TRUMPET MUTE PITCH: AN ANALYSIS OF THREE HISTORIC MUTES

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ABSTRACT

Musical scores and historic writings from Claudio Monteverdis *Orpheo* to Ernst Johann Altenburgs treatise on trumpet playing mention that mutes of the baroque era raised the pitch of the trumpet by a whole tone. On the other hand, playing experiments with surviving trumpet mutes generally show a rise in pitch of only approximately a semitone. This conundrum remains unsolved.

In this paper we use data from acoustical measurements of three late eighteenth-century historic trumpet mutes, formerly associated with trumpets by the Viennese maker Anton Kerner (1726-1806), now in the Utley Collection at the National Music Museum. These mutes have been measured with trumpets by Johann Leonhard Ehe II and III (ca. 1710 and 1730) and a reproduction of a trumpet by Hanns Hainlein from 1632 in the same collection. In addition we will discuss the acoustical behavior of a differently-shaped mute developed by the late Ralph Bryant for copies of the 1632 Hainlein trumpet.

1. INTRODUCTION

In an earlier paper [1], one of the authors (Pyle) used a computational model to calculate the pitch rise produced by a mute in a baroque trumpet. The hypothesis tested was that the shape of earlier conical Renaissance trumpet bells with a wider throat allowed the same mute to be inserted further into the bell, hence shortening the air-column length more than in later baroque trumpets with narrower throat and wider final flare. The computation was based on measurements of trumpets by Hanns Hainlein from 1632 and Johann Leonhard Ehe III from 1746. The conclusion was that the mute raised the pitch by approximately a semitone in the Ehe trumpet, and more than a semitone but much less than a whole tone in the Hainlein. The computation left the question unresolved and therefore experimental measurements were desirable.

There was a considerable variation in bell contours between earlier and later trumpets. Rarely does a natural trumpet survive with its unambiguously matching mute, but only this kind of match would definitely indicate by how much a specific mute raises the pitch of a particular trumpet. The spectrum of trumpet-bell shapes during the seventeenth and eighteenth century falls into two extremes. The bell type of the renaissance and early baroque trumpet, as exemplified by the Hainlein, has a wide throat and almost conical bell with very little flare. Later baroque trumpets, such as those by the Ehe family, have a much narrower bell throat and much wider final flare. See Figure 1.

Surviving mutes, such as those shown in Figure 2, show an even greater variety of shapes [2]. The leftmost mute appears built so that either end can be inserted into the bell. The two ends have somewhat different tapers, indicating that it might have been made to fit two slightly different bell contours.

Figure 1: The three trumpets tested. From left to right, Johann Leonhard Ehe II (ca. 1710), Johann Leonhard Ehe III (ca. 1725-30), and Hanns Hainlein (1632, copy by Joe Utley).

This paper focuses on three mutes, formerly in the possession of Dr. Gerhard Stradner in Vienna, that are now part of the Utley Collection at the National Museum Museum in Vermillion.

The three historic mutes were formerly associated with a trumpet by Anton Kerner (1726-1806) in Vienna; however, their actual date is difficult to determine. Expertly turned from fruitwood (likely plum), they show the skills of an experienced turner. All three are basically identical in shape, although they vary slightly in workmanship. The external shape is more sophisticated than that of any of the Prague or Nuremberg mutes. The pear-shaped curvature allows a snug fit with the flare of a specific trumpets.

CT scans, such as that in Figure 4, show that BA-102 is the crispest, because it was turned from the hardest wood section the turner had at his disposal; therefore this exemplar was used for the testing described below. BA-101 has extensive woodworm damage and therefore leaks, while BA-097 is made of a wood section of slightly lesser density and therefore the turning is not as regular as that of BA-102. The backbore is carefully shaped and flaring, changing from hyperbolic to slightly flaring. BA-097 is interesting for its remains of a tied-on brass wire.

A comparison of the bell profiles of these instruments with the external shape of the mute (Figure 5) shows how it fits into these trumpets: the mute BA-102 is a near-perfect match for the Ehe II trumpet, NMM 7250. It also fits quite well into the trumpet by his nephew Ehe III, NMM 7160. BA-102 fits rather less well into the bell of the Hainlein trumpet copy, and at the same time it can be inserted much further into this instrument.

