Guide to 3D printing of serpents designed by Mark Witkowski

m.witkowski@imperial.ac.uk

A guide to downloading, 3D printing and assembling the Bate Collection Anon (#504) and Dittes (#500) Serpent models (v5, new for 2021).

www.bate.ox.ac.uk
www.serpentwebsite.com

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You can request downloads of all the 3D printer files required to make these serpents by visiting www.serpentwebsite.com and following the instructions given there. Before you start making, read this document and watch Paul Schmidt's "how to" video documentary at https://youtu.be/pDgu9FIfCWs.

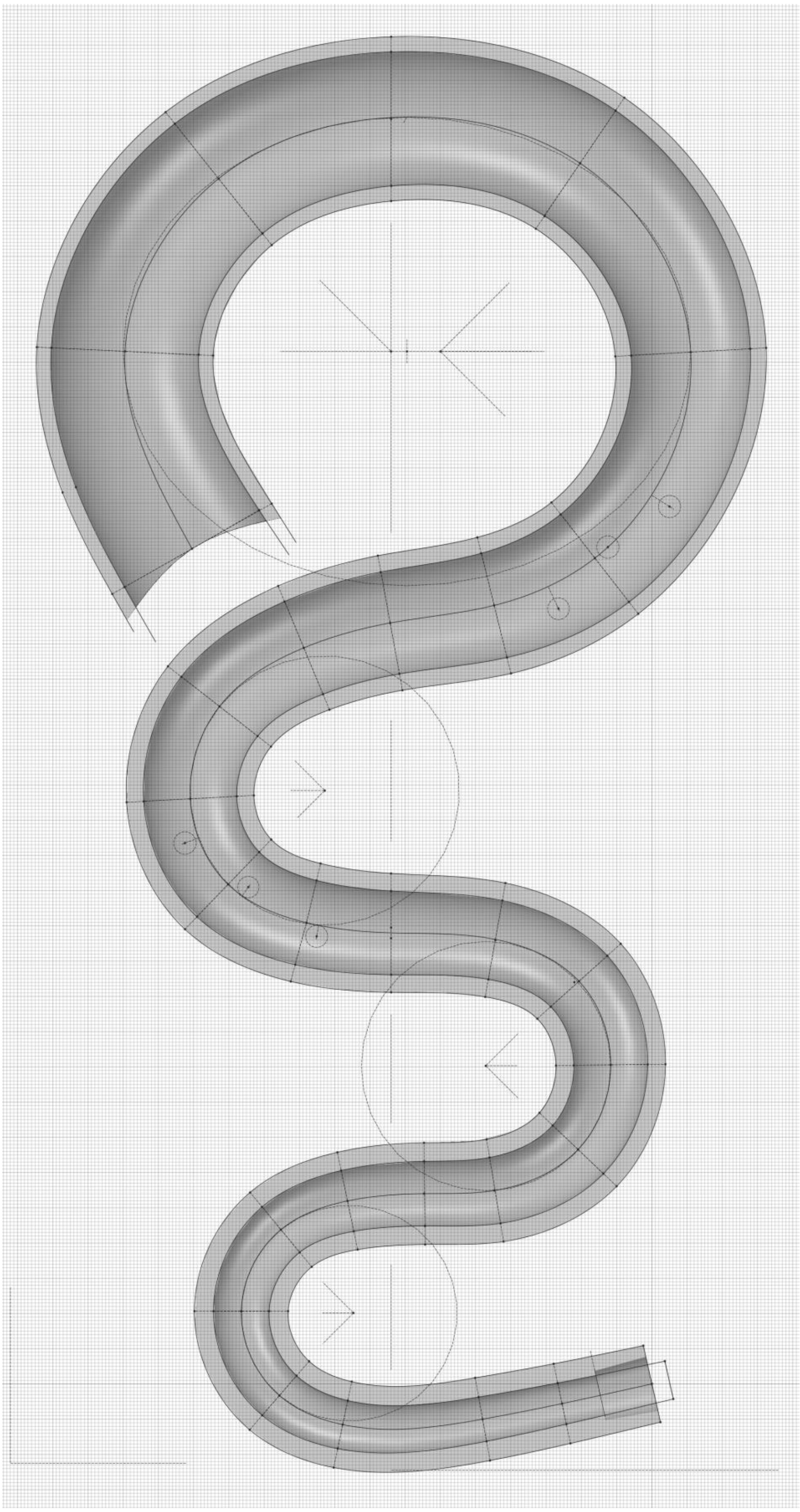

Figure 1: Geometry of the Bate "Anon" Serpent

Introduction

This document describes the making by 3D printing of two full size replica serpents, after original instruments held by the Bate Collection, Oxford (www.bate.ox.ac.uk)[1]. Both are of the “Church serpent” type. The first, referred to here as the "Anon" serpent (Bate inventory number #504[2]) is an artisan instrument in somewhat distressed condition. The second, referred to here as the "Dittes" (inventory #500[3]) is an altogether more sophisticated instrument in original but still playable condition. If in doubt, choose the Dittes v5 design – it tunes to concert pitch and has the best tone. The Anon is an artisan instrument at arbitrary pitch – “of its time”.

You can hear Joel Daniel play “Lo, How a Rose E'er Blooming” on the Anon serpent in four overlaid parts: https://youtu.be/J2It-kcVA90. Paul Schmidt tests the (v3) Dittes serpent: https://youtu.be/1PysqokLFa8. Using the Dittes v5 model, Joel Daniel plays “Duet No. 1” by Jean-Baptiste Metoyen: https://youtu.be/4lD4fpu_f2w and “Concertante” by Harold L. Walters, a piece originally composed for Solo Tuba with Piano accompaniment: https://youtu.be/6AmInbMRRP4.

These Designs are intended for "home" printing by individuals using readily available and relatively low cost filament deposition (FDM) 3D printers and can be completed with a materials cost of well under £100. The 3D printer files for these instruments may be freely downloaded from www.serpentwebsite.com – and follow the links.

The serpent is a wood bass horn with a characteristic curved shape and six finger holes for playing and a near conical bore. Although they look like something out of the dark ages, they were invented in 1590 by Canon Edmé Guillaume of Auxerre and were used for many centuries to accompany sung liturgy in French churches. When played softly the serpent complements the human voice extremely well. When played more loudly the serpent provides a solid bass line and they were introduced into military bands from about the 1750s onwards being used extensively throughout Europe and in the USA until the 1830s.

Serpents are one of the most easily recognised and memorable musical instruments in any historic collection. Most collections will hold several examples; the Bate Collection has a dozen in various forms (some are shown in Figure 2). However, the serpent does not fit well into the modern orchestra and these instruments fell into disuse and languished in obscurity, unloved, for more than a hundred years until the early music revival of the 1970s. There is now a surprisingly active body of serpent

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[1] See the new publication by Douglas Yeo (2019) "Serpents, Bass Horns and Ophicleides at the Bate Collection", available directly from the Bate Collection.

