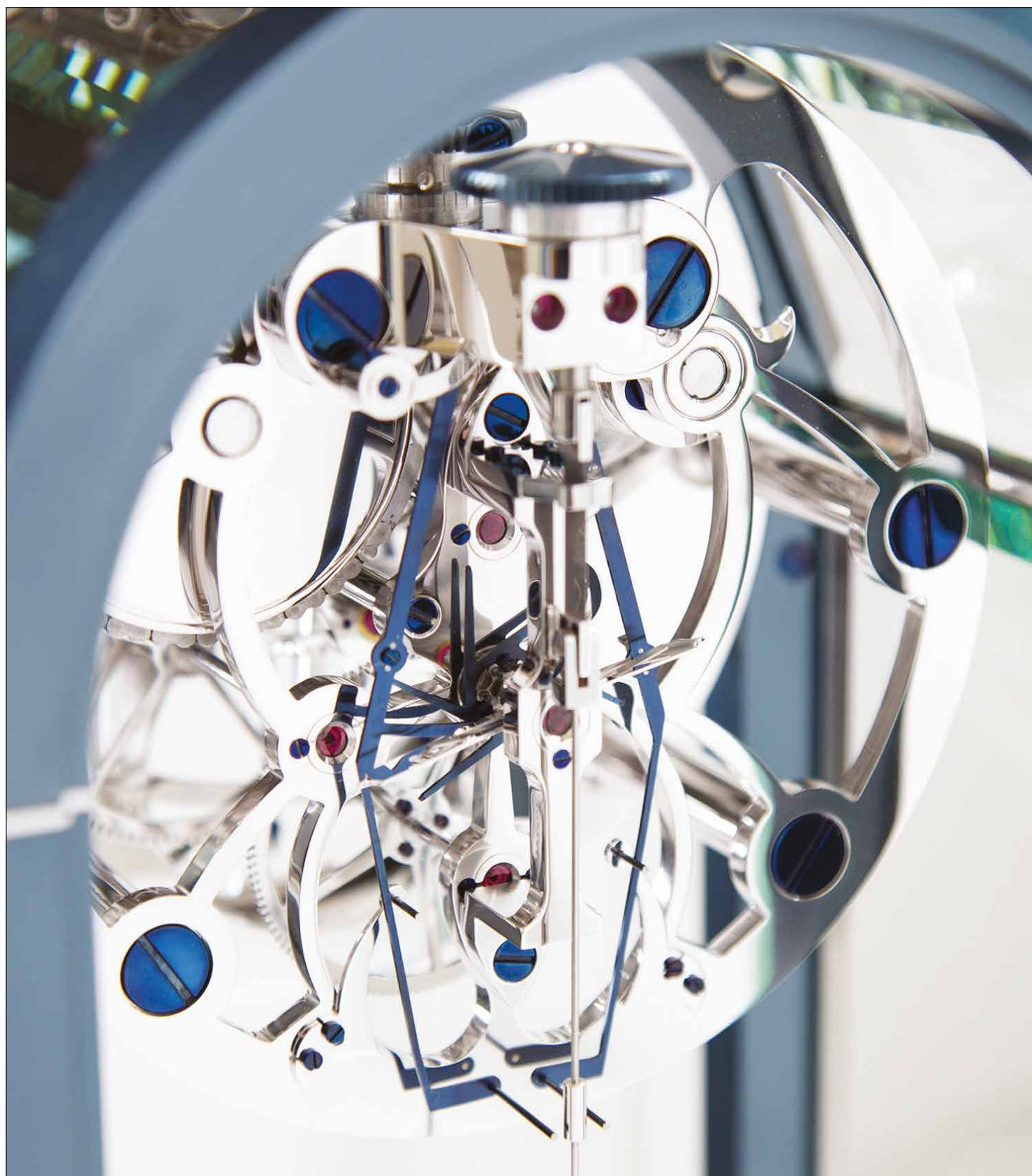


OFFICIAL JOURNAL OF THE BRITISH HOROLOGICAL INSTITUTE

The Horological Journal



NOVEMBER 2020
www.bhi.co.uk



The Clock as a Work of Art, Part 4

Silver Soldering for the Clockmaker

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The ability to fabricate small brass parts for a clock is both useful and time-saving compared with machining a component from solid. The soldering process is a simple one, bonding two items by melting a joining metal, but this apparent simplicity can disguise many things that can go wrong.

