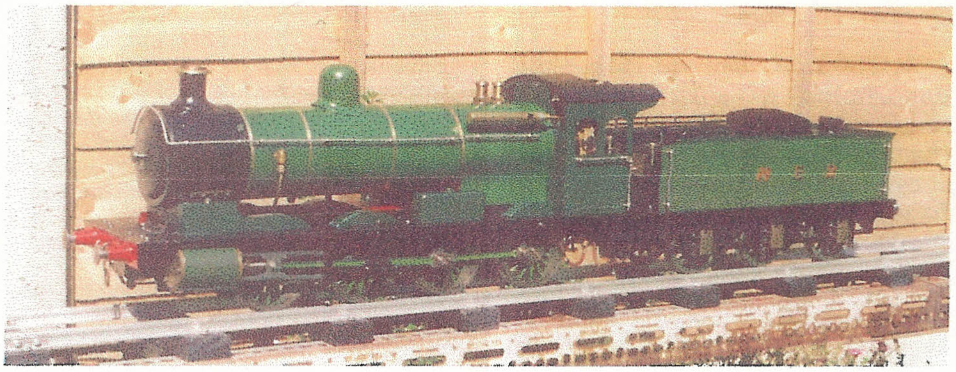
Lempor Draughting (or Bodgers Blastpipe)

by Bill Roebuck



Photograph 1: The Author's LBSC Netta as completed.

I had intended to write this article on improving the steaming of an engine some years ago, but retirement and house moving got in the way, and the text quietly disappeared into the mists of 'things to do one day'.

The investigations into better draughting were prompted by the completion of an LBSC 3½" Netta (photograph 1), which did not run or steam as freely as it should, and the blast sounded 'tearing'. Something would have to be done. As an aside, it may be worth checking your smokebox is completely airtight so your existing arrangements have the chance to work correctly before embarking on this journey. A tiny hole too small to stick a pin into can completely destroy the smokebox vacuum, and no amount of blastpipe tinkering will make much difference. Guess how I found that out!

Some years ago an article in *Model Engineer* suggested that steaming could be improved by making the blast nozzle 15.5% of the cylinder diameter, then drawing up the blast cone to an included angle of 6° and positioning the choke so the generated cone filled it (or adjusting the orifice: choke height ratio to between 1:9 and 1:10). I suspect these proportions dated back to Henry Greenly, but I have to admit that the re-draughting of a previous LBSC locomotive in this way resulted in the engine becoming a consistent and predictable steamer which ran much more freely due to the lower back-pressure. Netta, unfortunately, did not respond to this treatment. You couldn't say it didn't steam, but it certainly didn't steam well or reliably, and being at the time dependent on injectors for boiler feed reliable steam was essential.

