The Playing Techniques of the Serpent

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1. The instrument

1.1 Construction and form factor

The majority of serpents are constructed from two bisected tubes of wood (traditionally from the walnut tree), mirrored-formed in a double-curved ‘S’-shape, and bound together with leather.[1] This leather has usually been dyed black, although other colours, paints, patterns, and varnished wood finishes exist. Metal serpents, usually built from copper, are encountered far more rarely, while some instruments are built today from various forms of plastic resin moulding or 3D-printing.

Serpents feature two groups of three finger holes on the front side of the instrument. The first of these groups is found immediately before the third bend, accessed by the middle three fingers of the left hand (1: left index, 2: left middle, 3: left ring), and the second group is found at the start of the fourth bend, accessed by the middle three fingers of the right hand (4: right index, 5: right middle: 6: right ring). Some serpents have additional tone holes covered with keys that can be operated by other fingers or thumbs (→ 2.4). The charts below refer to an instrument with B, F-sharp, and C-sharp keys; to apply to instruments without keys, ignore the columns referring to these tone holes.

Serpent mouthpieces are generally made out of wood (historically also ivory or metal, modern mouthpieces are sometimes made from other animal horn or plastic), and are connected to the body of the instrument through a metal bocal. This bocal can vary in form and length depending on the desired aesthetic and/or fundamental pitch, but always feature a continuously expanding conical bore diameter. The mouthpiece is secured into the bocal using a string binding, sometimes with additional wax, while the wider end of the bocal contains a similar binding or cork rim for an airtight insertion into the instrument. Serpents do not have a tuning slide, with physical intonation adjustment only possible through degrees of insertion of the bocal into the instrument, although such adjustments have minimal effect in comparison with the role of the embouchure (→ 3.1).

The top of the serpent is protected using a metal sheath. Additional metal bracings between some or all of the bends of the instrument are found on some serpents, particularly those featuring tighter bends and a more compact length. These instruments, found commonly from British or German nineteenth-century manufacturers, are known as ‘military serpents’, and also often feature additional metal and/or ivory decorations around the finger holes, keys and/or bell. While this and many other form factors of serpent were experimented with since the seventeenth century (→ BH 1.1), the historically French design of instrument, also known as a ‘church serpent’ (*serpent d’église*), forms the basis for all serpents manufactured since the mid-twentieth century.

1.2 Practical considerations and posture

As aerophones made of wood and lacking any water key system, care must be taken to avoid excessive build-up of moisture inside the instrument. Drying cloths must be passed through the mouthpiece and bocal at regular intervals, and a ventilator should be attached to the instrument

1 Some rare forms of serpent form different shapes, such as the figure-of-eight serpent Piffault. Despite a lack of keys and similar bore profile to ‘S’-shaped serpents, these are described by some as a form of bass horn (→ BH 1.1).

during breaks and when not in storage, especially under particularly humid conditions. It is also recommended to oil the inside of the instrument at regular intervals. Both historical and modern serpents are considerably more fragile than metal labrosones, and are more difficult to repair or replace, and so any gestures that require physical manipulation of the instrument (→ 4.4) or otherwise involve placing the instrument at risk of damage should be avoided.

The serpent is usually played while seated, either suspended between the legs or with the instrument resting on one leg, with the angle of the bocal being adjustable to allow the embouchure to meet the mouthpiece. The instrument can also be played while standing by inverting the right hand to support the lower half of the instrument and adjusting the angle of the bocal. This requires inverting the fingering of the right hand (4: right ring, 5: right middle, 6: right index) and also can limit the usability of keys (→ 2.4), although some instruments have forked key designs to allow for use in either position. This position can also be employed while seated, and is preferred by some due to the directional sound projection from the bell pointing forwards rather than upwards.

2. Resonant characteristics and acoustic properties

2.1 Resonant frequencies and spectral components

Serpents have a nominal resonant length of 8-ft C, with a fundamental pitch (with all holes closed) of C2.[2] Pitch content generated by a serpent is defined by a combination of the resonant frequencies (or ‘modal resonances’) of the instrument’s air column (as well as the performer’s body), and their spectral components, which are controlled by vibrations of the lips (‘buzzing’) when they form an embouchure, a system known as a ‘cooperative regime of oscillation’ (→ TU 5.2). The serpent’s rapidly expanding conical bore and lack of bell flair results in a notably weaker cooperative regime of oscillation than found with modern labrosones, with common practice writing reaching only the sixth harmonic, and the extreme upper tessitura reaching the eighth harmonic. Due to the hand-crafted nature of serpents and lack of consistency in placings of holes, keys, bocal forms, mouthpieces, and overall design forms, each individual serpent will have, to an extent, its own resonant characteristics with its own unique spectral content.

Chart 1 presents the spectral content created by a serpent approximated to equally-tempered pitches (to the nearest quarter-tone). Columns represent the progressive uncovering of holes from the bottom (bell) to the top (mouthpiece end) of the instrument (including keys inserted in their respective holes’ positions along the tube), and rows display each overtone series. A blank space indicates that there is no significant pitch difference (more than a quarter-tone) from the preceding hole combination. Multiple fingering combinations for one column indicate that these produce approximately the same pitches (within a quarter-tone) (→ 2.3).

2 Some historical serpents are found in D, likely used as instruments in C when conforming to the *ton d’église* (church pitch) standard of ca. A = 392Hz, commonly used in French churches and opera houses in the early nineteenth century. This discrepancy is arguably the reason behind Berlioz’s description of the serpent in as being a transposing instrument in B-flat having encountered an instrument built for C at A = ca. 392Hz.

