Design and manufacture of Northumbrian Smallpipes for use in schools

This document is not a quotation and is intended as a discussion tool. It represents my thoughts on the possibilities of quantity manufacture of a standard school set of Northumbrian Smallpipes.

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1 INTRODUCTION

This document describes the design of Northumbrian Smallpipes intended for production in quantities of 100 to 500 sets. The design is for use by children in school. The design is also suitable for other areas of musical education where group teaching and the ability of sets to play together is important. The design is specifically aimed at quantity manufacture of all the parts by commercial, small part machine shops and not for the manual production of single sets. I believe that sets conforming to the specification described in this document will enable the teaching of the Northumbrian Smallpipes to move out of the specialist niche it currently inhabits into mainstream music teaching.

Northumbrian Smallpipes are currently available from individual makers, usually working alone, producing sets one at a time to order. The manufacturing methods used are very labour intensive and this is reflected in the purchase price of a standard 7 keyed set starting at £500 for the cheapest set up to £1000 for the same type of set made to a good quality. Lead times for a set from a good maker is currently from 6 months to more than a year. A good maker can produce around 30 sets a year and the most prolific maker claims to do 50 sets a year. If schools are to be able to purchase sufficient sets, the price for a set will need to be reduced and the lead-time for manufacture shortened.

In order to reduce the manufacturing cost of a set of pipes to a realistic level, the design of the instrument will need to be revisited. This can be approached in 2 ways.

The first is to look at the availability of suitable sets from existing makers and see what price and delivery can be quoted. This approach can only result in limited cost saving because, as far as I am aware, none of the existing makers have any experience of volume production or design for production. Automating the traditional techniques currently used would only be viable if production quantities were measured in large thousands rather than small hundreds. I do think that the possibility of placing an order with a professional maker should be explored as a comparison with the option described below. The availability of a well thought out specification will be essential to ensure that suppliers understand the level of commitment, quality and accuracy that will be needed to avoid difficulties in service.

The second is to review the functional requirements and the way a set is to be used. From this review, produce a requirement specification and a design, using modern materials and manufacturing methods, for a set that meets these requirements. This approach is likely to offer the lowest unit cost and the most reliable "in service" functionality. The requirement specification will be the same as the one need for the "traditional maker" approach.

2 SPECIFICATION OF THE SET

I have tried to keep all the specifications measurable so that conformity will be easy to establish.

2.1 General concepts

All parts will be interchangeable between sets (including the reeds).

The design will be robust and appropriate to a school environment.

Hand fitting and adjustment will be minimised.

Total part count will be kept to a minimum.

Damaged or defective parts will be replaceable on site without special tools or skills.

Playing will require no unusual techniques.

The standard keyed set will be optimised for the keys of G and D.

The unkeyed set will be optimised for the key of G

The note holes in a chanter will be standard and not hand adjusted to suit an individual reed.

The design should be "scaleable" so that as a pupil's skill exceeds the capability of the set, a chanter with more keys or extra notes on the drones can be added.

No single component should cost more than 10% of the total set cost

Reeds will be readily available as "service replacement" parts for the life of the instrument.

Reeds will be easy to fit on site without special skill.

All major, non-replaceable components could carry a number unique to that set. Major components, supplied as spares, will be unnumbered.

2.2 Extra requirements applicable to non-traditional manufacture

Component design will be rationalised for economical CNC manufacture.

Cheap, modern, replaceable seals will be used for fixed and moving joints.

All manufacture and assembly should be within the capabilities of non-specialist, skilled and semi-skilled, artisans.

2.3 Materials

All materials will be safe in use - not brittle, toxic or sharp.

Air containment materials should maintain an airtight condition without additional treatment

2.4 Playing Pressure

The pipes will play in tune at a pressure of 12" watergauge ±1/2" Watergauge or 22.5mmHg ±1mmHg. *NOTE: This choice of pressure needs to checked with experienced teachers. The modern trend is for sets to play at a lower pressure. The lower the playing pressure the more demanding is the setting of the reeds.*

2.5 Playing pitch

The set will play at A=440Hz

2.6 Chanter

The chanter will be fitted with 7 keys *Chanters could have 5 keys missing out the top b and* *the middle d# to reduce the cost and to simplify setting of the reeds.*

Unkeyed chanters will be available and interchangeable in all respects with the keyed chanters.