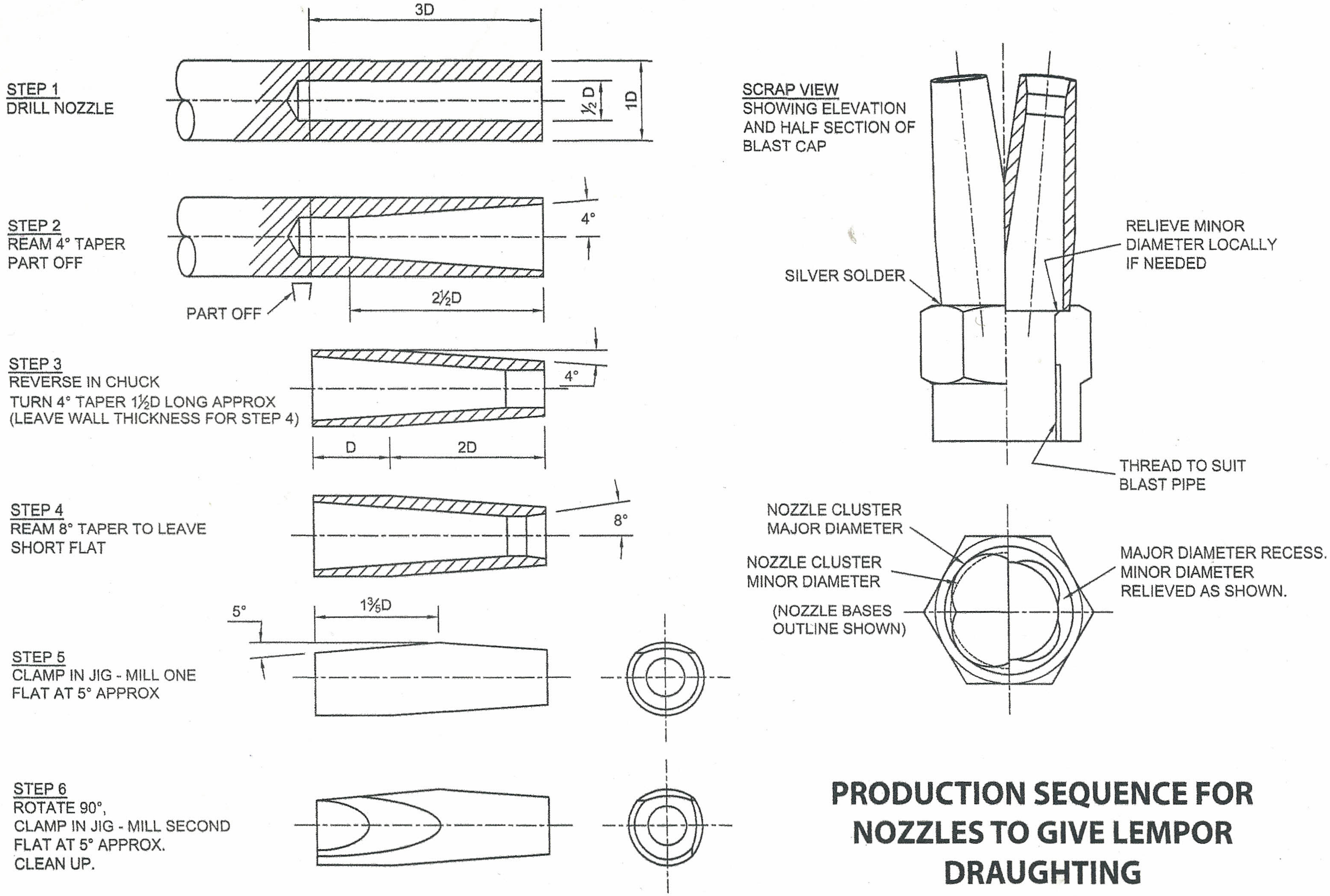
Much reading of books and magazines followed to try and get a better idea of which way to go in improving the draughting. The main consensus seemed to be that a properly designed single blast-pipe/single-chimney arrangement should be capable of making all the steam required, but the ideas, dimensions and proportions required to achieve this were often vague and mostly contradictory. One designer made frequent reference to the American Master-Mechanics smokebox proportions, without ever actually saying what they were or how to calculate them. I did extrapolate from the dimensions of one design reputed to steam well and made the required bits to suit Netta, but I think it might be best to draw a veil over the result. I still get asked whether I subscribe to the 'get-you-home' service for steamless engines.

My research implied that the way to go was with multiple jet blastpipes of the LemPor variety (Lemaitre meets Porta). The LemPor blastpipe comprises four De Laval style nozzles set in a cross, all leaning slightly outwards (photographs 2 & 3). The four steam jets would certainly fill the chimney choke, although LemPor draughting is usually used with a draught tube. This is like an extended petticoat pipe (photograph 4), but I thought that improvements might be achieved without this. Some doodling on the drawing board soon produced what looked like an acceptable set of nozzle proportions based on a bit of rough scaling from photographs of full size ones being machined (photograph 5). Some form of jig would have to be made to machine the nozzle bases so they would sit in a cluster for brazing together, and tapered reamers would also have to be made, but apart from that the process looked fairly straightforward.

Photograph 2: A set of Lempor nozzles at the Welshpool & Llanfair Rly.

Photograph 3: As photograph 2 but with a blower fitted.

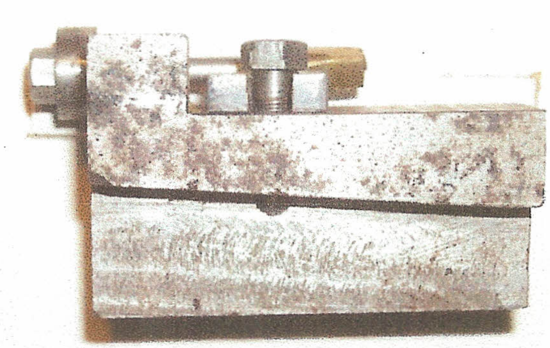
Photograph 4: Fabricated draught tube for W & L Beyer Peacock locomotive.