[2] Bate #504: Serpent D’Eglise – Anon (French) "Leather-covered wood; both middle-fingerholes offset for both hands above; brass ferrule on crook socket, the socket also brass-lined internally, the lining covering the end-grain; bell lipped like an elephant's trunk." Max H = 805 mm Max L = 2470 mm Bore = 25.8-100 mm (description from the Bate Collection catalogue).

[3] Bate #500: Serpent D’Eglise - Dittes "Thin walnut, leather covered. Plain fingerholes. 6 brass bands round the body, the ends turned up and riveted, two of them joined by an ornamentally turned stay, may be an early addition. The tuning collar slides on the brass crook. Ivory mouthpiece with brass stem." Max H = 815 mm Max L = 2302 mm Bore = 26.5-100 mm (description from the Bate Collection catalogue).

players and enthusiasts[4] and a good choice of fine replica instruments are available, at a price.

Due to its sinuous shape and complex form the Serpent is perhaps ideal for 3D printing technology. The 3D printed instruments described here are modelled on examples of French made church serpents produced by unknown craftsman and which were very probably made in the early 19th century. They are currently held in the Bate Collection in Oxford (inventory #500 and #504). The original instruments were measured specifically for this project and modelled using *RS DesignSpark Mechanical*, a free to use CAD (Computer Aided Design)[5] package to create the printable objects.

The body of the prototype "Anon" instrument was printed in 20 sections on an Ultimaker2 3D printer at the Imperial College Advanced Hackspace (*http://icah.org.uk)* and the parts assembled by gluing. The mouthpiece and bocal (mouthpipe) add an extra six (seven for the Dittes) parts. The Dittes variant was printed on a "PrintrBot metal" 3D printer in a home environment.

b, c, d – courtesy of the Bate Collection, Oxford

Figure 2: Church and Military Serpents

3D printing in PLA or PET-G material takes some 200 hours and the finished serpents weigh about 2Kg. These full-sized (approx 800mm tall) 3D printed musical instruments look similar to the original (Figure 3), sound well and play very authentically - that is, they're just as difficult to play as the real thing. The Anon original is unplayable so no direct comparison is possible, but the playable original Dittes and its 3D copy sound very similar.

Half-size tenor serpents ("serpenteaux") can also 3D printed - taking only 50 hours, then glued and assembled as with the full size instruments. The Anon miniature was printed with black and yellow stripes, the Dittes miniature in the red, yellow and black stripes reminiscent of the very poisonous coral snake.

The Dittes serpent design has previously been available as version 3 (v3) since 2016, superseded by a more recent design (new for 2020), Version 5 (v5), which offers a number of improvements and changes following comments by various players and

[4] See the Serpent Website, *www.serpentwebsite.com*
[5] https://www.rs-online.com/designspark/mechanical-software

makers. Version 5 (v5) has small corrections to the overall geometry of the design to make it closer to the original (and has a calculated acoustic path length 1.7cm shorter than v3). The tone holes are now undercut with the intention of improving the tone quality. The bocal receiver has been extended allowing for greater range of fine tuning if required. An adjustable bocal has also been introduced that allows for a significantly greater range of fine pitch adjustment, better matching the original arrangement.

Figure 3: 3D-printed "Anon" serpent and 19th Century original (left). 3D-printed Dittes serpent and original, with ½ sized 3D printed tenor serpent (right)

Watch Joel Daniel play "Lo, How a Rose E'er Blooming" on the Anon serpent in four overlaid parts: https://youtu.be/J2It-kcVA90. Joel notes: "*My first attempt at playing multiple tracks on the Serpent to discover how 'in tune' it plays. The tune comes directly from the book, Carols for A Merry TubaChristmas. I am playing the 'Anonymous' 3D printed Serpent and have less than 12 hours on the instrument at the time of recording. Additionally, I am playing on a 6 1/2 AL small shank tenor trombone mouthpiece instead of the 3D printed mouthpiece that came with the CAD files. I find that the printed mouthpiece produces a very 'airy' tone which is consistent with the historical record of this instrument.*"

Figure 4: Joel M. Daniel (Marinesandpiper) plays the Anon Serpent

Joel has also completed several copies of the Dittes (v5) serpent - of which he notes "*It plays 1000 times better than the Anon!*"

It should be pointed out that there is nothing about the serpent - design, making or playing - that is for the fainthearted or the easily distracted[6]. The 3D-printed version, while not calling on traditional woodworking craft skills[7], still requires a significant investment in time, care and attention to complete. However, assuming you have access to a suitable 3D printer, then the materials cost is low compared to a purchased instrument – less than £60 for the printer filament – and only a few simple hand tools and some consumables (varnish and adhesive or plastic solvent) are required to complete the full sized instrument[8].

Before you Start

Before you start, check out Paul Schmidt's video documentary about his experiences of printing his copy of the Dittes serpent: https://youtu.be/pDgu9FIfCWs and maybe read this document through to the end. Note that the video describes construction of the earlier release of the Dittes serpent so there are some small differences in detail.

Quality of 3D printing is essential for all wind instruments. There must be no air leaks, unintended holes or delamination between printed layers. Using a thicker than normal surface skin (3 layers, 1.2mm) and greater infill percentage (30-35%) than usual is strongly recommended to assist with air-tightness and rigidity of the final instrument. The prototypes were made using PLA filament material, though PET-G material generally has far superior mechanical and acoustic properties in this application being less brittle and offering improved interlayer adhesion.

All the design files you will require can be downloaded for personal use for free. Before starting you should download them all and confirm that they will be suitable for your slicer program and printer combination (for instance, Cura and an Ultimaker 3D printer). The parts are all designed to fit easily within a 200x200x200mm print volume, though check with Table 1 (Anon) or Table 2 (Dittes) for detailed dimension requirements.

Equipment and materials

To complete the full sized serpent you will need:

Resources:
- The .stl design files (download)
- Access to a 3D Printer (min 140mmW x 112mmD x 160mmH) for an extended period

Various hand-tools:
- Modelling knife,
- Plumber's pipe deburring tool (optional),

[6] And possibly even for the entirely sane.
[7] If this is your forte, consider the "Squarpent" – www.serpentwebsite.com/SQPT_concept.htm.
[8] Take particular care when using hand or motorised tools - obviously - and wear suitable eye-protection; use solvents and adhesives responsibly in a well-ventilated area - always under adult supervision.

