The Trombone of Anton Schnitzer the Elder in Verona: A Survey of Its Properties and Their Acoustical Significance

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The growing interest in the performance of Renaissance music for brass instruments has created an increasing demand for accurate reproductions of period trombones. The reconstruction of such instruments has raised many questions concerning the effect of geometrical design, materials used, and processing techniques on tone quality and playing behavior. Performers and audience members, lacking understanding of these parameters and their acoustical effects, are generally unaware of their relevance to historical performance. There are few primary sources at our disposal that offer information on the manufacturing process, thus one is forced to rely on information that can be obtained only from scientific analysis of surviving instruments.

Approximately half of the surviving sixteenth-century trombones are the work of members of the Schnitzer dynasty of Nuremberg. Of the three instruments attributed to Anton Schnitzer the Elder, the trombone made in 1579 (see Figure 1) represents one of the most important sources for study for scholars of the early trombone.[1] Unlike the majority of surviving instruments, the acoustically important parts of this trombone are in original condition, making the instrument particularly suitable for scientific analysis. Additionally, there are several original documents relating to the instrument, including an official letter of acquisition and numerous inventory entries that allow us to trace its early history.[2] Furthermore, some music that may have been played on it survives,[3] thereby offering insight into associated musical characteristics, such as tessitura. Finally, a mouthpiece preserved with the instrument is presumed to be from the same period. It is one of only four mouthpieces associated with surviving Renaissance trombones.[4] The fact that its cup diameter resembles that of modern mouthpieces makes it particularly interesting for purposes of modern reconstruction and performance.

Figure 1: Trombone by Anton Schnitzer the Elder (Nuremberg, 1579).
Verona, Accademia Filarmonica, catalog no. 13.301. Photo by Maurizio Brenzoni.

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References to this instrument in scholarly literature are generally brief, and few of these mention its physical properties. The catalog of the collection of the Accademia Filarmonica, by John Henry van der Meer and Rainer Weber,[5] and an unpublished restoration report by Max and Heinrich Thein[6] offer the most detailed information, but even the data provided there falls far short of an in-depth analysis of the instrument. The main purpose of the study described here was to conduct a comprehensive analysis of the physical properties of the instrument and determine their acoustical significance. A secondary objective was to investigate its properties for purposes of reproduction and performance. A team consisting of Rainer Egger (Basel), his associates, and the author constructed an exact copy of the instrument and its associated mouthpiece, based on the data derived from the present study. Comparison of the input impedances of the original and our copy reveal that the copy has an acoustical footprint comparable to the original instrument.

Methods

The documentation of the physical properties of historical brass instruments poses many challenges. The complex concerns surrounding construction and preservation restrict the use of certain measuring devices, often to the detriment of the accuracy of the results.[7]

Measuring the bore profile with conventional measuring tools

The acoustical properties of resonant air columns depend mainly on the bore profile. When sound and playing characteristics of different instruments are analyzed, geometry plays a dominant role. In compiling bore lists, acousticians apply a rule of thumb that states that a difference of 1% of the total bore diameter will have a measurable acoustical effect. In the case of the present instrument (hereafter indicated by its catalog number, 13.301), the error of measurement should ideally be smaller than 0.1 mm. The cross-section of brasswind instrument tubing, particularly in historical instrument tubes, is not perfectly circular. As a result, it is necessary to measure every diameter on two axes, 0° and 90°, and extract an average value.[8] Standard vernier callipers were used to measure the tubing; for the bell profile and mouthpiece, calibrated probes were necessary. The zero point was set at the intersection of two radials placed across the end of the bell, and thereby the distance the probes intruded from that zero point could be measured. Knowing the intrusion of various diameters, a bore list could easily be derived.

Measurement of the wall thickness with an ultrasonic gauge

The principle of ultrasonic wall-thickness gauges is based on the measurement of the time of transmission of an ultrasonic impulse. Consequently the thickness of the material may be determined mathematically, based on the velocity of sound traveling through the material being tested. Brass is a copper-zinc alloy, therefore as the amount of zinc increases, the value of the speed of wave propagation decreases.[9] The principal advantage of using this method is to be able to gauge thickness without requiring access to both sides of the wall. The main disadvantage is that it cannot be used for inhomogeneous materials such as wood because the speed of propagation is not constant. Rooney and Reid describe in detail the principles of this method and its implementation for the measurement of thin wall tubes.[10] The measuring device used in the present research is the CL 5, made by GE Inspection Technologies.[11]

Material alloy analysis with X-Ray Fluorescence

X-Ray Fluorescence (XRF) is a non-destructive method used to investigate the chemical composition of materials. The method is specifically appropriate for the analysis of historical brass alloys, and as such has been used by several researchers for this purpose. The principle of XRF is based on the excitation of the elements present in the sample by means of primary X-ray radiation. The emitted secondary X-ray radiation is analyzed by an energy-dispersive detector.[12] The measuring device used in the present research is the handheld XRF, type Spectro X-Sort made by Ametek-Spectro in Kleve, Germany.

