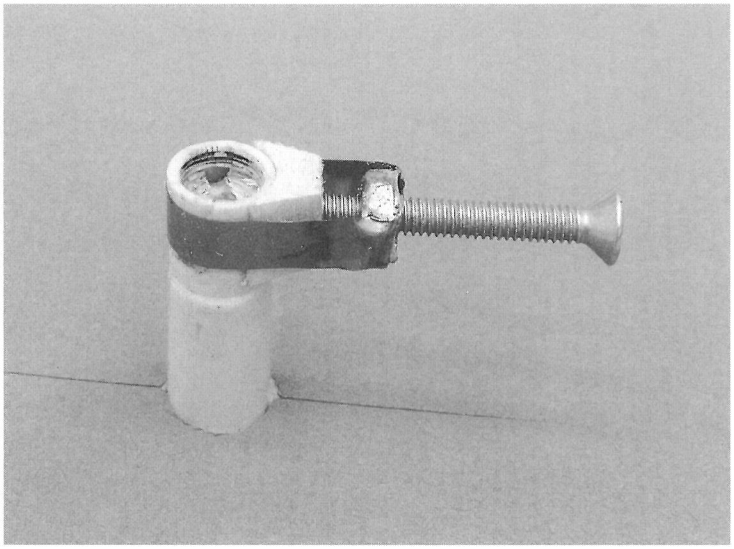


Figure 53. A miniature band clamp made from tinplate and a nut and bolt. The end of the screw bears upon a shaped wooden pad.

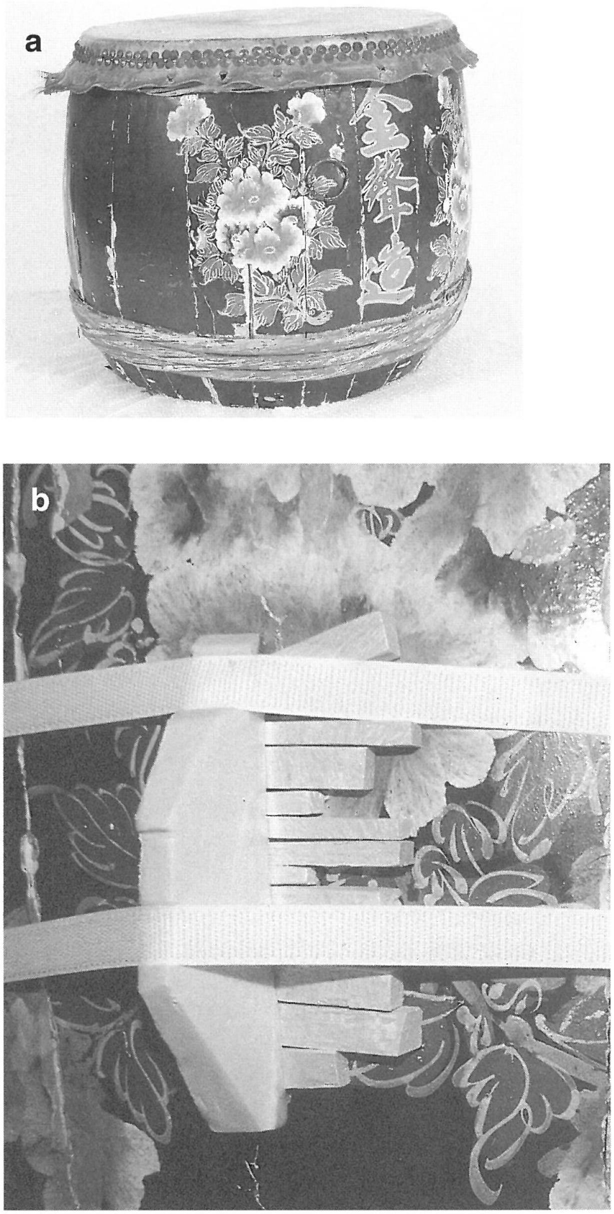


Figure 52. Chinese drum. (a) Before treatment, showing lifting paint and gesso. (b) Fabric bands used in conjunction with Styrofoam and balsa wood wedges to apply gentle pressure to the areas where the gesso is lifting. The bands are wrapped around and attached at the rear of the drum with Velcro.

Guitar makers and repairers have devised a creative variation of a band clamp for pulling cracked and out-of-plane wood components together (see Teeter 1975). A worm-driven guitar tuning head is used to put tension on a thin wire attached to a block of wood. As the tuning head is turned, the wire draws the pieces together (Figures 54 and 55). A similar backing system was used to apply pressure to the back of a drumskin (Figure 56, a,b) and to repair other areas of the Chinese drum mentioned previously (Figure 57, a,b,c).

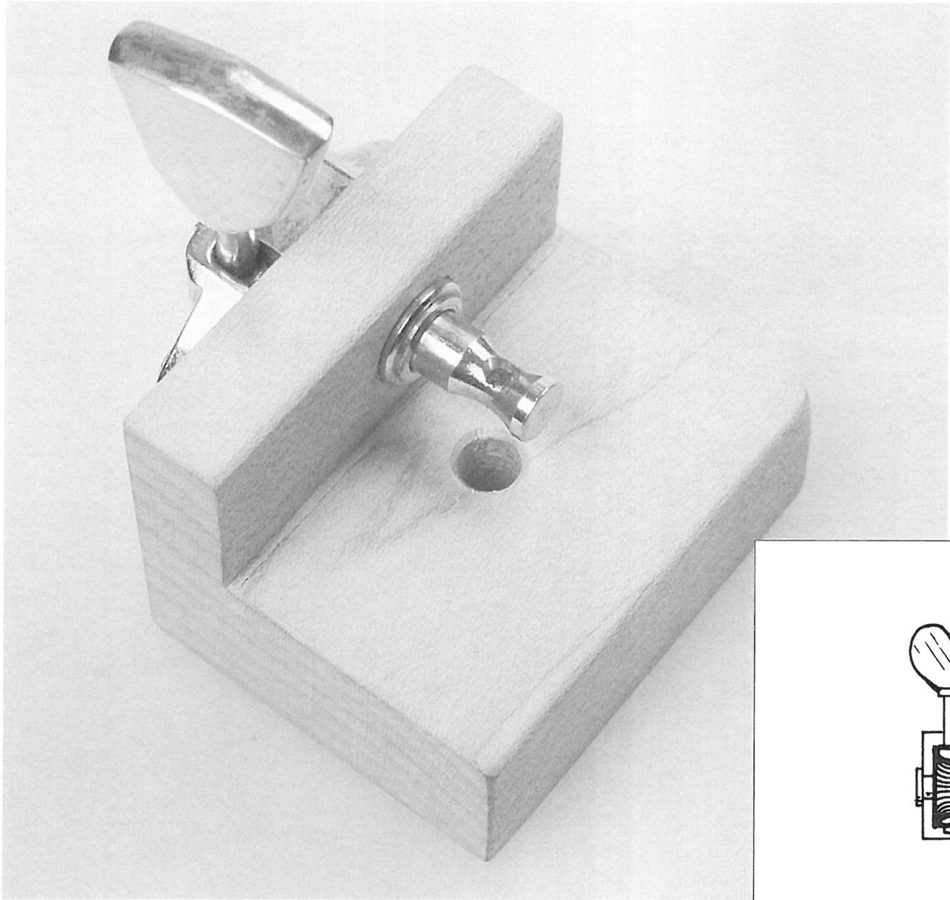


Figure 54. The creative application of a guitar tuning head to make a clamp for thin wood.

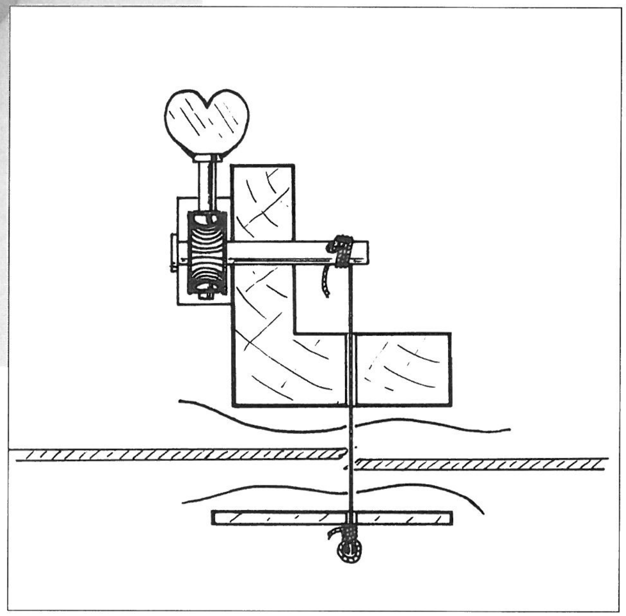


Figure 55. Cross section of the guitar tuning head clamp shown in Figure 54. As the tuning head is turned by the worm gear, the wire draws the wood block up with considerable force.