The chanter/bag interface will allow the chanter to be removed without risk of damage to the chanter reed.

The chanter/bag interface will protect against accidental exposure of the reed.

The notes of the chanter will be in tune to a tolerance of +5cents –10cents of the specified pitch.

The end cap of the chanter will be removable for cleaning of the bore

2.7 Chanter reed

Chanter reeds will be in tune at the playing pressure when fitted to a standard (control) chanter or test rig.

NOTE "in tune" will need to be properly specified. See appendix 1 for my first effort at specifying the accuracy of tuning needed

2.8 Keys

Keys will be interchangeable on all chanters.

Keypads should seal without oil or other potions.

Keypads may require specialist fitting but once fitted to the key they will seal when fitted to any chanter.

Keys complete with fitted pads will be available as "service replacement" items.

Key springs will be simple to fit and adjust on site.

2.9 Drones

A standard set will comprise 3 drones: -

A "d" drone playing the d above middle c

A "G" drone playing the G below middle c

A "D" drone playing the D below middle c

Drones will be fitted into a single stock.

Drones will each play only a single note.

The capability to add a tuning bead should be available (at extra cost).

Drone to drone stock tennon should be identical for all of the drones

Drones will be fitted with a valve to stop the airflow when not sounding.

2.10 Drone Reeds

Drone Reeds will be designed for simple, repeatable, construction.

Drone reeds will play in tune at the correct pressure when fitted to a control drone.

Reed should be constructed of non-organic materials not affected by environmental changes. *This may not be possible but it is a valid target.*

2.11 Bag

The bag/stocks assembly will be airtight. *With the stocks "corked" the inflated bag must not lose more than 50% of its air when subjected to a 5lb "squeeze" for 15 minutes.*

The bag should not require additional "seasoning" to maintain performance.

The bag will be clean. *No oils or other contaminants transferred to the user by handling or playing.*

The bag will be cheap to make and easy to replace on site.

Bags, fitted with all stocks, will be available as "service replacement" items.

2.12 Bag Cover

Bag covers will be machine washable.

Bag covers should be simple, without Zips, and easy to fit to a set

2.13 Stocks

The chanter stock will allow the chanter/reed assembly to be removed from the bag without exposing the reed.

2.14 Bellows

Bellows will be durable.

Bellows should be cheap.

Bellows valves should require no maintenance.

Bellows will be available as "service replacement" items.

Bellows strap will be available in a range of sizes *(define?)*

3 DESIGN PROPOSALS

This section offers design solutions, ideas and some of my thoughts to help achieve the requirements set out in the requirement specification above

3.1 General concepts

Interchangeability of parts will be achieved by creating fully dimensioned and toleranced part drawings for all components. Components will be produced using modern manufacturing techniques appropriate to the volumes being made. The design of the components will be rationalised to suite the chosen manufacturing method. All parts will be inspected and inspection gauges used to ensure interchangeability and to avoid the need for any hand fitting.

It is unlikely that the quantities will justify the use of mouldings or other high volume production methods so I expect that all of the manufactured components will be machined from raw materials using NC or CNC machine tools. The material chosen for the components should combine easy machineability, sufficient strength and appropriate visual appeal.

The sealing of the sliding joints between the standing and the sliding part of the drone is quite interesting. The requirement dictates that the joint is loose enough to allow the easy sliding of the top part to tune the drone to the correct note without taxing the strength of a young player and yet stiff enough to ensure that the setting is not lost during playing. The joint must maintain its seal at all times. The traditional method of using thread wrapping lubricated with oil or grease takes too much hand adjustment to achieve the required function and can need frequent maintenance to keep it functioning correctly. I have seen o/rings used on Irish bagpipes but they required regular lubrication to avoid excessive wear. I think that a commercial lip seal fitted to the standing part would achieve the function required at an economical cost without the need for any maintenance.

