THE MAIL-MAKER'S TECHNIQUE

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Mail has been used since very early times and it is therefore surprising that so little is known about the methods and tools used for its construction. As it appeared unlikely that original tools or further information would come to light, recent research has been carried out on new lines. It was hoped that the methods found to be the most practical would produce mail similar in appearance to the medieval riveted mail. These methods would have to be accessible to armourers of the past and as far as possible be methods still in use in the present day, for basic techniques seldom die out. Many of these techniques are so fundamental that it is doubtful if they have changed much in the last 2,000 years. Because so much mail was produced the method would have to be a fast one allowing for division of labour within in the workshop. The most skilled task, which is the final linking, would have to be done by the master craftsman, who could be kept supplied with the necessary rings and rivets. The early stages in the production of mail – the simple, laborious tasks – would be left to apprentices and assistants. Such a system is often found in a small workshop.

For the production of mail the first necessity is wire. There has been much controversy in the past as to whether or not the ancient mail-maker had at his command the art of wire-drawing. This is the process by which wire is drawn through successively smaller and smaller holes. There are several ways of doing it, but the effect is always the same – a rod of metal becomes progressively longer and thinner. The wire may be drawn through the same hole many times, the hole being closed up between one drawing through and the next. The tool used for this operation (fig. 1), which is a form of swage, looks somewhat like a screw-press and consists of two blocks of steel which can be forced together by a large screw and lever. This screw is used to bring the steel blocks about two- or three-thousandths of an inch closer together between one drawing through and the next. In one or both of the steel blocks, often only in the lower one which is fixed, is cut a tapering hollow through which the wire is drawn. The blocks are narrow and the taper can be quite slight. This type of tool has been much used because the steel blocks can be replaced and also because the hollow can be filed to nay shape required even if the wire has a very complex cross-section. It is useful for making complicated mouldings in metal.

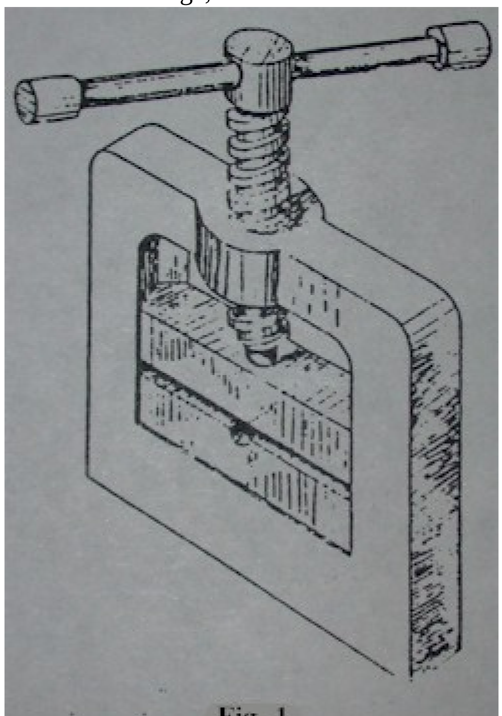


Fig. 1

The second type is a true draw-plate and, though simple to use, it is hard to make and, once made, cannot be altered. It consists of a plate of very hard steel with a large number of tapering holes in it. Each hole is slightly smaller than the last and the wire is drawn through one hole after another. This system is fast, but has obvious disadvantages. Both of these methods are used today where wire is made by hand.

The wire can be drawn through by hand or with a windlass. When drawn by hand the end of the wire is first tapered with a hammer or file and passed through a hole slightly smaller than its diameter. It will be a bar rather than a wire when the process is started. The tapered end is gripped in a pair of tongs with one handle bent so that the hand shall have something to pull against. To grip the wire firmly the inner surfaces of the tongs are cross-hatched with the ridges sloping backwards. The effect is somewhat similar to that produced when two files are pressed together. The tongs can be hooked to a belt passed round the waist, and the drawer can then exert a greater pull on the wire when walking backwards. This method is useful for producing long wires.