2.2 Tone hole acoustics

The serpent was developed with a wide, conical bore in order to create stronger low spectral content than instruments of similar resonant lengths, for example, trombones and bassoons. However, this results in a limited effectiveness of finger holes for pitch alteration. These function acoustically as high pass filters, the effectiveness of which is defined broadly by the ratio between the diameter of the tone hole and the instrument bore at that point. Given their need to be covered by fingertips, the relatively small size of the serpent's tone holes compared with the instrument's bore result in them having a relatively minor effect on pitch selection, compared with, for example, cornettos and recorders. Meanwhile, the tone holes can only be spaced as widely apart as is possible with the middle three fingers of each hand, compromising their acoustic positioning. Differentiation between which hole(s) in each groups of three are covered or uncovered is therefore minimal, particularly in the lower register which make use of the lower three holes where the bore is at it's widest (→ 2.3).

Chart 1 illustrates how the tone holes of the serpent have been placed in such a manner as to enable production of most diatonic pitches between C2–C5. Nevertheless, there are some notable exceptions to this, and many natural overtones deviate significantly from equally-tempered pitches. In particular, one can observe how the effectiveness in pitch modulation of uncovering holes weakens as the pitch ascends, from a major seventh with the fundamental to no change with the eighth harmonic. Chart 2a combines the spectral content shown in Chart 1 with the techniques and technologies detailed below to create a practical chromatic fingering chart, while Chart 2b follows the same principle but without the availability of keys. These charts are to be used as guides only; the tone hole combination chosen will always depend to an extent on the individual instrument (→ 2.1) and the relative strength of the embouchure (→ 3.1, 3.2).

2.3 Forked or cross fingerings and fractional hole covering

A forked or cross fingering refers to any combination of hole coverings where there is at least one open hole between at least two closed holes. The most common of these are used in Charts 2a and 2b to aid production of some chromatic pitches, particularly E-flat, E, and A-flat. Given the same total number of closed holes, combinations with lower open hole(s) are generally flatter than those with higher open hole(s), but the difference is often negligible (→ 2.2). Forked fingerings result from a trial-and-error process of covering and uncovering holes to reliably recreate desired pitches, which are often specific to an instrument, mouthpiece, and/or performer. Similar experiments result in fractional hole covering, where the finger tip only partially covers a hole. This technique is used primarily to aid production of chromatic pitches that are difficult to create without keys (→ 2.4). They can also be used to aid in production of glissandi, but these are generally more effectively produced through lip bending (→ 3.2). Fractional hole coverings are otherwise avoided in common practice, as they result in more unstable and unreliable pitches and/or timbres (→ 2.5).

2.4 Keys

Keys are first-class levers used to actuate felt pads which uncover additional tone holes unreachable by fingers. These aid in production of pitches that are difficult to produce reliably and otherwise require significant lip-bending (→ 3.2), forked fingerings, and/or fractional hole coverings (→ 2.3). These keys are closed-standing, meaning they need to be engaged (depressed) to be opened. While the position and amount of keys is not standardised, the most common variants are as follows:

Position	*Hand, finger*	*Pitch*
Front, middle of fourth bend (beyond sixth hole)	Right hand, little finger	C sharp
Front, end of third bend (between the third and fourth holes)	Left hand, little finger	F sharp
Rear, between second and third bends (before first hole)	Left hand, thumb	B

More rarely found is an E-flat key, positioned between the fifth and sixth holes. Serpent keys can aid in creation of stable pitches, however, the holes underneath them are no larger than finger holes. They can therefore aid in pitch selection (as with finger holes, more so when closer to the mouthpiece than the bell of the instrument (→ 2.2)), but a strong level of embouchure control is still required (→ 3.1) as the holes are still small in diameter relative to the bore of the instrument. In this manner, serpent keys should not be confused in acoustic effect with valves, or indeed with the larger keys found on ophicleides and some other models of bass horn (→ BH 2.2).

2.5 Dynamic and timbre

The serpent originated as an instrument used to accompany voices in a liturgical setting, and its timbre is traditionally sonically associated with the extremely long reverberation time found in French Gothic cathedrals. Without such an external acoustic resonance, the instrument's wide, continuously expanding bore profile and lack of bell flair results in a notably quieter dynamic range and 'darker' spectral content (that is, with limited higher harmonic enrichment) than is found with modern labrosones. Pitches with one or more open hole(s) generally have a lower maximum dynamic level with a 'darker' timbre (often with more white-noise content) than those with all or most holes closed, particularly in the lower register. Extreme dynamic effects such as non-linear sound propagation or exceeding the bell cut-off frequency are not possible. Chart 3 indicates the subjective maximum and minimum volume levels of the serpent at various pitches alongside their respective longest possible durations in a single breath (in seconds). Dynamic notation follows the conventions used with other tuba family instruments (→ TU 4.2).

While timbral range is inexorably linked to dynamic level, variance in timbre is effected more significantly by the choice of mouthpiece with the serpent than with modern members of the tuba family. Historical church serpent mouthpieces were commonly found with a sharp right angle between a hemispherical cup and the shank. This design aids in creation of the strong pressure pulse needed to promote secure intonation, but also filters out a significant portion of lip-reed resonance, making the background 'white noise' resonances more audible, thus resulting in a more 'breathy' sound. Mouthpieces built for some military serpents and bass horns have a more rounded backbore and deeper cup shape (→ BH 2.4), resulting in a stronger lip-reed sound that is richer in fundamentals and other low spectral content. Regardless of mouthpiece choice, the 'white noise' component of serpent's timbre is more present than with modern tuba family members, particularly at lower dynamic levels, and/or when multiple tone holes are opened simultaneously (→ 3.6).