The interchangeability of the Chanter reed is the most challenging from a manufacturing point of view. The current "standard" hole spacing used by the top makers is well documented but, in my experience there is still a need for more work to define the actual positions with sufficient accuracy to preclude the need for individual adjustment of chanters. The manufacture of chanter reeds is subject to the most variations. To the best of my knowledge, only Colin Ross is producing chanter reeds in commercial quantities, and even his reeds need a significant amount of hand fitting to match them to a chanter. I don't believe that there has ever been any quantity of chanters produced to a standard design so there is no experience to show how the production of a standard reed can be achieved. I believe that reeds can be produced that will demonstrate the necessary degree of similarity to enable interchangeability amongst chanters manufactured to rigorous accuracy. In order to achieve this there is a need for some experimentation and the production of suitable testing/set-up equipment.

3.2 Materials

The chanter and the drone parts will need some strength and could be made from vacuum impregnated hardwood. All machined parts traditionally made in wood may be machined from either a suitable plastic material or from vacuum impregnated hardwood. There are now methods of improving the performance of common hardwoods like Beech by vacuum impregnating them with a setting resin. The resulting material combines the structural strength of the wood with the surface finish of a moulded plastic.

The other parts would be better in a machineable plastic like Acetal, which is easy to machine, cheap, stable, non-toxic, strong, and available is several colours.

All parts traditionally made from leather may be manufactured from modern synthetic materials. I have seen an example and have details of a Northumbrian pipe bag made from rubberised canvas. All the joints are glued and the set has been in use since before the war.

The bag and bellows design should avoid the need for additional sealing materials e.g. oil or tallow.

The bag may be made from rubberised canvas and manufactured by gluing. It may be possible to connect the bag to the stocks by using some sort of clamp rather than by wrapping with thread as on the conventional sets.

Bags could be produced from PVC by heat sealing the joints (this is commonly done in the medical world). A bag produced in this way could cost less than £1 in the quantities we are thinking of.

The bag could have a plastic tube sealed in as the connection to the chanter and another sealed in as the connection to the bellows thus removing the need for a separate blowpipe stock to be fitted to the bag.

3.3 Chanter

Unkeyed and/or 7 keyed smallpipe chanter playing at concert pitch.

There are reasons why the traditional pitch (1 tone flat) may be chosen but I believe that it is more appropriate to design the sets in concert pitch so that they can play alongside other concert pitch instruments (recorders, pianos etc.). If sets are required at other pitches for local reasons this is possible with an increase in the cost.

The chanter will be fitted to the bag by a method that allows it to be removed without exposing the reed to risk of damage. The chanter must be mechanically locked to its stock to avoid accidental separation. One possibility is a screw threaded tennon, rather than a friction fit tennon.

The end cap should be threaded and screwed onto the chanter. In order to reduce the length of the bored hole, the chanter cap may incorporate the bottom of the chanter from just below the bottom D hole.

This may be a reasonable time to question the number of keys fitted to the chanter. Some cost could be saved and some of the difficulties of reed fitting could be removed if the top B key was left off. It is also possible that the D# key could be left off as it is only an accidental in the keys of G and D.

3.4 Chanter reed

It is difficult to see how the design and development of a mass producible reed made from synthetic materials can be undertaken as part of this process. The current retail price of a Colin Ross reed is £17 and the reeds as supplied, require too much special adjustment for the final adjustment by school music teachers to be viable. There is a need for some special jigs and tools here - one technique that is used in the manufacture of Oboe reeds is a scraping fixture that allows the blades to be much closer to their finished thickness before they are folded and fitted to the staple. I also think that it may be possible to make the blades of the reeds individually and only bring them together when tying to the staple - I don't know if there is any downside from using blades from different bits of cane. Archie Dagg did this and claimed success.

I expect that it would be possible to check each reed on a playing fixture mimicking the function of the chanter. Reeds would be fitted and checked against (say) 3 notes Top g. Middle c, and bottom D. Reeds that pass this selection process (i.e. are within a specified tolerance of the required pitch at the correct pressure) will have a final tweak before packaging. I would expect reeds made in this way to be interchangeable.