The drawing can, on the other hand, be done with a windlass. The tongs have both handles curved at the end and an iron isosceles triangle with one short side is hooked over both of them with the apex of the triangle pointing towards the wire. The short side of the triangle has a bend in it in which rests the first link of a long chain which passes round the windlass. When the chain is tight and the windlass turning the iron triangle causes the tongs to grip the wire tightly. An increase of pull will correspondingly increase the grip of the tongs on the wire. This method is useful for short thick wires, but it has obvious disadvantages for long wires.

Drawn wire has grooves all along its length. This is the result of an irregular draw-plate; but even machine drawn wire, which has been drawn through a smooth steel draw-plate, tends to have these marks. On mail the marks are easy to see, through a lens if not with the naked eye. It is uncertain when wire-drawing was first used, but bronze wire showing draw-plate marks and stone draw-plates of about 2000 B.C. have been found. It is likely that the presence of mail in any civilization proves that the knowledge of wire-drawing was in existence at that time. If wire were not fairly easy to make it would not have played a part in the construction of armour when so many other substances were available. Even before the use of steel, wire might have been drawn through bronze. The art of hardening bronze has been lost, but it is evident that it was basically a process of work-hardening. Most metals become harder by being hammered or bent. It is likely that wire would be drawn through a tool of the screw-press type, shown in fig. 1, because much wire in mail shows a cross-section with one flat side and the other often rounded. It is easy to see how this would naturally follow from the use of such a tool. When this wire was bent into a circle the flat side would tend to turn inwards, and this has in fact partially happened in many examples of mail made from wire of this particular cross-section.

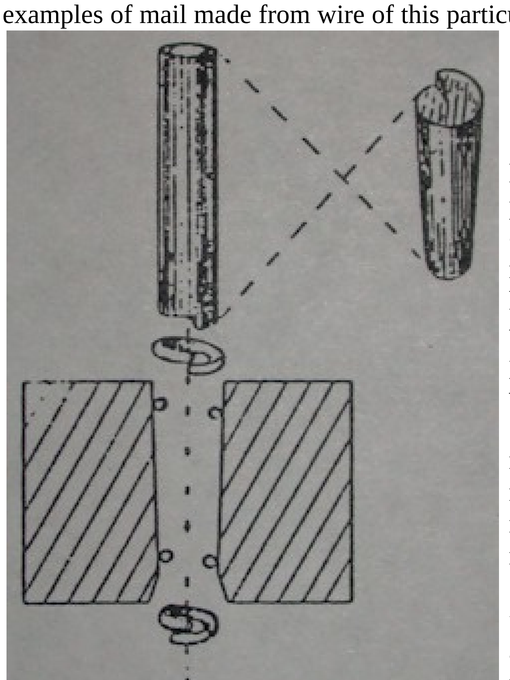


Fig. 2

The wire has now to be coiled up to form rings (pl. XV, 1). This would be done by twisting it round an iron rod of suitable thickness, remembering that the ring will become smaller when the ends to be riveted are overlapped and larger gain when they are flattened for punching. In practice there would probably be a large selection of cores of various sizes in a mail-maker's workshop, and they might be fitted with wooden handles and either a slot or a hole for starting the coil of wire (pl. XIV, *b*). The length of these iron cores would control the necessary length of each piece of wire. The drawn wire would not have to be in very long lengths.

Once the wire has been coiled it must be cut up to form rings. The cutting is often done with a saw when butted rings are required, but it is doubtful if the medieval mail-maker used a saw as all the rings, except the whole rings punched from a sheet, were riveted.