PRODUCTION SEQUENCE FOR NOZZLES TO GIVE LEMPOR DRAUGHTING

Left - Photograph 5: Lempor nozzles in process of being machined. Note taper is longer than on the miniature set.

Right - Photograph 6: Side view of the model milling jig.



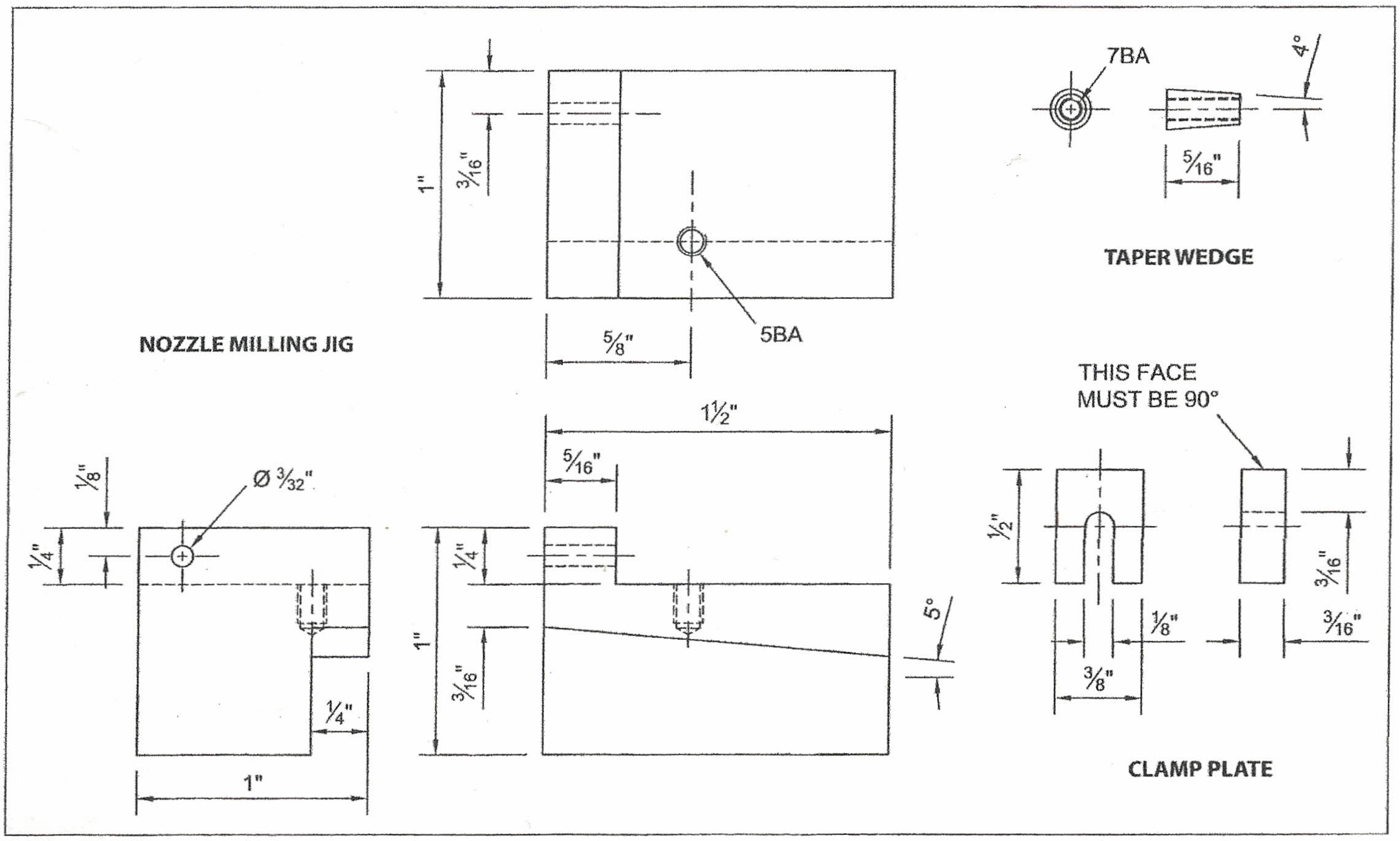
Purists and 'proper' model engineers will no doubt wince at the imprecise nature of what follows, but SMEE does stand for the Society of Model & Experimental Engineers. If my ad-hoc unscientific approach undoubtedly seems a bit rough and ready, then that's probably because it is. Mathematics, geometry and I met at school, recognised we would never understand each other, and passed on like ships in the night. If my teacher had been granted the foresight to tell me I would need to know about these things so I could build steam engines in my old age I might have paid more attention. As it is, guesswork and empiricism suffice. If this offends you I apologise, but I am sure the editor would be pleased to receive your mathematical treatise on the design of exhaust systems, then we could all get it right first time.