As a judge at the National Model Engineering Exhibition for the Horological Class entries, I have the opportunity to examine many clocks. A common fault, even on some very fine ones, is what I call the 'Black Plague': a surface stain that creeps from an imperfect joint. I explain my own theory for the cause of this phenomenon at the end of this article, and hope that my account of good practice with silver soldering might help to avoid it.

I have used silver soldering as a routine process in my workshop on boilers for steam locomotives and as a bonding process in making tools and equipment. On my regulators, I use silver soldering in the fabrication of five components for each movement, which I shall outline in this article. One should be aware that another term for silver soldering is hard soldering; there is also soft soldering, which uses a lead-based material at a relatively low temperature.

The following account of the process is not a definitive guide as there are many items such as ready-mixed flux and solder paste, and grades of solder that I have never felt the need to explore.

The Process

Silver solder

Lead with a melting point of 327.5 °C is widely used as a component in alloys used to solder electronics and plumbing. One of the reasons its use in clockmaking is limited is because of its visibility along a joint line, where it oxidises to a black colour; this is unacceptable in fine clockmaking.

The advantage to clockmakers of silver solder over lead, apart from its strength, is its colour which, being alloyed with copper, is more akin to brass. It does however require a higher working temperature. Silver solders are available in a range of working temperatures from 610–800 °C. For clockmaking, we need concern ourselves only with solders of the lower 610–650 °C range.

The silver content of the solder makes it a lighter colour than brass and for this reason, fillets and joint lines must be as small as possible.

In my experience, solder in wire form of 0.5 mm–0.75 mm diameter is the most useful size for clock components.

I cut solder into small pieces, which makes them convenient to put in place with tweezers once the water has boiled away from the flux, **Figure 1**.

There are silver solders which have a higher copper content, making them more brass-like in colour and therefore more suitable for the repair of musical instruments where joints are more visible. These solders have a higher melting point, around 800 °C, and demand a suitable flux. The higher working temperatures, however, make them unsuitable for use on a small component where it is very easy to overheat and burn away the flux.



Figure 1. Silver solder is available in a range of diameters from 0.5 to 1.5 mm. I cut solder into small lengths for convenience in placing them on the workpiece.

Capillary Attraction

The important working characteristic of silver solder is capillary attraction; it has the ability to draw molten solder into a joint at tremendous speed. Joints have to be a close fit; the closer it is, the greater the penetration. It would be almost impossible to make a joint on a clock component so tight as to prevent capillary attraction. The fluidity of molten solder renders it of no use as a gap filler.



Figure 2. A suitable demonstration of a reservoir is to prepare a disc with a pilot hole through its centre. A small piece of solder is dropped into the pilot hole after the job is coated in flux.

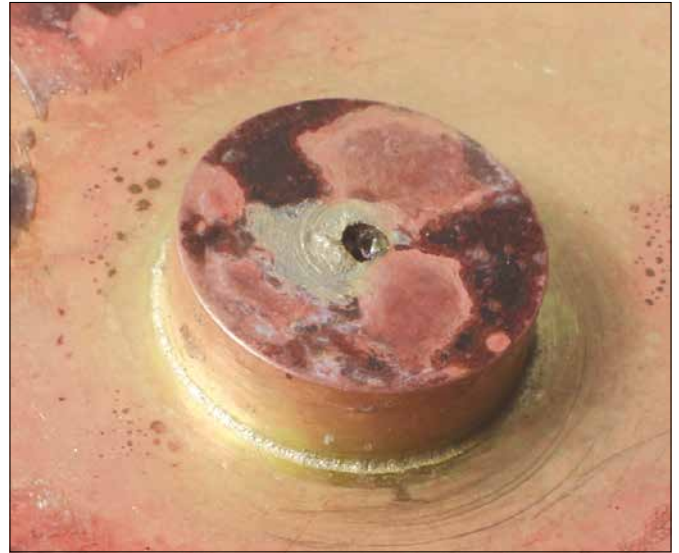


Figure 3. The solder is protected from the flame in the pilot hole during the heating of the work. A fine witness line of melted solder proves complete penetration of the joint.