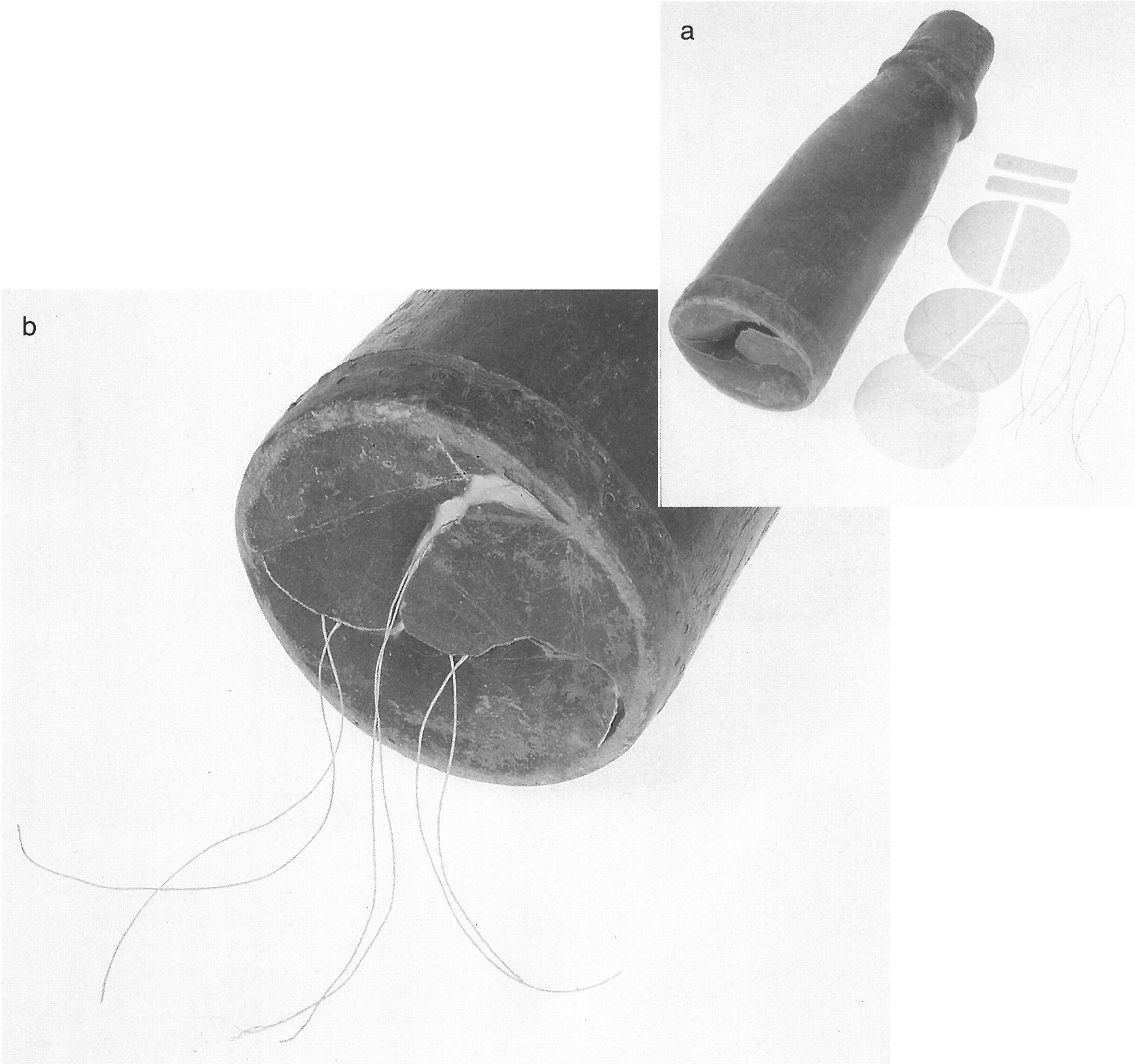
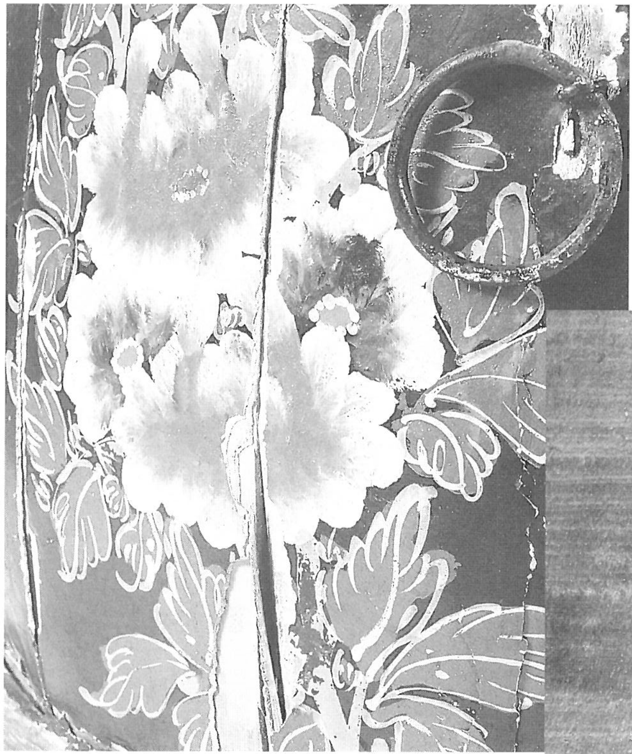


Figure 56. (a) African drum with torn drumskin. On the right are the pieces of Coroplast and matboard and the string used for the clamping system. (b) The Coroplast and matboard were strung together and inserted through the tear in the drum head. By pulling on the string, the Coroplast–matboard assembly provided gentle pressure against the drumskin's inside surface. This made it possible to repair the drumskin using Japanese paper and a heat-setting film that was held between the inside of the drumskin and the clamping assembly. Heat was applied using a hot spatula on the front side of the drumskin. Once the drumskin was backed, the string was snipped away, and the Coroplast–matboard assembly was removed from the bottom opening of the drum.

a



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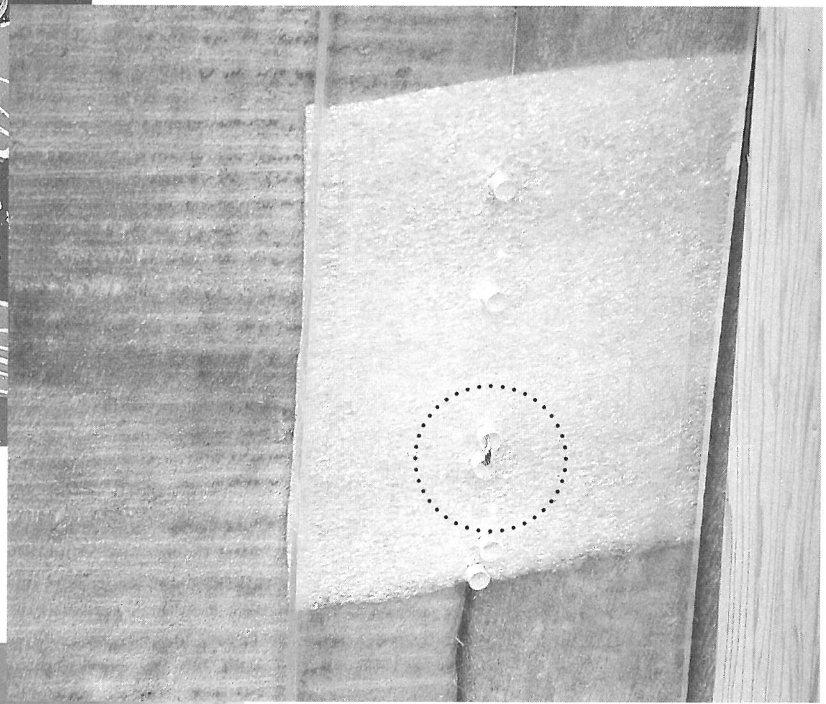

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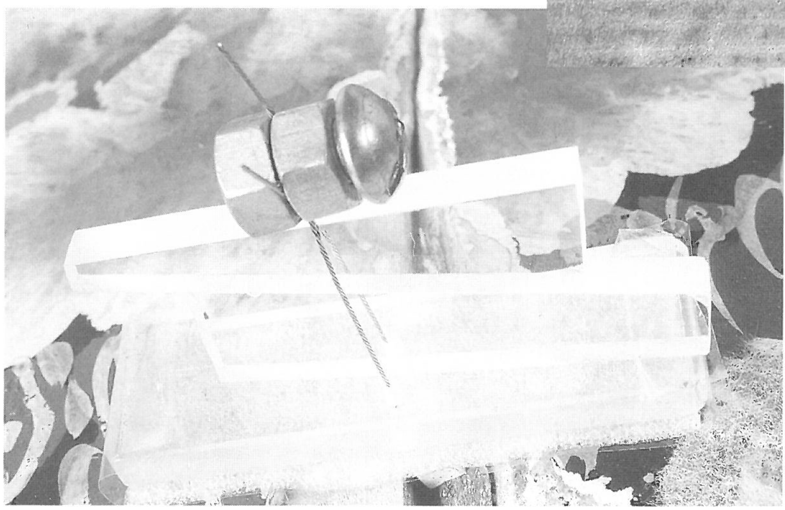


Figure 57. (a) Detail of the Chinese drum shown in Figure 52a, before treatment, where gesso is lifting. (b) Inside view. A piece of foam-padded Plexiglas with holes drilled through it was inserted through the bottom opening of the drum and positioned against a crack between two wooden slats. Metal wire (highlighted by dotted circle) was strung through two holes drilled in the Plexiglas and inserted through the crack to the outside front. (c) Outside view. A second piece of padded Plexiglas was also strung onto the wire. The wire was secured using two nuts and a bolt. A pair of Plexiglas wedges were then used to keep the wire taut and to apply pressure. A tourniquet could have been used instead of the wedges.