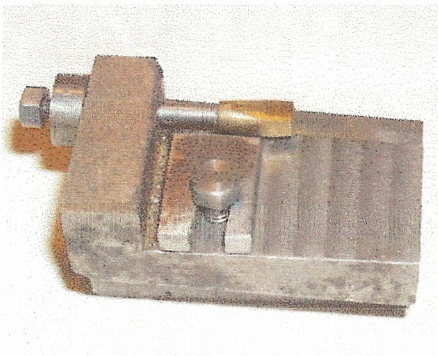
Task 1: Select your nozzle size

This is straightforward (at least up to about 0.375"). The equivalent single orifice blastpipe size either from the drawings or calculated as above becomes the outside diameter of each nozzle. Well, sort of. I went for the next 'standard' size above, and had no problems. Whatever you decide, the nozzle choke diameter is half the outside diameter, so the total area of the four nozzles is the same as the area of a single hole. As an example, if the calculated blastpipe size is ¼" (D), nozzle OD is ¼" (D), choke dia. 1/8" (½D). Nozzle length should be about 3D – i.e. 3 times the nozzle OD. This works for nozzles up to about 3/8" dia. Over that you are a bit on your own but it should be possible to extrapolate for larger values. I have to say there does not seem to be any magic to the design size that you end up with. Exhaustive testing has shown that the odd 64th up or down makes no difference to the end result - the spread of the nozzles ensures the chimney choke is filled, and the smokebox vacuum should automatically follow. No doubt the mathematicians out there will pick me up on this, with complicated trigonometrical formulae to calculate every dimension down to three decimal places. Providing they provide a table I will look forward to using their result, but unless you make your own nozzle choke drills you are still tied to number or metric equivalent twist drills.

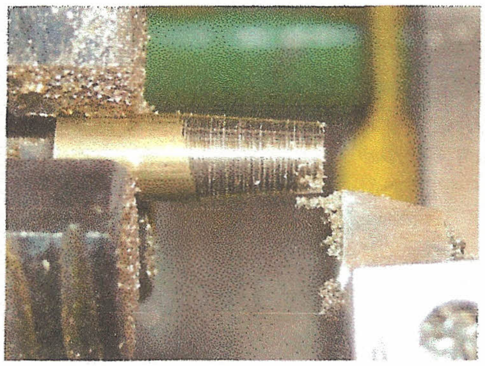
Task 2: Make the Reamers

The D-bit style reamer angles of 4 and 8 degrees were a compromise to give a 'fit' from the drawing. They were machined from silver steel in the usual way by setting the top slide round. There does not seem any criticality in the angle – use the degree graduations provided. The critical factor is in the depth they are used – it is important to leave the short parallel portion in the nozzle. You could include this parallel part on the end of the taper portion to save having to set depth stops, but it will mean you need a separate reamer for each size of nozzle. See the paragraph regarding the machining jig before altering the top slide back to turn parallel – the nozzle taper wedge clamp needs to be machined at the same taper angle as the 4° reamer. In deference to the importance of the job I machined the half diameter down on the

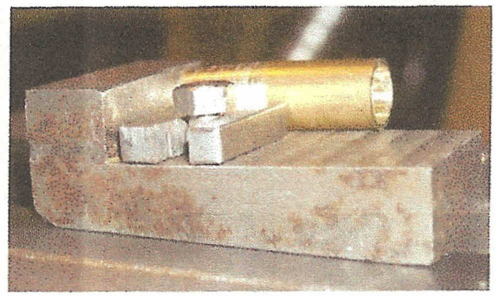




Photograph 7: Top view of the milling jig.