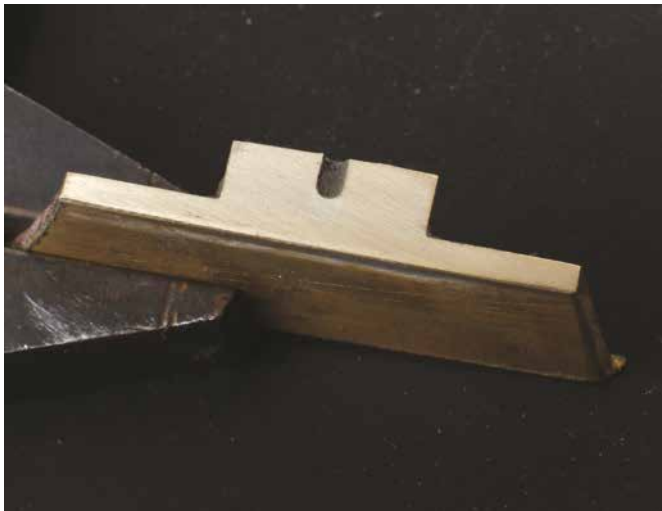


Figure 4. The test piece is then sliced in half to show a cross-section of the sample. It reveals a small amount of solder left in the reservoir, but not enough to force solder to spread on to the sheet.

Feeding Solder into a Joint: The Reservoir Principle

Waving a silver solder stick or wire at a glowing assemblage in the hope the solder will go where one intends is doomed to failure. All you will achieve is the formation of molten globules of solder that will roll around the surface, almost certainly sticking to where they are not needed.

Solder needs to be introduced to the work screened from direct exposure to the flame. Solder wire of 0.5 mm thickness will burn away, disappearing instantly if exposed to a flame.

The best way to introduce solder to the inside of a joint is by placing it in a reservoir made in a sacrificial part of the work. The solder can nestle until the temperature of the workpiece itself melts the solder, and it then flows into the work. More solder can be introduced if necessary, once the work is at the right temperature.

On reaching the correct temperature a fine witness line of silver will flash round the joint, proving complete penetration of the jointing surface. See **Figures 2–5**.

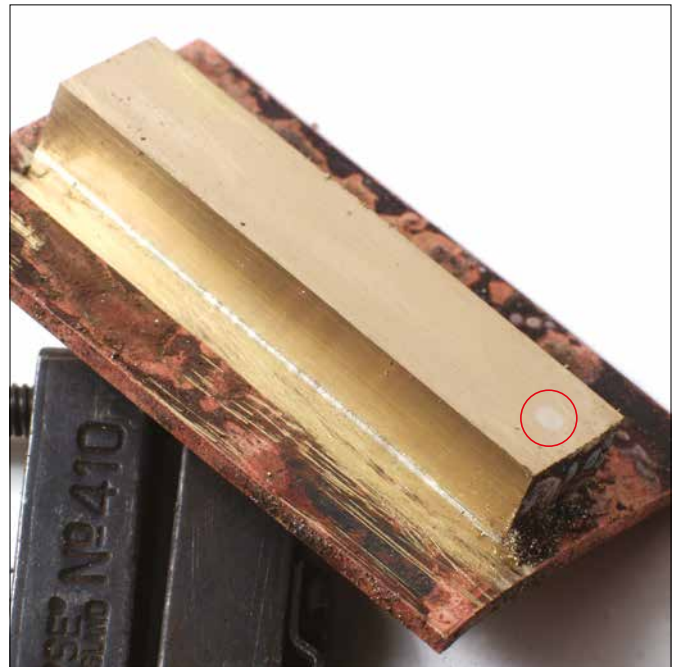


Figure 5. A similar test to the previous one in which a square-section bar is soldered to a plate. The reservoir, just visible at the right-hand end of the bar, has been filled. That end of the work is sacrificial, and will be removed. On a job where a straight edge is produced, it is possible to run a sharp square graver along the fillet to make it less visible.

Flux

Flux is required to stop metals oxidising, thereby guaranteeing that the solder will fuse effectively. Any trace of oil or grease on the work will stop the flux working. In order to ensure cleanliness, therefore, brass surfaces are wiped clean with alcohol before the application of flux. Be wary of using abrasive paper for cleaning, as particles can be embedded in the brass and could be a contributory factor in the problem of the 'black plague'.

