Rotary and Piston Trumpets: New Perspectives

Dr Colin Bloch

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New research since Jack Burt's 2004 paper[1] makes it timely to review the growing symbiosis between rotary and piston trumpets. Repertoire-driven use of rotary trumpets is now *de rigeur* in many orchestras, nurtured by globally roaming conductors and players and emerging understandings of synergies between the two types. This paper focuses on the effects of rotary and piston configurations on performance. Greater familiarity is assumed with the piston trumpet; light is shone more on where the rotary trumpet differs.

Figure 1: Piston and rotary trumpets in C. The most manifest differences are the valves, the lengths and

The trumpet is the only orchestral instrument prevalent in two such distinct configurations but the differences are more extensive than the valve mechanisms. The choice of instrument could rest on repertoire, culture and tradition, opinion and taste, venue and ensemble, or player or conductor preference. Rotary and piston trumpets are voices speaking the same language but in different dialects; neither is 'better' but either can be more suited to a repertoire or circumstance.

The Vienna Philharmonic trumpet section enthusiastically adopted piston C trumpets from the early twentieth century until the 1930s.[2] The Chicago Symphony Orchestra from 1965 was the first in the USA regularly to use rotary trumpets. Playing a rotary trumpet informs playing on a piston trumpet.

Rotary trumpets are increasingly required for performance and auditions in the USA. "*Since rotary trumpets have been used in U.S. orchestras more and more, the amount of auditions requesting or requiring that candidates be accustomed to the instrument have increased. The expectation of owning or having access to the instrument has increased."*[3] *"For a person wanting an orchestra job in the US, playing a rotary is becoming expected. All the major US orchestras use rotaries on a regular basis…more orchestras are requiring rotary trumpets in auditions."*[4]

Rotary trumpets are suited to chamber and recital music. Cited examples of using a rotary C in the recital repertoire include Enescu's *Legénde*, Honneger's *Intrada* and Stravinsky's *L'Histoire du soldat*.[5]

Players familiar with both types might observe that the rotary trumpet has a more tapered and rounded edge to the sound, slurs more smoothly, has a more fluid and legato delivery, blends well,

suits the classical and romantic Austro-German repertoires, and can be less physically stressful to play; but that the piston trumpet can be more crisp, strident, bold and incisive, with greater dynamic range in the higher register and more suited to later and other repertoires and to light music and jazz. A rotary C trumpet also blends surprisingly well with Bb piston trumpets.

> **Chris Martin**: *"I have…daily sessions on both Bb and C rotaries…I have seen big gains in accuracy as well as noticeable improvements in the clarity and presence of my sound on piston trumpet. My legato…has improved greatly thanks to my increased practice on rotary valves as well."*
>
> **Adolph Herseth**: *"Playing successfully on the rotary trumpet makes the piston trumpet feel that much more comfortable."*[6]
>
> **Gabriele Cassone**: *"*(Rotary trumpets)*…have a sweeter, more melodious sound than piston valve trumpets when played softly, and a brighter sound when played loudly, so they are capable of a greater variety of timbre across the dynamic spectrum."*[7]
>
> **Jack Burt**: *"Many listeners find the tone of most rotary trumpets is broader and less compact…blend more easily…Response is gentler…soft playing can be achieved with greater ease… Almost every difficult passage* (in the Haydn trumpet concerto) *is made easier by playing the rotary as opposed to piston B flat trumpet."*[8] *"Rotary trumpets play more easily in tune and blend better…I feel safer in the upper register when playing with them."*[9]
>
> **Maurice Faulkne**r: *"*(The rotary trumpet has)*…a full round beauty of sound…a warm, luscious brass sound. One has to hear it to understand it."*[10]
>
> **Vincent Bach**: *"*(The rotary trumpet has)*…a glorious, noble tone of fascinating beauty and unique quality."*[11]