Hose clips, cable ties, and similar devices can be made in a variety of sizes and materials (Figure 58). The more powerful metal ones, which are driven by a screw acting on a rack, are very useful to apply pressure to cylindrical objects such as split chair legs. The plastic ones are better for lighter duty applications. Figure 59 shows the application of a plastic clip to a split in a wooden artifact.

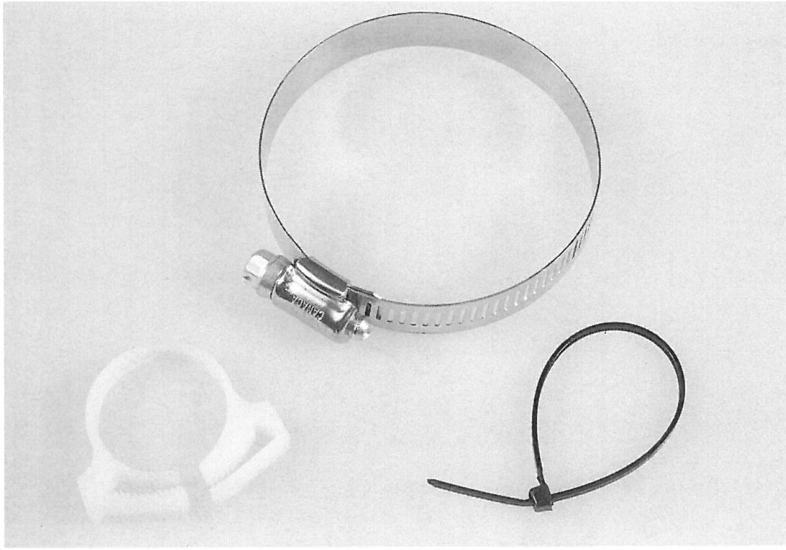


Figure 58. Hardware store, automotive, and electrical hose and wire clips have a wide range of applications.

Turnbuckles

Turnbuckles have left- and right-handed threads at opposite ends so that when the centre portion is turned, both ends move outward or inward (Figure 60). They were designed for use on such applications as the tightening of ships' rigging and guy ropes, but they are very adaptable for situations where pressure needs to be applied outward as well. Figure 61 shows a turnbuckle being used to draw two pieces of flexible wood together.

Figure 59. A plastic hose clip applied to a crack in the wooden arm of a lyre. The plastic is isolated from the wood with silicone paper. These durable plastic fittings can be squeezed with a pair of pliers and are surprisingly powerful.

The tourniquet, or Spanish windlass, applies tension by twisting string or rope (Figure 62). Depending on the thickness and material of the rope, enormous force can be exerted. There are three drawbacks: the turning bar must be held in some way to prevent it from unwinding; the rope may stretch under prolonged tension, releasing clamping pressure; and the string or rope can give way without warning. This application should definitely be checked in a dry run to ensure the required tension can be achieved while the twisted material still holds together. The string or rope can be doubled if necessary, as long as the extra bulk is not an encumbrance.

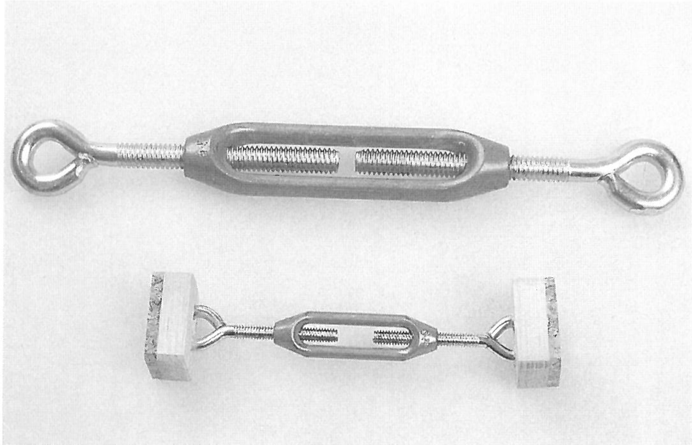


Figure 60. Turnbuckles can be used to apply pressure outward. The one on the bottom has had wooden pads added to distribute the pressure over a wider area.

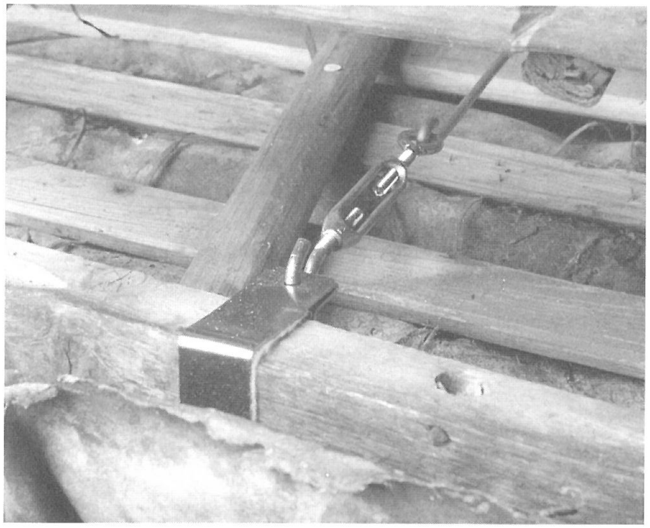


Figure 61. This turnbuckle was used to provide tension to draw two wooden members together inside a kayak. In contrast to most applications, in this case the device was permanently attached. Note the foam padding between the stainless steel hook and the wooden member.

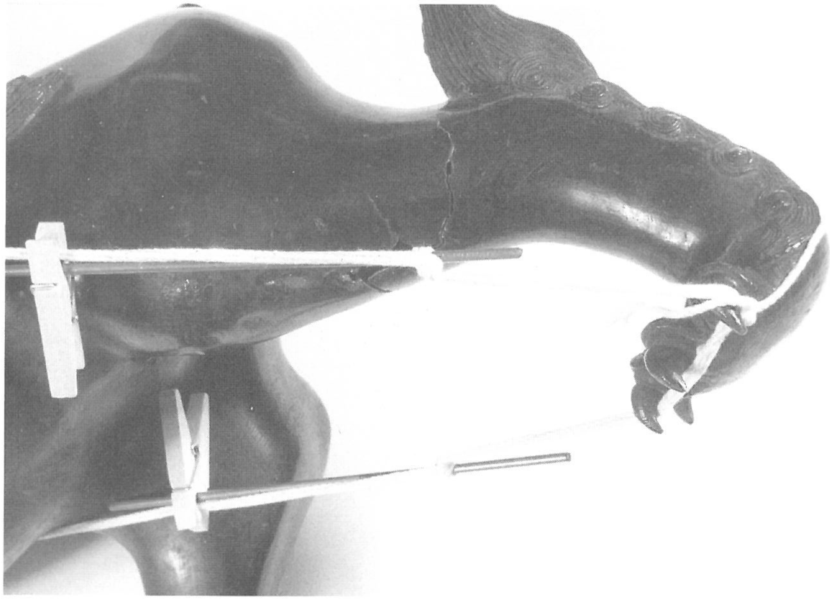


Figure 62. Two string tourniquets are used to bring the leg of a cast sculpture back into alignment. The clothespins prevent the metal tourniquet levers from unwinding.

Wedges

Wedges have been a standby of craftsmen since prehistoric times and even today, with access to all sorts of sophisticated devices, they are still very useful. They can be used for powerful applications (e.g. gluing pieces of wood) where they are driven in with a hammer, or in light applications where small ones are inserted with finger pressure. Figure 63 shows tiny plastic wedges used to apply pressure to a veneered surface. Other examples in combination with other clamping systems are shown in Figure 52b and Figure 57c. The angle of the wedge is important. If it is too shallow, it may not exert enough force before it is fully inserted, and if it is too steep, it may tend to slip out. For wood applications, an angle of between 5 and 10° is about right. Slippage of the wedge can be modified by coating it with paste wax (which will lower its friction) or using pumice or other abrasive powder (which will increase its friction). Traditional artisans lower friction by wetting the sliding surface with saliva.