It is more likely that the cutting would be done by some form of wire-cutters (pl. xv, 2). As the rings are riveted after the cut ends have been flattened, all trace of the method used to cut them has disappeared. The rings now have to be overlapped before they are flattened for riveting. In any one garment they are always overlapped in the same direction. This direction of overlap, almost always the same, ca be easily remembered by substituting the hands for the flattened ends of the ring. If the ring is looked at edgewise with the rivet joint uppermost, the right hand will be nearest the body when placed flat against the left. The reason for this similarity in all mail of all ages and sizes is easy to explain when the full technique is known. In order that the overlapping may be carried out in the correct manner the core must be wound in a clockwise direction, when regarded from the handle end towards which the core is wound. This gives a formation like a right-handed thread on the coil formed. It is not of the least importance from which end of the coil the cutting is started. This is the natural way for a right-handed man to wind the wire when the core handle is held in the right hand. It will be seen later how important is the direction of wind, and thus the direction of overlap, in the processes which follow.

For overlapping, the rings are now driven through a tapering hole in a steel block with a punch which has exactly the diameter of the smallest part of the hole (fig. 2). The head of this punch is shaped that both ends of the ring, one higher and the other lower, are forced down the howl with equal pressure. At the bottom of the block the hole becomes larger again so that the ring drops out after it has been overlapped the correct amount (plate. xv, 3). An alternative method is to fix the punch in a vise or a block of wood and, after placing the ring on it, to hammer the steel block, with its tapering hole, over the punch. As the ring emerges at the top of the block the ends that are later to be flattened are struck by the hammer, and this tends to seat the wires together at the overlap. It will be seen later why this is important. With a constant wire-thickness and size of core and a regular cutting the overlap will always be the same and the ring will remain perfectly circular. If the rings are measured after the overlapping has been done, they will be found to be of very great accuracy. It would be the advantage of future research if the measurement of mail rings was standardized. It has been found best to use a micrometer accurate to a thousandth of an inch for this purpose. The measurements of ring diameters are taken across the ring parallel to the overlap. After overlapping the rings only vary in external diameter by two- or three-thousandths of an inch.

In all the processes so far described the rings can be worked cold, but as soon as the metal becomes hard by working it must be annealed. To accomplish this it must be heated red hot and left to cool. It

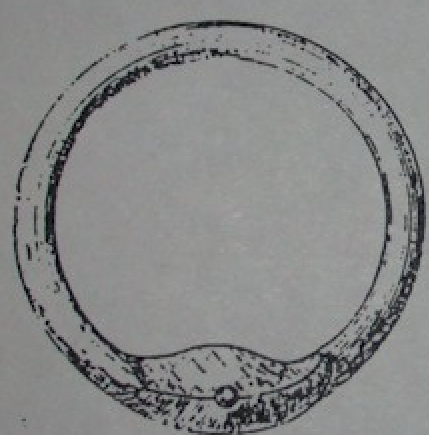


Fig. 3. (about 4/1)

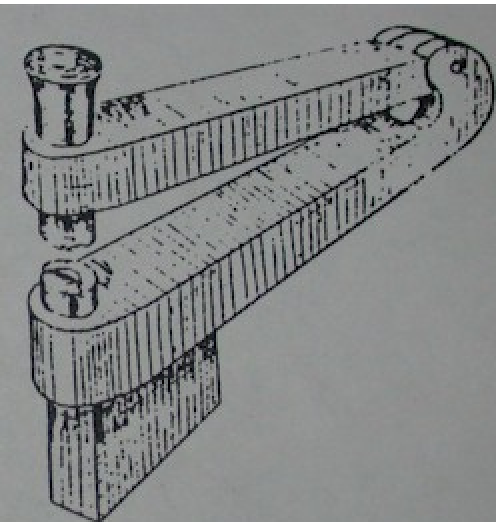
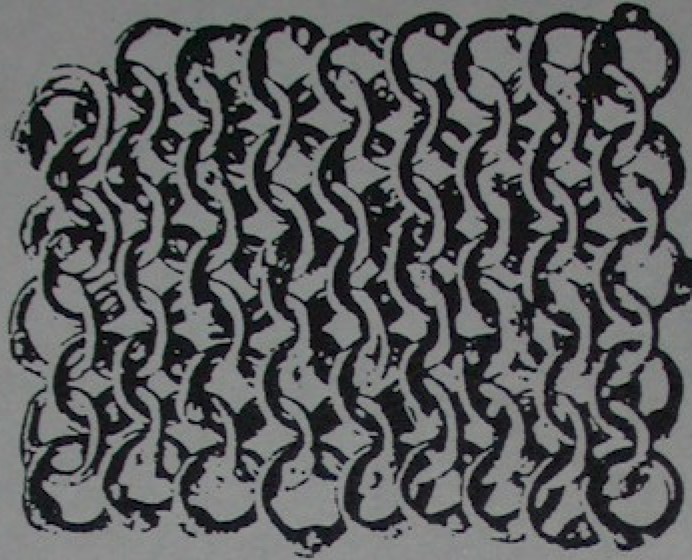


