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SOME ASPECTS OF INTONATION ON THE BASSOON

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1. INTRODUCTION

The intonation of a double-reed woodwind is notoriously flexible. A bassoon may be played sharp or flat to a considerable degree - in some cases a semitone or more. In fact, the player may need this facility for adjustment to compensate for deficiencies in the basic tuning of the instrument. The general notion is that, as the player blows harder, the pitch rises. Harder blowing also leads to a louder sound. With all wind instruments, this seems almost a self-evident truth. A counteracting effect is the force of the player's lips on the reed blades. With skill, it is possible to some extent to vary pitch and loudness independently. The point of application of the lip force - and whether both lips are applied opposite each other or "staggered" - is also significant.

Much thought and ingenuity has been expended on explaining the pitch changes on the basis of a frequency-domain representation. The instrument has a set of nearly harmonic resonances whose responses are coupled together by nonlinearities in pressure/volume flow relationships at the reed. Higher order harmonics are called into play as the instrument is blown harder, and the pitch settles to a "majority vote" value - higher because the resonance spacing is wider than harmonic. An attempt to explain the lip-force effect (and to some extent also that of the blowing pressure) is the change of reed volume which ensues. Large percentage changes of this volume may be achieved with the small volume of a double reed.

The difficulty with a frequency-domain representation of the events taking place in the conical tube of a bassoon is that the reed motion and its associated effects depart grossly from the ideal of a simple sinusoid - or even an assembly of a few harmonically-related sinusoids. Direct observation shows that the reed closes for a fixed length of time during each cycle, standing open for the rest of the period. The reed does close, even at pianissimo level; it acts as a periodic interruptor of an otherwise steady stream of air from the player's mouth into the instrument. The pitch of the note is governed by the exact moment at which the periodic reed closure occurs. A time-domain model of the wave motion in the bassoon tube and the forces acting on the reed may help to clarify this process.

2. TIME VARIATION OF REED PRESSURE

When the player begins a note, air passes between the open reed blades into the conical tube of the instrument. The volume enclosed by the reed forms a local enlargement of the tube. The pressure developed in the tube entrance by this air stream has a sharp onset and a gradual decay as is shown in Fig.1.