Flux is supplied in powder form and mixed with water to a consistency similar to yoghurt and free of any lumps. I



Figure 6. The preparation of flux requires care, as its activity is essential to the flow of molten solder.

stress this point because I believe lumpy flux to be the most common reason for a gap formation in a joint. I suspect if a lump of un-mixed flux is left it forms a crystalline structure, which interrupts the continuous flow of the silver solder.

When flux is stored for a long period it can become lumpy and must be crushed back to its powder form to ensure a smooth mixture, **Figure 6**.

Never re-use a dried-out flux mixture left over from an earlier job.

A very small amount of washing-up liquid will make application of flux easier by reducing surface tension on the brass parts. The detergent content is quickly burned away on heating with no detrimental effects.

Workspace and Heating Equipment

I use a Sievert torch with a Standard No. 394102 22mm burner which is adequate for most clockmaking jobs.

I assemble a workspace using vermiculite bricks. These can be cut and drilled to shape to suit individual jobs. It is essential to have a secure docking arrangement for the burner where it can be rested whilst still alight.

Heating Up the Work

It is important to heat up the work piece slowly and evenly. Thin sections leap up to temperature while heavier sections take time. For this reason, I recommend a larger burner with a soft flame which reduces the chance of the blast blowing away the molten flux.

The first stage of heating is quite dramatic with water boiling out of the flux, resulting in powerful forces exerted on components. Small parts can easily be dislodged by the violent boiling action, therefore provision must be made to secure parts when necessary. This boiling action gives way to a crust formation that persists until the flux reaches its operating temperature. The crust eventually melts and everything turns liquid again. You can observe the flux cleaning the brass as areas of bright brass become visible. Continue to apply heat until the brass begins to glow slightly; be aware that larger masses will lag in reaching the required uniform temperature.

If you heat up too quickly, thin sections can rise above the flux operating temperature and exhaust the ability of the flux

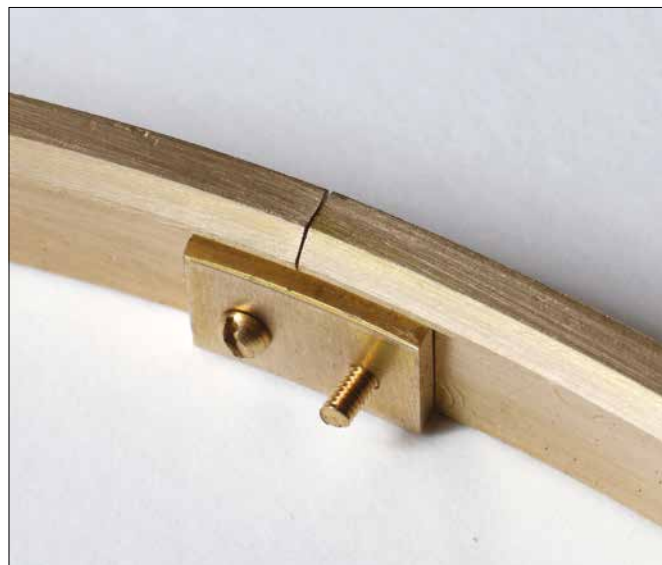


Figure 7. Bezel joined, secured by 10BA screws.

to clean the surface. When brass approaches 620°C it will begin to glow slightly. Gauging of temperature is dependent on workshop lighting conditions and is a skill to be acquired through experience. Remember the two golden rules: **ONLY THE HEAT FROM THE COMPONENT MUST MELT THE SOLDER** and **NEVER APPLY THE FLAME TO THE SOLDER**.

On reaching the solder melting point, the solder will flash through the joint. This will be evidenced by the joint showing a liquid silver gusset. If you feel satisfied that the penetration is complete, remove the flame. If necessary, more solder can be added through the reservoir hole or a joint area that will subsequently be machined away, but do not overdo it.

Do not re-apply the flame unless any fresh solder is shielded from it. Too much solder will allow it to spread where it is not wanted. As silver solder is considerably harder than brass and almost impossible to remove without causing damage to a brass surface, excess of it is therefore to be avoided.