Evaluation of intonation and response with input-impedance measurements

A brasswind instrument is an acoustical system whose acoustical properties can be characterized essentially by its input-impedance, the ratio between the pressure and the flow of air at the mouthpiece. An input-impedance curve represents the reaction of the instrument to the energy impulse produced by the player. A peak in the impedance curve

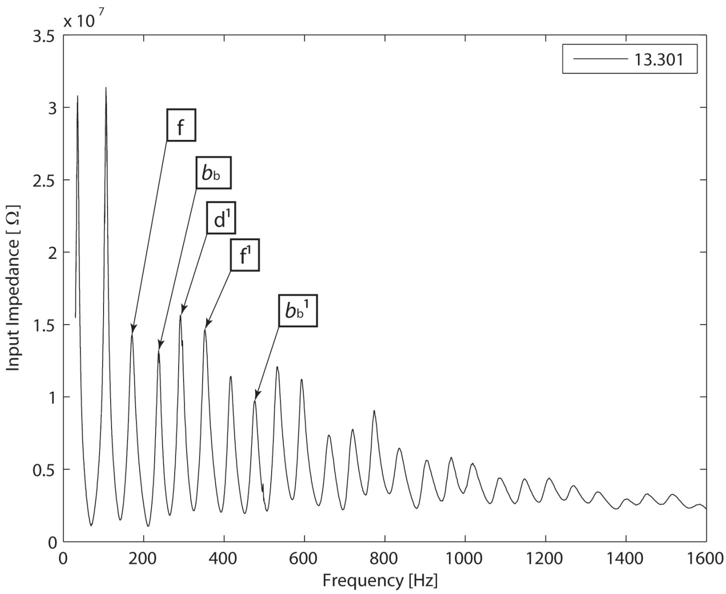

Figure 2: Input impedance curve of no. 13.301 (a^{1}=448Hz).

means that a maximum of energy is retained within the instrument, a pre-condition to constitute a tone. The inherent tuning of a brasswind instrument can thus be ascertained by the location of these peaks, also called resonances. To a certain extent, the amplitude of the curves indicates the quality of response of the instrument. However, questions persist regarding the interpretation of these values. A commonly accepted rule of thumb is that a higher peak indicates a better response.

Figure 2 shows the input impedance curve of 13.301 and its related tones. A detailed overview of frequency ranges, measuring accuracies, and the usage of this method is given by van Walstijn et al.[13] The measuring tool used in the present research is the Brass Instrument Analysis System (BIAS).[14] The pitch of the original instrument is a^1 = 448, which sounds as *b*♭^{1} with the slide closed. Figure 2 displays the impedance of the instrument without crooks. The author chose to analyze 13.301 as an instrument in B♭ with the slide completely closed, since analysis of it as sounding in A at a^1 = 472 Hz would have involved considerable additional effort to adapt the measuring method. Using the original tuning bits preserved with the instrument, it is possible to tune it down to 440 Hz, thereby making it usable for performance with other instruments at a^1 = 440.

Restoration

In 1869 the instrument was relocated from the Accademia Filarmonica to the Museo Civico in Verona, but it was returned to the library of the former institution in 1969.[15] At that point the instrument was in urgent need of preservation measures (see Figure 3a) and consequently underwent restoration in 1990 by Heinrich and Max Thein of Bremen. Their restoration was conducted with extraordinary care and the outcome is a testament to their craftsmanship and attention to detail. The Thein brothers carefully marked the added parts, though further analysis was required in order to identify clearly the original parts. A useful clue for identifying tubes made after the mid-nineteenth century is the absence of a soldering seam. The technique for manufacturing seamless tubes was first developed in the nineteenth century because of the need for such tubes in steam engines. These tubes had to withstand high pressure that would have caused soldered tubes to burst. William Aitken describes the attempts of both Charles Green in 1838 and Thomas Attwood in 1850 to develop manufacturing techniques for seamless tubes.[16] It seems, however, that George Fredrick Muntz's process, patented in 1852, was the first to achieve production.[17] As early as 1864, six different factories in Birmingham produced 8,500 tons of seamless CuZn38 tubes, specifically for use in steam engines.[18] The Wieland Werke, a brass manufacturer at that time in Germany, produced seamless brass tubes from 1865 on.[19] The absence of a solder seam thus identifies a tube as being from the mid-nineteenth century or later. All of the tubes on 13.301, including the slides and crooks, have solder seams, which is an indication that they probably were made before the mid-nineteenth century. However, the older technique of tube-making could also have been used after the introduction of seamless tubing.