3. Sound production and articulation

3.1 Embouchure

The embouchure has a significantly more important role in serpent lip-reed sound production than with the modern tuba family. While its acoustic function remains the same (→ TU 5.3), the lack of a bell flare results in a notably weaker reflection of the pressure pulse created by the 'buzz' of the embouchure (→ 2.1). This leads to reduced reciprocal 'slotting' between embouchure and instrumental resonances, limiting the overall degree of pitch control provided by the acoustic structure of the instrument. Such weakness is exacerbated when holes are opened, which further hinder the instrument's intonational stability (→ 2.2). Serpent performance practice therefore requires greater muscular support from the embouchure muscles than with modern labrosones, as well as higher levels of ear training and preparation, while external reference pitches can aid in accuracy of intonation, similar as when exceeding the bell cut-off frequency with modern labrosones (→ TU 4.1.3). The requisite higher lip pressure can also lead to premature embouchure fatigue, which in turn can effect intonation owing to the significant role of lip bending (→ 3.2).

3.2 Lip bending and factitious pitches

While modulation of lip resonance frequency is used on modern brass instruments (→TU 8.1), 'lipping' or 'bending' is significantly more important in serpent performance practice due to the relatively weak harmonic structure of the instrument (→ 2.1, 2.2). In the lower register, the cooperative regime of oscillation is at its weakest, and lip bending is necessary in order to produce chromatic pitches, while from the third harmonic upwards, it is used to make the adjustments needed to compensate for the instrument's natural resonances, particularly but not exclusively when lacking keys. Chart 4 illustrates the potential lip-bending range of the spectral content found in Chart 1 (to the nearest quarter-tone). A factitious 'pedal note' is present an octave below the first fundamental (not to be confused with the non-factious pedal notes of the modern tuba family (→TU 8.1.2)), which can also be 'lipped' up, producing a range of C1–E2. This is controlled in pitch by the lips, with tone hole combinations primarily affecting timbre (→ 2.3).

3.3 Legato, glissando, vibrato, and lip trills

As a result of a strong reliance upon lip bending, legato articulation can be aided by the tongue ('legato tonguing', common in trombone performance practice) in order to avoid unintentional glissandos, notably in the lower register, when executing rapid oscillations, and/or when hole changes occur only within one group of three fingers. The smoothness and speed of an embouchure legato gesture is inversely proportional to the distance between the notes (→ TU 5.3.2). Lip trills are possible between adjacent fourth and fifth harmonics or higher (→ Chart 1), while between lower or non-adjacent harmonics, notation as rhythmic legato gestures is more appropriate. Glissandos can effectively be produced between any pair of notes across the instrument's range (commonly through lip bending, but also at slower speeds through fractional hole covering (→

2.3)), as can vibrato effects, which are most commonly produced on labrosones using lip amplitude modulation (→ TU 8.3.1).

3.4 Multiphonics ('split tones'), whistling, and ingressive sound production

The relatively weak harmonic structure of the serpent results in multiphonics (also known as 'lip multiphonics' or 'split tones' (→ TU 8.4)) being more difficult to produce than on modern labrosones. Nevertheless, experimental practice has led to the production of some multiphonics, although these cannot yet be reliably reproduced or standardised across instruments. The strong role of lip bending (→ 3.2) means that the audible pitch content of serpent multiphonics deviates from instrument's natural overtone resonances significantly more than with modern labrosones. The results shown in Chart 5 illustrate a work-in-progress demonstrating research undertaken thus far. In a similar manner to higher tuba multiphonics, serpent multiphonics are inherently fragile gestures, being limited to a *piano* dynamic, and are not consistently sustainable for medium-to-long durations. Whistling through the serpent works in a similar manner as with modern labrosones (→ TU 8.5), as does ingressive sound production (→ TU 8.6), with the relatively small size of serpent mouthpieces leading to ingressive lip-reed sound production being even less stable than with a tuba.

3.5 Articulation with the tongue, vocal tract, and other muscles

Articulation with the tongue, vocal tract, and other muscles functions fundamentally in the same manner as with the modern tuba family (→ TU 9). The wide, conical bore and relatively weak dynamic range of the serpent allow oral articulation (for example, [t], [g], or [p]) to be particularly well defined. Flutter- and slap-tongue are also both effective, although the weaker harmonic structure of the instrument prohibits any clear slap-tongue pitch content, with this technique best suited for percussive effects. These factors also lead resonance (formant) modulation with the tongue and oral cavity to be highly effective, although in the lower register care must be taken to avoid unintentional lip bending (→ 3.2). Any other extremities of articulation, for example, abdominal articulation or breath accents, should also be used with caution for similar reasons.

3.6 Air noise (non-lip-reed) sound production

Air-noise sound production functions with a serpent in the same way as with modern labrosones (→ TU 7), although the wide, continuous conical bore of the instrument leads to 'white noise' resonances being generally more prominent, especially when using a mouthpiece featuring a sharp-angled backbore (→ 2.3). As with the tuba, the fundamental modal 'white noise' resonances contain a very soft pitch content (an objective *pianissimo*), as listed in Chart 6 (regarding pitch content → TU 7.2.1), although this is immediately filtered out by any closed formant shapes. These pitches are considerably more limited in range compared with the tuba due to the limited efficacy of tone holes in altering fundamental resonant pitch (→ 2.2). The unavoidable air sound alongside the lip-reed sound present in the highest register of the modern tuba family can be heard to an extent across the complete compass of the serpent, particularly in the lower register. Conversely, the strong 'white noise' content of the serpent's timbre enables easier blending of air and lip-reed sound across registers and dynamic levels than is possible with modern labrosones. Treated independently from lip-reed sounds, air sounds are easily controllable, although the small cup of the mouthpiece precludes the effective use of air sounds created with the embouchure away from the mouthpiece, or with the mouthpiece inverted.

