

The Acoustical Identity of the Bass Trumpet

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The bass trumpet has the same compass as the tenor trombone. It emerged as a recognised species of brasswind in the second half of the 19th century, a time when valve trombones were far more prevalent than now. The organological literature fails to provide any acoustically significant basis for differentiation between trombone and bass trumpet. Measurements of acoustical parameters such as input impedances of some bass trumpets, slide and valve trombones from the Edinburgh University Collection of Historic Musical Instruments and other sources are presented alongside results from sounding these instruments using artificial lips. The possibilities for correlation of physical, acoustical and performance characteristics are explored. It is believed that the systematic detailed measurements underpinning this paper have not been made previously, and that the synthesis of acoustical with physical measurements can be a valuable approach in the study of historic brass instruments of all kinds.

1 Introduction

The bass trumpet is similar to the common C or B \flat trumpet, but pitched one octave lower, in 8-ft C or 9-ft B \flat , see Figure 1. It is an established species with orchestral repertoire (Wagner, Strauss, Janacek and other composers), and is also used in east European bands. Orchestrally it is generally played by trombone players. The tenor valve trombone is also in 8-ft C or 9-ft B \flat pitch with an orchestral and band repertoire: an example is shown in Figure 2. Players report a (subjective) difference from their experience in playing the instruments. Do these instruments differ acoustically?



Figure 1: EUCHMI (4045) Bass trumpet in 9-ft B \flat (Robert Schopper, Leipzig, c 1910)

Six instruments of German and east European origin from the Edinburgh University Collection of Historic Musical Instruments [1] and one lent by a musician (William A. Giles) were systematically measured, both physically to determine their acoustically significant design features and acoustically.



Figure 2: EUCHMI (3830) Valve tenor trombone in B \flat (Zimmermann, St Petersburg, c 1905)

The sample set consisted of:

- EUCHMI (3847) Bass trumpet in B \flat (Schuster, Markneukirchen, c 1900)
- EUCHMI (4045) Bass trumpet in B \flat (Schopper, Leipzig, c 1910)
- EUCHMI (2858) Bass trumpet in B \flat (V.F. Cerveny, Koniggratz, c 1900)
- WAG (1) Bass trumpet in C (Alexander, Mainz, 1983) with first valve operated
- EUCHMI (3753) Tenor slide trombone in B \flat (Mitsching-Alschausky, W.-Elberfeld, Germany, mid 20th century)
- EUCHMI (3830) Valve trombone in B \flat (Zimmermann, St. Petersburg, c 1905)
- EUCHMI (3472) Armeeposaune [valve trombone] in B \flat (Schamal, Prague, c 1880)

2 Physical measurements

2.1 Bore profile

The bore profiles of the instruments are superficially similar: neither bass trumpets nor valve trombones are constrained like slide trombones to have substantial cylindrical sections. Figure 3 shows the bore profiles of two bass trumpets and a slide trombone, together with a Kaiserbaryton (euphonium) for comparison. Several parameters for comparing brass instrument bore profiles were measured for the sample set.

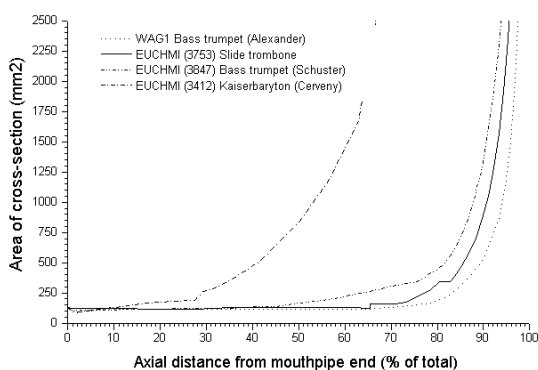


Figure 3: Bore profiles of three of the sample set with the bore profile of a euphonium (upper line) for comparison

2.2 Minimum bore diameter

The smallest bore diameter is usually a short distance from the mouthpiece receiver. For the sample set the minimum bore diameter was:

Table 1: Minimum Bore Diameters

Bass trumpet (WAG1)	10.5mm
Bass trumpet (3847)	11.6mm
Bass trumpet (2858)	11.6mm
Bass trumpet (4045)	12.3mm
Slide trombone (3753)	12.3mm
Valve trombone (3830)	12.0mm
Valve trombone (3472)	12.0mm

2.3 Conicity

The term "conical bore" is loosely applied to brass instruments. A well-defined parameter corresponding to the concept of conicity is K , defined as the ratio of mid-length cross-sectional area to minimum cross-sectional

area [2]. The sounding length of the tube of each instrument was measured (without operating any valves or extending slides) following a path along the centre of the cross-section of the tube [3]. The bore diameter at the mid-length point of the tube was measured. For the sample set the values of K are:

Table 2: Parameter K

Slide trombone	(3753)	1.12
Valve trombone	(3830)	1.27
Bass trumpet	(WAG1)	1.31
Valve trombone	(3472)	1.44
Bass trumpet	(3847)	1.56
Bass trumpet	(2858)	1.65
Bass trumpet	(4045)	1.73

The categories of bass trumpet and valve trombone overlap in their K values, and are all distinct from Tenorhorns (baritones) at the same pitch K values typically 2.5 - 3.5) and euphoniums (K values typically 4.0 - 8.0).

2.4 Cylindricity

Similarly, the term "cylindrical bore" is loosely applied to brass instruments. A useful parameter corresponding to the concept of a cylindrical bore is C , defined as the distance from the mouthpiece receiver to the point where the cross-sectional area is double the cross-sectional area at the mid-length, expressed as a proportion of the tube length [4]. For the sample set the values of C are:

Table 3: Parameter C

Bass trumpet	(4045)	0.71
Bass trumpet	(2858)	0.72
Bass trumpet	(3847)	0.74
Slide trombone	(3753)	0.78
Valve trombone	(3830)	0.78
Valve trombone	(3472)	0.80
Bass trumpet	(WAG1)	0.82

The categories of bass trumpet and valve trombone overlap in their C values. Baines [5] recognises two types of bass trumpet; examples (4045), (2858), and (3847) correspond with the 'Moritz' pattern. The Moritz pattern bass trumpet is less "cylindrical" than trombones, and the Alexander model bass trumpet is more "cylindrical" than trombones. and are all quite distinct from Tenorhorns and euphoniums at the same pitch (K values typically in the range 0.60 - 0.65).

There is in fact at least one other type of bass trumpet, having a mouthpiece receiver designed to take a standard trumpet mouthpiece with a narrower shank than a

trombone mouthpiece. Since it was desired to use the same (trombone) mouthpiece for all the instruments being measured, examples of this narrower receiver pattern was not included in the sample set.

2.5 Bell flare

The flare of the bell has important effects, both on the reflection of acoustic energy internally to allow standing waves, and on the radiation of sound from the instrument. The maximum value of the horn function [6] was calculated from the instrument geometry [7]. The corresponding cut-off frequencies of the bell flares are:

Table 4: Cut-off Frequencies

Valve trombone (3830)	791 Hz
Bass trumpet (4045)	794 Hz
Slide trombone (3753)	837 Hz
Bass trumpet (3847)	881 Hz
Bass trumpet (WAG1)	1029 Hz
Valve trombone (3472)	1108 Hz
Bass trumpet (2858)	1158 Hz

Again, there is no clear distinction between bass trumpets and valve trombones.

3 Acoustical tests

Acoustical tests were carried out on the sample set, all using the same mouthpiece (EUCHMI 1586). The main tuning-slides were adjusted so that the instruments when played by a human player sounded F_3 at c 20 cents below $A_4 = 440$ Hz equal temperament.

3.1 Acoustic impedance

Acoustic input impedance was measured using *BIAS* system [8] for the valve and slide settings required for the note F_3 (no valves operated for the $B\flat$ instruments, the first valve operated for the C instrument). Figure 4 shows peak envelopes.

The equivalent fundamentals of the modes (indicating the harmonicity of the modes) were fairly consistent for all specimens and did not show a marked difference between bass trumpets and trombones. This method can successfully distinguish between instrument species, but showed a null return in this case, see Figure 5.