Emery ("wet and dry") abrasive paper, medium to fine
Miscellaneous flat and curved needle files (miniature "diamond" types work well)
Drill bits (3mm, 2mm) and holder
Miscellaneous paint brushes

Materials:

Two 1Kg reels of PLA or PET-G material (plus some extra for reprinting failures and mistakes, they happen!)
Sanding sealer primer (brushable)
Plastic Weld solvent (or other suitable adhesive)
Plumber’s PTFE tape, waxed thread

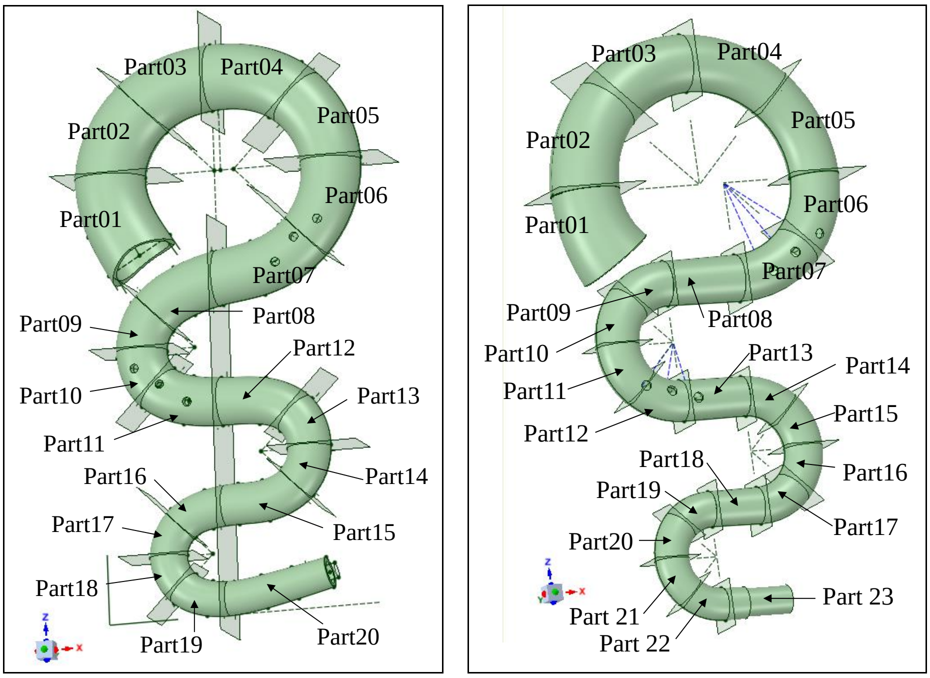

Figure 5: Serpent main body parts and their relationships; Anon shown left; Dittes v5 shown right

Printing the Serpent

Using the slicing (stl to gcode converter) application (e.g. “Cura” for the Ultimaker series) that came with your 3D printer prepare printer files for each component part. If necessary, convert each of the 20 (23) parts and preserve your naming convention (to "gcode" files for Cura).

To allow each component part to be built upwards from the printer bed (buildplate) the parts have been rotated in the up-down (Z) printer axis so that the relevant horizontal and vertical cut lines lie flat on the printer bed. These rotation values are shown in column **B** of Table 1 (Anon) and Table 2 (Dittes). A negative value indicates a counter-clockwise rotation for the part as designed relative to the printer buildplate. It will be obvious if the parts do not sit flat on the printer buildplate. The Anon parts 3 have been rotated to give a “herringbone” pattern due to the print layer striations, the Dittes v5 has been sliced and the parts rotated in 45º increments to give a “progressive” pattern to the surface of the assembled instrument.

Using the print settings described below a full sized serpent will take a substantial time to 3D print (over 200 hours in total) using FDM technology. Table 1/Table 2, column **C**, summarises the estimated time it will take to print each component part of the full size serpent. These figures assume a print layer thickness of 0.2mm (double the typical 0.1mm layer thickness – although 0.1mm is especially recommended for the mouthpiece parts), a print wall thickness of 1.2mm (three layers), 50mm per second print head speed, and 30% inner fill. If you change these values the print time may change dramatically – doubling, for example, if a 0.1mm print layer thickness is chosen, about 25% longer overall for a print wall thickness of 1.6mm.

Print each part individually or in small groups in the colour(s) of your choice, ready for assembly. Check for failed or sub-standard prints and discard. An element of organisation and perseverance is required to complete all parts of the print successfully. It is strongly recommended that you label and number each part as soon as it is printed to aid assembly, Figure 6.

Print the four parts (five parts for the Dittes) of the bocal and the two parts of the mouthpieces in a matching or contrasting colour material. The Dittes has an additional decorative ring at the north (bocal) end that slips over the start of the body.

Figure 6: 3D printed parts for the "Anon" serpent prior to assembly

Figure 7: 3D printed parts for the "Dittes" prototype (v3 shown) serpent prior to assembly. v5 parts are similar but not identical.

Print step summary:

- Choose 3D print settings to estimate achievable overall print times and quality
- Convert (slice to gcode) each component part using the slicing application supplied with your 3D printer
- 3D print each component and check for print quality
- Print the bocal (mouthpipe) and mouthpiece parts

Assembling and finishing the serpent print

You should now have 20 (23) separate 3D prints of the serpent body. Label and check them against the drawing and against each other in order to confirm that they are a complete set and they all fit together as they should.

The inner burrs that appear where the part attached to the printer bed can be removed with a plumber's pipe deburring tool, modelling knife, abrasive paper or rounded file and smoothed as required. The outer burr can be filed and then trimmed away. There should be no ridge on the inside or outside surfaces when placed together.

The two alignment holes on each adjoining flat surface should be opened up with a 3 mm drill to ensure a short length of 3 mm diameter printer filament material will sit in each comfortably (with a 1.8 or 2 mm drill and 1.75 mm filament material for the tenor serpent)[9]. Make sure the length of filament used does not hold the adjacent parts apart and that all surface burrs from the drilling are removed prior to assembly.

Is internal sealing required?

If there is any possibility of air leak or diffusion through the finished wall of the serpent you should seal the inside surface of every piece before assembly by brush coating it with a suitable finishing sealant material. The prototypes were internally coated with three brushed applications of solvent based “sanding sealer”[10]. This both fills small pinhole gaps in the surface and gives the inner surface a nearly smooth, somewhat glassy appearance. The brush on resin product XTC-3D is very effective at smoothing the surface of 3D printed items and leaves a smooth, glossy surface.

Sealing is highly recommended at this stage, to ensure air-tightness and possibly improve sound quality - as there is little possibility of remedial action on the internal surface once the instrument is assembled. The jury is out as to whether the ribbing due to the printing layers is acoustically significant; but it must cause some acoustic turbulence at the surface region.

Preparing and joining the parts.