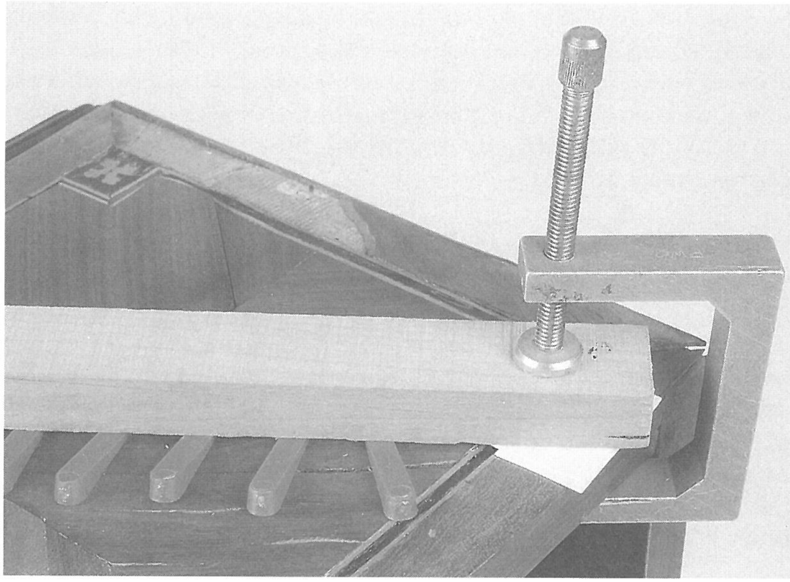


Figure 63. There are many ways to apply gentle force to a veneered surface. In this example, small plastic wedges are used.

Weights

Putting a weight on top of an object that is being glued (Figure 64) is the simplest and most dependable method of applying force — although, of course, the object being glued must be horizontal, or nearly so. This technique is especially useful for lighter applications. Nevertheless, extremely high pressure can be achieved on a small point by allowing a heavy weight to bear upon a small surface area. For example, a weight of 10 kg with a surface area of 10 cm^2 will exert a force of 1 kg/cm^2 (100 kPa). However, if this weight tapers downward to a surface area of 1 cm^2, the pressure exerted will increase to 10 kg/cm^2 (1000 kPa).

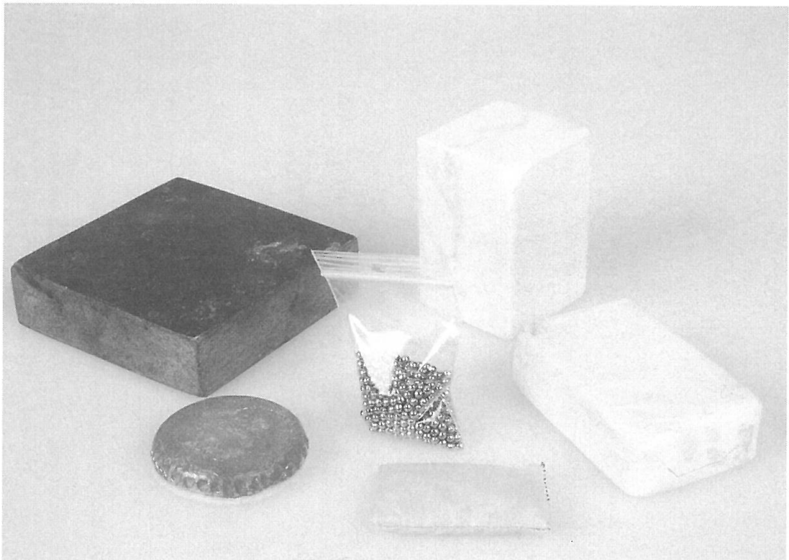


Figure 64. A variety of materials can be used to apply pressure to horizontal surfaces. Examples shown here include stone (left and rear) and lead slabs, one covered with Tyvek; a bag (foreground) filled with lead shot; and a plastic bag containing steel balls.

Making sure that a heavy weight can be suspended safely above an object, and ensuring that the weight is applied exactly where needed, are both essential considerations. Figure 65 shows how a heavy weight can be suspended above a bench top so that its force can be directed exactly where required by means of a wood dowel. The wood dowel rests on a Plexiglas pressure pad, the surface area of which dictates the load per unit of surface area. As the weight is acting directly downward, the string simply balances the weight; it has very little tension and carries almost no load.

On a much smaller scale, a thin wooden applicator stick can be held vertically with a spring clamp while weights such as hexagonal nuts are added to it (Figure 66). This has proved very useful for adhering light materials such as quill, bark, and straw.

Lead is a good material for making weights because of its high density, but it is toxic in normal use. This can be dealt with by coating the metal with a dip plastic of the sort used for coating the handles of tools (although this material should not be used in contact with heritage material because the plasticizer can migrate to the surface causing stains) or covering it with fabric or sheet plastic. In either case, the resultant surface is much kinder than the bare metal to artifacts, as well as to human skin. Where high mass is not important, weights can be made of other less dense metals or stone. Sawn sections of railway track make very useful weights, as do flat polished stone slabs that are available from stonemasons.

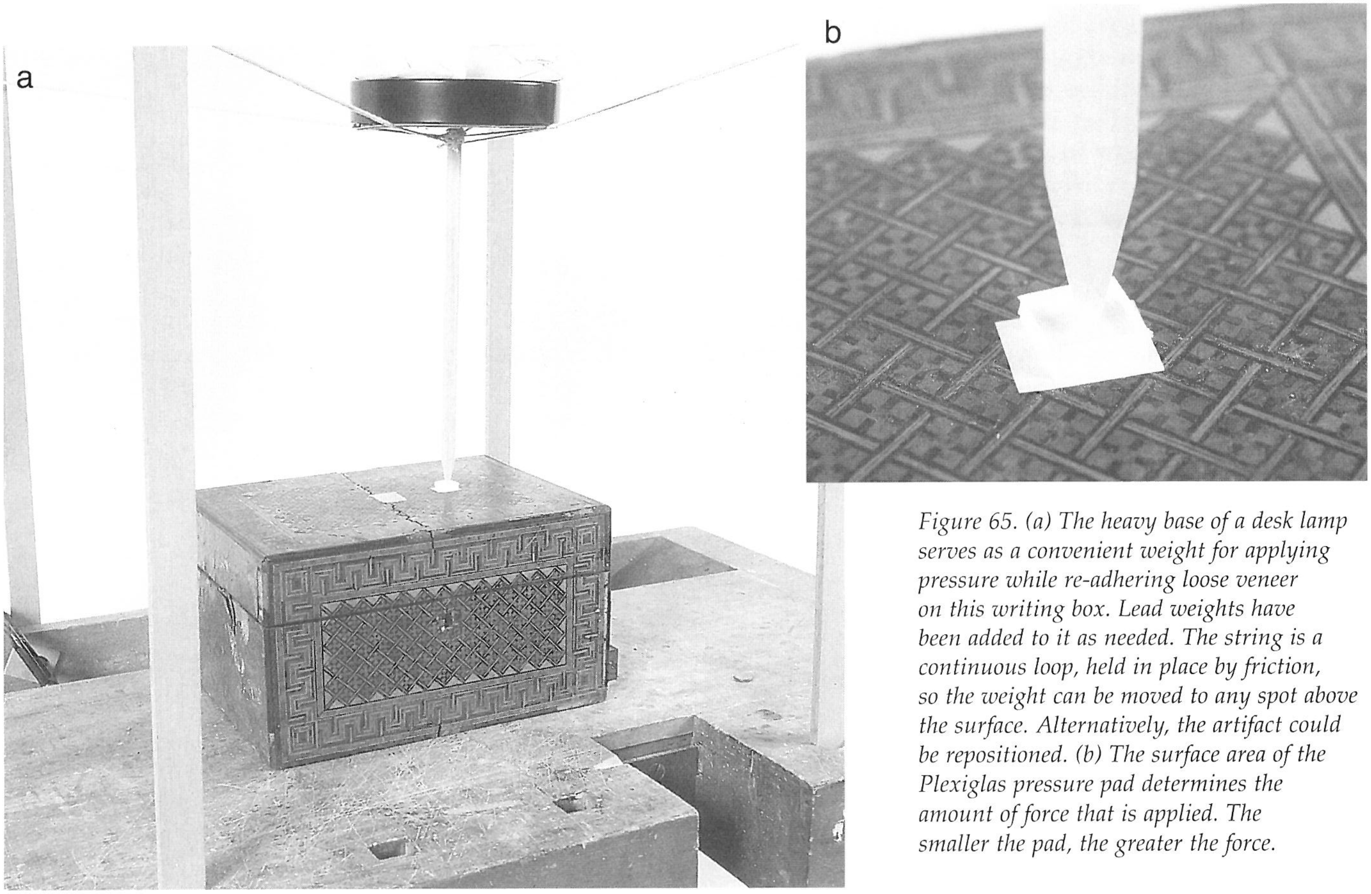


Figure 65. (a) The heavy base of a desk lamp serves as a convenient weight for applying pressure while re-adhering loose veneer on this writing box. Lead weights have been added to it as needed. The string is a continuous loop, held in place by friction, so the weight can be moved to any spot above the surface. Alternatively, the artifact could be repositioned. (b) The surface area of the Plexiglas pressure pad determines the amount of force that is applied. The smaller the pad, the greater the force.