3.5 Keys

Keys need to look professional and they must be reasonably strong to survive school use. The keys that I make take about 2+ hours each to make. I could probably do a key in an hour if I created some jigs and made in batches of a single design. The manual keymaking requires a high degree of skill with hand tools and that adds to the cost. Assuming that some automation could reduce the time to make a key by 50% and, given the likely minimum hourly rate for a skilled artisan of £15/hour, the minimum cost of a key made manually is likely to be about £20. I have thought for some time that keys may be manufactured using the "Lost wax" investment casting process. With this process a set of carefully "handmade" keys are used to produce a set of resin moulds into which wax is cast. The wax keys are fitted to a runner system, coated in ceramic and baked to remove the wax and to harden the ceramic shell. The metal for the keys is then injected and allowed to cool. After the keys are cut off of the casting gate they should need only a little fettling and a light buff before drilling the pivot, fitting the spring and fitting to the chanter. There are a number of choices for the material for the keys. I think that aluminium alloy could be used and finished by anodising. The anodic coating can be coloured and a careful choice of colours will make the sets visually attractive if a touch non-traditional. The key springs, if fitted to the key, must be easily replaced without the need for special tools. I would like to look into the possibility of using music wire springs, similar to the method used for flutes and clarinets, as this would greatly simplify the manufacture and be readily available for replacement. There may be a possibility of developing something radical to combine the function of spring and pivot.

3.6 Drones

Provide only 3 drones fitted into a single stock. 1 off small d drone, 1 off large G drone and 1 off large D drone. Most players don't use the small g drone, as it is difficult to keep in tune and working reliably.

Standard drones will each play only a single note. The set will play using only 2 drones for each key – the small D drone and the G drone for the key of G and the small D drone and the large D drone for the key of D. I don't think that the extra notes will be missed in a school teaching environment (and the lack of complexity will be a blessing).

The drone to stock tennon could be identical for all of the drones. I think that the tennon should be threaded so that the standing part screws in and the seal is achieved by either a gasket or by careful design of the mating face. This would make the set more reliable as the reed would be protected against accidental exposure.

I think that it may be possible to standardise the sliding part and just have different lengths of standing part. There could be a significant saving of manufacturing cost if this can be achieved without compromising the functionality of the drones.

The Drone sliding part shown above has a number of original ideas that will make it suitable for School use.

- The on/off valve at the top is simple and robust. It is held in by a simple pin and needs no maintenance. In use it is rotated through 90° and when in the on position the hole lines up with the bore of the drone thus avoiding the side hole used with the traditional piston valve and improving the quality of the tone produced.

- The part count is small compared with a traditional design and could be reduced to just 2 parts by making the top cap as part of the body.
- It may be possible to standardise the size of the sliding part for all of the drones (one size fits all) without compromising the function

3.7 Drone Reeds

Drone Reeds must be designed for simple, repeatable, construction. Each reed must be checked on a checking fixture to ensure that it plays at the correct pitch and pressure.

Reed could be constructed of non-organic materials not affected by environmental changes i.e. Brass body with a plastic tongue.

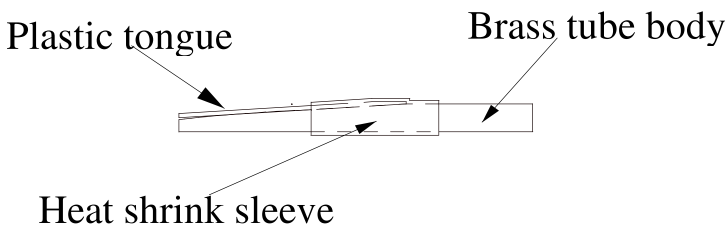

Figure 2

3.8 Bag Cover

Bag covers could carry the badge of the school or be made in the colours of the school. The design of the cover should be simple to produce, without Zips, and easy to fit to a set without the need to disassemble the set.

3.9 Stocks

Simple design with no metal ferrules unless needed for strength. Drones could be locked in using a screw head of a type that requires a special tool to release, thus protecting the reeds from tampering.

The drone stock should be mechanically clamped to the bag rather than tied as traditional sets. I have a couple of ideas for this but the method will depend on the type of bag chosen.

The chanter stock will be in 2 pieces similar in concept to the Ross replaceable chanter stock. The part fitted to the chanter will be screwed on and will fully enclose the reed

3.10 Bellows

The traditional design of the bellows is very labour intensive and the cost of manufacture is likely to be a significant part of the manufacturing cost of a set. It is likely that a fresh look at the design will enable the cost to be much reduced and the functionality and ease of use increased.