4. Instrumental mechanics and other options for sound generation and modulation

4.1 Finger hole trills, key trills, tremolos, and timbral trills

The compromised acoustic structure and rudimental mechanics of the serpent limit their effectiveness at sonic modulation (→ 2.2) in comparison with bodily mechanics (→ 3.1). Nevertheless, finger holes and keys can be used for articulation, including trill gestures, which can be created between any two neighbouring pitches in Chart 1. Timbral trills (*bisbigliando*) are possible between any neighbouring hole and/or key combinations where no change of pitch is indicated, for example, between the multiple options for a G2 in the second harmonic, or for an F-sharp 3 in the fifth harmonic. While these gestures can have a rhythmic and/or percussive effect (→ 4.2), timbral modulation is more effective using the tongue and/or vocal tract (→ 3.5), as alternate combinations for the same pitch result in limited perceptible timbral differentiation. The maximum speed of any finger hole or key trill is limited by finger musculature, notably regarding combinations which require some fingers to close holes or engage keys while oscillating others of the same hand.

As with valves (→ TU 10.1), tremolos can be created by combining finger hole and/or key trills with lip trills, where the potential maximum speed of oscillation is inversely proportional to the size of the interval between the two notes, and is limited by complexity of finger combinations required. Rapid oscillations between larger intervals in any register or any interval in the lower register are likely to be perceived as glissando or vibrato effects rather than as tremolos between two individual notes. Finger hole and key trills without lip-reed sound can have, at most, a minor timbral effect on any non-lip-reed resonances (for example, air noises (→ 3.6) or vocalisations (→ 4.4)), and these can be easily overwhelmed by the mechanical sound of trill production itself (→ 4.2).

4.2 Use of finger holes and/or keys alone

Covering a tone hole with a finger creates a quiet percussive sound, while a louder sound is created when opening and even more so when closing a keyed hole. These sounds, generally inaudible when combined with a lip-reed sound, can be mitigated altogether by covering a hole or depressing or releasing a key at a slow speed, or exaggerated by use of extra force. These effects increase proportionally when multiple finger holes and/or keys are operated simultaneously and/or in rapid succession, while louder effects can also be created by 'flicking' a key (opening and closing a key rapidly in one gesture). A performer will generally strive to create as little extraneous mechanical noise as possible, but an audible percussive sound is unavoidable when complex, rapid finger movement is required alongside quiet instrumental resonances, especially when involving keys. The maximum perceived mechanical dynamic, produced by trilling or flicking all three keys and hitting all finger holes in rapid succession, is approximately an objective *mezzo-forte*, notably quieter than the percussive sounds that can be created by the keys of some bass horns (→ BH 4.2).

4.3 Use of bocal and mouthpiece alone

In addition to mouthpiece buzzing (→ TU 5.2.1), it is also possible to buzz with the mouthpiece and bocal together without the instrument. These processes bear closer relation to those involved with serpent lip-reed sound production than with modern tuba due to the altered role of the embouchure (→ 3.1), but can still cause premature embouchure fatigue. Bocal and mouthpiece buzzing produces a stronger tonal centre with a lower range than buzzing with the mouthpiece alone, but it is not strong enough to produce any clear modal resonances, and thus the two techniques can be treated anomalously. While the pitch range will vary according to the performer and their own mouthpiece and bocal, a range of ca. D2–A4 is generally possible, with all muscular articulations (→ 3.5) and air sounds (→ 3.6) also available. By partially closing the end of the bocal with the palm and shifting the embouchure (→ TU 5.3.2), a factitious pitch of ca. D1 can also be produced.

4.4 Vocalisations, other uses of the body, and external equipment

The use of the vocal folds while playing the serpent functions in the same manner with as modern labrosones (→ TU 11.1, 11.2), although the 'darker' timbre and lower dynamic range of the serpent (→ 2.3) can necessitate greater sensitivity towards balance between lip-reed and vocalised sounds. Other physical gestures (→ TU 11.3) are generally less effective due to both the lack of metallic percussive resonances and the fragile nature of the instrument (→ 1.2). Movement of the legs and feet is generally not possible if the instrument is being played in a seated position. The serpent's sound can be combined with both live and pre-recorded electronics (→ TU 12.5), while amplification can help overcome the instrument's acoustic limitations (→ 2.5) through sensitive use of microphones.

Serpent mutes or other bespoke resonance filtration devices to not exist, while experimentation with external objects should be undertaken as with any instrument preparation (→ TU 12.2), paying particular respect to the serpent's fragility and necessity to avoid sources of moisture. Experiments with woodwind mouthpieces (→ TU 12.3) have not yet led to production of specialist adapters, resulting in extra time being needed to swap mouthpieces and ensure an airtight fit. Research to date with a baritone saxophone mouthpiece has resulted in the pitch material shown in Chart 7, with tone hole mechanics functioning in a similar manner as with lip-reed sound (→ 4.1). In general, higher harmonics are more fragile and difficult to produce reliably than lower harmonics, particularly those notated in parentheses. Such practice has not yet been reliably reproduced using a bassoon reed, although initial testing suggests that this is effective at producing rich, albeit significantly more unstable harmonic spectral material.