Fig. 4.

must not be quenched in water. This heating will be found necessary every now and then while drawing the wire and before overlapping. A mail-maker would thread the rings on a length of wire and heat them in a forge. It is best to anneal the rings again after the overlapping so that they are quite soft before flattening.

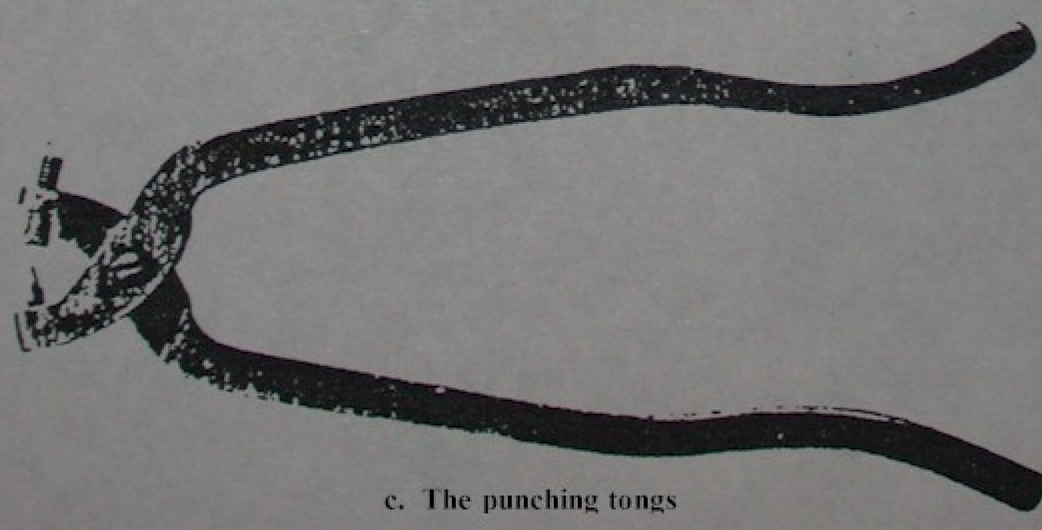
Now comes the swaging out or flattening of the rivet joint. This is the most important process as far as the finished appearance of the ring is concerned. It is this process which produces the formation round the head of the rivet so characteristic of riveted mail (fig. 3). It is convenient to call this typical formation the ‘water-shed’ formation for want of a ready-made term.

The swaging is done between two steel dies or moulds which are held in the correct position one with another by two iron arms hinged together (fig. 4). Underneath the lower arm and above the upper arm are two projections which are in line with each other and with the dies. The lower projection serves simply to hold the tool in position. It can be held in a vice or fixed in a big block of wood in the same way that anvils are often set up. In a mail-maker’s workshop the latter method would probably be used as vices would be far too useful to be constantly employed for holding a tool of this sort. The upper projection forms an anvil which is struck with a two pound-hammer bringing great pressure an any ring which is between the dies and forcing the joint to take their shape. One blow of the hammer should be sufficient, but it is a good plan to give two strokes. The first is a light stroke to seat the two round wires together at the overlap and the second a heavy one to squash the ends of the wire firmly together and to spread them into the dies.