Figure 1 illustrates the manifest differences. Interestingly, the flügelhorn shares DNA with the rotary trumpet in (1) the short leadpipe entering the first valve in the earlier positioned valve cluster, (2) the 1-2-3 route through the valves, (3) the slightly broader conicity and larger inner volume, and (4) the traditionally less cupped mouthpiece. A shared characteristic with its rotary trumpet cousin is *"…the flügelhorn…will retain characteristic mellowness at any volume."*[12]

Provenance

Rotary and piston trumpets are of similar age but different provenances. The rotary valve was invented in the USA and the piston valve in Europe yet each thrived on opposite sides of the Atlantic. Edward Tarr conceded that *"It will probably never be possible to draw an absolutely clear picture of the development of the different valve systems."*[13]

In a golden age of invention between 1815 and 1840 the milestones of manufacture and patent of both valve types were:

- a trumpet with three cylindrical piston valves was first made by Sattler in Leipzig in 1820: the modern piston valve was patented by Périnet in Paris in 1839; and
- a cornet and two trumpets with rotary valves were first made by Adams in Massachusetts in 1824 and 1825: the modern rotary valve was patented in Vienna by Riedl in 1835.

Piston valves: From 1806 the court horn player Heinrich Stölzel (1777-1844) and the mine musician Friedrich Blühmel (1777-1845) worked independently in Prussia on piston box valves. In 1815 Stölzel added two cylindrical pistons to a French horn which led to a dispute, resolved in 1818 with a ten-year Prussian joint patent[14]. *"Stölzel was the first to plan an actual valve, while Blühmel made the first more or less satisfactory one...a curious and clumsy contraption, square in section...heavy and rather sluggish."*[15] The first trumpet with three cylindrical piston valves was built in Leipzig in 1820 by Christian Friedrich Sattler (1778-1842) but was not patented. Stölzel's three-valve piston 'trompette' (a cornet variant) appeared in France in 1826. The modern piston valve was patented in Paris in 1839 by François Périnet of Savoye who *"adopted the principle of building up curved passages inside the piston, but by placing them on the diagonal he was able to reduce its over-all diameter and therefore the attendant friction and inertia."*[16] *"It had staggered ports, no sharp angles, slides at right angles to the casings and air passing optimally in the open or closed positions."*[17]

Rotary valves: The first rotary trumpet was made in 1825 in Lowell, Massachusetts by Nathaniel Adams (1783-1864) who had made a rotary cornet in 1824.[18] Recognisably modern rotary valves were built in 1835 by Joseph Riedl (d 1840) with Josef Kail (1795-1871). Kail is credited with independently inventing the rotary valve, inspired by beer keg taps, but Riedl patented the modern rotary valve in Vienna in 1832, *"the earliest known official recognition of an undoubted rotary valve."*[19].

The Main Configuration Differences

The two instruments illustrated (Figure 1) and used in the pitch accuracy test here are among the 'best in class' of professional C trumpets. Figure 2 compares the two. The main differences between rotary and piston trumpets are: (1) the position of the valve cluster along the air column, resulting in differences in (2) the wrap and (3) the profile or conicity of the bore. A rotary trumpet's valve cluster is closer to the mouthpiece, resulting in a shorter and wider wrap with additional bell bracing and more gradual conicity. The combination of these and other differences results in distinctively different playing qualities. Rotary trumpets embody some elements of the natural trumpet, including Vienna keys and a garland on a wider bell.

PISTON C TRUMPET		**ROTARY C TRUMPET**
Vincent Bach, USA	*maker*	**Ricco Kuhn, Germany**
CL 229 25H (1994)	*model / year*	T 053 / C X (2014)
25H	*lead pipe*	C3 55 interchangeable
yellow brass silver plated	*materials and finish*	copper brass, nickel silver garland, silver plated
none	*accuracy keys*	Vienna keys Ab, A, Bb
1st valve slide saddle 3rd valve slide ring	*tuning adjusters*	1s/ 3rd conjoined trigger, adjustable Ab key
main tuning slide	*water keys*	Bb Vienna key + 3rd slide
11.73 mm (0.462")	*bore: maker's data at the valve cluster*	1st valve: 11.00 mm 2nd valve: 11.17 mm tuning slide: 11.20 mm
464 cc	*internal volume*	505 cc
22.204 mm	*mean bore*	22.121 mm
124 mm	*bell diameter*	130 mm
2	*bell braces*	2
10.34 mm	*valve travel*	7.82 mm
4,084 mm^2	*frictive area*	1,196 mm^2
7.41 mm	*inter-valve*	15.61 mm