Charts

Unless otherwise specified, charts refer to a serpent with three keys (C sharp, F sharp, B) (→ 1.1)

● = closed hole, ○ = open hole, ⊙ = depressed/open key, ⦶ = partially covered hole

Chart 1: Spectral content

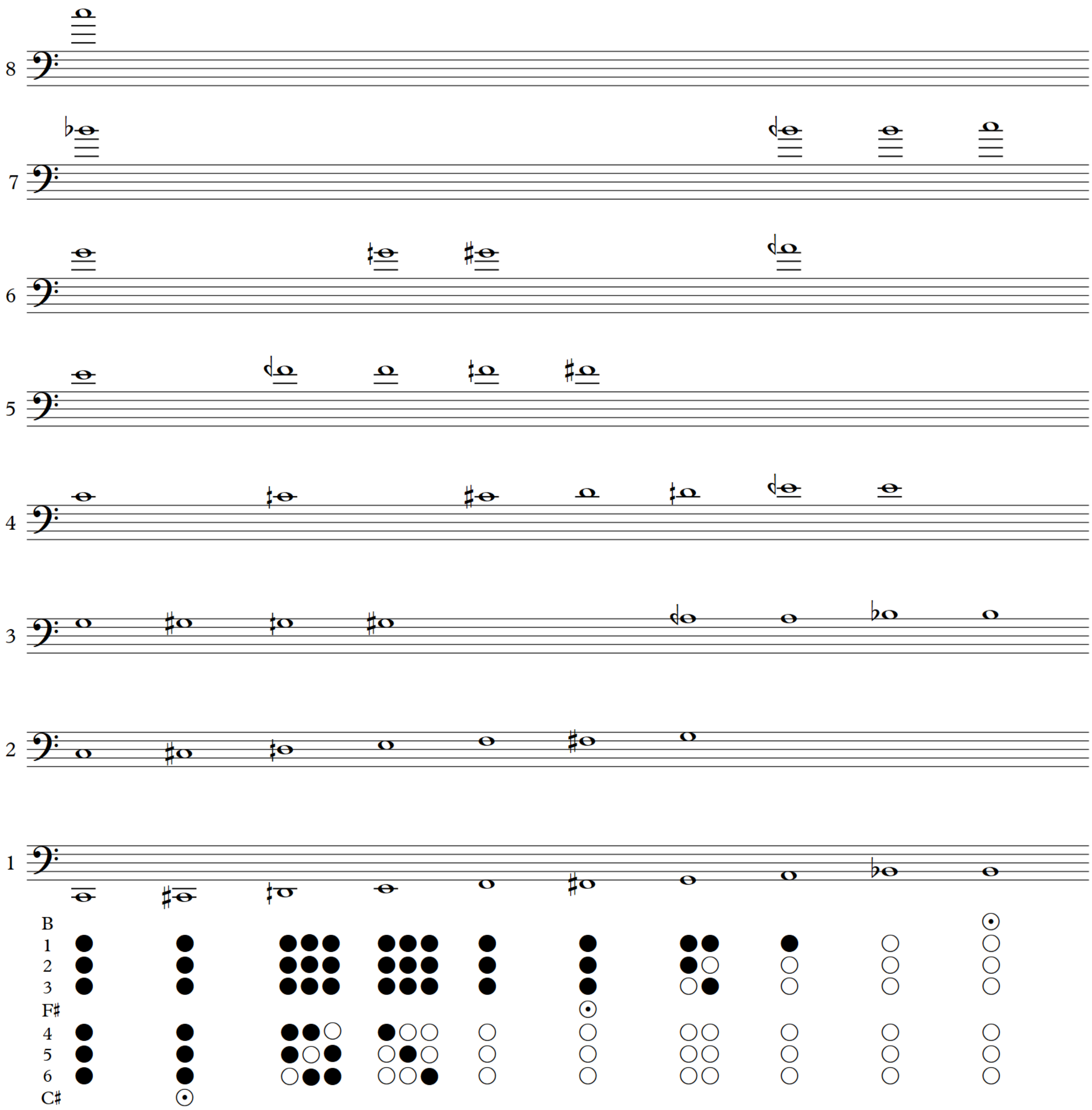


Chart 2a: Chromatic fingerings (with three keys)

