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# THE ACOUSTICS OF THE GEMSHORN

T. Charnley, R. Perrin and K.J. Stone

Physics Department, Loughborough University of Technology

## INTRODUCTION

The resurgence of interest in medieval music has led to a revival also in the making of many long-abandoned instruments such as the gemshorn, which is a traditional folk recorder dating back to before 1300 A.D. It ceased to be used about 1500 A.D. Originally made from the horn of the chamois it later became more common to use the horns of domestic animals.

## CONSTRUCTION OF INSTRUMENT

Our gemshorn was made from the horn of a cow: it was about 225 mm long and about 50 mm in diameter at the wide end, with a variable thickness of the order of 5 mm. The core was removed after soaking in a solution of papain at 70°C for two weeks. A fume cupboard is essential for this and the actual extraction of the core should be done in the open air - preferably in a gale! We understand that the traditional method of decomposing the membrane which binds the core to the horn proper is to bury it in the ground for several months.

A knife edge, similar in dimensions to that of a recorder, was cut about 30 mm from the wide end which was then fitted with a plaster-of-paris plug. A slot was filed in the top of the plug so that on blowing the air hit directly on to the knife edge (fig. 1).

## MEASUREMENTS

When blown gently a soft recorder-like sound was produced, the pitch increasing as the pressure was increased. At higher pressures the note changed to a high pitched whistle. In this higher register increasing pressure increased the intensity but had a negligible effect on the pitch.

The horn was blown with air from a cylinder through a simple pressure reduction and stabilising system. Only the lower register was examined in detail as the upper is of no musical importance. The sound was very pure with virtually no harmonics. The variation of pitch with pressure is shown in fig. 2. It will be noticed that a range of pitch of about a semi-tone could be obtained by controlling the pressure, but the player in consequence would have no control of loudness. For pressures above 58 mm water gauge the frequency was constant at 1524 Hz.

One very small hole was then drilled about half-way down the horn and the frequencies were measured as it was gradually increased in size, keeping the pressure constant at 30 mm water gauge. These measurements are plotted in fig. 3. The hole was then plugged and similar measurements made in turn with two other holes at some distance from the first. From these results it was clear that the position of the holes was immaterial but that the size was important. Fitting a small tube over the hole and so increasing the horn's effective thickness caused the pitch to drop. The behaviour was, therefore, not that of a small organ pipe but of a Helmholtz resonator: the gemshorn is more closely related to the ocarina than to the recorder and it is not surprising that many shapes of horn have been used successfully to make this instrument. In the higher register however the behaviour does seem to be that of a small organ pipe, ie, the position of the hole is important.

The ideal Helmholtz resonator is a volume, v, with an elongated neck of cross-sectional area A and length t. If it is assumed that the air enclosed in the volume acts as a pure spring driving the air in the neck, which acts as a pure mass, then $\omega_0 = c\sqrt{A/tV}$, c being the velocity of sound [1]. Fig. 3 shows that the variation of frequency with hole diameter is in agreement with this expression. The slight variation in wall thickness caused a slight frequency change in the appropriate direction and a check on the volume (97 ml) produced a result which was roughly as predicted by the formula.

TUNING SCHEMES

Accepting that the instrument is a Helmholtz resonator it is possible to calculate a tuning scheme for it, assuming a constant applied pressure. If the horn has to be tuned so that it can be played in unison with another instrument its lowest note must be adjusted before any finger holes are cut. If a small change is required then a small hole drilled and reamed to suit will suffice. It may be in any position but it is convenient to place it near the knife-edge hole, and for subsequent calculations it will be regarded as part of the latter. For a large adjustment it is preferable to reduce the volume by pouring a little plaster-of-paris into the tip of the horn. An estimate of the quantity can be made since $f \propto V^{-\frac{1}{2}}$. Adjustment is only possible in the direction of increased frequency.

If it were possible to measure the area and depth of each aperture we would find $f^2 = k\Sigma(A/t)$. We may therefore consider each finger-hole to have associated with it a value $X = A/t$ and the knife-edge hole and tuning hole combined an effective value $X_0$. With no finger holes open, $f_0^2 = kX_0$.