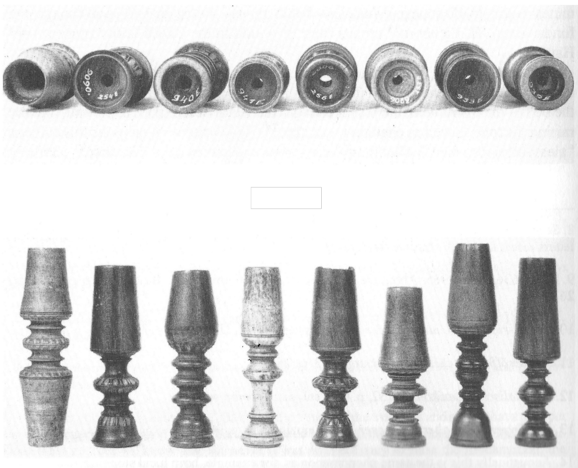

Figure 2: Baroque trumpet mutes in the National Museum of Prague [2].

Figure 3: Three mutes formerly associated with a trumpet by Anton Kerner (1726-1806). Date unknown. From left to right, BA-102, BA-101, and BA-097.

Perhaps this was the reason why one of the three mutes has a brass wire tied to it. The wire might have served to anchor a leather strap, by which the mute could be pulled out of a trumpet into which it disappeared.

The best mute among the three historic ones in the Utley Collection, BA-102, was selected to be tested with the three trumpets shown in Figure 1.

2. EXPERIMENTAL METHODS

The BIAS apparatus developed at the Institut für Wiener Klangstil was used to measure the input impedance and impulse response of the trumpets with bell open and with the mute inserted. The mutes alone (BA-102 and the Bryant mute) were also measured.

After some three centuries, it is not surprising that the cross sections of the bells on the Ehe trumpets were no longer exactly circular. The mute did not fit snugly into the bells, and consequently there was considerable air leakage between mute and bell. The outside of the mute was therefore wrapped with a cloth to form a reasonably airtight seal between the mute and the bell. This also meant that the mute could not be inserted quite as far into the bell as originally intended.

Although the bell cross section of the Hainlein copy was more accurately circular, mute BA-102, even with the cloth,

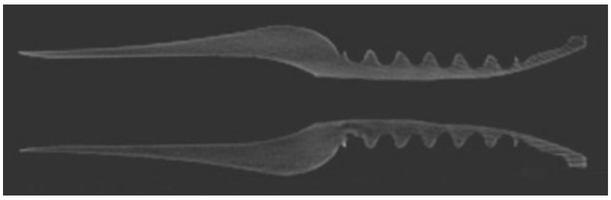

Figure 4: Computer tomography scan of mute BA-102.

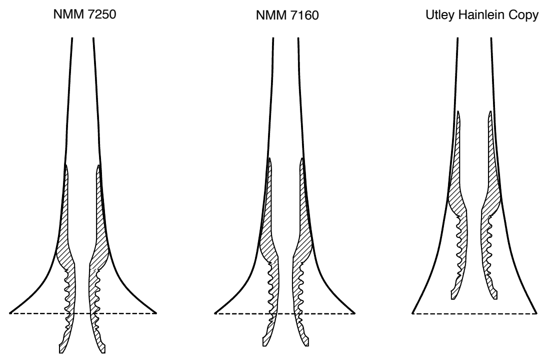

Figure 5: Profiles of mute BA-102 inserted into three trumpet bells. From left to right, the trumpets are in the same order as in Figure 1. Note the wider bell throat and the smaller flare of the earlier Hainlein trumpet compared with the later Ehe trumpets.

could not be made to seal adequately. A close examination of Figure 5 shows that only the shoulder of the mute touches the bell. Measurement of this trumpet-mute combination was thus abandoned. Instead, a different Hainlein copy, made by one the authors (Klaus), was measured with the Bryant mute that was made especially to fit it.

The acoustic measurements on the Ehe II and Ehe III trumpets were so similar that results will be shown only for the Ehe II.