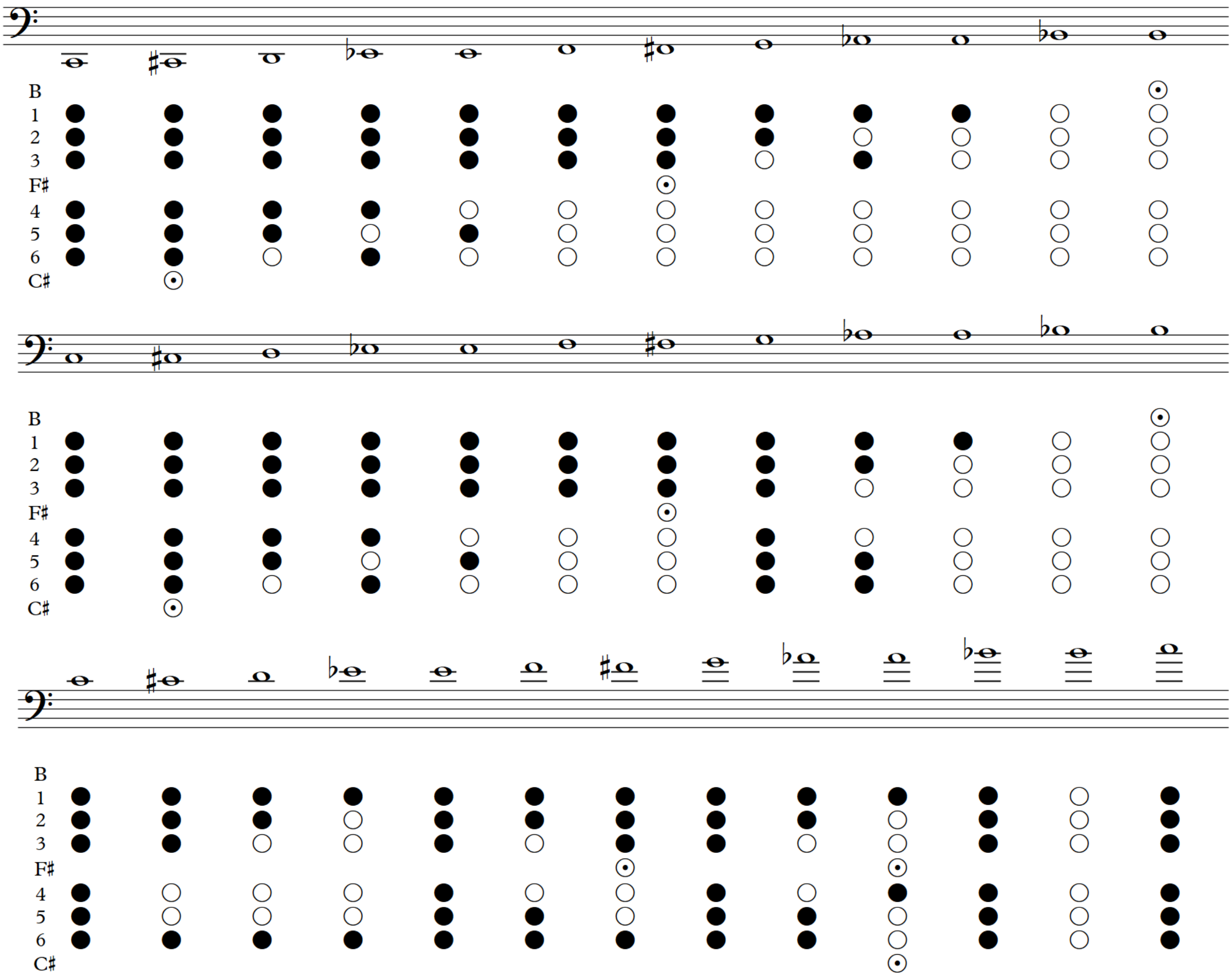


Chart 2b: Chromatic fingerings (without keys)