Figure 2: Piston and rotary trumpets' specifications and metrics

Valve cluster position: Rotary valve clusters are about 9% along the length of the air column which enters at the first valve. Piston valve clusters are about 38% along the length of the air column which enters at the third valve (Figure 3). In academic experiments showing that the valve cluster placement contributes more to the rotary trumpet's ability to slur smoothly than the type of valve, rotary and piston valves were placed at different points along the instrument's tubing revealing that (1) the two types of valves produce practically identical slurs when placed at the same location and (2) the closer the valves were placed to the mouthpiece, the smoother the slurs became.[20]

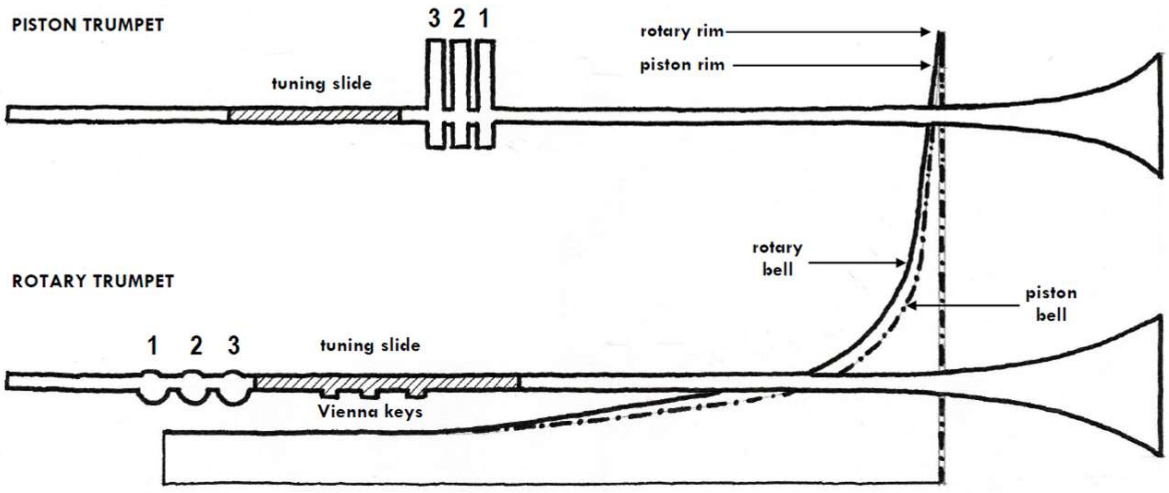


Figure 3: Piston and rotary configurations shown unwrapped. Note: (1) the relative positions of the valve clusters and tuning slides, (2) Vienna keys within the rotary tuning slide, (3) the air stream entering the third valve (piston) and first valve (rotary), and (4) bell sizes and profiles shown in the underlay with the piston bell shown dotted (vertical scale x5)

Valves: A rotary valve is sealed and rarely opened. It spins only 90□, has a much smaller frictive area, is less concerned with gravity and has a shorter travel length. Piston valves plunge, engaging more with gravity, and have more than twice the frictive surface area of rotary valves, resulting in more friction and inertia to be overcome and more susceptibility to wear.[21] Rotary valves have longer inter-valve tubing (facilitating conicity through the cluster); because the cluster is closer to the mouthpiece there is no water key between the valves and the mouthpiece but it is quick and easy to clean and lubricate the rotors through the short (often interchangeable) leadpipe. The rotary air column route through the valves is more two-dimensional, whereas the piston route is more complex and three-dimensional (Figure 4). Piston valves each have three internal through-airways, whereas rotary valves need two and their rotors are interchangeable (where of equal bore). On each piston valve due to airway congestion there are domed protrusions within two of the airways, constricting the valve bore by a sudden 15%. Complexity in the piston route is not a liability; it is a successful design, it works well, and it may contribute positively to the different response and more incisive articulation of the piston trumpet.