Marks at 3 cm from the end of the bell indicate that the garland once rested loosely on the bell; Figure 3 shows that it was reattached to the bell when it was restored. Some minor dents have been removed. A piece of conical tubing has been added to the bell, as shown in a detail in Figure 8. The bell cross-brace and the first slide-brace have been reinforced.

Figure 3: (a) 13.301 before restoration (Verona, Museo Civico); photo anonymous, © Accademia Filarmonica Verona.
(b) 13.301 after restoration (Accademia Filarmonica); photo by Maurizio Brenzoni.

The mouthpiece

The mouthpiece is engraved with the word "NVRMBERG" and is composed of three parts: the shaft, which is made from sheet brass; a soldered ferrule; and a turned cup. The mouthpiece has a cup diameter of 23.1 mm (see Figure 4). It weighs 42.8 gram and intrudes 26.7 mm into the instrument. A ferrule made of sheet brass covers the solder seam, thereby strengthening the assembly of the shaft. The wall thickness of the shaft is 0.35 mm; it is cylindrical at the soldered end but conical from the middle to the distal end.

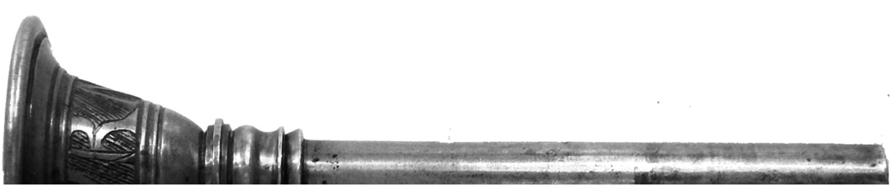

Figure 4: Mouthpiece preserved with 13.301. Photo by Michele Magnabosco.

Apart from the flat rim, specific cup form, and bore diameter, the most striking feature of acoustical design of this mouthpiece is the form of its backbore (see Figure 5). The larger diameter of the throat of the mouthpiece required a reverse-conical (actually, "belly"-shaped) backbore in the shaft so that it could fit into the smaller diameter of the mouthpiece receiver. This type of backbore is to be found in several surviving sixteenth-century brasswind mouthpieces. Mouthpieces used for performance on early trombones typically have a flat rim and a bowl-shaped cup, but are turned from one piece of brass, implying a modern, conical back-bore design. The question remains: What is the acoustical significance of playing on a mouthpiece with belly-shaped backbore rather than one in modern style?

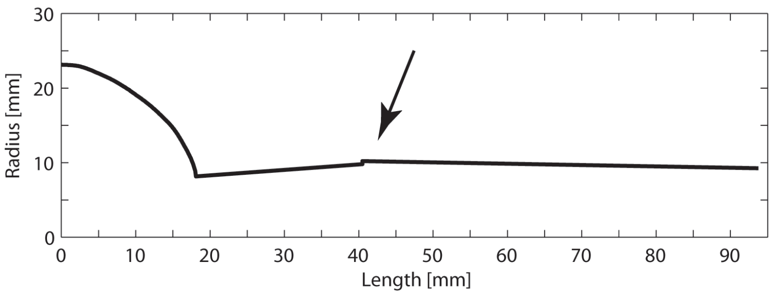

Figure 5: Bore profile of the Verona mouthpiece with characteristic belly-shaped backbore.

Acoustically, the highest pressure point inside the instrument is at the mouthpiece; therefore, tiny changes to any part of the geometry of the mouthpiece will have appreciable effects on playing behavior and radiated sound. The mouthpiece has two main acoustical functions: it lowers the high resonances and it boosts the instrument's resonances in the area of the mouthpiece's own resonance. A historical mouthpiece usually has two such resonances (see Figure 6). Their positions along the frequency axis will therefore greatly influence the acoustical characteristics of the instrument. The three major acoustically important parts of the mouthpiece are the cup, the throat, and the backbore. Of these, the cup volume and the design of the backbore exert the greatest influence. The volume of the cup affects both tone quality and pitch and can alter the latter by as much as 35 cents.[20] Enlarging the throat diameter has the same acoustical effect as decreasing the volume of the mouthpiece: it increases the resonance frequency.