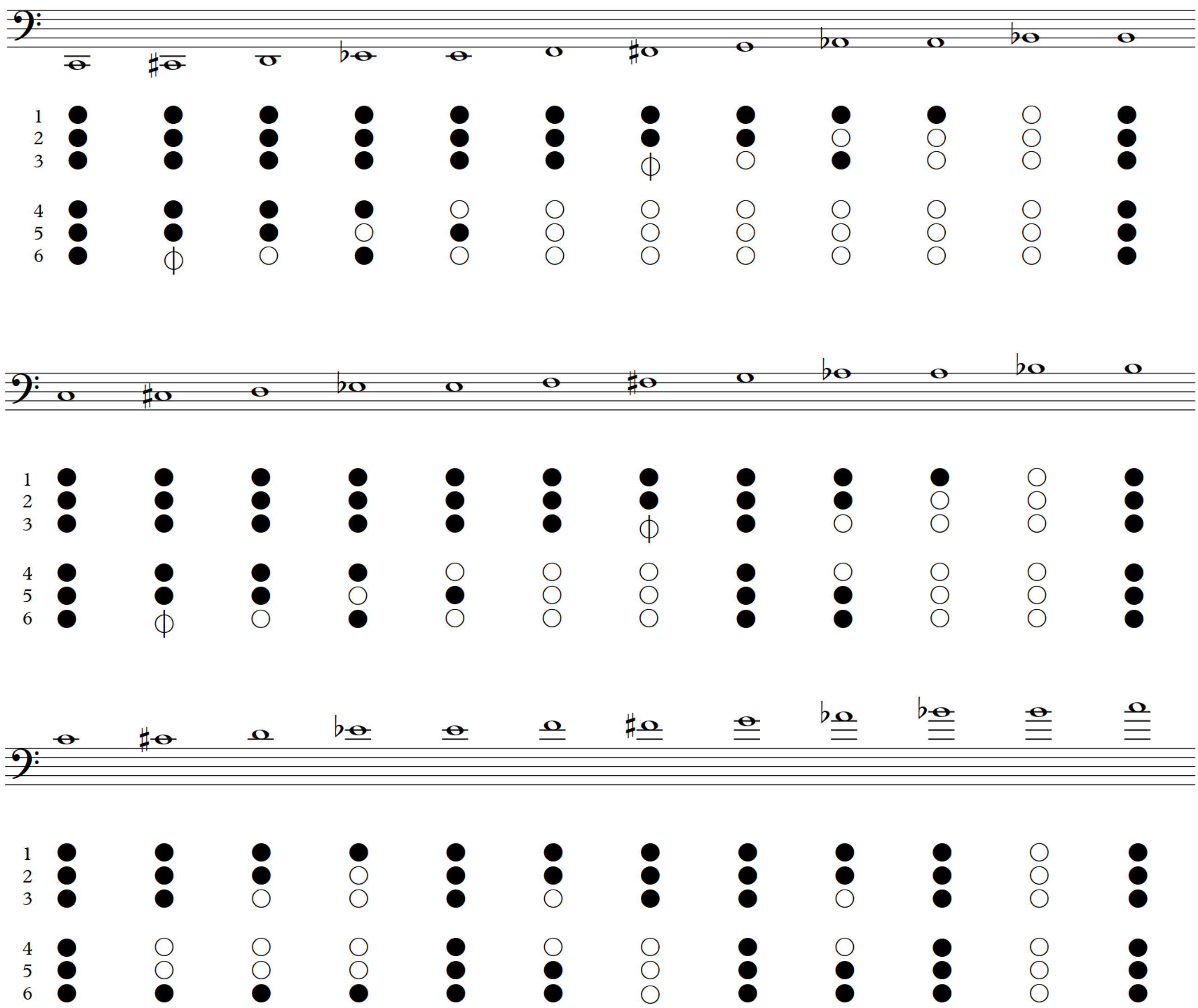


Chart 3: Dynamic curves and durations

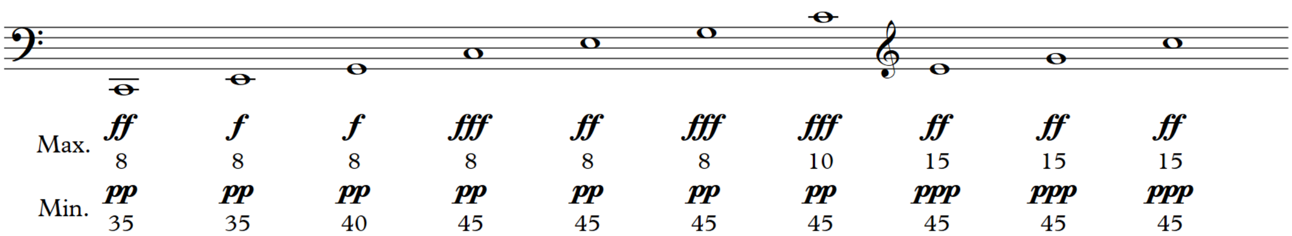


Chart 4: Lip bending ranges

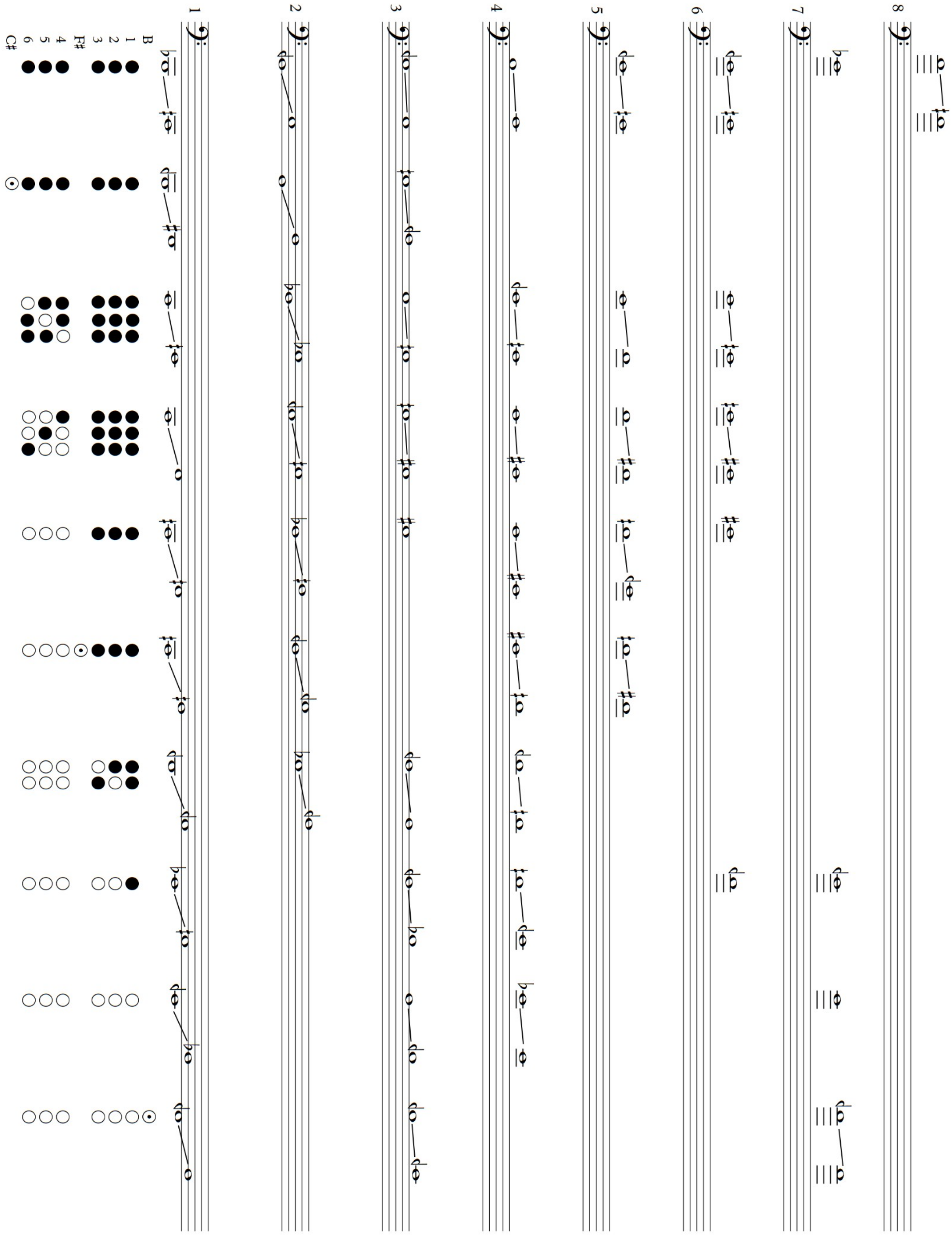
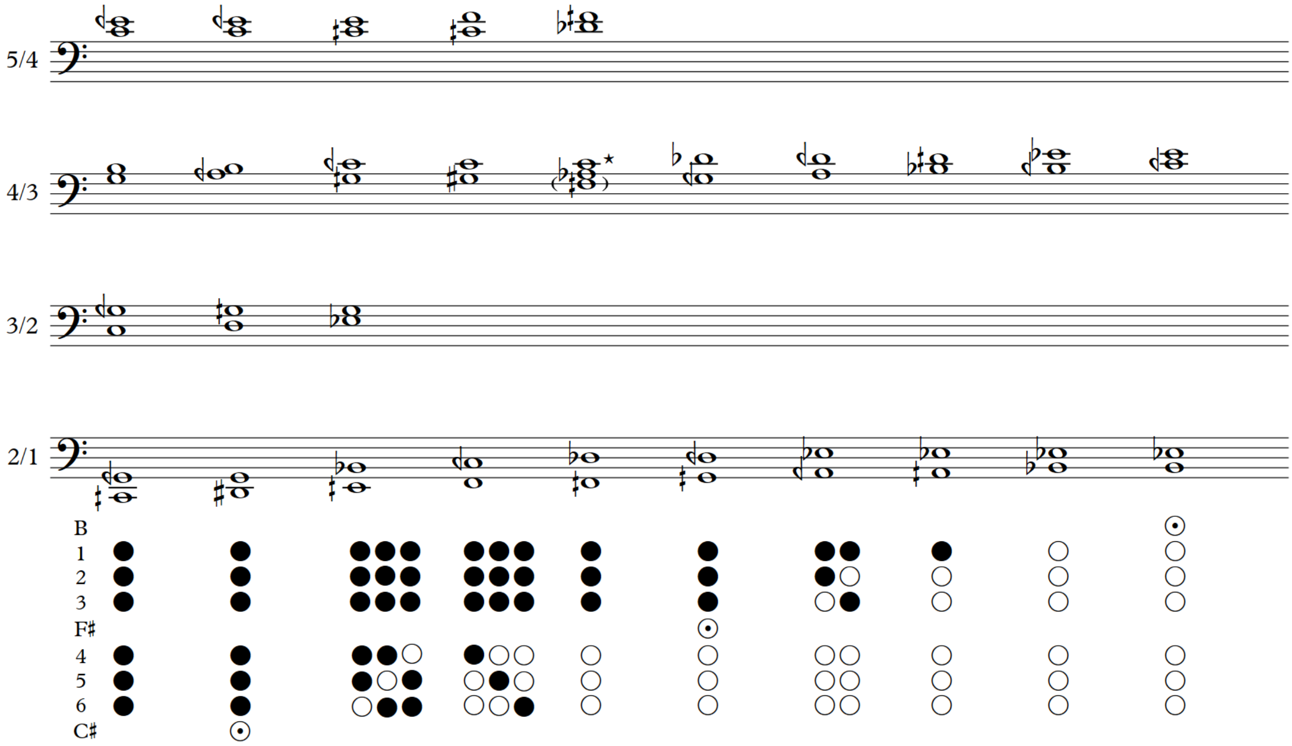