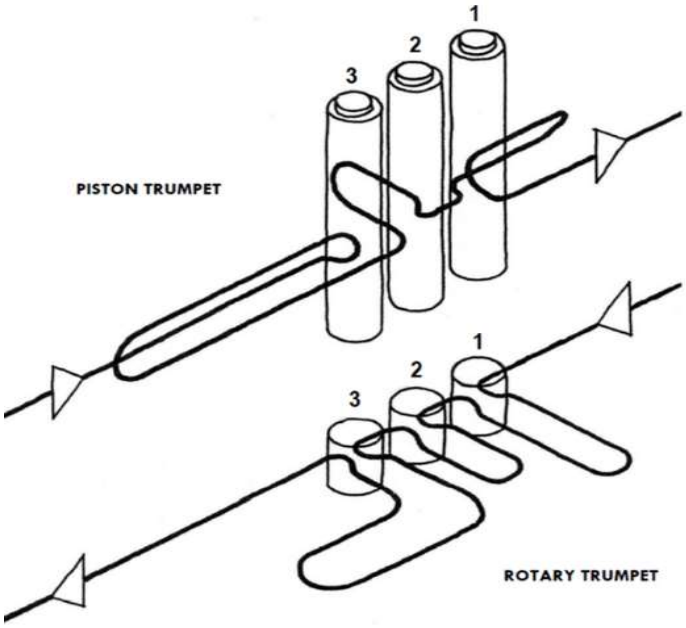


Figure 4: Air column routes through piston valves (entering the third valve) and rotary *valves (entering the first valve).*

Wrap: The rotary trumpet has a shorter, wider wrap, with the centre of gravity being comfortably closer to the player. *"The tighter bends of piston trumpets break down the harmonics within the vibrating tubes and create an edgier tone. The gradual bends of the rotary trumpet are therefore seen to have a big impact on the rounded sound."*[22]

Lead pipes: A rotary trumpet's leadpipe, often interchangeable and of larger bore, travels in a short straight trajectory directly into the first valve (as on a flügelhorn). By not having the piston trumpet's added length, narrower wrap, tuning slide (with internal steps), and water key aperture, opportunities for disruption early in the air column are minimised.[23] The played note is thus modulated earlier, allowing a longer air column length for its development in tone and volume.

Bores: A rotary trumpet's bore where entering the valve cluster can be about 6% narrower than a piston trumpet's; this is because the rotary valve cluster is in a different and much earlier position in the air column length.

Conicity and internal volume: Rotary trumpets can be conical earlier in the air column, facilitated by the earlier position of the valve cluster. A rotary trumpet's greater internal volume coupled with its conicity results in distinctive differences in tone.

Bells and rims: Rotary bells have an earlier and more gradual flare and wider neck and rim, usually with a nickel silver garland[24] adding rigidity and mass.[25] Rotary bells are traditionally made of heavier copper-rich metal with two bell braces compared to one on piston C trumpets. Comparative bell profiles are shown on Figure 4.[26]

Vienna keys[27]: Rotary trumpets have between one and four but often three lever-activated cork-padded Vienna vent-keys (similar to oboe keys), also known as 'klappen', which increase accuracy in the higher register by interrupting impedance and reducing resistance. They are highly effective in exposed entries such as the opening Ab in Tchaikovsky's 4th symphony, and in the octave C-C leaps in Strauss's Also Sprach Zarathustra and in his Alpine Symphony (e.g. rehearsal numbers 70 and 110). All rotary trumpets have at least the Bb Vienna key (F-Bb-D-F) which can be used as a water key although rotary trumpets empty quickly and completely by inversion. The other three keys are the A key (E-A-C#-E), the Ab key (Eb-Ab-C-Eb) and rarely a G key (D-G-B-D). Vienna keys also add mass and light bracing; replacing the tuning slide for one without Vienna keys makes a noticeable difference.