The backbore is more important than the bore diameter of the throat and can alter the pitch by as much as 30 cents. In order to investigate the specific effect of the belly-shaped backbore of the Verona mouthpiece, an exact copy was made, together with another, using a modern backbore design, keeping all other dimensions the same. Both mouthpieces were made with the same tools and have the same cup and throat diameter; only the bore design was different. The shaft of the original mouthpiece was measured from the outside, so that by subtracting the known wall thickness, the bore profile could be determined.

The input impedance curve in Figure 6 indicates that the main resonance of the mouthpiece is strongly altered by the backbore and thus alters the playing behavior significantly. To demonstrate more clearly the wide divergence between the belly-shaped- and conical-backbore mouthpieces, we also determined the resonances of a Dennis Wick 9 BS mouthpiece. Surprisingly, the main resonance of the Wick mouthpiece is closer to the original belly-shaped-backbore mouthpiece than is the main resonance of the modified copy with modern-style (conical) backbore. If one uses both mouthpieces on the same instrument, the varying mouthpiece resonances will result in a different impedance behavior of the overall instrument. This will consequently produce differences in the intonation and playability of the instrument and ultimately the sound as well. Thus the use of a historical mouthpiece with belly-shaped backbore is a more logical choice if one aims to recreate the playing behavior and sound of the original.

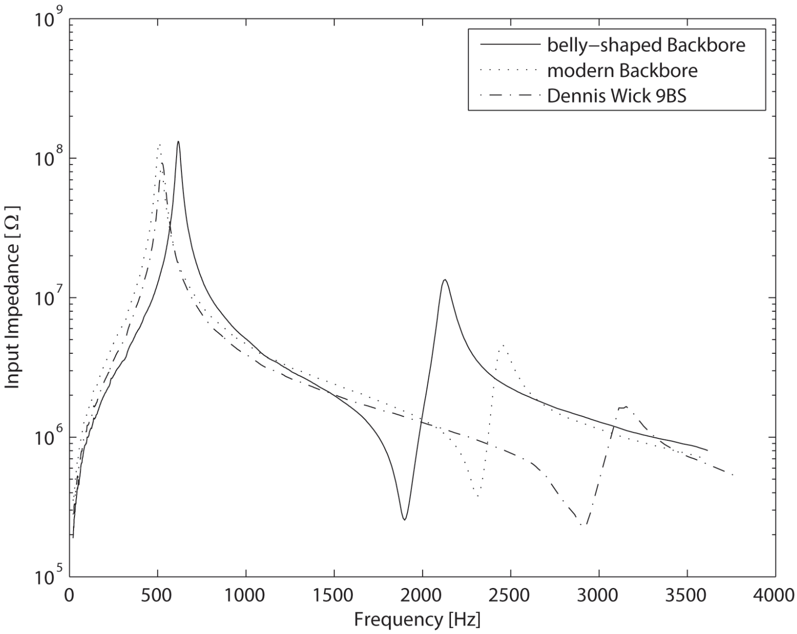

Figure 6: Logarithmic depiction of the resonances of a copy of the Verona mouthpiece with belly-shaped backbore and one with modern backbore—i.e., one that is conical with largest diameter at the distal end. In order to demonstrate the wide divergence between them, the impedance curves are also compared with that of a Dennis Wick 9BS mouthpiece.

The bell

The garland is engraved "MACHT. ANTONI. SCHNICZER. ZV. NVRNBERG [crown] M.D.LXXVIIII." Spinning marks are visible, implying that the bell was turned on a mandrel attached to a lathe, as is still done by modern makers. However, the marks could also be the result of a later restoration. At some point the bell was broken into two parts and subsequently restored with an additional conical tube (see Figure 3). Underneath this tube a point of fracture is still clearly visible. Presumably this irregularity in the bore would cause distortion in the playing behavior and most likely would also degrade the playing quality. The bell is 526 mm long and at approximately the halfway point a gilded ball weighing 56 grams is attached. There are still many open questions concerning the acoustical function of this ball. Observation in a numerical, finite-element model reveals that it alters the vibrational behavior of the instrument considerably. Analysis of these influences on sound and playability is beyond the scope of this paper and requires further research.

The scaling of the bell has the opposite acoustical function from the mouthpiece in that it has the effect of raising the low-pitched resonances. Furthermore, its geometry defines which waves will be radiated and which will be reflected back into the instrument to