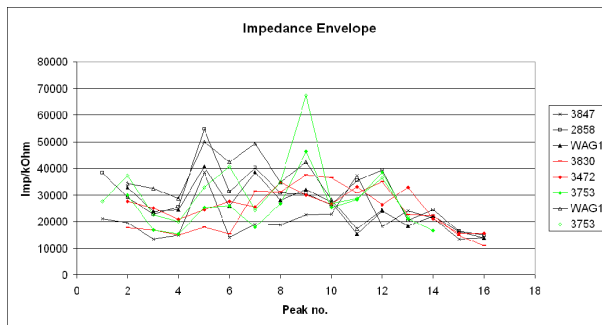


Figure 4: Envelopes of the acoustic impedance peaks

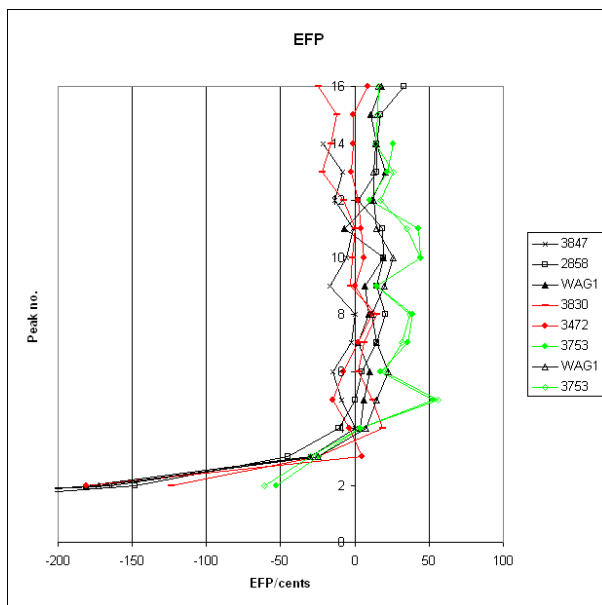


Figure 5: Equivalent fundamental pitch (in cents relative to $B\flat_1$) of the first sixteen modes of vibration of the sample set

3.2 Mouth pressure considerations

The instruments were sounded using an artificial mouth in the School of Physics, University of Edinburgh [9], again using the same mouthpiece. All measurements were taken using one particular setting of embouchure control parameters, optimised for the production of F_3 at c 20 cents below $A_4 = 440$ Hz. The mouthpiece was fixed in a holder made specifically for its shape. This allowed the mouthpiece to firmly clamped in place against the artificial lips so as to maintain the stability of the embouchure whilst changing between instruments. The relation between mouth pressure and sound output for this steadily maintained embouchure was investigated for each instrument [10]. For each complete set of measurements with one embouchure (optimised for a particular instrument) there was little variation in the threshold mouth-pressure required to sound each instrument. The

sound levels produced by a given mouth pressure varied between instruments but there were no significant differences to distinguish between instrument species.

3.3 Spectral analysis

While sounding the instruments with the artificial lips, the radiated sound was recorded at a point on the axis of the bell and at a distance of one bell radius from the plane of the bell, the sound level was also measured at this position. The radiated sound was also recorded in a position corresponding to the location of a player’s ear in normal playing position. There is a high noise level at this position caused by air leakage at the artificial lips, limiting the useful frequency range of these ‘ear’ position measurements to approximately 3kHz. Improvements in design may help with this and allow more detailed study of the radiated sound close to the artificial mouth. The embouchure settings and the position of the instruments (mouthpiece receivers) in the room were kept constant throughout these measurements. Note that these measurements were carried out in a laboratory and not an anechoic chamber. The normalised spectral centroids were calculated with a program provided by Beauchamp [11] using the first 30 harmonics. It is generally accepted that differences higher than 0.2 units in normalised spectral centroid should be perceptible [12].

Looking at the spectra for the sound measured at the bell there is no discernible difference between instrument species (three examples are given in Figure 6), and the spectral centroid numbers confirm that there is no clear distinction between instrument species (the Alexander having the brightest sound followed by the trombones and then the other bass trumpets). When measured at the ‘ear’ position, results are similar with the brightness of the sound varying slightly between instruments (the Alexander again having the brightest sound) but with no clear distinction between instrument species.