Lead shot can be enclosed in bags of various shapes, which can be adjusted to suit specific applications. However, over a long period of use, the individual lead shots will abrade each other and produce fine particles of lead. For this reason, the shot should be enclosed in polyethylene bags rather than cloth. Where high mass is not an issue, cloth bags filled with coarse sand have some applications. They have the additional advantage that they can be warmed in an oven to prevent hot glues from gelling too quickly, or to make certain materials more flexible. A very fine weave of cloth is necessary to prevent smaller particles of sand from leaking out.

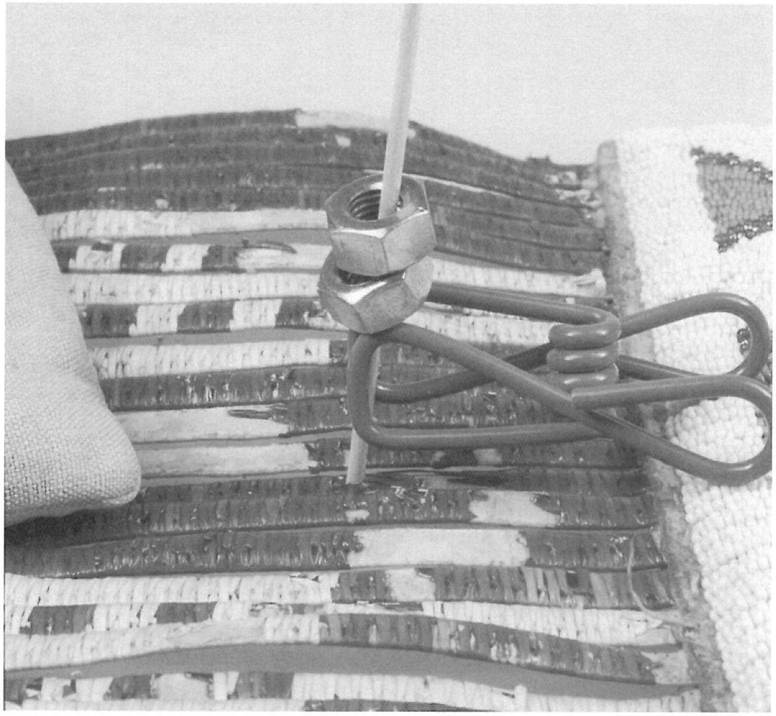


Figure 66. This simple adaptation allows gentle pressure to be applied to small, fragile surfaces. Although any form of weight can be added, these hexagonal nuts are especially convenient because they come in many sizes and have ready-made holes through their centres.

Vacuum pressure

Vacuum applications are a variation on using gravity to apply force, and they have a wonderfully subtle advantage. A column of air extending upward into space can be made to exert its weight — nearly 1 kg/cm^2 (100 kPa) at sea level — simply by removing the air above a surface. Because we live at the bottom of a sea of air, the pressure of the air acts equally in all directions. If, for example, we remove the air from the surface above a table top to clamp a lifted veneer, it is the air pushing up from below the table as much as the air pushing down from above that produces the clamping force. In other words, this pressure can be brought to bear in any direction, with pressure evenly distributed over the entire surface. The most challenging complex surfaces, compound curves, and large surfaces where the back may not be accessible to attach a more conventional clamp, are all candidates for vacuum clamping. Further information on vacuum techniques for large and complicated applications can be found in Merrick (1990) and Robinson (1993).

One example of this principle is the vacuum table used for lining paintings, which exploits the gentle, controllable nature of vacuum application. A thin membrane is placed over the painting and air between the membrane and the painting is removed with a vacuum pump. Atmospheric pressure, or a portion of it depending on the pressure of the pump, then exerts itself over the whole surface. This method is also used in vacuum bagging, a clamping method that holds adhesive-coated components such as laminates together with atmospheric pressure while setting takes place. Figure 67 shows the re-attachment of loose veneer using this method, and Figures 68 and 69 show the vacuum reforming of a chair seat made of birchbark and quill.

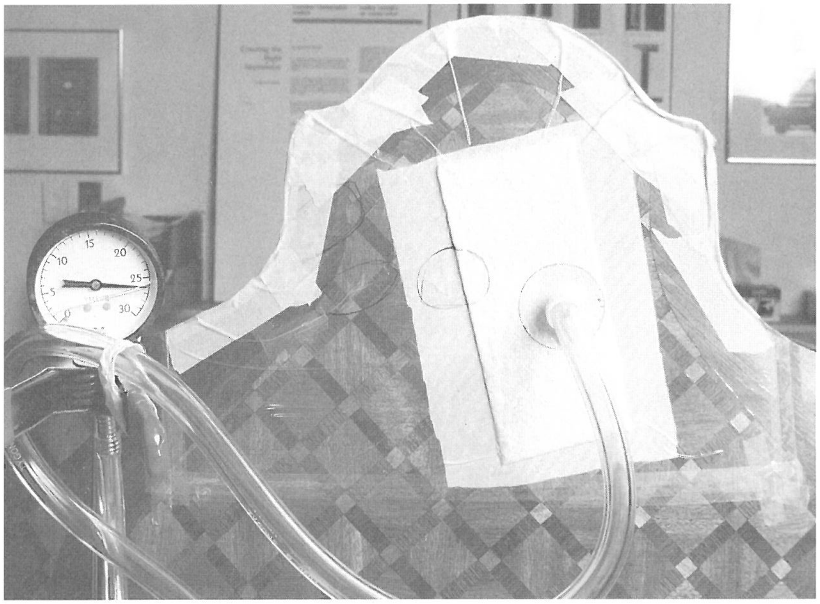


Figure 67. Vacuum clamping to assist the re-adhesion of veneer. The surface of the veneer is covered with a transparent membrane, which is held down around its edges with sticky tape to ensure it forms an airtight seal, and a vacuum pump is connected. Adhesive is applied to the underside of the veneer to hold it in place, and then the pump is turned on to reduce the pressure between the membrane and the veneer.

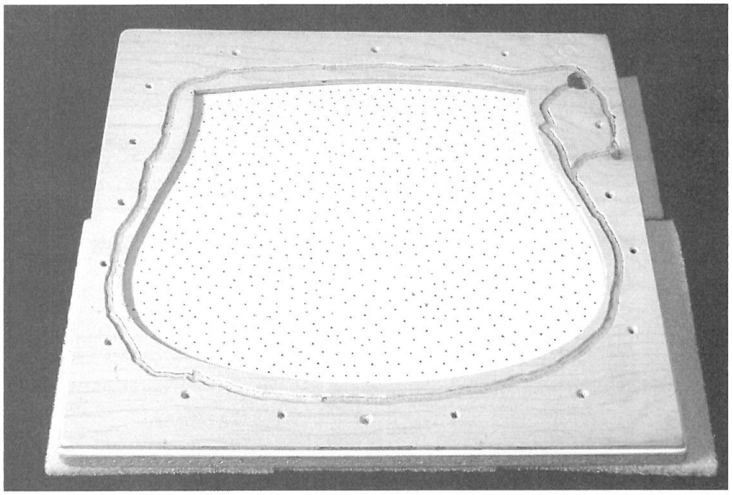


Figure 68. Vacuum reforming. In preparation for this procedure, a profile was prepared from plywood with a groove routed around the outside to act as an air channel. An absorbent cushioning material was inserted below.

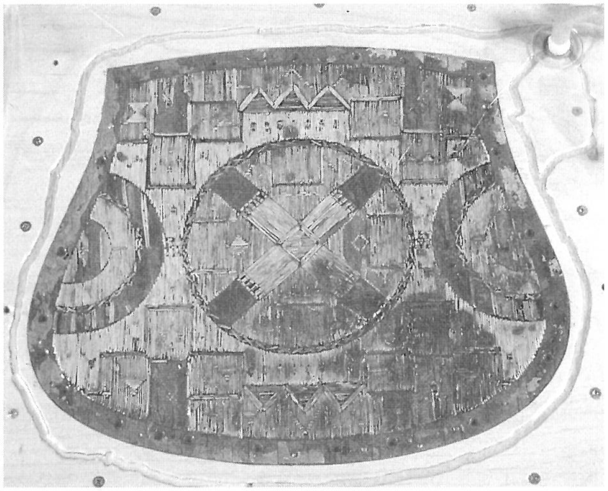


Figure 69. Vacuum reforming of the distorted chair seat made of birchbark and quill. The seat was pre-treated by exposing it to methanol vapour to plasticize the bark. Once the bark was soft enough, the seat was inserted into the profile (see Figure 68) and covered with polyethylene membrane. An air hose was attached to the corner and the air pumped out between the membrane and the seat. The vacuum remained on until permanent set had been achieved.

Figure 70. Pressure from within was the only way to restore the shape of this flattened and distorted Inuit sealskin float.