2.1. Finding the frequency of the pedal tone

In a professional-grade modern valve trumpet, the frequencies of the second and higher impedance peaks closely follow integer multiples of the instrument's pedal tone. (The lowest peak is much flatter than the pedal tone.) The frequency spacing between consecutive peaks can then be used to estimate the fre-

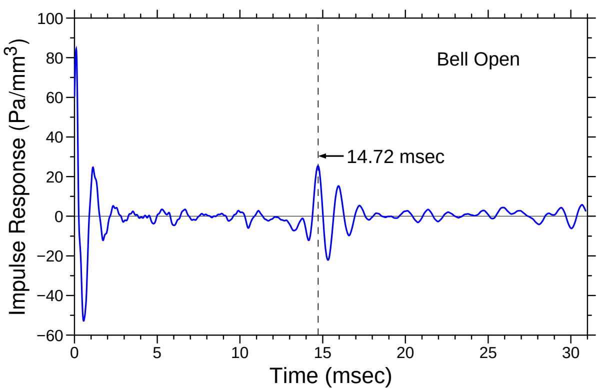

Figure 6: Impulse response of the Ehe II trumpet (NMM 7250).

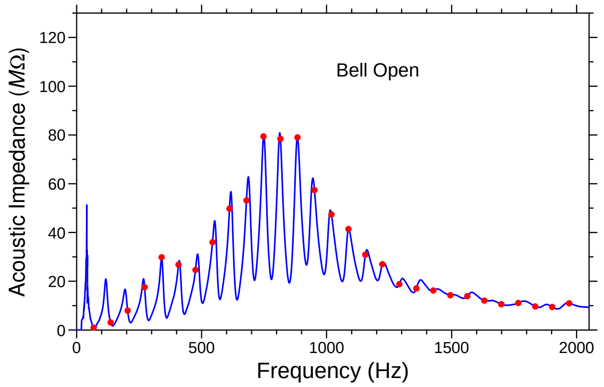

Figure 7: Input impedance of the Ehe II trumpet with the bell open.

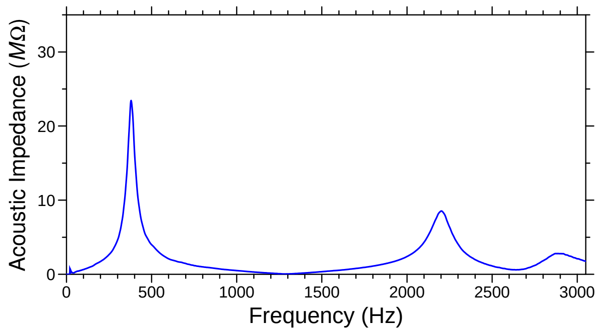

Figure 8: Input impedance of the BA-102 mute.

quency of the pedal tone. This was not the case with the baroque trumpets examined here. The spacing between peaks was much less uniform than on the modern trumpet. Therefore, the impulse response was used to calculate the pedal-tone frequency.

Figure 6 shows the impulse response of the Ehe II trumpet. The time of the largest positive response following the initial ringing of the mouthpiece is taken to be the period of the pedal-tone frequency. In this case, the period of 14.72 msec corresponds to a pedal-tone frequency of close to 68 Hz, or a tuning frequency of A4 = 408 Hz for a trumpet in D.

Figure 7 shows the input impedance of the Ehe II trumpet with dots placed on the impedance curve at harmonics of the pedal tone. The dots lie reasonably close to the impedance peaks except for the lowest three peaks and those above about 1200 Hz (the sixteenth harmonic is 1088 Hz). Note that the height of the impedance peaks diminishes rapidly above 1200 Hz, due to the loss of energy through radiation from the bell.

2.2. Acoustical relatives of the muted baroque trumpet

There are two more-recent forms of muted brass instruments that bear some acoustical similarity to the muted baroque trumpet: the echo cornet and the fully-stopped horn. These have been studied and offer some insight into what might be expected in the present case [3][4][5].

The mute, or echo bell, or the hand, seen from the upstream side within the instrument, looks like a Helmholtz resonator. That is, within the frequency range of interest, it has but a single mass-spring resonance determined by the compliance of the cup volume (the "spring") and the inertance of the narrow neck (the "mass"). Below the frequency of this resonance, the mute

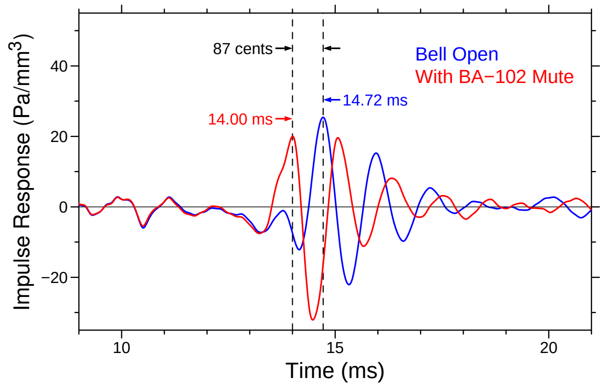

Figure 9: Expanded view of the principal reflection in the impulse response of the Ehe II trumpet, with bell open and with the BA-102 mute.