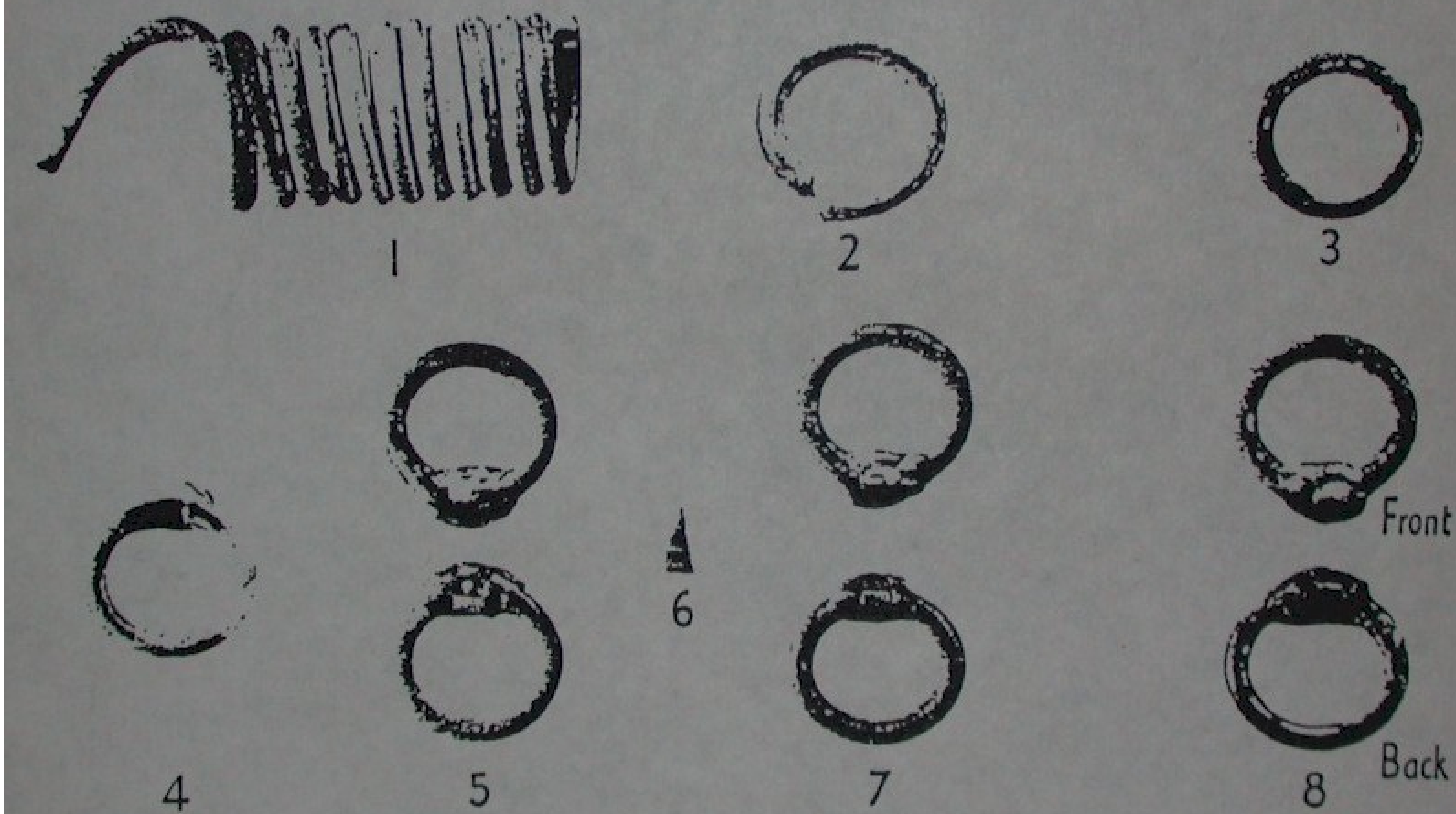
a. Modern reproduction of mail made by the processes described