Air pressure

Air pressure greater than atmospheric pressure can be used to reshape flexible objects that have become flattened or distorted. A variety of devices are available, including party balloons, weather balloons, condoms, and inflatable medical devices used in surgery and therapy. One example of this technique (Figures 70–73) is an Inuit sealskin fishing float that was inflated with a rubber weather balloon while it was moist, and then allowed to dry under pressure. Once the skin was dry, the balloon was deflated and removed, leaving the float in its original inflated shape. An alternative to this method would

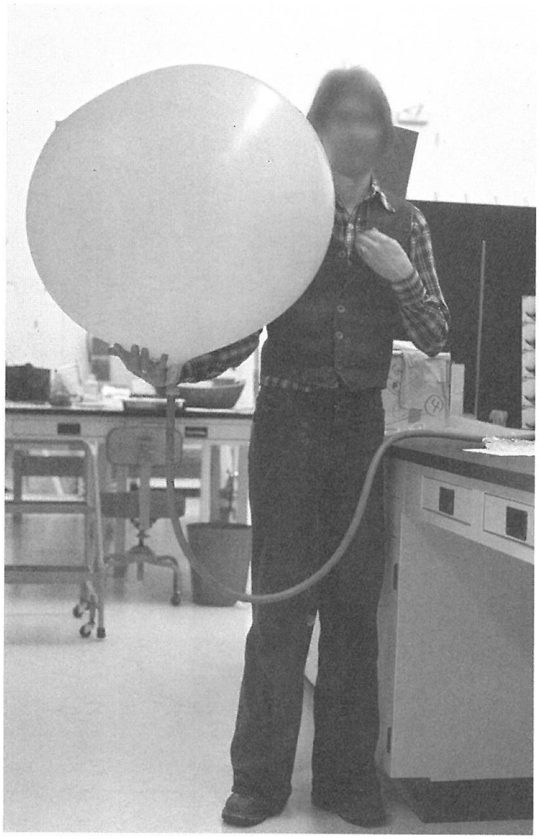


Figure 71. A weather balloon is tested for leaks before insertion.

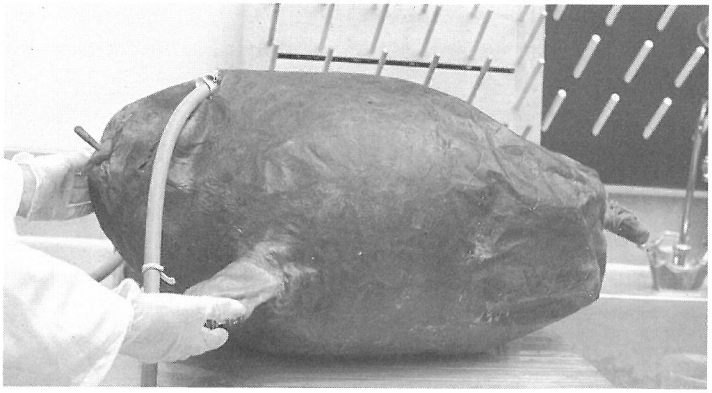


Figure 72. A weather balloon is inserted into a convenient aperture of the damp float, and then inflated.

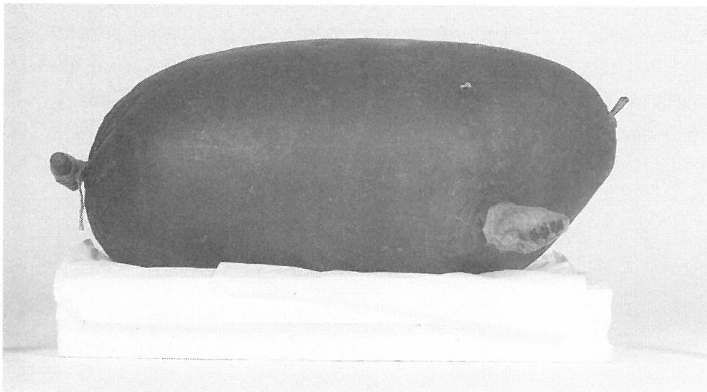


Figure 73. The finished sealskin float restored to its original shape.

have been to use a high airflow without an interior balloon. This works when there are few enough holes in the skin (i.e. minimal leakage) that a slow flow of air will keep the float continuously inflated while it dries. Naturally, in this application the internal pressure would have to be very low.

Air-filled hypodermic syringes have also been used in some applications. Force can be magnified by using a small syringe (say 1 mL) connected through flexible tubing to a larger one (say 10 mL). The plunger of the small syringe is moved its entire length, while the plunger of the larger syringe moves only one-tenth of the distance, thus multiplying the force 10-fold.

An application of high-pressure air for applying pressure to wooden edging is described by Gyving (1989).

Hydraulic pressure

Hypodermic syringes filled with water or other fluids are potentially useful for applying pressure to awkward-to-access locations, but they have the disadvantage of potential leakage and resultant messes. Also, the pressure they are able to apply is fairly low, thus limiting them to very gentle applications. In most cases, it is far better to use a mechanical solution if at all possible.

High-pressure hoses filled with water can be used to apply pressure evenly to intricately curved shapes. The hose is brought up against the piece to be clamped and held in place by a support with matching profile. Once the hose is filled using a hydraulic pump, pressure is applied evenly all along its length. When using this technique, the pressure rating of the hose must be known and the hydraulic pump must be fitted with a pressure gauge so that the rating of the hose is not exceeded. This is a variation on the air-filled hose described above.

Extremely powerful hydraulic systems are manufactured for a variety of applications, but they are not usually encountered when dealing with museum objects.

Magnets

The force of magnets is dissipated through solid objects, so their use as clamping devices has traditionally been limited to thin materials. However, with the recent development of powerful rare earth magnets, considerable force can be applied locally and through surprisingly thick materials. The work being clamped needs to be sandwiched, either between two magnets of opposite poles or between one magnet and a piece of metal that will be attracted to it. Tinplate is very useful because it can be cut and shaped very easily to conform to the contours of the work. It also resists corrosion, making it safer to use with water-based adhesives or where moistened materials are being reshaped under pressure. Even so, covering the tinplate with thin Mylar or polyethylene attached with double-sided tape adds extra protection (Figures 74 and 75).

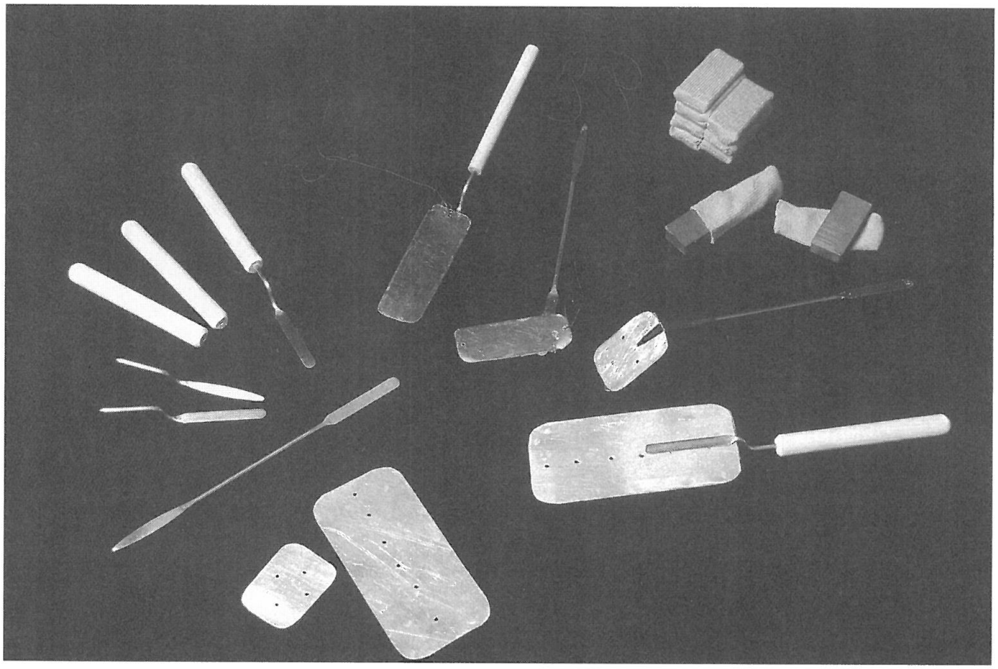


Figure 74. A variety of magnets and tinplate tools can be used for reaching into narrow spaces. The magnets are covered in soft fabric.