The top and bottom surface of each component should be made flat and smooth by finishing with a file (smaller parts) or medium grade emery paper for the larger diameter parts. Most effective is to place the emery paper on a flat surface and rub the

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[9] The filament pins used here are not structural and only used to ensure registration between parts, and may be substituted for another material of equivalent diameter.
[10] The brush on solvent based sanding sealer product from HMG paints was used on the prototypes.

flat surface of the part with a circular motion using moderate pressure over the emery surface. Continue until all the print ridges have been removed and the end surfaces of the part are flat, smooth and lightly abraded.

In no particular assembly order, each part must be joined to its neighbour by gluing. Place short lengths of filament material into the matching holes and check (and double check) that the two adjacent parts both match and fit closely – look for any light through the join when they are held together. If so, cut, sand or file down any raised points and carefully clear away any plastic shavings or swarf.

As no two parts are the same, always check that there is no discontinuity or ridge between the two parts to be assembled. Remember that while most parts follow a natural inner curve some parts curve away from each other. The alignment pins offer no guidance in this respect[11]. Attaching temporary labels to each part can really help in keeping track of what fits with what. Keep a diagram of the complete instrument to hand and keep checking; once glued it's too late to change.

The parts can be permanently fixed together with Plastic Weld (Methyl dichloride) solvent, with UHU glue or other adhesive such as a fast setting two-part epoxy resin. Paul Schmidt used Weld-on 16 from Sci-grip[12] solvent based adhesive which seems very effective on both PLA and PET-G filament types.

If using liquid solvent, and when ready to make the join, brush each surface with Plastic Weld. Two coats applied in quick succession to each surface appears to work well, before pressing together firmly and holding for a short while until the joint hardens. If small gaps appear along the seam formed, a small quantity of Plastic Weld can be brushed into the gap, which will spread by capillary action to close the gap. Slightly larger gaps can be closed by carefully filing around the join with a small elliptical modelling file to a depth of about one millimetre and brushing solvent into the ridge formed. The filing action forces powdered material into the gap, which is melted as a filler by the solvent.

Equally, other adhesives can be applied to the surfaces before joining – follow the instructions (and handling precautions) on the packet. Note that setting times may be considerably extended and the parts may need to be held or clamped into place while this occurs. Two part epoxy resin does not shrink when hardening and can be use to good effect to close small gaps and make repairs if the instrument is broken or damaged in use.

The four (five for the Dittes serpent) parts of the bocal are prepared and assembled in a similar manner. Print, assemble and complete the mouthpiece. Once completely assembled the full size serpent appears quite rigid and of a good weight (1,800 - 2000 gms[13]).

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[11] The alignment pins could, of course, have been variously offset and then there would be no ambiguity.

[12] www.weldon.com, but available locally through suppliers.

[13] Rather less than the estimate from Cura shown in the tables. The actual print times were generally shorter than the Cura estimates as well.

Making and fitting the Bocal

The **Anon** serpent has a fixed bocal assembled from four parts, prepared and assembled as with the main body. There is a taper at the instrument end of the bocal which fits directly into a matching taper receiver on the instrument body. There is no pitch adjustment, though an adapter kit is available to use a length of standard 16mm (5/8th inch) tube to alter the length of the bocal for pitch change.

The **Dittes v5** serpent design comes with an adjustable 3D printed bocal in five parts (Figure 8, right, lower), modelling the original, Figure 8 (left). Use part "p23 straight" for this option. After printing the bocal will be loose in the receiver socket at the end of the instrument. The end of the bocal must be wound with tape or waxed thread to ensure an airtight and stable fit. Joel Daniel reports that he used a single layer of Bagpipe waxed thread wound around the end of the bocal[14]. This achieves an air-tight fit allowing for easy fine tuning to concert pitch by sliding the bocal in and out of its receiver (Figure 9). If necessary, a ±21mm adjustable "jubilee" hose clip can be used in lieu of the turned brass ring of the original to record and maintain the insertion depth.

If necessary, the pitch of the instrument may be raised further by the simple expedient of cutting off the required length of the inserted end of the adjustable bocal with a hacksaw (do this in easy stages). The first two stages (bocal parts 1 and 2) of the adjustable bocal can be printed at 100% infill (i.e. solid plastic) to allow a clean cut when shortened.

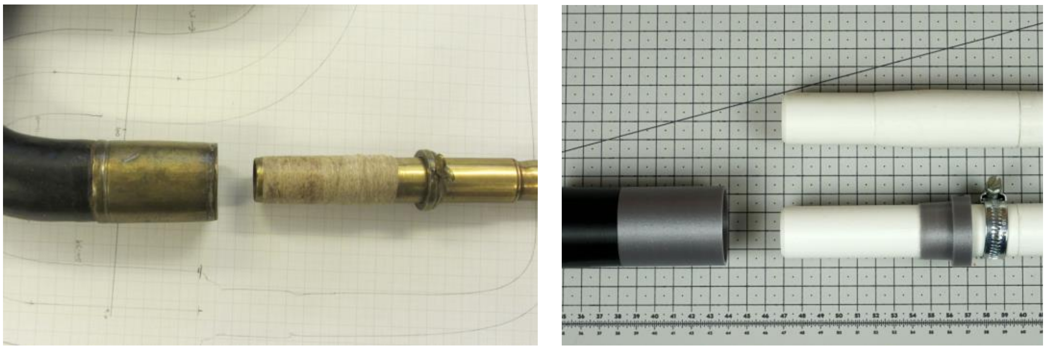

Figure 8: Original Dittes arrangement (left), fixed (right upper) and adjustable bocal kit (right, lower)

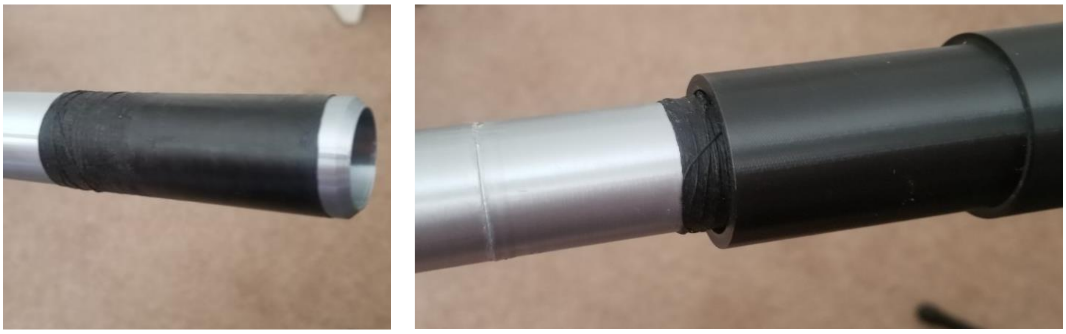

Figure 9: Use of bagpipe waxed thread on the adjustable bocal (Joel Daniel)

[14] One method for winding the thread onto the bocal can be found at https://serpents.ch/sample-page/s-bogen/?lang=en.