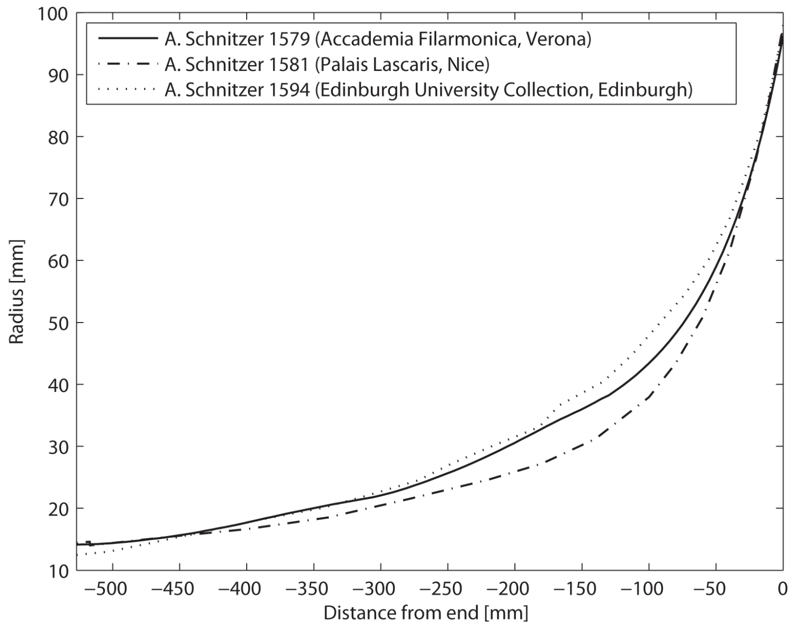

Figure 7: Comparison of the bell design of three trombones made by Anton Schnitzer the Elder/Younger.

constitute a standing wave. The pressure of a sound wave travelling through an instrument falls as the cross-section increases, so there is a direct relationship between the dimensions of the bore and the acoustic characteristics.[21] This relationship can be represented by the bell's horn function,[22] a value that defines which waves will be reflected and which will pass through. The most important effect of the horn function is the so-called "cutoff frequency."[23] Like the brassiness potential parameter, the cutoff frequency is an important parameter that governs the timbre of the instrument to a large extent.[24] Arnold Myers investigated several bell profiles and their associated horn function, including a trombone made by Anton Schnitzer the Younger in 1594, currently in the Edinburgh collection. Comparing the horn function of modern-shaped bells with greater terminal flare with that of the 1594 instrument, Myers concluded that the potential barrier reflects the high-pitch components less effectively, "thus giving the sackbut a mellower sound."[25]

Figure 7 indicates that the bore shape of 13.301 is similar to two other similarly scaled instruments made by the Schnitzer family, preserved in Edinburgh and in Nice.[26] It is possible that the differences shown are due to inconsistencies in measurement, since the author himself measured only the Verona instrument.

The slide

The slide section of 13.301 consists of three slides—two outer and one inner, the latter consisting of a descending slide tube and an ascending tube. The external slide fits well and clamps onto the second outer slide. The external slide thus consists of a double-walled construction, illustrated in detail in Figure 9. The acoustically effective bore at the entrance measures 10 mm in diameter, which is similar to the instrument made by Anton the Elder preserved in Palais Lascaris in Nice. The smaller the diameter of the bore, the more pronounced the instrument's resonances will be. As well, the speed of propagation will decrease and thus the wave will need more time to reach the end, seemingly making the instrument longer and thereby lowering the pitch. In general, it can be said that an instrument with a small bore will allow one to play easily in the higher ranges because the resonances are more pronounced and the playing accuracy will generally be better than in wide-bore instruments. However, instruments with small bores are difficult to play in the low register because of the high frictional resistance. Thus the relatively small bore of 13.301 indicates that this instrument should be easier to play in the higher registers.

Crooks and tuning bits

Three straight tuning bits and three detachable crooks are preserved with the instrument. The tuning bits have respective lengths of 80.4, 104.3, and 134.3 mm (see Figure 3a). The crooks intrude 20 mm into their ferrules and weigh approximately 52 grams. Their cumulative length is approximately 193 mm, which gives them an effective acoustical length of 173 mm. There is much confusion as to how these crooks and tuning bits relate to each other and to the instrument, and also as to their acoustical significance. The ferrules are all provided with marks consisting of a combination of the symbols X, V, //, and /. Diagonal marks, either single or double (/ or //) are engraved on various parts of the slide. All parts of the descending outer slide tube are marked with // and all parts of the ascending slide tube, with /. These marks leave no doubt as to the proper assembly of the various slide parts and the bell-bow, but unfortunately they do not yield sufficient information on the arrangement of the tuning crooks and the various other parts belonging to the bell. In addition to the marks on the slide and the ferrules, each crook has a V or IIII engraved on the side.