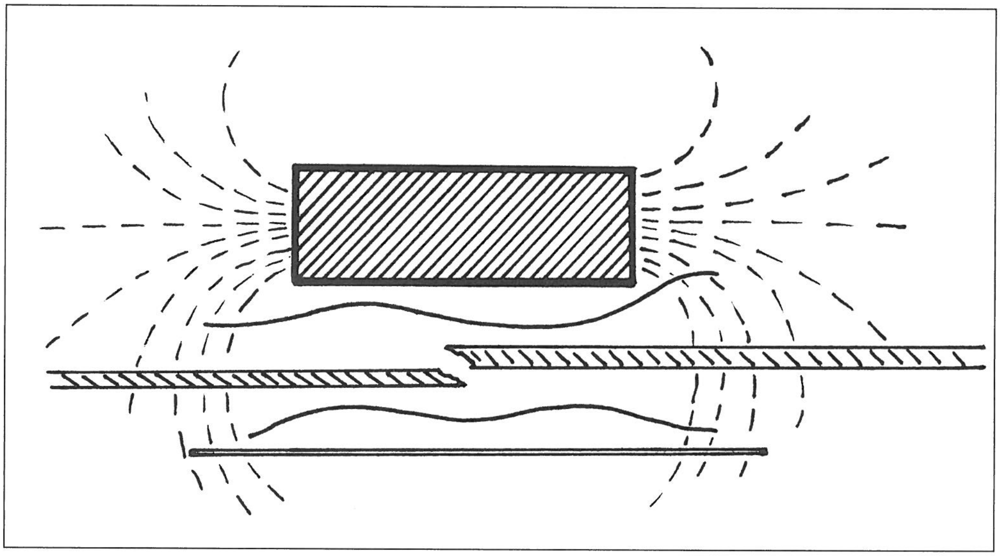


Figure 75. Cross section showing how magnets and tinplate pieces are positioned during gluing of thin, flexible materials.

Figures 76–79 show how magnets and tinplate were used to back and adhere the skin covering of a kayak.

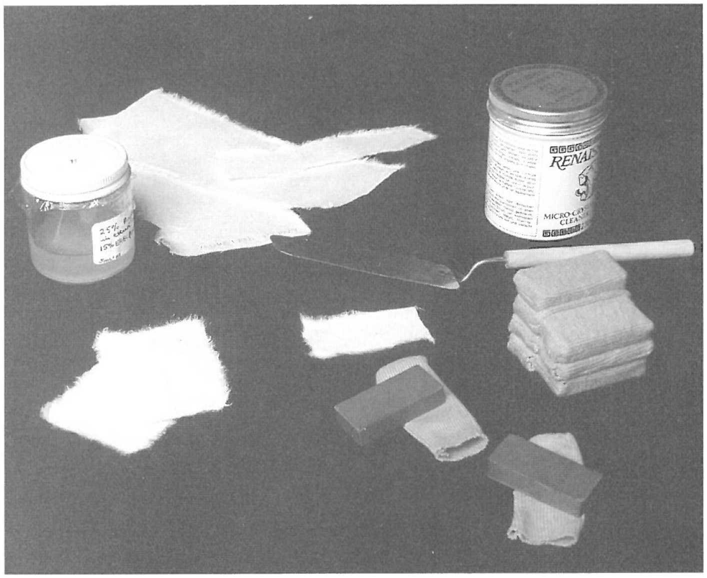


Figure 76. Magnets and tinplate were used in combination with cellulosic paste and Japanese paper to apply backings to the torn skin of a kayak. The tinplate was coated with microcrystalline wax so that it could be removed from the interior after the adhesive had dried.

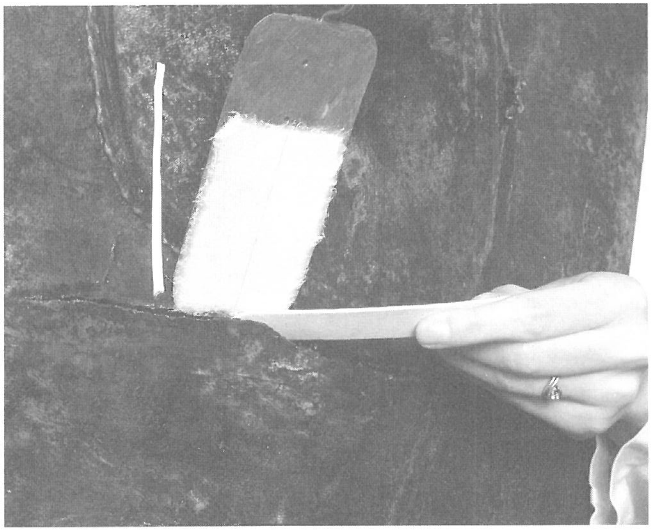


Figure 77. Tinplate with adhesive-coated paper is inserted into a crack in the kayak skin.

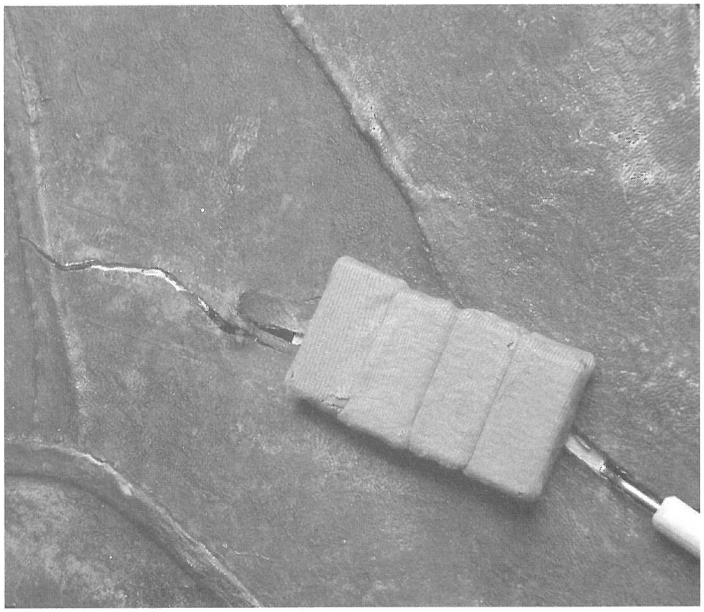


Figure 78. After the tinplate is inserted and positioned, magnets are placed over the crack to provide pressure while the paste dries.

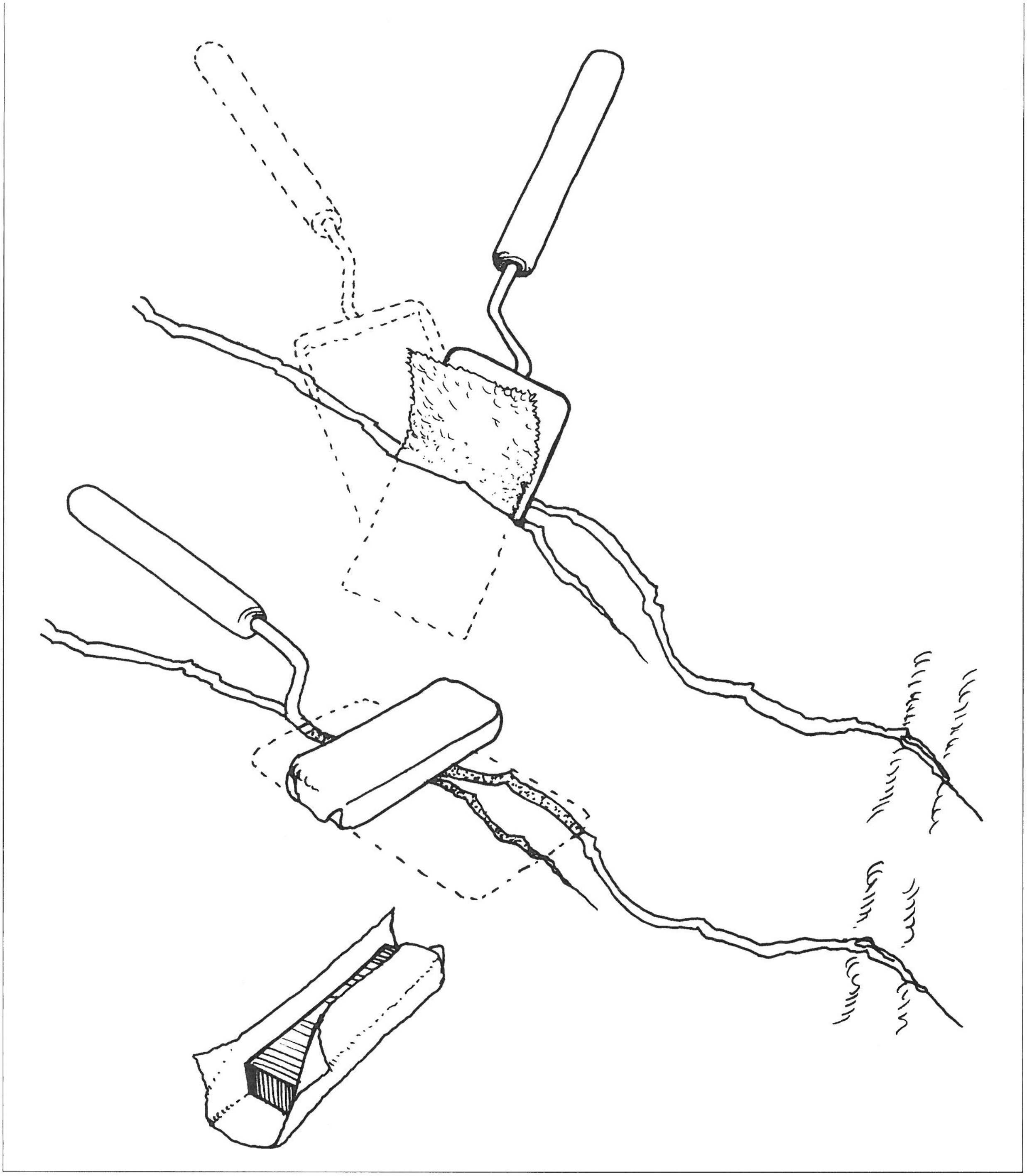


Figure 79. This diagram shows the procedure for inserting the adhesive-coated paper, tinplate, and magnet.