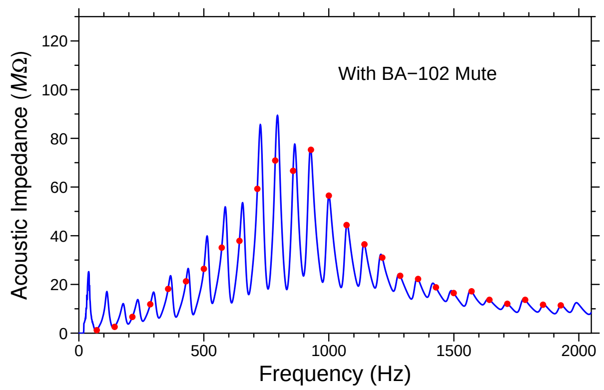

Figure 10: Input impedance of the Ehe II trumpet with BA-102 mute inserted (with cloth wrapping).

presents a mass-like load to the instrument and lowers its resonance frequencies. Above, the mute looks spring-like, and raises the resonance frequencies. Near the mute resonance, the mute appears to split the nearest unmuted resonance into two, one above and one below the original.

For the mute to raise the pitch consistently throughout the playing range of the instrument, it is then desirable that the mute resonance frequency lie below, or at least in the lower part of, the playing range.

3. EXPERIMENTAL RESULTS

3.1. The Ehe II trumpet with the BA-102 mute

The impedance of the BA-102 mute is shown in Figure 8. As expected, it has only one resonance below 2000 Hz, but that one is just below 400 Hz. This is close to the sixth harmonic of the pedal tone, that is, it is *not* below the playing range. The lesser peaks seen at 2200 and 2900 Hz arise from standing waves in the narrow neck.

Figure 9 shows the effect of the mute on the impulse response of the Ehe II. There are two reflections of nearly equal amplitude, neither as tall as the principal peak for the open bell. The earlier peak is the larger. Taking its time as the period of the muted pedal tone, the pedal tone frequency moves from 67.9 Hz to 71.4 Hz, a pitch rise of 87 cents.

The impedance of the muted trumpet, Figure 10, shows that

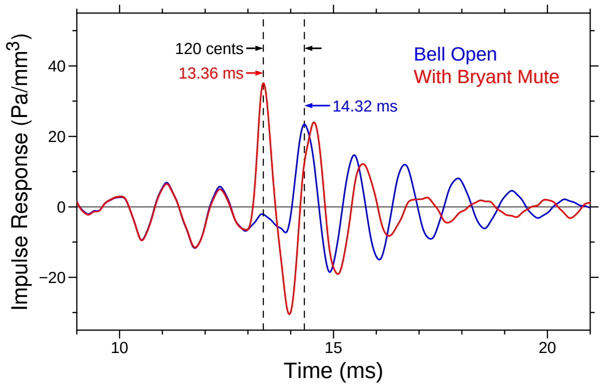

Figure 11: Expanded view of the principal reflection in the impulse response of the Hainlein trumpet copy, with bell open and with the Bryant mute.

below about 900 Hz, the impedance peaks do not lie as close to harmonics of the pedal tone as for the unmuted trumpet. Above 900 Hz, they agree almost exactly. With radiation losses reduced by the mute, the impedance shows small but quite distinct peaks well beyond the 1200 Hz "cutoff" of the open bell.

3.2. The Hainlein trumpet copy with the Bryant mute

The interior contour of the Bryant mute differs greatly from that of BA-102. The cup volume is a little smaller, but this is outweighed by the much narrower and longer throat through the neck. The result is that the Bryant's Helmholtz resonance frequency is 200 Hz, nearly an octave below that of BA-102. The mute was custom-made to fit the Hainlein bell, and has a cork ring that makes a fully airtight seal with the bell.