Interestingly, the painting by Ludovico Carracci discussed by Markus Raquet and Klaus Marius may yield additional insights into the meaning of these crooks.[27] The instrument depicted on this painting shows several morphological similarities to 13.301, and it is depicted with two tuning crooks between the slide and bell part sections. Marin Mersenne's illustration in Harmonie universelle (1636) offers another iconographical source that bears on the discussion here,[28] for it shows an instrument with four crooks inserted between the bell and slide sections. It raises the question: Is 13.301 missing one crook, or is the third crook an extra one? One way or another, an even number of crooks—either two or four—is needed to establish the proper connection. In order to determine the significance of these crooks, one could construct an extra crook and measure the input impedance differences. Another approach, however, is to construct a computational model based on the scaling. This technique has been described previously in this Journal.[29] An unknown input impedance can be calculated from a known scaling because there is an unequivocal relationship between the two values. One crook has an effective acoustical length of 173mm, two crooks will add 346 mm to the acoustical length; four would add an additional 692 mm. Table 1 indicates that the instrument is lowered one tone using two crooks, and two tones using four crooks.

Impedance peak	**Note (A =448Hz)**		
	No crooks	**2 crooks**	**4 crooks**
No. 4	*b♭*	*a♭*	*f♯*
No. 5	*d¹*	*c¹*	*b♭*
No. 6	*f¹*	*d♯¹*	*c♯¹*
No. 8	*b♭¹*	*a♭¹*	*f♯¹*

Table 1: Possibilities for transposition with combinations of crooks.

Wall thickness

The wall thickness of early trombones is a controversial topic (see Figures 8 and 9). As Henry George Fischer points out, the opinions of several respected scholars stand diametrically opposed on this issue.[30] Apart from its effect on weight, the thickness of the wall greatly influences the vibrational behavior of the instrument. Richard Smith states that vibration amplitude is inversely proportional to the fourth power of wall thickness.[31] How—and especially, how much—these vibrations effect the radiated sound is still an open question. Wilfried Kausel and Thomas Moore demonstrated the effect of wall vibrations on sound under extreme conditions.[32] They concluded that the wall vibrations of brasswind instruments do affect the radiated sound.[33] The significance of these structural vibrations for both player and audience in a performance situation is still under debate.

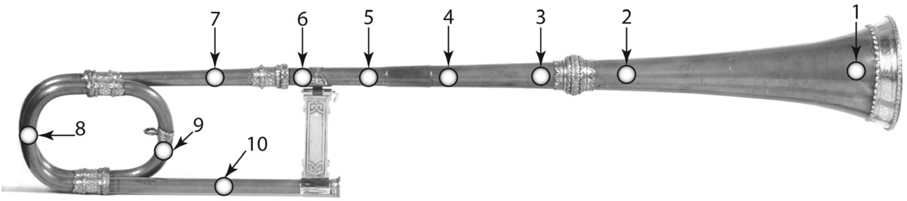

Figure 8: Wall thickness measuring points. Photo by Maurizio Brenzoni.

Measuring point	**Wall thickness [mm]**	
	0°	**90°**
W1	0.25	0.22
W2	0.35	0.36
W3	0.34	0.35
W4	0.34	0.31
W5	0.25	0.22
W6	0.27	0.29
W7	0.30	0.31
W8	0.75	0.74
W9	0.75	0.75
W10	0.5	0.49

Table 2: Wall-thickness measuring points of the bell section, measured on axes of 0° and 90°.

These results indicate that raw material of approximately 0.35 mm has been used. The thickness varies due to the technique of manual forming on the mandrel, and reaches its minimum at the end of the bell flare. The crooks and bell bow were made of 0.75 mm. material. Thicker material enables a builder to bend the crooks more easily and still achieve a circular cross-section. The straight tube between the tuning coil and the slide (Figure 8, point 10) has a wall thickness of 0.5 mm. Some makers contend that a thicker wall at this point affects the playing behavior. Although these assertions have not been proved, they raise the question as to whether this was intentional on Schnitzer's part or merely coincidence.

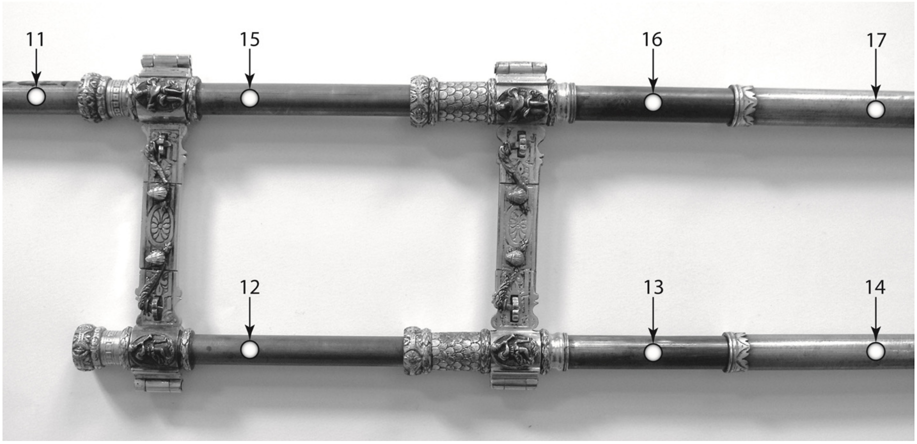

Figure 9: Wall thickness measuring points on the three slides. Photo by Michele Magnabosco.