Photograph 8: Turning the 4° external taper (step 2).



Photograph 9: Turned nozzle blank clamped in the milling jig (step 5).

mill, but I think this was to give my ego the impression I was working accurately – you will no doubt file yours carefully down. Harden and temper to straw (any shade – it's only going to be used on brass) – probably best to do all the quenching by plunging vertically into the water or oil to minimise warping.

Task 3: Make the Machining Jig

The only thing to decide before making this is the maximum size of nozzle you anticipate making. The dimensions shown will cope with up to ¼" nozzle OD, which is ample for 3½" gauge. If you want to make big nozzles for 7¼" gauge engines you will have to increase the dimensions marked with an asterisk to suit. To 'prove' the design I made a set of 3/8" dia nozzles, and machined the flats on a temporary fixture. It did work, but I would not like to have to do it again. The nozzles must be securely clamped for milling the flats.

The jig as drawn can be cut from an 1" square off-cut of steel, but any size near this will do. It needs to be rigid enough not to flex when clamped in the mill vice. Do not be tempted to machine a jig to compound angles so as to machine both flats at one setting unless you like throwing away spoilt nozzles. The drawings show the other bits needed – the end of the clamp iron must be at 90° to the face. I made my clamp iron 1/8" thick, but this is not really thick enough so I have shown 3/16" on the drawing. The slot should be a fairly good fit to the clamp screw. Turn the nozzle taper clamp to the same nominal 4° taper as the reamer (see paragraph on making reamers), and tap 7BA. If you are making larger nozzles you could increase this – i.e. 5DA if your minimum nozzle ID was going to be 1/8". Brass would be a good choice, but steel will give you a better thread for clamping purposes. As they are to some extent sacrificial if you are a cautious type, or are anticipating mass production of nozzles, make two or three whilst you are at it (photographs 6, 7 & 8). You will also need to make a pull rod for the taper wedge (not detailed). Mine is 3/32" steel about 1" long with some 7BA thread on each end. As usual it is too long for the smallest size nozzle (hence the thick washer) and just about long enough for the largest size.

Task 4: Make the Nozzles

Making nozzles is very easy, if a little tedious. First set the top slide round to about 4°. If your 3-jaw chuck is reasonably accurate then use that, otherwise use the 4-jaw – the material needs to run about centred or you may ream your way out of the side of it.

Step 1: Chuck your selected size of brass rod with about 1" projecting and if using a 4-jaw adjust to run true and from now on only slacken and tighten the same adjacent 2 jaws – I always use 1 and 4. Yes, I know this does not automatically ensure re-chucking exactly concentric, but it will be near enough for our purposes. Well equipped engineers will use a good 3-jaw or collett. Centre the blank, and drill though with your choke size drill.

Step 2: Estimate the depth of the main taper (about 2½D), set a stop on the reamer if you like and then gently ream the nozzle to depth. Aim for a good finish but don't panic if it's not. Part off to length.

Perform the above 4 times for each set of nozzles to be made. I found it easier to turn and ream all the nozzle blanks at the same time for the three sizes I had decided on (calculated size plus one size above and below). To save grief later, keep each set of nozzles of the same size together in a little bag, as telling them apart once finished is frustrating. Photograph 5 shows some full size nozzles at various stages of machining. Yours should look a bit like these.

Step 3: Take each parallel blank in turn, grip in the chuck by the reamed end, and use the top slide to turn the outside taper with light cuts and a sharp tool (photograph 9). If you are really picky you will measure the taper as you go, but I did all mine by eye. The main thing is to leave enough 'meat' for the 8° reamer.

Step 4: the depth of the 8° internal reverse taper is a bit important, as you should leave a short flat between the tapers. I did the first one by eye, then used the tailstock graduations to ensure consistency. Take this step gently – your hold on the nozzle blank is precarious. If you would feel happier set a reamer depth gauge first.