Chart 5: Multiphonics



*The lower parenthetical pitch (the second harmonic) is generally more perceptible than the third harmonic.

Chart 6: Air noise pitch content

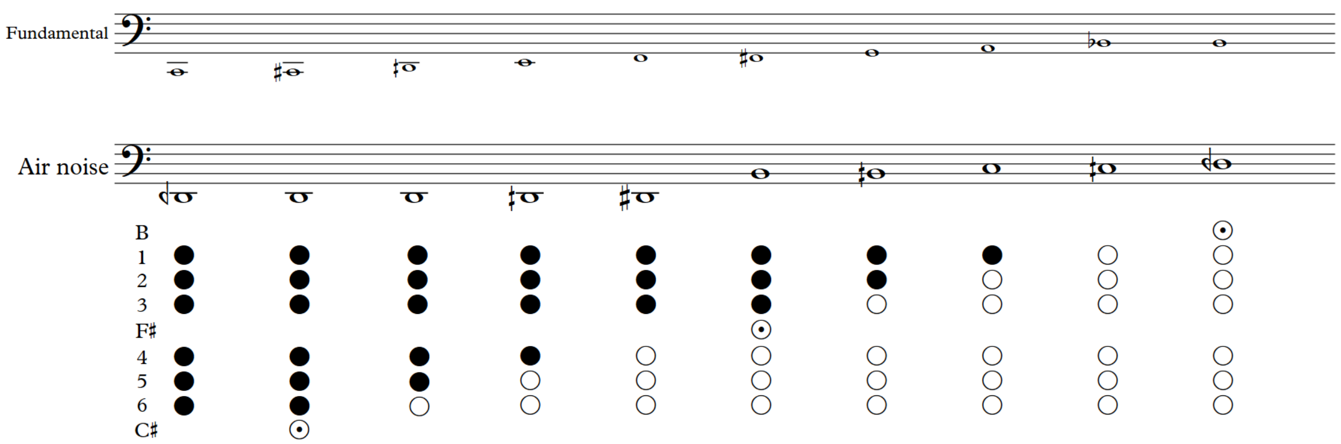


Chart 7 Spectral content with baritone saxophone mouthpiece