Measuring Point	Wall thickness[mm]	
	0°	90°
11	0.35	0. 45
12	0.47	0. 5
13	0. 38	0. 39
14	0. 30	0. 29
15	0. 49	0. 50
16	0. 40	0. 39
17	0. 30	0. 30

Table 3: Wall-thickness measuring points on the slides, measured on axes of 0° and 90°.

Raw material

The vibrational behavior of brasswind instruments is a function of wall thickness, processing techniques, and the raw material used. The proportions of the various components impact certain physical properties, such as the elasticity module. It will also influence the recrystallization process, which is a key factor in the manufacturing process. XRF analysis revealed that all parts, without exception, are made of an alloy of approximately 20% zinc and between 1 and 1.5% lead. Only the cup of the mouthpiece contains a higher lead component of about 3%. Today, CuZn37 (composed of 63% copper and 37% zinc) and CuZn28 (72% copper and 28% zinc) are the typical alloys used for reconstructions of early brasses. The difference between an alloy of 37% zinc content and one of 20%

(as found in 13.301) is considerable, and one assumes that this difference will affect the structural vibrations. However, this requires further research. The XRF spectrum of the gilded ferrules indicates the presence of two elements in addition to copper, zinc, lead, and gold: silver and mercury. Silver was first applied to the brass ferrule, as is still done today by some modern makers. The presence of the element mercury favors the hypothesis that the ferrules were fire-gilded. In this case, mercury was needed to form a gold amalgam, which was applied to the object. Heating causes the mercury to volatize, leaving behind a thin layer of gold.

Intonation

A benchmark for a good instrument design is one in which all fundamental frequencies of the pitch centers of playable notes lie close to a harmonic series. A straight tube has impedances which are found at uniform distances from each other. The resonances of a straight tube do not lie in a harmonic series, therefore a straight tube is not useable from a musical point of view. Interaction between bell, mouthpiece, and body design are required in order to bring these resonances together in a harmonic series and make a musically useful sounding body. A rule of thumb used by makers in judging a good instrument is that the deviation within the harmonic series should not be more than 15 cents. Analyzing the intonation of trombones is a particular challenge, since the closed position is the only one that can be determined precisely. Despite this difficulty, closed position still gives us a good insight into the acoustical qualities of the instrument, based on its geometrical design. Using the analysis software BIAS, it is possible to calculate

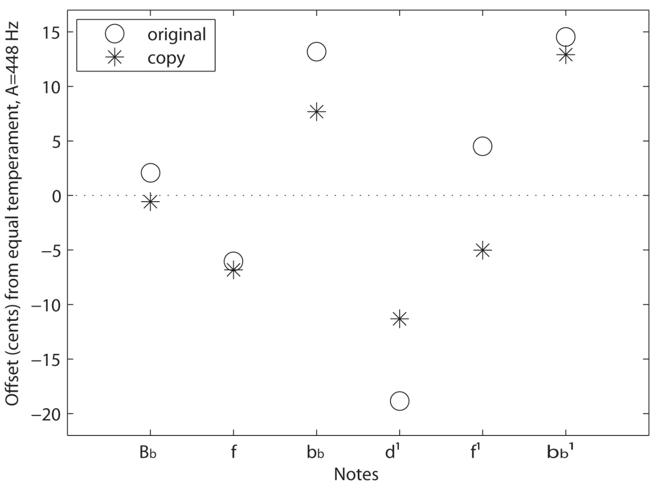

Figure 10: Intonation deviation from equal temperament in cents.

the intonation, using equal temperament as a reference. The instrument was measured without its crooks (see Figure 10).

The intonation analysis indicates that *b♭*, *d¹*, and *b♭¹* are at the farthest limits accepted for use today, using equal temperament as a reference.

Reconstruction

For research purposes, the author built a prototype of the instrument in cooperation with Rainer Egger, based on the findings mentioned above. The analysis of this instrument and extensive playing tests confirmed our hypotheses about it. All tubes were soldered, using an argentiferious soldering alloy. In the construction of the bell, the soldering seam was hammered by hand. As in the original, the parts were clamped rather than soldered, except for the slide-bow, which was soldered with low-melt solder. For the acoustical planning and development of the reconstruction, the Brass Instrument Optimization Software (BIOS©) was used.[34] Both the original and the copy were measured in the same room at the same time with the same measuring gear (see Figure 11).