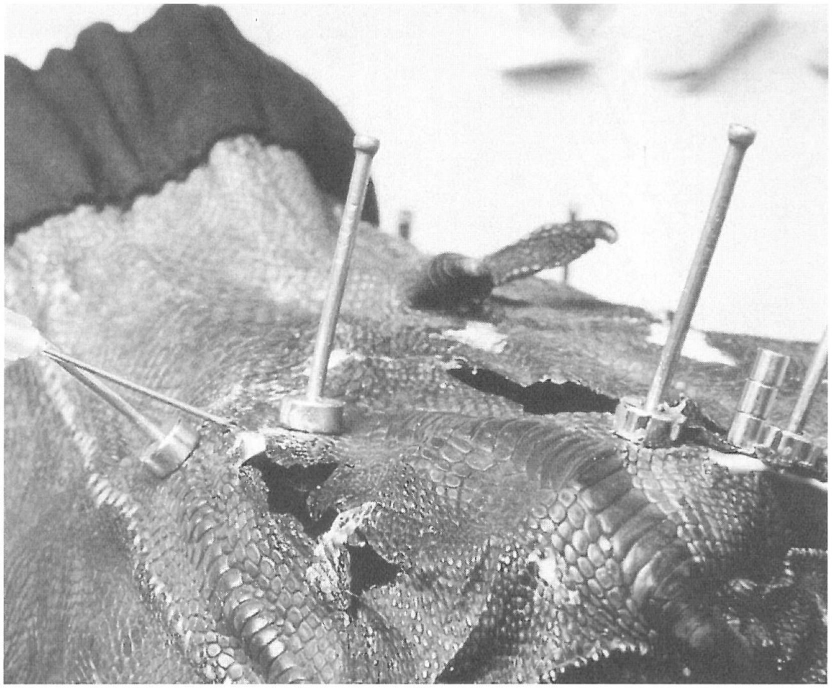


Figure 80 shows the use of very powerful rare earth magnets for clamping the adhesive on a loon skin bag.

Figure 80. Rare earth magnets are used to apply pressure during the backing and repair of a loon skin bag. Finishing nails make convenient handles for positioning the magnets.

When working on such intricately shaped objects, it is sometimes necessary to shape the tinplate backing pieces to conform to the inner surface (see examples in Figure 81) to ensure pressure is applied evenly.

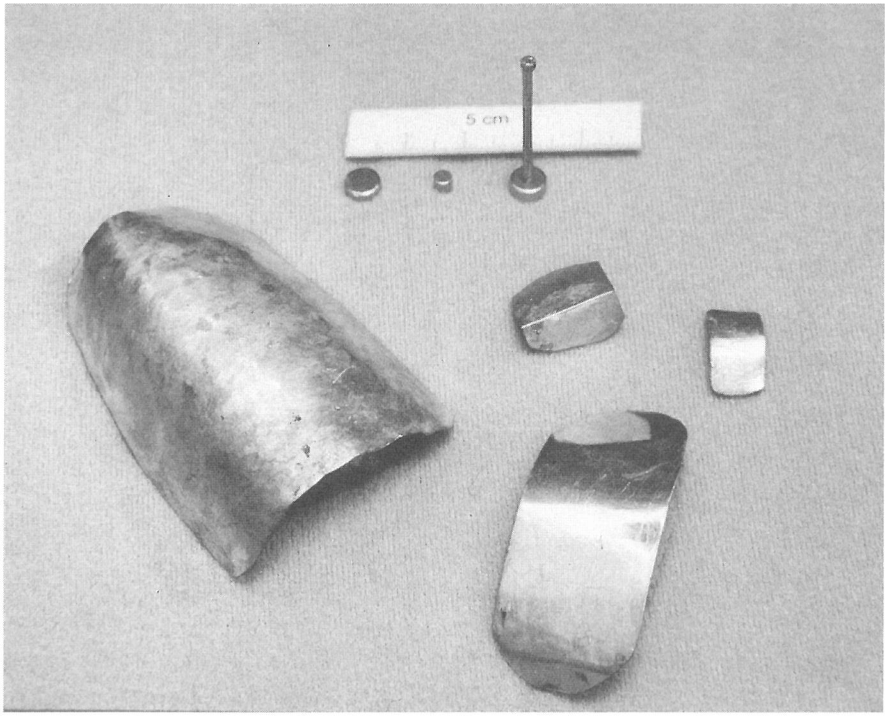
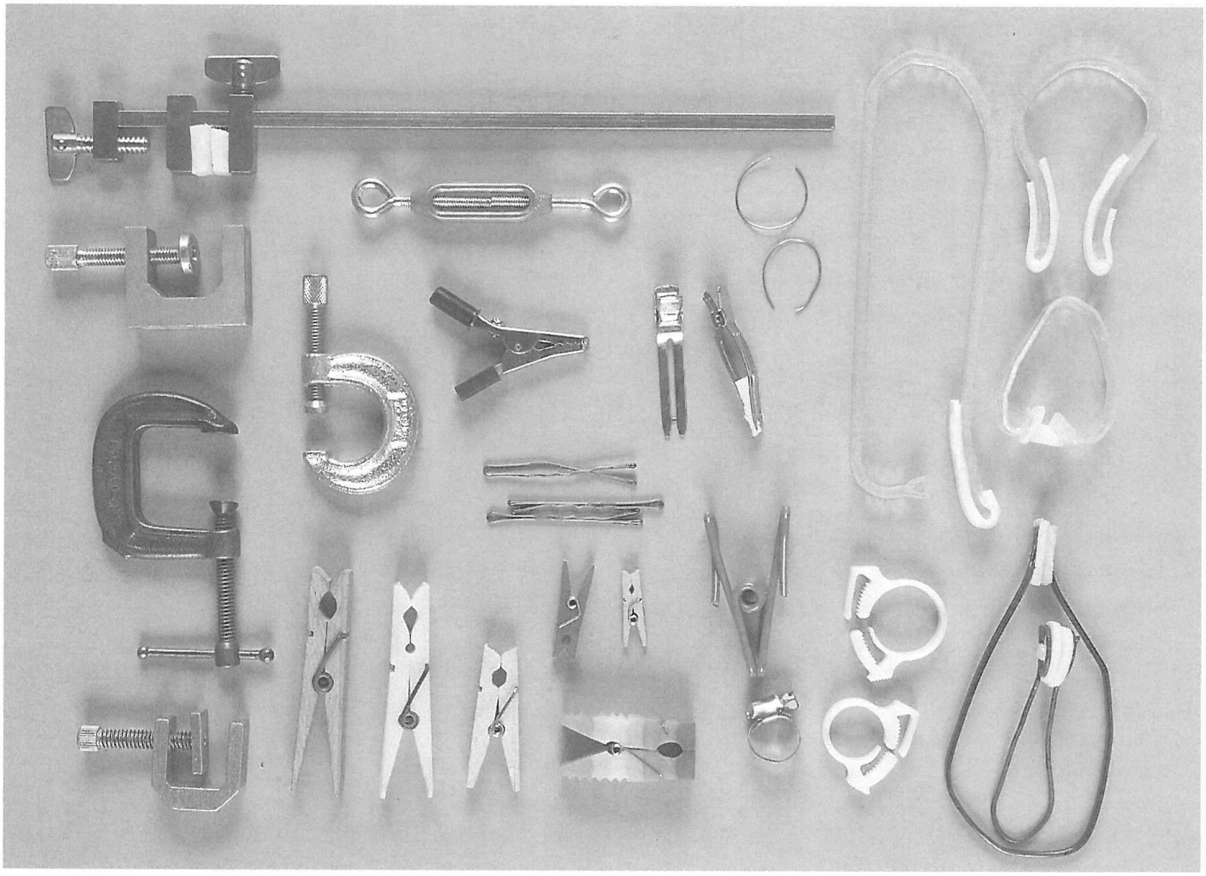


Figure 81. Detail of the shaped tinplate pieces and magnets used in the example in Figure 80.

Conclusion

We hope the discussion and examples in this book prove to be useful for our readers. However, complete coverage of this topic is impossible. There are so many ways of holding things together temporarily that inevitably we will have made some omissions. We encourage readers to contact us with their ideas and experiences so future editions can be more complete. We will, of course, give full credit for any ideas we publish.



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