It would be useful if the inlet valve and the bag non-return valve could be combined, possibly contained in the bellows outlet. The flexible part of the bellows could be fixed around the edge in the manner of the Irish pipe bellows (nails and glue)

I have been working on a different concept of bellows manufacture where the Leather (or leather substitute) is fitted into a specially shaped slot around the edge of the bellows plate and clamped in place with a 2mm diameter soft plastic rod. This would enable the manufacturing cost of the bellows to be at least halved and the robustness of the finished item would exceed the current hand made item.

I propose to use a hinge machined from a single piece of polypropylene fitted into a slot inside the leather of the bellows and screwed to the bellows plates with self-tapping screws. This would give a strong hinge (polypropylene hinges get stronger with use!)

I propose to design a combined valve and blowpipe connection block fitted to the inner plate of the bellows. This valve will combine the function of both the air inlet valve and the bag non-return valve. This will remove the need for a complex blowpipe and this item can be just an extension of the normal bellows connection tube. This design feature will also have the advantage of moving the bellows air inlet valve from the top plate of the bellows, where it is a considerable nuisance to players, often getting obstructed by the players sleeve

I propose to construct the arm strap from nylon webbing and Velcro to combine low price with modern functionality.

4 PROJECT TEAM

4.1 Project leader

Responsible for the administration of the project. Acquiring and controlling the funding. Authorising the placing of orders. Acting as the focus for all of the project activities.

4.2 Design authority

Responsible for all aspects of the design - production of manufacturing documentation sufficient for all aspects of the manufacture, obtaining quotations for the manufacture and assembly of the components, liaison with the manufacturers of components and assemblies, oversee the manufacture and testing of prototypes.

4.3 Evaluation group

A small group of competent players preferably with teaching experience. This group would evaluate the prototype instruments(s) for playability, survivability and fitness for the requirement. I suggest that the group could include the following people:-

Jane Robson, Anthony Robb, Kathryn Tickell, Colin Ross, Alistair Anderson

The group should be involved from the start of the project.

5 PROJECT PLAN

The project can be split into a number of distinct phases in order to reduce the risk and to ensure that the best solution to the requirement is achieved.

5.1 Phase 1 Feasibility study

This phase is mainly a communication and study phase intended to identify the main risk areas, check the feasibility of the project and do sufficient design and detailing to prove the viability of the design.

5.1.1 Tasks

1. Agree a provisional design specification.
2. Research the end users requirements (talk to teachers and schools)
3. Produce a “request for quotation” document and circulate it to all full time makers.
4. Evaluate the key manufacturing methods and get specimen quotations
5. Gather and evaluate the price and the delivery quotations
6. Obtain sufficient funding for remaining phases.
7. Produce preliminary design layout drawing and detail part drawings for any unusual parts.
8. Get specimen price and time quotations for the manufacture of the parts.
9. Produce test parts to validate important design features.

5.2 Phase 2 Prototype manufacture

1. Complete the detail drawings and check the accuracy.
2. Produce a set of prototype parts from the detail drawings.
3. Assemble a set of pipes and check the function.
4. Develop the drone reed design and make sufficient handmade prototypes to validate the repeatability of the design.
5. Update the detail drawings to include any changes
6. Make modifications to the design to achieve the required performance.
7. Finalise the design specifications and drawings.
8. Design the reed testing equipment and produce prototype.
9. Source the materials and any proprietary components.
10. Get feedback from players and teachers on the instrument

5.3 Phase 3 manufacture of trial batch

1. Produce sufficient pre-production prototypes to trial the use of sets made to this design at a school.
2. Establish the potential production quantities

3. Obtain firm, competitive quotations.
4. Produce production plan and identify capacity for all the required tasks.

5.4 Phase 4 manufacture of production batch

1. Agree funding
2. Place orders
3. Monitor progress
4. Inspect finished sets
5. Deliver

6 DELIVERABLES

6.1 Phase 1

Requirement specification for a set of Northumbrian small pipes

Design layout drawing(s) showing the design features to scale. The layout will show how all the requirements incorporated in the requirement specification will be achieved.