As an **alternative** option for the Dittes v5 a tapered bocal design is also provided (Figure 8, right, upper). It must be matched to the part “p23 tapered” (provided separately). As with the Anon bocal, this is designed to be fully inserted into the bocal receiver socket to a fixed depth, the tapered section of the bocal engaging the body of the instrument firmly. This arrangement is shown in Figure 8 (right, upper) and is adequate for undemanding purposes but convenient in everyday use.

This bocal offers limited pitch adjustment and can be withdrawn by some 30-40mm from the body of the instrument, flattening the pitch further, but cannot be inserted more to raise the pitch as the taper and internal end of the bocal engage with the body. Thread or PTFE tape *must* be used to ensure an airtight fit if the bocal is to be withdrawn in this way. Using the adapter part the tapered receiver can be used with the adjustable bocal[15]. However, the tapered bocal cannot be used with “part 23 straight”. Opt for the first adjustable option if possible, less flexible but more authentic.

Mouthpieces

Two 3D printable mouthpiece designs are included and generally play well, though individual preference will determine choice. Both designs model serpent or ophicleide examples from the Bate collection, but are not thought to be original to either instrument. The example designated "mouthpiece2" is a classic shallow cup design, usually regarded as producing a softer tone, typical of church use to accompany voices. The example designated "beehive", named because of the internally extended cup shape, can give a more robust tone, typical of use in military bands or outdoor use. Paul Schmidt tests both in his video. Mouthpieces are best printed with a 0.1mm layer height and the “cup” and “shaft” parts deburred before assembly by gluing.

To ensure a smooth finish, SLS (Selective Laser Sintering) rather than filament based FDM 3D printing of these parts may be better. There are several suppliers of manufactured serpent mouthpieces in cast or traditional materials to modern or traditional designs: for instance by Jeremy West[16], Sam Goble[17] and J.C. Sherman[18]. A modern brass instrument mouthpiece can also be adapted to use, maybe a 12C as a starting point. The standard shank just fits into the bocal socket.

Assembly step summary

- Remove the burrs around the print base and open up the alignment holes
- Seal the interior surface to make airtight
- File or sand (emery paper) the top and bottom surfaces of the parts
- Insert alignment pegs between parts and (double) check shape
- Use solvent or glue to attach all the parts together
- Fill any gaps between parts
- Assemble the bocal and mouthpiece

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[15] The adapter ring fills the taper in “part 23 tapered”, it cannot be used with “part 23 straight”.
[16] https://www.jeremywest.co.uk/serpent-mouthpieces.html
[17] https://samgoble.com/the-maker/serpent-mouthpieces.html
[18] http://www.jcsherman.net/rogers-serpent-mouthpieces

Printing a ½ size tenor serpent (serpenteau) or ¼ size worm

Given the length of time and amount of material required to complete a full size serpent print you might consider making a half-size replica to check that the geometry of the design is sound and to get practice at assembling and finishing the instrument. At the printer settings recommended above, the overall print time is reduced to about 50 hours. Easy. Note that the mouthpieces printed at half-size are very thin at the shank end and a specific bocal end part for the tenor serpent is included in the Dittes file pack. When printed at the recommended size it provides a mouthpiece socket of the same size as the full sized serpents. If making a tenor serpent, print the “serpenteau” mouthpiece parts at 50% size to match.

The half size tenor serpent, or serpenteau, is regarded by some as suitable for children as a learning aid or for those with a limited finger span. The tenor serpents are rather thinner than the full size 3D printed instrument, they play, but are probably not strong enough to be handled with any gusto.

The procedure is similar to that for the full size print; each part must be loaded into the slicing application and also reduced in size by 50% (x0.5). It is now possible to layout half the component parts onto a 200x200mm 3D print table for simultaneous printing. Figure 10 (left) shows a printer table layout for the even numbered parts, Figure 10 (right) the odd numbered parts of the tenor serpent. Figure 11 shows the 3D prints, in black and yellow, before and after assembly – giving a slightly venomous and rather waspish appearance to the finished item. The tenor version of the Dittes serpent (Figure 3) was printed in red, yellow and black parts - the colours of the very poisonous coral snake.

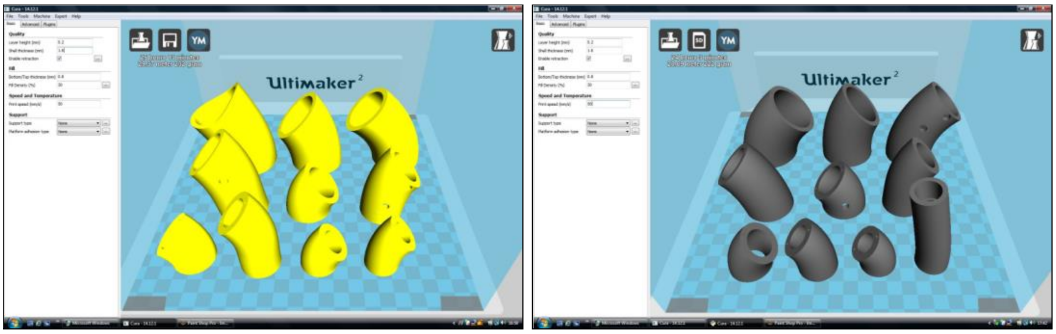

Figure 10: Alternate yellow/black tenor serpent components on the print table (Cura screenshots)

Figure 11: The tenor serpent before and after assembly

Assembly and finishing of the tenor serpent are as for the full size serpent. The reference holes between parts are now half size and may be opened with a 2mm drill and 1.75mm filament used for the registration pins.

A quarter sized or soprano serpent, sometimes referred to as a "worm", can also be printed by reducing the size of each part to 25% and the parts prepared and assembled as before. Note that the mouthpiece in Figure 12 is printed half-size (and so not to scale), about the size of an "acorn" mouthpiece used for a curvo cornett. Small print blemishes were filled with epoxy resin. Probably not playable, but it might make an interesting bangle.

Figure 12: A 3D printed ¼ sized soprano serpent or "worm"

External finishing

While the author has a point to make, not everyone will like the "3D printed finish" look. The instrument can be painted, though some experimentation will be required to find a paint that both adheres well to the printed surface and covers the striations. The Rust-oleum brand "Universal" spray paint range appears to work well. Test on a piece of scrap printed part or in a inconspicuous place first.

For a smooth external finish the rough printed exterior can be sanded down to remove the worst of the striations, major blemishes and the joins ridges smoothed over with filler, and then coated with XTC-3D resin paint. Once set, this can be sanded again to remove any small ridges and spray painted with several light coats. Again the Rust-oleum universal product seems to work well. Rust-oleum used to make a simulated "leather finish" spray paint, but this has been discontinued. A satin or matt black should work well for traditionalists, but a custom paint job would be good too.