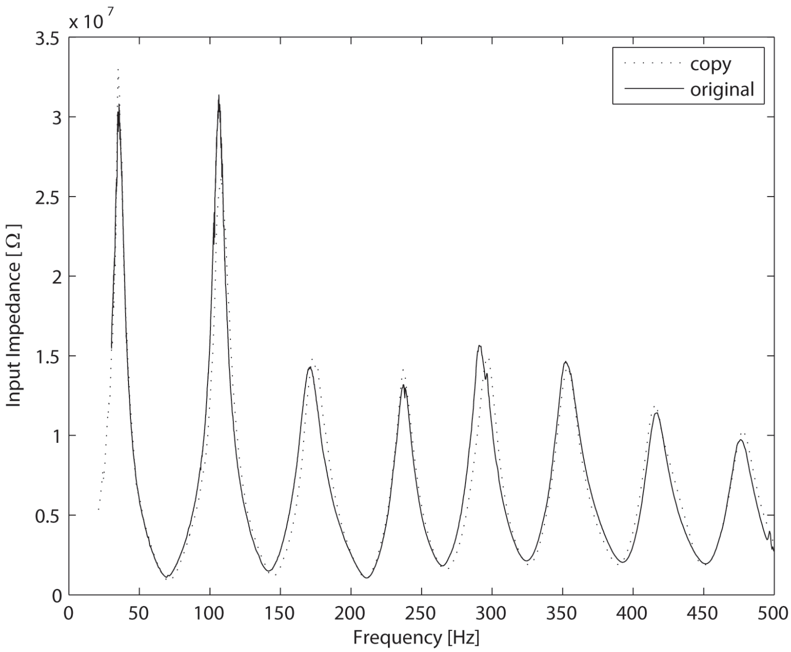

Figure 11: Comparison of the impedance curves of original instrument and copy.

As visualized in Figure 11, the acoustical footprint of the copy is very similar to that of the original. The curves match well. The differences in amplitude could be attributable to leakage in the original, to the energy losses due to thinner walls at certain points, or to general frictional loss. Furthermore, the difference could also be attributable to the fact that modern alloys have been used for the copy. In the course of further research we intend to construct another copy using raw materials closer to the original specifications.

Conclusions

From the research presented, the following observations can be made: (1) The instrument is well-suited for reproduction and for use in historically informed performance practice. (2) The use of a mouthpiece with a belly-shaped backbore has an important influence on the playing behavior and tonal characteristics of the instrument, and thus its use should be taken into serious consideration by performers. (3) The wall thickness of the bell ranges from 0.25 mm. to 0.35 mm, which is thin in comparison to modern bells. (4) The use of two crooks lowers the pitch one whole-tone, while the use of four crooks lowers it by a major third. (5) The raw materials Schnitzer used consisted of a brass alloy with approximately 20% zinc and 1% lead. (6) Mercury has been found in the gilded parts, which is an indication that the ferrules where fire-gilded. The meaning of the crooks and especially their arrangement requires further research. Furthermore, the acoustical meaning of both the bell ball and the material composition need further study.

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NOTES

[1] Markus Raquet and Klaus Martius, "The Schnitzer family of Nuremberg and a Newly Rediscovered Trombone," *Historic Brass Society Journal 19* (2007): 11–24, here 19. Raquet and Martius incorrectly give the date as 1578.

[2] Marco Di Pasquale, "Gli strumenti musicali dell'Accademia filarmonica di Verona: un approccio documentario," *Il flauto dolce* 16–17 (October 1987), 14.

[3] Ibid., 3.

[4] The other three surviving mouthpieces include one attached to an instrument made by Anton Schnitzer the Elder, in the collection of the Palais Lascaris, Nice; one anonyomous mouthpiece associated with a trombone made by Pierre Colbert, in the Rijksmuseum, Amsterdam; and another anonymous mouthpiece recently discovered by the present author, associated with a trombone made by Anton Schnitzer in the collection of the Hessisches Landesmuseum, Kassel. There are however questions about the authenticity of the Colbert mouthpiece.

[5] John Henry van der Meer and Rainer Weber, *Catalogo degli strumenti musicali dell'accademia filarmonica di Verona* (Verona: Accademia Filarmonica,1982), 72–74.

[6] Max Thein, Heinrich Thein, unpublished restoration report (Bremen, 1990).

[7] Recommendations for Access to Musical Instruments in Public Collections (CIMCIM, 1985).

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