Once happy the solder has penetrated the joint, stand back and marvel at the unsightly mess you have! The job now resembles a volcanic post-eruption. (I remember many years ago, my then-young daughter was drawn into the workshop by the flame and glowing metal of a soldering procedure. As the work cooled in the hearth, she was disappointed that I had seemingly destroyed a beautifully made shiny item. Later that evening she was able to examine the 'horror work piece' transformed into a shining perfect component. My status as Tubal Cain was re-established.)*

Once cool, the work will be discoloured and covered with solidified lumps of flux. Do not attempt to remove the vitrified flux by force. It is very hard and brittle and at this point, there is a danger of scratching and marking the work by forcible removal.

The answer is to overcome impatience and soak the assembly overnight in water or commercial cleaning salts

* Tubal Cain is considered by many to be the father of blacksmiths, first referred to in Genesis 4:22 as the forger of all instruments of bronze and iron. He was probably born between 4000 and 2350 BC. A reincarnation came in the twentieth century when the name was adopted as the *nom de plume* of T. D. Walshaw (Tom), who wrote many books in the 'Workshop' series and restored the turret clock in Kendal town hall.



Figure 8. The bezel is supported face-down on vermiculite blocks to ensure alignment.



Figure 10. After cleaning, the screw heads are ground away leaving a neat appearance inside.

containing citric acid. The flux will soften and can be washed away. Then examine the assembly, paying close attention to any gap in the solder along a joint line. Staining is inevitable, but this can be removed by the usual finishing and polishing methods.

Worked Examples

It is advisable to make soldering the first operation of fabrication.

Do not spend a lot of time finishing sections with the intention of then sticking them together with silver solder. Wherever possible, plan the making of a fabrication where evidence of joint fillets can be machined off. Concentrate attention where joint lines cannot be machined away, but will be seen on the work as a solder fillet. To ensure these fillets are as neat as possible, the solder must be introduced away from the fillets from a reservoir or sacrificial section.

For someone who has never tried silver soldering or simply wants to improve their technique, I would recommend a dummy-run using scrap materials. The following five worked examples cover most cases of a silver-soldered joint as seen in a clock.



Figure 9. The silver solder was applied to the inside of the joint sparingly, with just enough solder to flash along the joint line. Once it appears on the outside edge, you can be confident the strap joint is fully penetrated.



Figure 11. After cleaning up and polishing, an invisible joint is revealed. What a silly photograph to attempt!

Component 1: Bezel Joint

The only way to achieve an invisible joint on a rolled bezel is to use silver solder. The joint needs to be held securely during the soldering process to ensure no movement occurs. I attach a strap to the inside of the bezel then tap and screw with brass 10BA screws, **Figure 7**. Space is left behind the lip of the bezel to allow the dial to slip in easily. See **Figures 8–11**.

Component 2: Beat Adjustment Plate

This item has to be fabricated and attention paid to ensure no solder runs on to the sheet area of the item. The parts of the fabrication are planned with a generous allowance of brass to be removed.

The positioning of the two thick parts of the item is guaranteed by treating them as a single part of the fabrication with a central bridging that can be machined away. Silver solder is fed into the joints through reservoir feeder holes, drilled at each end of the bridge in sacrificial material that will be cut away.

The finished article is marked out using datum points from the solid bridge area. See **Figures 12 and 13**.

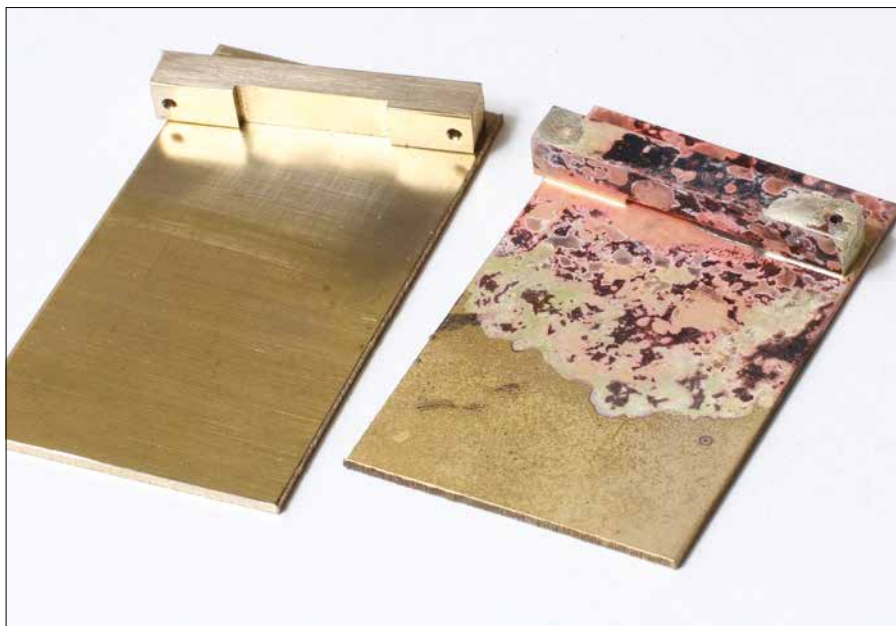


Figure 12. Plate and bridge piece before and after soldering.