When completed original serpents were always somewhat fragile, easily damaged if dropped or knocked. The 3D printed serpents are equally easily damaged, the PLA material fracturing if subjected to even moderate mechanical shock – consider using PET-G which is more resiliant. Covering in traditional leather binding may help robustness, but the uncovered instrument is easily repaired by gluing, where a covered one may require significant disassembly if damaged. A soft carry bag suitable for these instruments is available from the Early Music Shop.

Playing and post production notes

Once printed and assembled the serpents should be ready to play[19]. Several fingering charts are available to act as a guide[20], though some experimentation may be required. Joel Daniel has kindly supplied the chart shown in Figure 13 for the Dittes v5 model. In principle the serpent can be played over a range of some three octaves. Also note that the available finger tone hole spacing is notoriously inadequate and some notes will have to be played by "lipping" to achieve the desired pitch[21]. The introduction of additional keys eventually overcame this problem to a large extent. Some improvement in tone may be achieved by slightly rounding the tone hole exits with a “cone” of abrasive paper. Proceed with caution as this step is hard to reverse.

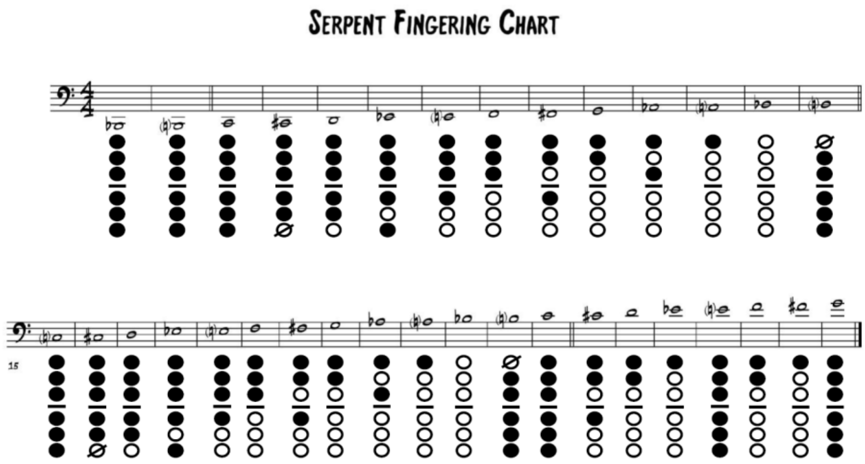

Figure 13: Fingering Chart for the Dittes v5 model (Joel Daniel, Marinesandpiper)

Complete failure to sound or very unexpected playing properties are most likely to be due to air leaks. Check the push-fit connections between mouthpiece and bocal

[19] https://www.serpentwebsite.com/play.htm
[20] https://www.serpentwebsite.com/s_finger_big.pdf, for instance
[21] Paul Schmidt’s video sums it up well – "*...take control of the instrument with the embouchure*".

receiver socket and between bocal and its receiver into the instrument. A wrap of plumber's PTFE sealing tape can help. Otherwise inspect the body of the instrument carefully for flaws and gaps between segments (even very small ones). They can often be filled with epoxy resin or any propriety hardening filler, or painted over with sealer. Internal air leaks are very difficult to address once the instrument is assembled.

Other uses for the CAD design

Traditionally serpents are carved from wood, either in two halves (the "French" method), or more usually as multiple parts (the "English" method) with the parts assembled by gluing and wood stapling. More recently CNC routers have been used to create these carved parts, though the machine carved parts must still be assembled and covered. If you wish to take this route, please contact the author about "sliced for CNC" versions of the serpent print files. Some example slicings are shown in Figure 14. The two parts in the left hand example represent the "traditional" approach, but will require a substantial block of wood and a full size routing machine. The same files might be used to cut a mould for fabrication in fibreglass or resin.

The corresponding upper and lower parts in the right hand example overlap by a centimetre or two and are designed to minimise the size of the wood blanks required while allowing the long grain of the wood to align with the direction of the airway. The parts are designed to be made on a CNC router with a 300x300mm minimum bed. Assembly would be a challenge.

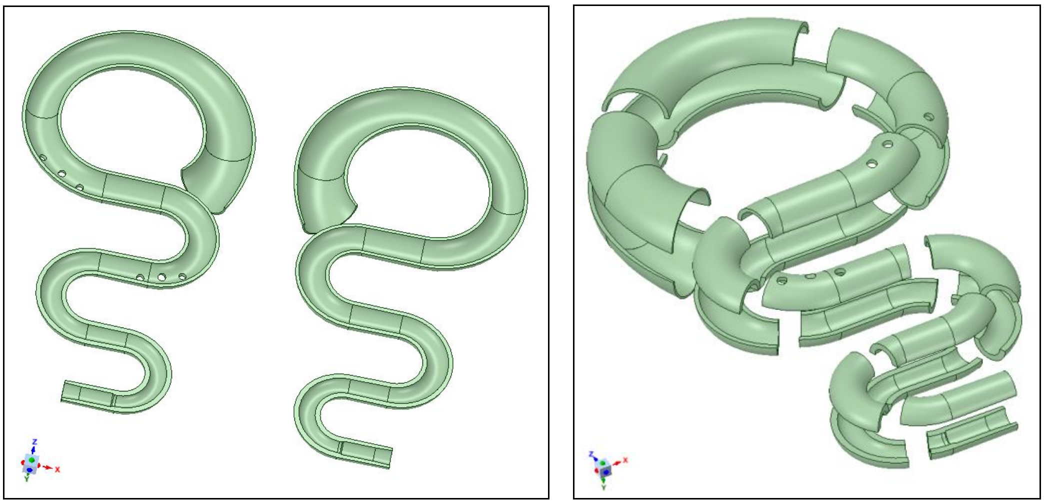

Figure 14: The Dittes serpent sliced for CNC milling: halved, left; segmented, right.

Maker feedback

The serpent community is small. Makers of these 3D printed serpents are invited to send comments, notes and suggestions for improvements to the author who will endeavour to incorporate them in future releases for the benefit of all. Reports of performances using the serpents and other interesting notes can be submitted to the Serpent Newsletter for wider dissemination to the serpent community.

Paul Schmidt printed and assembled a copy of the Dittes serpent (based on v3, September 2020) and has prepared a comprehensive (96 minute) video of the whole process, which he has kindly shared on YouTube (contributing as "youtuuba"):

https://youtu.be/pDgu9FIfCWs

Paul has also provided a short extract (five minutes) of the Dittes v3 being played with both the printed mouthpieces in the lower and upper registers:

https://youtu.be/1PysqokLFa8

Highly recommended viewing before you start. Further notes on constructing the Dittes serpent are to be found in the October 2020 issue of the serpent newsletter[22].