Table 5: Normalised Spectral Centroids, bell and ‘ear’ position, no valves operated

	Bell	‘Ear’
Valve trombone (3830)	3.55	4.3
Slide trombone (3753)	3.75	4.8
Bass trumpet (3847)	3.4	4.3
Bass trumpet (4045)	3.45	4.0
Bass trumpet (2858)	3.4	3.7
Bass trumpet (WAG1)	3.9	5.5

(The valve trombone (3472) has a configuration not comparable with the other instruments and so was omitted from these measurements.)

The measurements were repeated with the 1st and 3rd

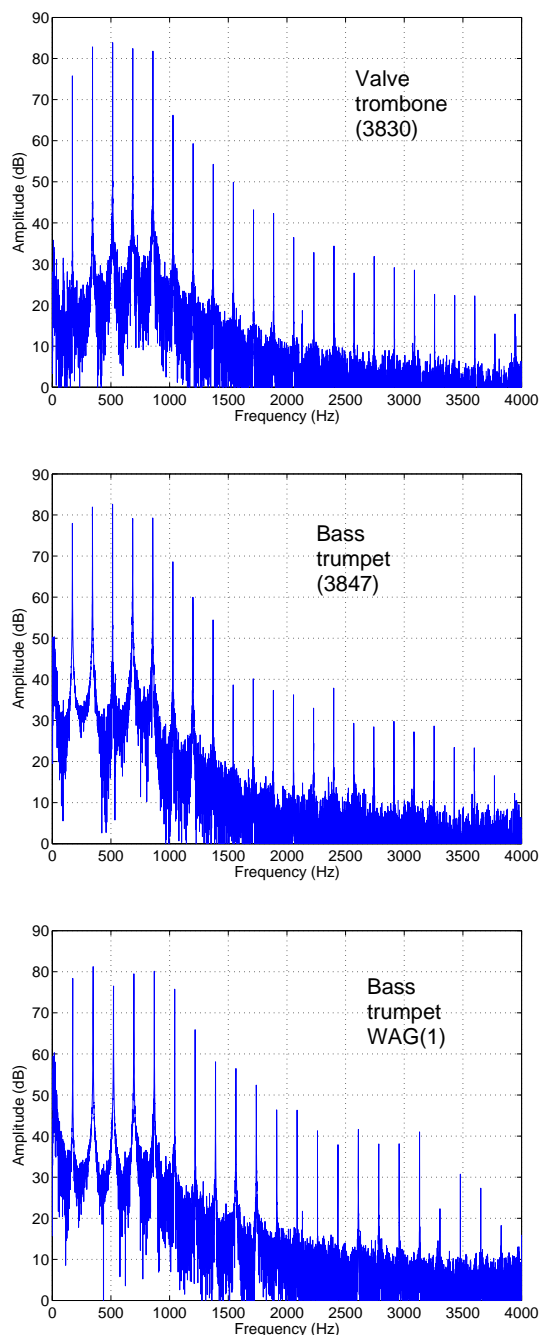


Figure 6: Spectra of radiated sound measured at the bell for three instruments playing the same note at the same sound level

valves operated (4th for the bass trumpet in C with the 1st valve already operated). The necessary valve tuning-slides were adjusted so that the instruments when played by a human player again sounded F_3 at c 20 cents below $A_4 = 440$ Hz equal temperament. The results for this V13 valve combination were similar: the spectral centroid numbers showing slight variations in brightness

but with no clear distinction between instrument species (again the Alexander having the brightest tone measured at the bell, though not at the ‘ear’).

Table 6: Normalised Spectral Centroids, bell and ‘ear’ position, V13

	Bell	‘Ear’
Valve trombone (3830)	3.4	4.3
Bass trumpet (3847)	3.6	5.0
Bass trumpet (2858)	3.4	3.8
Bass trumpet (4045)	3.75	5.5
Bass trumpet (WAG (1))	4.0	4.5

(The slide trombone (3753) was omitted from these measurements.)