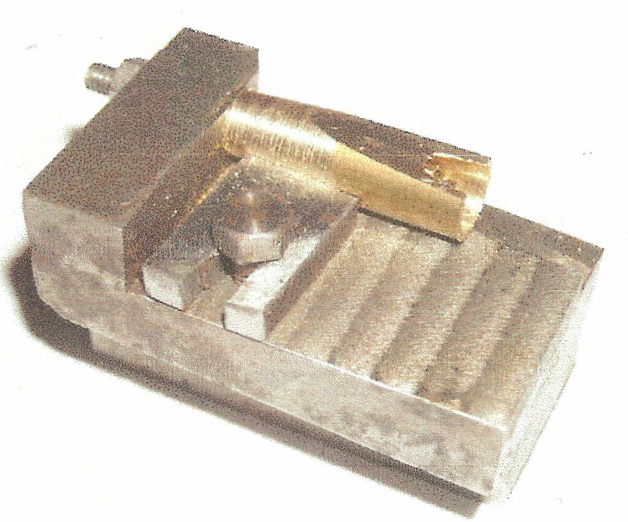
Step 5: With all four nozzles turned set the machining jig up on the milling machine (or whatever method you use for milling). Clamp the first nozzle in as shown in photograph 10, and using a new, sharp end mill gently mill the first flat. Maximum cuts here of 5 thou – less if you are of a nervous disposition. Being heavy handed at this stage means lots of naughty words and a spoilt nozzle – you have been warned. It is difficult to give exact figures for the amount to be taken off for each flat. Aim to get a crescent-shaped cut-out showing like the illustration (photographs 11, 12, 13), with the flat about 3/5ths of the length of the nozzle. Repeat for all 4 nozzles in a set.

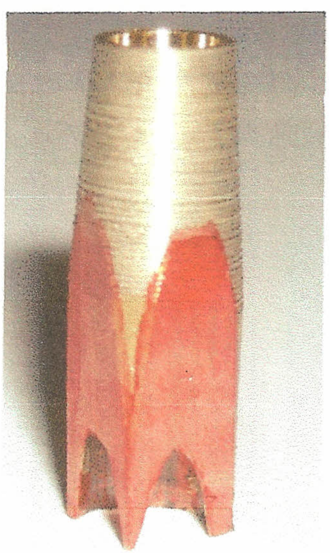
Step 6: Slacken the taper clamp, turn the nozzle through 90°, take up the taper clamp enough to hold while you tighten the clamp iron up close to the milled flat. Then tighten the taper clamp, and mill the second flat to the same setting as the first.

The two flats should cut into the nozzle to leave the 'point' as shown just above the nozzle base in photographs 14 to 17. Within reason there is no major criticality here – a few thou either side of optimum will be perfectly all right as we will make the nozzle holder to suit. The important thing is to make all the nozzles in a set as near identical as you can. If you are making several nozzles of different sizes, get all the machining done now whilst you are in the swing.

To be concluded

Below - Photograph 10: After milling the first flat on a nozzle.





Left - Photograph 11: Lempor nozzle after milling both flats.

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Concluded from page 185, December 2011

With a set of 4 nozzles machined try putting them together to make a cluster. When you have retrieved them for the umpteenth time from the darker recesses of the workshop floor, take the easy way out and stick them upside down in a bit of blu-tack. You can then check with the callipers for the small and large diameters. I suspect it is only possible to specify these accurately in advance after some sort of complex trigonometric calculation process, but as they will vary anyway depending on the depth of the flats, it is probably best to take the easy way out and measure them.

Photograph 12: View looking up the nozzle cluster.

Photograph 13: One used, one new. Note thicknesses of metal showing on nozzle ends.

Task 5: Make the Nozzle Holder

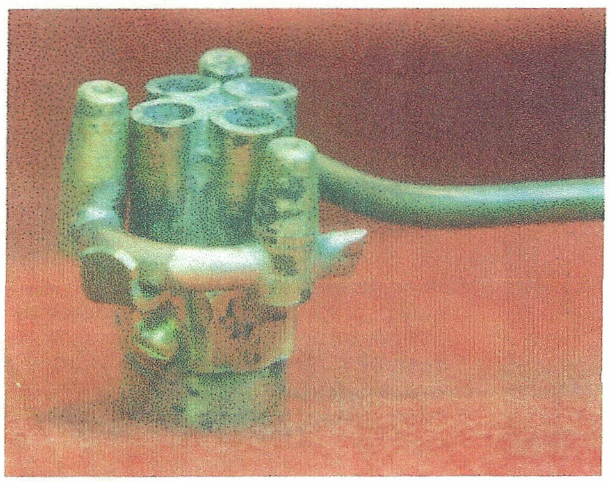
There isn't much to say about this. The picture in 'More Blastpipe Musings' article published in the January 2011 issue of *EIM* showing a full size one being machined points the way here. The thread should match the one on the top of the exhaust pipe from the cylinders, and the shallow recess diameter should approximately equate to the larger diameter of the nozzle cluster, with the hole through the middle about the same size as the minor diameter of the cluster. I found it best to make the shallow recess a bit on the small size, then machine out 4 recesses to accept the nozzle major diameter as a snug fit. It is easier to be accurate if you achieve these recesses on the mill using the rotary table and a suitable size end mill (a good reason for using 'standard' sizes for the outside diameter of the nozzles). It is also possible to file them out, but the problem here is to get the larger radius only in the rim of the nozzle holder – you need the recess to rest the cluster on.