Preliminary costing for all the parts.

Estimated time scale for manufacture.

Quote for phase 2

Quotations for supply of "traditional" manufactured sets.

6.2 Phase 2

Complete manufacturing package comprising: -

1 full set of detail drawings, dimensioned and toleranced to ensure interchangeability of components.

1 set of assembly drawings and assembly instructions

Competitive quotations for all parts, including supply of materials.

Sketches drawings and specifications for any tooling or setting equipment required to produce finished sets.

Production plan detailing the time scales for manufacture and identifying who will do all of the tasks.

6.3 Phase 3

10 complete sets of Smallpipes all working to the agreed specification.

Final production documentation

A quotation for production of complete sets in required quantity.

7 COSTINGS

~~Note the prices given below are my estimates (guess) for the manufacture of a single set based on an average hourly cost of £20/hour and a batch quantity of 100 sets. I have assumed that the time costs include materials. I have assumed a cost of £2000 associated with the design and development including making samples and £800 in tooling costs associated with the manufacture and assembly of the sets. I have spread these costs into the spreadsheet below. NOTE this is just a guess and I will need to do some design work and produce some drawings to validate the part costs.~~

I have quotes that suggest a cost of around £250/set in batches of 200 and just over £360/set in batches of 100. If the quantities could be greater then the price would be even less possibly close to the £200/set figure.

8 TIMESCALES

I estimate that it will take 2 months to produce a design layout and sufficient detail drawings to obtain reliable quotations.

I estimate that is will take 6 to 8 weeks to produce a prototype set and assemble it for initial trials.

I estimate that it will take 3 months to get the parts manufactured and a further month to solve any unexpected problems before a batch of working sets is available (say 10 sets).

Once the bugs are out of the design and all the parts are available I estimate that sets could be assembled at the rate of 2 to 4 per day by a reasonably competent artisan.

9 APPENDIX 1 TUNING

The Northumbrian Smallpipe chanter tuning is more demanding than other instruments as the notes of the chanter are played with the droned sounding. This accentuates any errors particularly the intervals of a third and a fifth. Electronic tuners are cheaply available but display the pitch of a note relative to "even" temperament. Northumbrian Smallpipe chanters are usually tuned to "just" temperament. This works well for an unkeyed chanter but requires some compromise to achieve an acceptable result for keyed chanters playing in several keys (usually G & D). The tables below show the pitch setting for each note of the chanter relative to the zero position of an electronic "even temperament" tuner. The values are in cents (1 cent = 1% of a semitone). The permissible variations are my first guess at what might be acceptable and will need to be validated before any quotations are sought.

Unkeyed chanter tuning

Note	**G**	**F#**	**E**	**D**	**C**	**B**	**A**	**G**
Relative pitch	**0**	**-12**	**0**	**0**	**0**	**-14**	**0**	**0**
Permissible variation	**±2**	**+10 -0**	**±5**	**±2**	**±5**	**+10 -0**	**±5**	**±2**

The tuning of a keyed set requires a little more compromise

7 Keyed chanter tuning

Note	**B**	**A**	**G**	**F#**	**E**	**D#**	**D**	**C#**	**C**	**B**	**A**	**G**	**F#**	**E**	**D**
Relative pitch	**-14**	**0**	**0**	**-12**	**0**	**0**	**0**	**-12**	**0**	**-14**	**0**	**0**	**-12**	**-12**	**0**
Permissible variation	**+10 -0**	**±5**	**±5**	**10 -0**	**±5**	**±10**	**±5**	**±5**	**±5**	**+10 -0**	**±5**	**±5**	**+10 -0**	**±5**	**±5**

10 SOME IMPORTANT QUESTIONS

1. What pitch should the set be designed for (concert pitch i.e. G or Northumbrian flat pitch i.e. F)? *I think that concert G seems to be the general choice*
2. What tuning tolerance is normal in school instruments i.e. recorders?
3. What age range is the set to be target at?
4. What is the target cost?
5. Who will be the client - provide the funding, own the finished sets, deliver them to the schools etc?
6. Who will provide the effort to make the reeds, assemble the sets, tune them, support them in the field, etc?