With the first finger hole open, $f_1^2 = k\,(X_0 + X_1)$

$$\therefore \quad \left(\frac{f_1}{f_0}\right)^2 = \frac{X_0 + X_1}{X_0} = 1 + \frac{X_1}{X_0} = 1 + R_1$$

Similarly each hole has a property $R_i$ defined by $R_i = \left(\frac{f_i}{f_0}\right)^2 - 1$, $f_i$ being the frequency when that hole alone is open. When two or more holes are open their values of R are added, and the resultant frequency of f should be given by

$$\left(\frac{f}{f_0}\right)^2 = 1 + \Sigma R$$

$$\text{or} \quad f = f_0\sqrt{1 + \Sigma R}$$

We had made the instrument from the description in a paper by Richardson [2] who gives an empirical tuning scheme for a 4-hole gemshorn. This table is reproduced, with additions, as table 1. Five notes were obtained from the fully closed horn and the four holes individually. We used this data to calculate $R_I$ for the four holes and hence the notes expected from the possible combinations. It will be seen that these calculated values are in reasonable agreement with his experimental values.

It will be noticed that this scheme omits two notes from the octave. They could probably be obtained by controlling the pressure, but it would be nice to be able to "finger" them. We therefore propose the addition of two more holes tuned as in table 2. This should give a tolerable octave and although six holes are employed for a full octave, there is never any need for the player to lift more than three fingers at once.

The holes can, of course, be put anywhere convenient for the player!

This instrument has a small range, becoming difficult to blow when too many holes are employed. It has, however, a very low Q compared to a pipe and can produce a very sharp staccato as a result. If a greater range could be achieved, perhaps by attention to the design of the knife-edge and air jet, a Helmholtz resonator type instrument could be a serious instrument with a very pure tone and rapid response.

REFERENCES

[1] W.W. Seto, Acoustics, New York: McGraw-Hill, see p. 125 (1971)
[2] A. Parkinson, 'Guesswork and the Gemshorn', Early music, 43-46 (January 1981)