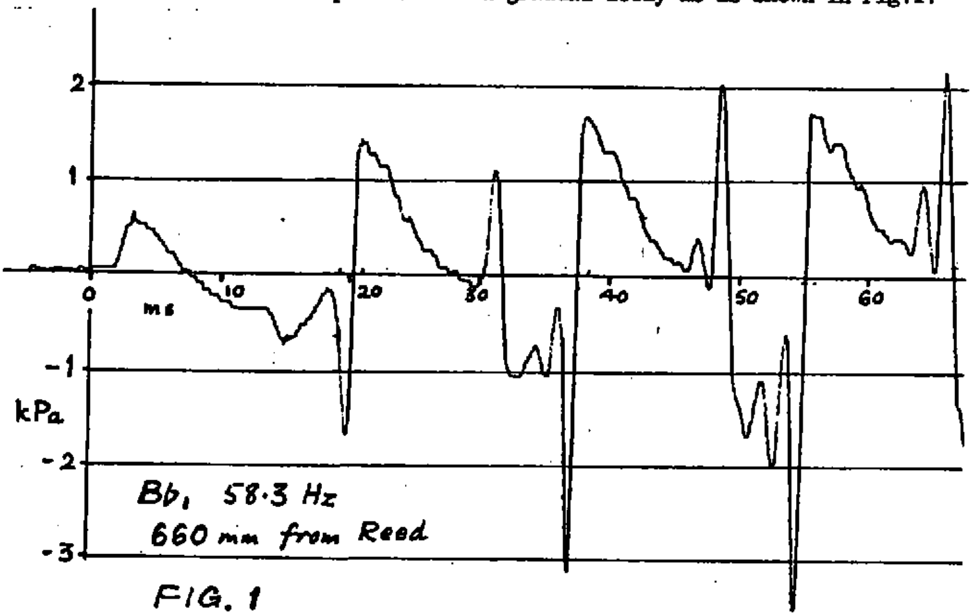

FIG. 1

This quasi-exponentially decaying pulse travels down the tube, encountering reflecting obstacles on the way. An inverted pulse is eventually reflected, carrying with it the imprint of its history. It returns to the reed with a time delay appropriate to the effective tube length controlled by the fingering. During this initial excursion, the difference between blowing pressure and internal reed pressure does not produce a force great enough to move the reed - the reed stays open, admitting an almost steady air stream. It is only when the negative-going reflection arrives back at the reed that the force is sufficient to pull the blades together. Once the reed has closed enough to start to reduce the air flow, the inertia of the air in the tapered tube ensures that the internal pressure falls still further - the reed closes more, and so on. The reed closes rapidly and catastrophically, as may be seen by stroboscopic illumination. It is the moment of triggering of reed closure that is important from the tuning point of view.

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3. TRIGGERING OF REED CLOSURE

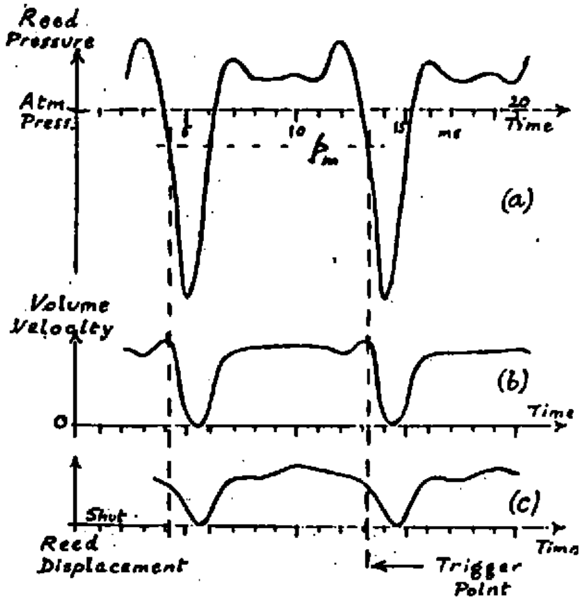

Fig. 2 REED EVENTS : A_2 110 Hz

The critical moment may be seen by noting the point at which the air flow goes through a maximum (see Fig.2). Before that moment the negative pressure pulls more air through the reed; after, the reed is beginning to shut and the air flow is reducing (Ref.1). The internal pressure p_m for this maximum flow to occur is given by: $p_m = P - Xs/2S$ (P is the blowing pressure, X the reed separation before the pressure is applied, s the reed stiffness and S the area of the reed blades). This assumes that the lip force remains operative throughout the reed motion - an assumption that could only be justified if the stiffness of the lip "spring" were small. A better assumption is that the lip stiffness is σ ; the lip moves with the reed - it relaxes somewhat as it goes, but does not lose contact. This modifies the expression for p_m to:

$$p_m = P - X(s+\sigma)/2S$$

The effective value of σ depends on the position at which the lip contacts the reed. Placing the lip nearer the root of the reed reduces the leverage of the force and so reduces the effective stiffness.

Insertion of typical values into the equation shows that p_m is in fact negative; to close the reed, suction is needed inside as well as pressure outside. p_m is raised (i) by raising P - blowing harder
(ii) by lowering X - increasing the lip force
(iii) by lowering - changing embouchure

Raising the value of p_m (making it less negative) means that the returning negative-going edge attains this value earlier, so triggering the reed closure sooner and shortening the period. A higher-pitched note, but also a louder one can be produced by blowing harder. To play louder without going sharp means that X must be increased to counteract the rise in P - the lip force must be relaxed. Similarly to play quietly without going flat, the reed must be "pinched".

4. EFFECT OF WAVE REFLECTIONS

Note that the reed closure is triggered by an appropriately negative value of p_m on the leading edge of the negative-going part of the reflected pressure signal. Changing p_m will change the moment of triggering, but how much the period is changed will depend on the slope of this leading edge. The edge is steep if the reflection has experienced little "smearing out" in the preocess. Energy is lost selectively from the transmitted wave at higher frequencies (above the "tone-holes lattice cutoff frequency") so the sharpness of the edge is degraded. The degree of degradation is worse if the reflection is poor - recognisable to the player as a "hard blowing note". Because of the less-steep edge, such a note is more susceptible to pitch variation. In any case, the leading edge is not of uniform slope; it tends to be steeper at the top and less steep lower down. It follows that the note may be flattened more than it may be sharpened. In an extreme case there may be a kink in the leading edge caused by some disadvantageous contributor to the reflection. This can cause a jump in pitch as p_m is altered - the phenomenon of "flying".