4 Conclusions

The bore profiles of bass trumpets and trombones cannot always be differentiated: the values of the taxonomic parameters which can be used to distinguish instrument species present overlapping ranges for bass trumpets and trombones. This finding is consistent with the lack of differentiation in the spectra (as summarised by the centroids).

The configuration (wrap) of bass trumpets and trombones however are different, in particular the distance from the player’s ears to the bell mouth. Further investigation of the radiated sound in different locations, particularly the ‘ear’ position, may indicate a difference in timbre as perceived by the player which is not accompanied by a difference in timbre which would be perceived by an audience.

The ‘Alexander’ pattern bass trumpet appears to be more distinguishable from both ‘Moritz’ pattern bass trumpets and trombones than ‘Moritz’ pattern bass trumpets and trombones are distinguishable from each other. The acoustical tests reported above were for consistency all made using the same mouthpiece. In practice players will in most cases use different mouthpieces and different playing styles to help them realise their concepts of timbre appropriate for bass trumpets and trombones. These considerations probably have a greater effect on the tonal characteristics perceived by conductors and audiences than the choice of basic instrument.

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References

- [1] A. Myers and R. Parks, *Trumpets and trombones: catalogue of the Collection Volume 2 Part H Fascicle iii*, 2nd edition. Edinburgh: Edinburgh University Collection of Historic Musical Instruments, 1998. ISBN 0 907635 37 7.
- [2] A. Myers and D. Murray Campbell, ‘Trumpet Design and Acoustical Characteristics’. In Stewart Carter, ed., *Brass Scholarship in Review: Proceedings of Historic Brass Society Conference at the Cité de la Musique, Paris, 1999*. New York: Pendragon, 2005, ISBN 1 57647 105 5, (in press)
- [3] A. Myers and Raymond Parks, ‘How to Measure a Horn’. *The Galpin Society Journal* (ISSN 0072-0127), 1995, **XLVII** pp.193-199.
- [4] A. Myers, ‘Trombone Designs in the Transition from Early Models to Modern’. In Monika Lustig, ed., *Posaunen und Trompeten - Geschichte, Akustik, Spieltechnik: Bericht über das 19 Musikinstrumenten-Symposium in Michaelstein, 20-22 November 1998*. (Michaelsteiner Konferenzberichte, Band 60). Blankenburg, Harz: Kloster Michaelstein, 2000. ISBN 3 89512 116 9, pp.39-52.
- [5] A.C. Baines, *Brass instruments: their history and development*. London: Faber, 1976, p.238.
- [6] A.H. Benade and E.V. Jansson, E.V., ‘On plane and spherical waves in horns with non-uniform flare, I: Theory of radiation, resonance frequencies and mode conversion’. *Acustica*, 1974, **31** (1), pp.79-98.
- [7] A. Myers, ‘The Horn Function and Brass Instrument Character’. In Stewart Carter, ed., *Perspectives in Brass Scholarship: Proceedings of the International Symposium on Historic Brass Instruments, Amherst, 1995*. New York: Pendragon, 1997. ISBN 0 945193 97 1, pp.239-262.
- [8] Acoustic Research Team, Institut für Wiener Klangstil.
<http://iwk.mdw.ac.at/smart/english/art/artmain.htm>
- [9] O.F.Richards, *Investigation of the Lip Reed Using Computational Modelling and Experimental Studies with an Artificial Mouth 2003*

- [10] A. Myers, Seona Bromage, and D. Murray Campbell, 'Acoustical Factors in the Demise of the Ophicleide'. Proceedings, International Symposium on Musical Acoustics, Nara, Japan, 31 March - 3 April 2004.
- [11] James W. Beauchamp. 'Unix workstation software for analysis, graphics, modification, and synthesis of musical sounds'. In *Audio Engineering Society*, page Preprint 3479, 1993
- [12] Kendall, R. A., and Carterette, E. C. (1996). 'Difference thresholds for timber related to spectral centroid,' in Proc. 4th Int. Conf. Music, Perception and Cognition (Montreal).