Figure 15: Paul Schmidt plays his 3D Dittes (v3) on completion (still from his YouTube video)

Paul reports that the 3D Dittes serpent offers the full range and tonality expected from the instrument. He has also played the 3D Dittes to his renaissance band colleagues, alongside his original Christopher Monk serpent. It seems the tone of the original Monk serpent was universally preferred. This is not altogether surprising as Monk was a very fine instrument maker; 3D printing of musical instruments is in its infancy, much still to do. Paul suggested that the tone of the instrument might be improved by undercutting the tone holes – this was done for the December 2020 (v5) release. Paul also used a light acrylic sealer on the interior to improve air tightness, but this did not noticeably smooth the print layer striations as would the use of a full sanding sealer.

Paul also reports that the Dittes copy and original Monk serpent share a very similar fingering pattern. Further investigation shows that the geometry and construction of the Dittes are surprisingly similar to that of instruments made by renowned serpent maker C. Baudouin of Paris, such as the 1820s example held in the NY Metropolitan Museum of Art[23]. Monk based his design on an existing Baudouin serpent then in his possession, now held in the Edinburgh collection[24]. Whether Dittes was a workshop

[22] Sign-up and receive your own copy.
[23] https://www.metmuseum.org/art/collection/search/506816 - check out the paint job!
[24] https://collections.ed.ac.uk/stcecilias/record/99182.

specialised in good quality reproductions to a pattern, or if Dittes was perhaps a retailer "own-branding" Baudouin made instruments is yet to be determined. New information gratefully received. The original Dittes has a faded paper label glued over where the Baudouin maker's mark would be expected - across the join, just inside the bell.

Undercutting of the tone holes (Dittes serpent model only, new for Oct 20)

Following comments by Paul Schmidt in which he recommends that the tone of the instrument would be improved by undercutting the inside edge of the finger tone holes[25] the October 2020 release includes this for the Dittes v3 and v5 serpent but not for the anon. The undercutting is a 3mm, 45º chamfer around the inside edge of each tone hole. If you prefer no chamfer, or wish to cut your own, the original part files without undercutting are also available. You must use either the set of undercut parts, or the set without undercutting, as they cannot be mixed - and the choice decision must be made before assembly begins.

The Spaltenstein 3D printed serpents

Father and son François and Marc Spaltenstein of Geneva have completed 3D printed versions of both the Anon and v3 Dittes serpents and have kindly shared their observations. Both instruments, they report, are easy to print and assemble, and play as expected. Both instruments were coated with paint, both improving air tightness and appearance.

François reports that he experimented on the "Anon" by adding a "thumb" hole at the point the left thumb naturally sits on the instrument (about 2.5cm "down" from the third left hand tone hole). A hole of 8mm diameter gives a good *si* (B) over two octaves and, with the hole open, the *ré* (D) and *fa* (F) are made easier. Increasing the hole to 12mm diameter, he reports, made a further improvement (Figure 16, left). This arrangement is not present on any known extant contemporary instrument[26] and when François' colleague Prof. Robert Ischer made a similar modification to an existing serpent it did not work at all and had to be reversed by filling the additional hole.

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[25] The late Christopher Monk is reported to have held a similar view.

[26] Not quite unknown though. Found in a military exhibition catalogue of musical instruments from 1890: "*Item 330. Serpent. Of wood, covered with leather. There are seven fingerholes, bushed with ivory; the extra hole, which is at the back, gives Bnat ... Lent by C. A. Barry, Esq.*" (Day, 1891, p. 160).

Figure 16: François Spaltenstein's strengthening modifications

François also reported the fragile nature of the printed instrument and sent notes relating to strengthening modifications he has made. He introduced a length of 5mm threaded studding through the first three coils of the Dittes copy, rather in the manner of the bracing indicated on the original, using washers and nuts to secure it in place (Figure 16, left). The instrument was further strengthened by attaching metal strips along the outside edges of the coils with screws and by gluing (Figure 16, right). François also strengthened the bocal in this manner.

Appendix One: Bate "Anon" Serpent print information

Bate Anon Serpent (#504) stl print files - full size										
A	B	C	D	E	F	G	H	I	J	K
file	rotation	hours	metre*	gram	Cost	W mm	D mm	H mm	file(Mb)	start
Bate anon serpent part01.stl	180	18.38	25.32	200	6	139	104	153	2.1	
Bate anon serpent part02.stl	0	16.75	22.73	180	5.4	138	101	133	3.2	
Bate anon serpent part03.stl	90	14.48	20	158	4.75	115	97	133	1.9	
Bate anon serpent part04.stl	-90	17.4	24.04	190	5.71	115	94	155	2.7	
Bate anon serpent part05.stl	0	14.35	19.58	155	4.65	122	90	127	2.5	
Bate anon serpent part06.stl	180	13.83	18.7	148	4.44	111	86	132	3.1	
Bate anon serpent part07.stl	-90	16.73	22.97	182	5.45	119	81	160	2.7	
Bate anon serpent part08.stl	90	11.92	16.14	128	3.83	107	78	119	2.3	
Bate anon serpent part09.stl	0	6.97	9.38	74	2.23	85	75	81	2.1	
Bate anon serpent part10.stl	180	6.82	9.12	72	2.17	84	73	79	3.3	
Bate anon serpent part11.stl	90	10.18	13.81	109	3.28	86	71	117	2.5	
Bate anon serpent part12.stl	-90	10.7	14.77	117	3.5	82	68	127	2.6	
Bate anon serpent part13.stl	0	5.55	7.51	59	1.78	75	64	73	2.9	
Bate anon serpent part14.stl	180	5.4	7.25	57	1.72	74	63	72	2.7	
Bate anon serpent part15.stl	-90	9.48	13.12	104	3.11	74	61	125	2.8	
Bate anon serpent part16.stl	90	6.08	8.25	65	1.96	71	58	86	2.4	
Bate anon serpent part17.stl	0	4.15	5.7	45	1.35	66	55	64	2.7	
Bate anon serpent part18.stl	180	4.2	5.52	44	1.31	64	54	63	2.5	
Bate anon serpent part19.stl	90	5.2	7.3	58	1.73	65	52	85	2.8	
Bate anon serpent part20.stl	-90	9.37	13.14	104	3.12	72	49	153	0.94	
		207.94	284.35	2249	67.49					
Bate anon serpent bocal01.stl	180	4.33	5.53	44	1.31	32	32	131	0.317	
Bate anon serpent bocal02.stl	0	2.01	2.41	19	0.57	46	30	60	8.45	
Bate anon serpent bocal03.stl	90	1.87	2.29	18	0.54	42	28	60	8.2	
Bate anon serpent bocal04.stl	-90	3.01	3.88	31	0.92	27	27	110		
		11.22	14.11	112	3.34					
Serpent bell mouthpiece01.stl	180	0.82	1.04	8	0.25	37	37	25		
Serpent bell mouthpiece02.stl	0	0.33	0.35	3	0.08	21	21	31		
		1.15	1.39	11	0.33					
Ultimaker 2										
0.2mm layer - recommend mouthpiece printed at 0.1mm layer										
1.2 shell wall thickness										
30% fill density										
50mm/s print speed										
*Assumes 3mm filament, 0.4mm nozzle										

Table 1: Anon Serpent download files, times, materials and dimensions

Note: These files as downloaded *have been rotated by the amount shown* so that the sliced surface sits flush with the print buildplate.