5. EFFECT OF REED CONDUCTANCE

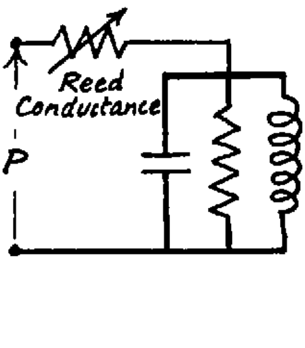

FIG. 3

The pressure profile of the wave travelling away from the reed can be understood with the aid of the analogous circuit described by Rocaboy (Ref.2) and shown in Fig.3. When the reed is open, the blowing pressure causes a current to flow in the parallel oscillatory circuit. The capacitor models the reed volume, the resistor and inductor the tapered entrance to the tube. The circuit is overdamped by the joint effect of the tube input resistance and the reed conductance. The pressure therefore shows a decaying profile. When the reed shuts, the conductance becomes zero and the remaining resistance is small enough for the circuit to oscillate. Only a half-cycle of oscillation takes place - the negative reed pulse - before the reed re-opens with the rising internal pressure and the process repeats. The time-constant of the decaying positive part is influenced by the reed conductance - and hence by the width of the reed opening. The blowing pressure and lip force therefore exert some control.

The overdamped portion of the transmitted wave for B_1 (58.3 Hz) can be seen clearly in Fig.1. The time-constant for the decay is about 4 ms. At this low frequency (period 17.2 ms) the decay is practically complete before the reflected signal returns, so that the reed pressure at that moment is entirely due to the latter. For a higher frequency, this will not be so. The returning pressure has to compete with the "tail end" of the decay still emerging and so p_m is not reached until further down the negative leading edge. There is thus a flattening effect as the scale is ascended unless counter-measures are taken to shorten the decay time - by reducing the reed conductance. In an extreme case p_m could fail to be reached at all and the note would not sound.

This emphasises the need - and natural tendency - to blow harder and squeeze the reed for the higher notes.

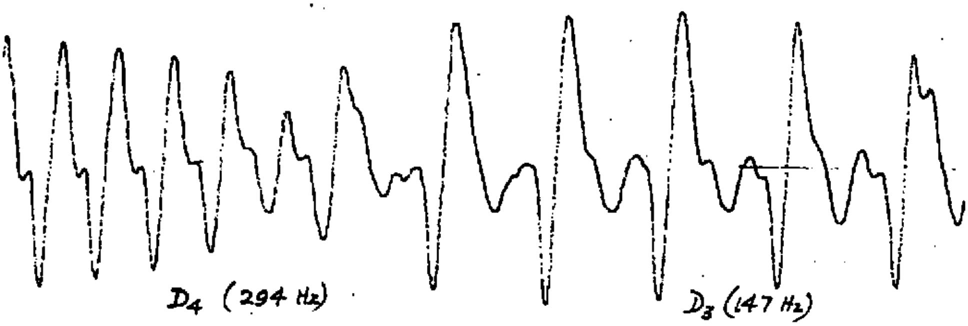

FIG. 4.

The effect of the change of reed conductance can be seen in Fig.4. This captures the moment of transition from D_4 to D_3 (294 to 147 Hz). The player is achieving this entirely by relaxing the lip force and lowering the blowing pressure. The decaying part of the wave emerging from the reed can be seen at the end of the positive-going portions. As the player relaxes to play the lower note, the time-constant of the decay lengthens. This means that the combination of the tail of the decay with a negative reflected pulse that arrives too soon does not give a sufficiently negative pressure to trigger a reed closure. However, a second pulse is already in train which will arrive late enough to avoid the tail of the decay. It therefore does trigger a reed closure after double the time interval. Instead of two pulses shuttling up and down the bassoon, there is now only one, and the pitch drops by an octave.

REFERENCES

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2 F Rocaboy, 'Proposed Model for Reed action in the Bassoon' Journal of the Catgut Acoustical Society, Vol.1 (Series II) Nov. 1989, 20-25