b. Core for wire winding



c. The punching tongs

Plate XV



Processes from coiled wire to finished rings

The dies must be the correct size and shape for the size of the wire and rings or the overlapped ends will jump apart. The two recesses must be exactly one over another or the ends will jump sideways, and they must be very slightly deeper in the centre or there will be nothing to prevent the overlap from being destroyed by the ring opening outwards. On the other hand, if the recesses are too deep, the ring will be bent and the wire outside the overlap cut and flattened. By experimenting with the shape and size of the dies it was found that the shape which gave the best result, and the shape which was the most simple to make, was one which produced a ring precisely the same as rings found in original mail (pl. xv, 4). The method for making the dies is explained later; it will then be clear that the method is one which would come easily to a craftsman working with a forge and fundamental tools. No attempt has been made to produce mail which looks like the original, but the shape of die found to be the best did give a 'water-shed' formation to the ring.

The rings can be worked cold for this process provided they are softened before and heated after it, but they work better when hot. The swage never gets hot because it has such a big mass compared with that of the ring.

This method of holding the two dies or forms in position one with another and hammering them together is extensively used today by metal-working craftsmen, especially those who do wrought-iron work. The swage block of this type has been used for one purpose or another all down the ages. It would be strange indeed is the mail-maker was not acquainted with it.

For different sizes of rings and different density of texture different dies have to be used. It is best to make them of a high carbon steel, which can be hardened.

Cast and rolled steel were not known to the medieval armourer and metal-worker, for the process by which large quantities of steel are manufactured has only been invented in fairly recent times. When modern steel comes from the foundry it is steel right through and hard to work even when hot. Very little work can be done to it when it is cold. The medieval armourer used a high quality soft iron to work with, which is almost unobtainable today, and when he had fashioned it to the shape he required he case-hardened it. Case-hardening was done be surrounding the piece of iron with crushed charcoal packed tightly into an iron box. The box was then placed in the forge and kept at red heat for some time. The carbon turns the outside of the iron into steel, and this layer of steel gets deeper as the process continues. Eventually the iron is steel right through, but this is usually a disadvantage. Iron tools with steel faces are better than tools which are steel right through because these are liable to crack and split. Much plate armour is case-hardened, for the outside is diamond hard while the inside is as soft as the original iron. This case-hardened plate is much stronger and will resist much harder blows than if it were steel right through.

Case-hardening has been known for thousands of years. Steel-faced tools and arrow-heads have been found which were made about 600 B.C. The arrow-heads were steel right through near the tips where they were thin.

It is best to make the steel dies separate from the rest of the tool. In this way many pairs of dies may be used with the same tool. It is also possible to ensure that they are exactly one above another. The cavities in the dies can be punched into them while the steel is soft by replacing one of the dies by a hard steel punch. This punch is best filed to shape, and it is this filing which gives the form later appearing as a 'water-shed' on the ring. When one die has been made, die and punch are removed and the punch is placed where the die was. The second die is now placed where the punch was and the two hammered together. The dies are now hardened by heating red hot and quenching in water or oil and are then tempered to a dark straw colour. When the steel is hardened in this way great stresses are set up inside it so that it breaks when attempts are made to bend or hammer it. Oil does not cool the metal so violently as cold water. These stresses are then reduced by tempering. The steel is polished and heated again as far from the working face as possible, and the colour of the oxide formed on the surface is watched. It changes from a light straw colour to blue, and when the working face reaches the correct colour it is instantly quenched.

After the rings have been swaged out their diameter will vary more from ring to ring than it did after the overlapping. This increased inaccuracy is still within the limits of the usual accuracy for riveted mail. On good mail the average variation between the ring diameters is about twelve-thousandths of an inch. This fact is another indication that the method here described is a correct one.