Figure 13. The only evidence of the soldering process is the small gussets of the internal corners. External joints are almost invisible after machining to size.



Figure 14. Component parts before and after silver-soldering together.



Figure 15. The tray is machined to size and polished whilst supported on a mandrel through the centre hole.

Component 3: Weight Tray

This fabrication has a continuous fillet around the central body. Silver solder is introduced through a pilot hole in the body that acts as a reservoir, enabling the solder to flow and form a minimal gusset around the joint, **Figures 14 and 15**.

Component 4: Clamping Screw

This fabrication is similar to producing a casting where all finished surfaces are machined, **Figures 16 and 17**.

Component 5: Winding Key

Silver soldering is the ideal way to make a perfectly parallel square hole, for example in a clock key. I always make the square of the winding arbor first and then make the key to fit, **Figures 18 and 19**.

The 'Black Plague'

The main reason for a job being spoilt is the discovery of a gap in the solder fillet. When cleaning up a job, examine the joint carefully using a magnifier and if a gap is found in the

solder fillet, it must be remedied. No matter how small it may look, this gap will not disappear. Unless a continuous line of solder is in evidence, there is a problem that will develop into the 'black plague'. After a few months, a black stain will begin to spread around the offending break and continue to grow; I have seen examples of 'plague' 3 mm across, **Figure 20**. It is almost impossible to remove by polishing and will inevitably return.

I am not sufficiently qualified to explain the true nature of this staining, but my guess is that in the heating up process, a small amount of flux that is not fully mixed forms itself into a crystalline fragment. This interrupts the flow of molten solder. If this resultant gap is exposed, the fragment of flux becomes chemically active through the presence of atmospheric humidity, forming the creeping stain.

The only time for remedial action is when examining a newly soldered joint.

In some cases a gap can be remedied by scratching into the joint, re-fluxing and re-heating. If fortunate, solder will



Figure 16. Each clamping screw is formed by silver soldering two brass sections (at left). A small nipple is left on the head section to act as a locator for the pilot hole in the body.

Solder is introduced through the pilot hole ensuring a fully penetrated joint (right).



Figure 17. All faces of the clamp are machined, with the gripping diameter knurled. A degree of elegance is added to the item by the use of a graver to finish the head with a concave face.



Figure 18. A square-section black bar is mounted in a self-centring four-jaw chuck and drilled to the across-flats dimension of the winding arbor. The bar is then transferred to the milling machine and a square channel milled using the witness marks of the drilled hole as guide. The top surface is then removed completely (shown centre). A flat piece of steel, shown left, is prepared to complete the fourth side of the square and soldered into position, right.



Figure 19. The bar is finally returned to the lathe and the external diameter of the key is turned. This diameter acts as a gripping surface when forming the rest of the body for connecting to the crank.

penetrate from inside the joint and fill the gap. It might be necessary to add more solder through the reservoir or a point that will be machined away. *Don't* attempt to add solder to the offending gap as it will flash across the surface, look unsightly and be difficult to remove.

If a gap is revealed through machining a face, remedial action is more complicated as there is a chance that parts will shift when the solder becomes molten. Unfortunately, the problem cannot always be solved and time is better spent starting again. For this reason, I stress the importance of planning work to make the soldering process the first operation on a fabrication.

My hope for this article is that it might de-mystify the black art of silver soldering and encourage clockmakers to use the process. It has some very real advantages in making clock components.



Figure 20. 'The Black Plague'. This bracket was made a couple of years ago from two flat sections, and a minute gap was evident in the joint. Misguidedly, I thought the gap was so small it would not be a problem. However, over several months the stain grew from the gap to form the large 3mm surface mark, shown above, which consigned the part to the scrap box.

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