Any designer identifier (e.g. “CMW”) and design date (mmyy) at the end of the filenames do not affect the part naming conventions. They can be used to relate the printable file back to the design file and distinguish between design changes. Please quote this with any enquiry. Design date and stl file dates may differ.

It is recommended that the mouthpiece parts be printed at a layer height of 0.1mm to improve resolution.

Appendix Two: Bate "Dittes" Serpent (v5) print information

Bate Dittes Serpent v5 (#500) stl print files - full size - Dr. C. M. Witkowski											
These parts have been rotated for a "45 degree" print - this is the 45 deg print, chamfer undercut version (23 parts)											
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
file	rotation	hours	metre*	gram	Cost	W mm	D mm	H mm	Notes	start	end
dittes v5 p01 (180).stl	180	12.83	41.74	124.50	3.16	121.50	110.90	127.50			
Dittes v5 p02 (135).stl	135	17.17	57.12	170.40	4.33	128.00	95.40	152.70			
Dittes v5 p03 (90).stl	90	14.36	47.27	141.00	3.58	120.10	88.60	150.30			
Dittes v5 p04 (45).stl	45	12.95	41.62	124.10	3.15	112.60	78.90	146.90			
Dittes v5 p05 (0).stl	0	12.10	39.35	117.40	2.98	108.70	70.80	144.00			
Dittes v5 p06 uc3 (-45).stl	-45	9.58	30.90	92.18	2.34	97.40	69.30	118.60			
Dittes v5 p07 uc3 (-90).stl	-90	9.10	29.22	87.14	2.21	94.60	67.00	117.90			
Dittes v5 p08 (-90).stl	-90	8.57	28.47	84.92	2.16	72.00	64.20	106.00			
Dittes v5 p09 (-45).stl	-45	5.38	17.02	50.76	1.29	76.50	61.80	79.30			
Dittes v5 p10 (0).stl	0	5.45	17.15	51.16	1.30	76.00	61.50	79.60			
Dittes v5 p11 uc3 (45).stl	45	5.32	17.00	50.70	1.29	74.20	60.30	79.20			
Dittes v5 p12 uc3 (90).stl	90	5.13	16.43	49.00	1.24	72.30	57.90	78.40			
Dittes v5 p13 uc3 (90).stl	90	6.77	22.91	68.33	1.74	56.00	56.00	91.00			
Dittes v5 p14 (45).stl	45	4.82	15.42	46.00	1.17	69.00	54.90	72.80			
Dittes v5 p15 (0).stl	0	4.90	15.75	46.96	1.19	68.80	54.90	73.30			
Dittes v5 p16 (-45).stl	-45	4.88	15.65	46.67	1.19	67.40	54.00	73.10			
Dittes v5 p17 (-90).stl	-90	4.77	15.16	45.20	1.15	65.50	52.00	72.30			
Dittes v5 p18 (-90).stl	-90	5.12	17.21	51.32	1.30	50.00	50.00	71.50			
Dittes v5 p19 (-45).stl	-45	3.97	12.56	37.47	0.95	60.80	48.60	63.70			
Dittes v5 p20 (0).stl	0	3.98	12.57	37.50	0.95	60.40	48.50	64.00			
Dittes v5 p21 (45).stl	45	3.90	12.34	36.81	0.94	59.10	47.60	63.70			
Dittes v5 p22 (90).stl	90	3.78	11.94	35.60	0.90	57.70	45.90	63.00			
Dittes v5 p23 (-90).stl	-90	4.80	15.51	46.27	1.18	44.40	44.40	95.00			
dittes v5 brass ring (0).stl	0										
		169.63	**550.31**	**1641.39**	**41.69**						
dittes bocal part1 (180).stl	180	3.88	13.21	39.00	1.18	32.00	32.00	125.60	0.25		
dittes bocal part2 (0).stl	0	3.33	11.53	34.00	1.03	30.80	30.80	101.10	0.34		
dittes bocal part3 (0).stl	0	1.35	4.54	14.00	0.41	39.30	28.20	46.60	2.37		
dittes bocal part4 (-45lf).stl	-45	1.28	4.33	13.00	0.39	38.30	29.50	46.40	2.45		
dittes bocal part5 (-90lf).stl	-90	3.60	12.41	37.00	1.11	26.10	26.10	140.00	2.22		
dittes bocal part5 tenor (-90lf).stl	-90	3.73	12.87	38.00	1.15	30.00	30.00	140.20	0.42		
		17.17	**58.89**	**175.00**	**5.27**						
serpent beehive stem (180).stl	180	0.97	3.40	0.30	0.30	39.40	39.40	25.00	4.39		
serpent beehive cup (0).stl	0	0.77	2.40	7.00	0.22	27.10	27.10	56.40	0.99		
serpent mouthpiece2 cup (180).stl	180	0.78	2.71	8.00	0.24	36.70	36.70	24.80	5.87		
serpent mouthpiece2 stem (0).stl	0	0.32	0.93	3.00	0.08	20.70	20.70	30.80	0.24		
These files have already been rotated into the recommended printer orientation.											
Cura slicer and PrintrBot Metal 3D printer											
0.2mm layer height - recommend print mouthpiece parts at 0.1mm											
1.2mm shell wall thickness											
35% fill density											
40mm/S print speed											
*assumes 1.75mm filament and 0.4mm nozzle											
Any designer identifier (e.g. "CMW") and design date (mmyy) at the end of the filenames do not affect the part naming conventions.											

Table 2: Dittes Serpent v5 download files, times, materials and dimensions

Part 23 can be printed using the alternative "dittes v5 p23 taper" part (included or available on request). This adds a conical taper at the entry point and can be used with the fixed bocal kit. However at least 30mm of extra tuning adjustment is still possible.

Any designer identifier (e.g. “CMW”) and design date (mmyy) at the end of the filenames do not affect the part naming conventions. They can be used to relate the printable file back to the design file and distinguish between design changes. Please quote this with any enquiry. Design date and stl file dates may differ.