The final process in the manufacture of rings is the punching of holes to take the rivets. The rivets are almost always of iron even if the rings are brass, and they are almost always wedge-shaped. The rivet backs are rectangular, while the front must originally have come to a point before the rivet was closed. It is necessary then that the holes should be in the same shape. Attempts were made to replace the dies in the swage with punches, but the shock of hammering proved too much for the small steel punch. It is necessary to squeeze the punch through the ring and into a shaped steel block with a hole in the centre. This block is, in fact, repetition of the swage-die with a hole in the centre of the 'water-shed'. The block and the punch are mounted in a tool somewhat like a pair of tongs (pl. xiv, c). The handles are squeezed and the punch is forced slowly through the ring, the metal from the hole being extruded on the other side. The pressure on the ring and the shape of the punch tend to destroy the 'water-shed' formation on the back of the ring, while on the front the effect is increased (pl. xv, 5). If the punch is long and thin and is pushed far enough, it finally breaks through the ring on the other side and a rectangular-backed wedge-shaped hole is the result. Sometimes rings can be found in mail where the metal has been extruded by the punch but not pierced. These rings look exactly the same as the ones produced in the experiment.

On no account must the punch, at its widest part, be more than one third the width of the swaged-out joint before punching. If it is wider than this the tendency will be to split the ring.

The rivets are best made out of wire. The wire is hammered out at one end into a fan shape, and then cut to a point with wire-cutters. This produces a four-sided end to the piece of wire tapering on all sides. This tapering end is now cut from the rest of the wire to form a rivet (pl. xv, 6). The rivets could also be made by cutting up strips of metal and in many other ways. The shape of the finished rivet is all that is important.

The rings are then opened and are ready for linking. It is not until this stage that the master-craftsman need handle the rings. He can concentrate on the actual linking, riveting, and building up of the garment he is constructing. The rings are linked together into the required formation and are then closed ring by ring. Then the rivets are inserted, a line at a time, and forced into the holes and out on the other side by a tool similar to that used for punching (pl. xv, 7). In the place of the punch, however, there is a block of metal with a depression similar to that in the swaging-die. The rivet, replacing the punch, passes through the hole in the ring and into the hole in the block of metal used for punching. Then, a line at a time, the rivets are closed by a similar tool with a rivet set in place of the perforated block (pl. xv, 8).

It is easy to see from the process of linking and riveting why all the rivet heads appear on the same side (pl. xiv, a). It would be troublesome to keep turning the tool round to suit each ring. The rivet heads should always be on the outside of the garment because the rivet backs cause less wear to the garment underneath, and also because the craftsman would want to see the rivet head after he had closed it. The rivets are simple to make, and drag the sides of the ring together firmly when they are closed.

Some mail rings bear armourer's marks on the rivet heads or backs. It would not be hard to punch these marks on to the steel dies used for the final processes.

All the stages in the process are fairly rapid and it can be seen that one man could concentrate on one stage and use the same tool or tools over and over again. This would make for fast working. It is easy to link and rivet one link a minute, but after long practice no doubt the building up of a garment would be a very fast process. Only the last stage is highly skilled; all the other stages are very simple to perform. The skill in linking consists in getting the correct combination of rings in order to shape the garment so that it is comfortable to wear. The actual closing and riveting is a very simple process.

In some mail the rings are very hard. The finished garment could be rolled up in charcoal and case-hardened to produce this effect. Finished mail would be very easy to case-harden as the structure is so open.

All the tools and methods used have their modern counterparts. All the techniques are in use today and are natural and obvious to the hand metal-worker as well as being accessible to craftsmen of the past. They are all very old, much used, processes. This is perhaps why no recognizable tools have come down to us. They are so simple and fundamental that either they cannot be recognized until the mail-maker's technique is known or they were so useful that as soon as mail-making died out they were converted to other uses. Tools were more valuable then, but the practice of altering tools to suit the job is still carried out on a large scale by the metal craftsman, especially when the tools are hand-made.

It may now be possible to recognize mail-maker's tools by the knowledge of how mail was made, and thus a greater understanding can be acquired, not only about the technique itself, but also about the origin and relationship of individual pieces. The swage makes the same mark over and over again. Thus, if rings made by the same swage were used in two different garments, it should be possible, by close inspection, to determine that both garments were produced in the same workshop or by the same tool.

It is to be hoped that further research will make it possible to fix dates and localities for the mail so numerous in museums and collections.