Figure 11 (corresponding to Figure 9 for the Ehe II trumpet) shows the principal reflection in the impulse response. The reflection with the mute inserted has nearly the same shape as the reflection with the bell open, but it is larger and, of course, occurs at an earlier time. The calculated pitch rise in this case is 120 cents, substantially greater than for the Ehe II trumpet, but still well short of a whole tone.

Figures 12 and 13 show the input impedance with the bell open and muted, respectively. For the muted trumpet, the lower harmonics of the pedal tone lie much closer to the impedance peaks than was the case for the Ehe II.

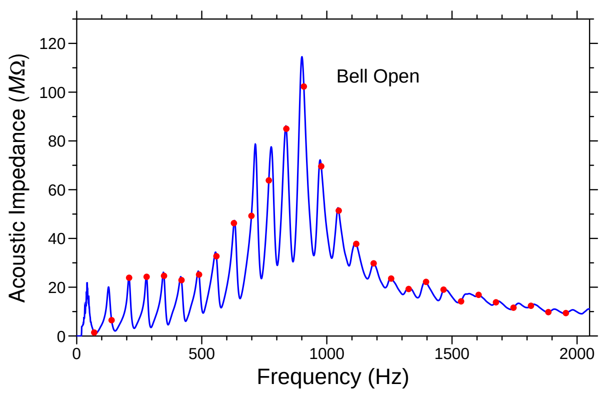

Figure 12: Input impedance of the Hainlein trumpet copy with the bell open.

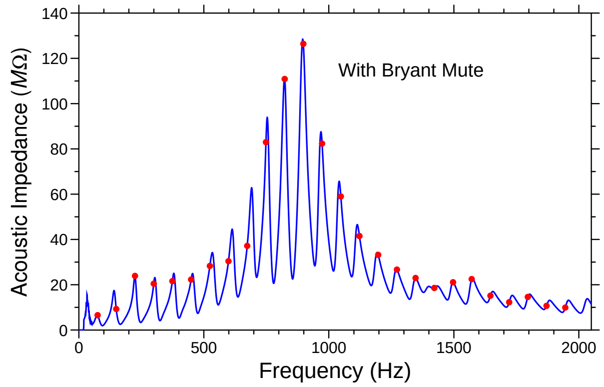

Figure 13: Input impedance of the Hainlein trumpet copy with the Bryant mute.

4. DISCUSSION

The present experiment seems only to have confirmed the computational model of Reference [1]. No combination of trumpet and mute that was tested came close to a pitch rise of a whole tone. Why did the historic mute BA-102 combined with the Ehe II trumpet yield a calculated pitch rise of less than a semitone? The cloth that was necessary to seal the mute to the bell flattened the pitch by reducing the distance that the mute could be inserted into the bell, but probably not enough to account for the shortfall of 12 or 13 cents. The three historic mutes are so close to each other dimensionally that their design must have met the needs of their day, presumably raising the pitch a semitone on the trumpet for which they were designed.

BIAS measurements made on the Ehe II trumpet without the cloth wrapping around the mute were clearly suspect. It was difficult to obtain consistent results, and both impedance and impulse response looked implausible. It is clear that the mute should fit tightly into the bell, minimizing or eliminating any leakage of air past the outside of the mute. Thus the exterior contour of the mute should match the interior contour of the bell as closely as possible.

In another paper at Vienna Talk 2015, Dr. Gerhard Stradner presented a new hypothesis to expain the absence of historic whole-tone mutes.

References

[1] R. Pyle, "A Computational Model of the Baroque Trumpet and Mute", *Historic Brass Society Journal*, vol. 3, pp. 79-97, 1991.

[2] J. Keller, "Antique Trumpet Mutes", *Historic Brass Society Journal*, vol. 2, pp. 97-103, 1990.

[3] Robert W. Pyle and Sabine K. Klaus, "The acoustics of the echo cornet," *J. Acoust. Soc. Am.*, vol. 112, p. 2211, 2002.

[4] Robert W. Pyle, "Pitch Change of the Stopped French Horn," *J. Acoust. Soc. Am.*, vol. 36, p. 1025, 1964.

[5] Robert Pyle, "Factitious Tones and Hand-Stopping," *The Horn Call*, Vol. XXI no. 1, pp. 36-43, October 1990

[6] Gerhard Stradner, "Transposing Mutes for Trumpets", in *Proceedings of Vienna Talk 2015*, Vienna, Austria, 2015.