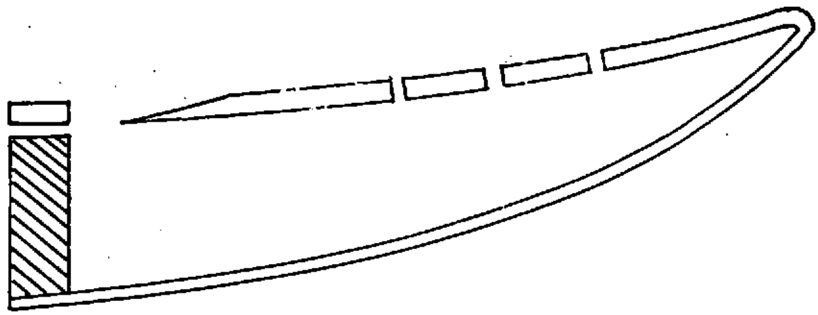

Fig. 1. The Gemshorn

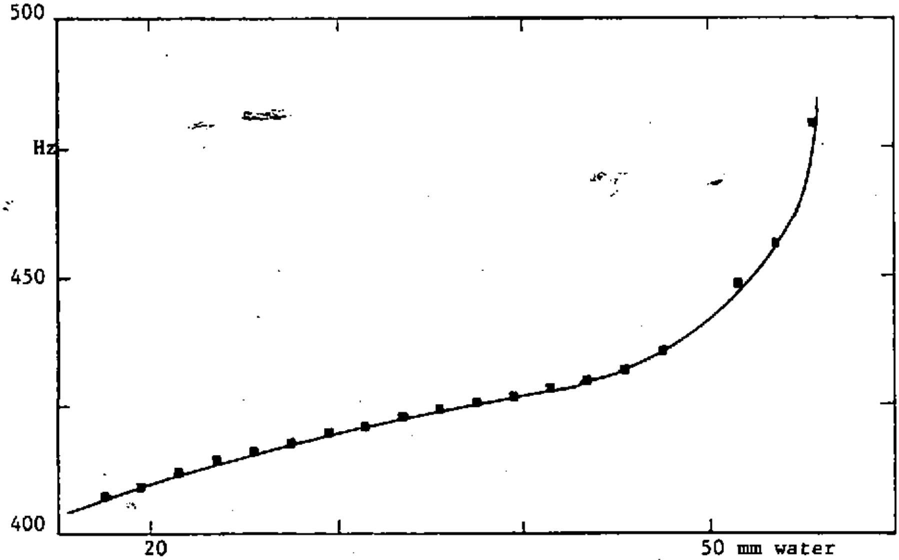


Fig. 2. Variation of frequency with pressure

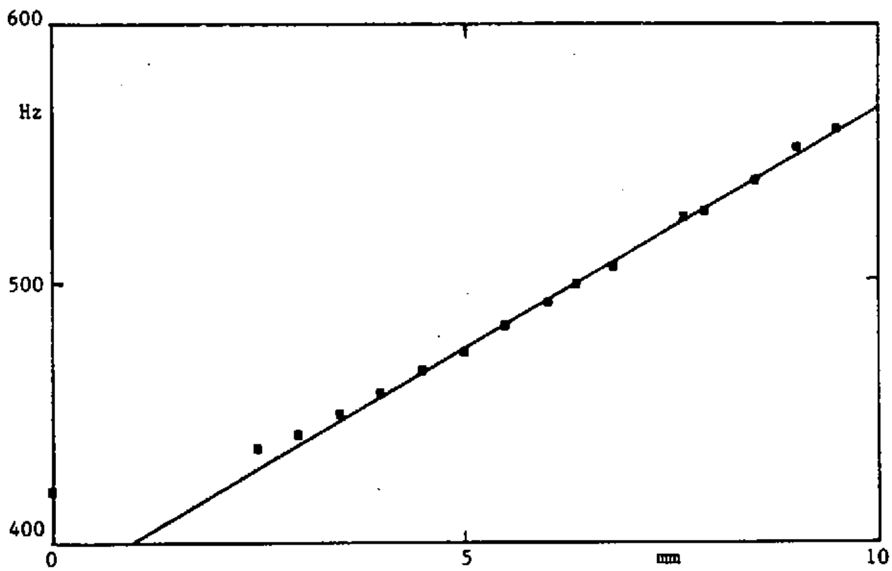


Fig. 3. Variation of frequency with hole diameter

TABLE 1

4-Hole Tuning Scheme

| Note | Frequency | Holes Open | R | Calculated Frequency |
|---|---|---|---|---|
| C | 261.6 | None | 0 | Tuned |
| C# | 277.2 | | | Unobtainable |
| D | 293.7 | R | 0.2605 | Tuned |
| D# | 311.1 | | | Unobtainable |
| E | 329.6 | Q | 0.5874 | Tuned |
| F | 349.2 | Q+R | | 355.6 |
| F# | 370.0 | P | 1.000 | Tuned |
| G | 392.0 | S | 1,245 | Tuned |
| G# | 415.3 | R+S | | 414.1 |
| A | 440 | P+Q+R Q+S | | 441.5 or 440.3 |
| A# | 466.2 | Q+R+S | | 460 |
| B | 493.9 | P+R+S | | 490 |
| $C^1$ | 523.2 | P+Q+R or all | | 512.1 or 529.2 |

TABLE 2

6-Hole Tuning Scheme

| Note | Frequency | Holes Open | R | Calculated Frequency |
|---|---|---|---|---|
| C | 261.1 | None | 0 | Tuned |
| C# | 277.2 | T | 0.1228 | Tuned |
| D | 293.7 | R | 0.2605 | Tuned |
| D# | 311.1 | R+T | | 307.7 |
| E | 329.6 | Q | 0.5874 | Tuned |
| F | 349.2 | U | 0.7818 | Tuned |
| F# | 370.0 | P | 1.000 | Tuned |
| G | 392.0 | S | 1.245 | Tuned |
| G# | 415.3 | R+S | | 414.1 |
| A | 440 | Q+S | | 440.3 |
| A# | 466.2 | U+S+T | | 464.3 |
| B | 493.9 | P+R+S | | 490.0 |
| $C^1$ | 523.2 | P+S+U | | 524.9 |