Now for the difficult bit – getting the nozzle cluster to sit straight in the nozzle holder for silver soldering. The method I adopted was to clamp the nozzle cluster in the vice, with the tips held more-or-less together by blu-tack. Thin soft iron wire was then wound round the nozzles and tightened to hold them – make sure the wire clamps the nozzles below the point where they start to diverge. The nozzle cluster will then sit in the nozzle holder ready for silver soldering.

Clean off the blu-tack, flux well, and silver solder with the nozzle holder upright and the nozzle cluster held down with a small block of rusty iron. It doesn't really matter if the iron wire gets soldered as well – the main thing is to use enough solder to give a good fillet round and between the nozzles. I only had one total failure out of six, and that was due to a moment of stupidity with a big stick of Easyflo-2. Whatever grade of silver solder is used it must be capable of leaving a fillet – one I tried was like water when hot and ran through the gaps. One other nozzle set twisted during the brazing, but seems to work just as well in the engine. Probably gives a nice swirl to the exhaust gases. Clean up as required, and the finished nozzles should look like photographs 12 and 13 (the clip is to support the blower).

Fit the completed blast nozzle, making sure the top of the nozzles finish within your calculated distance of the base of the chimney choke. Usually this is achieved anyway due to the height of the nozzle cluster. If necessary make a small extension piece to fit below the nozzle holder to raise it a little. If your old blast nozzle was the type with in-built blower holes you will have to make a new blower ring as shown to go round the outside of the nozzle cluster (photograph 14). The trick here is to only part-drill the actual steam orifice in the jets, then they won't block up during the process of silver soldering them to the tube. With the three blower tips soldered onto the copper tube, it is a simple job to drill gently until the drill breaks through into the copper tube. Bend into a ring to fit round your blast pipe and connect up. I fitted a small bracket to the nozzle holder to stop the blower ring being displaced during tube cleaning.

Photograph 14: Relationship between blastpipe cap and blower.



Task 6: Have a play

Engines fitted with LemPor draughting take a bit of getting used to. The first thing you notice is the lack of noise – more a soft CHISS-CHISS than a sharp CHUFF-CHUFF. Even when working hard the exhaust noise is much reduced, so if you are not careful you can work the engine harder than you might intend. The next thing you notice is the fire. Gone is the white glare – instead the fire seems to only burn with a bright red glow, and you start to wonder if it's about to go out. The third thing you notice is the steam. Lots of it. Netta now just about steams against one injector with only the driver as a load, but with 4 adults behind the evaporation rate starts to get embarrassing. The fire must get hot, as there always seems to be clinker after a run – perhaps the greater throughput of air at lower velocity gives more even combustion but less fierce burning. The one thing I can be sure of is that the engine will steam, so the object of the exercise has been achieved.

A by-product of the re-draughting is the lack of 'robins'. My other engines with conventional blastpipes all steam well, but tend to throw out red hot bits if asked to work a bit harder, as my collection of ventilated shirt sleeves to suit any occasion bears witness. I had been driving the rejuvenated Netta for a while before it dawned on me that the amount of half burnt coal coming out was negligible. After a Sunday afternoon's public running session the smokebox was often filled almost to the halfway line with ash without any noticeable fall off in steaming ability (photograph 15). The greater total blast nozzle area seems to result in a gas flow through the chimney with insufficient velocity to pull ash along with it except for very small particles, and these do not have the mass to travel any distance.

Continued on page 225 – just chat.