Tuning adjustments: A rotary trumpet's third valve tuning slide is operated by a thumb lever behind the first valve, sometimes conjoined to extend the first and third valve slides simultaneously, placing a low F natural within reach.

Suction release*:* Most rotary trumpets have a useful small aperture in the third valve barrel casing to allow suction-free operation of the third valve slide while playing without having first to depress the valve to release pressure. Tradition is the only impediment to this being standard on piston trumpets.

Bore and Internal Volume

Bore: Bore lore holds that rotary trumpets (and piston flügelhorns) are small bore instruments, which is not necessarily true. Rotary and piston trumpets are of similar bore but the myth has perpetuated because bore by convention is measured at the first slide, which on the two types are at very different positions in the air column length (Figure 3). A piston trumpet's bore measured at the position of a rotary trumpet's valve cluster would be similar.

Comparing bore measured at different points in the air columns of the two types sustains the misunderstanding that bore is a comparative indicator of playing characteristics. Bore as a measurement of comparing between instruments by different makers can be unhelpful as multiple variables apply. Some makers no longer advertise bore, or downplay it. Bore can be useful in comparing instruments within a maker's range. R Dale Olson: *"The brass performer should be fully aware of the inaccuracy of allowing this term to completely describe performance characteristics of an instrument."*[28]

Internal Volume: This is the measured volume of air within a trumpet with the valves engaged, indicating the quantum of air that has to be activated and thus tone quality and resistance. Knowing the internal volume allows a calculation to be made of the mean bore throughout (as if the air column were constantly cylindrical). The rotary and piston trumpets tested here have small but significant differences in internal volume (by 8.8%) and mean bore (by 4.3%).

To illustrate more sharply the effect of differing internal volumes on tone, a Bb piston cornet and a Bb piston flügelhorn were measured: both have the same air column length, but the cornet has an internal volume of 502cc and a mean bore of 20.816mm while the flügelhorn has an internal volume of 942cc (+87%) and a mean bore of 28.491mm (+38%).[29] A flügelhorn differs further from a cornet (1) by the early position of the valve cluster, (2) by an almost doubled internal volume, and (3) by a different conicity and bell flare.

Pitch Accuracy

The test identified modest discrepancies in the pitch accuracy profiles of the two instrument types (Figure 5). The test method[30] minimises subjectivity and foible but the indicative outcomes are broadly reliable. The test was conducted thrice at three-day intervals, aggregating the results. The same standard fingerings were used on both instruments. Tuning adjusters (valve slides extenders and Vienna keys) were not used. A standard Vincent Bach 1½C mouthpiece was used on both instruments.

The piston trumpet's pitch profile suggests that the overall plus / minus deviation would be reduced if the trumpet was tuned about 0.75 cents sharp to the C reference note. This is an inconsequential margin.

Both instruments are well in tune within normal tolerances and both would be easily adjustable where notes are inherently deviant (e.g. low C#, low D). Deviations of 2 cents in either direction are usually not material in ensemble performance.[31]

The reasons for these slight differences in pitch accuracy between the two types might be due to (1) the more gradual conicity of the rotary trumpet, or (2) different airflows within the valve clusters, their interface with the air column and differences in inter-valve tubing, or (3) different bell materials and weights, or (4) the different positions of the valve cluster, or (5) combinations of these factors.

The rotary trumpet has slightly less overall plus / minus deviation and thus has better pitch accuracy overall but on both instruments the deviation is small and easily corrected by mechanical adjustment or lipping.

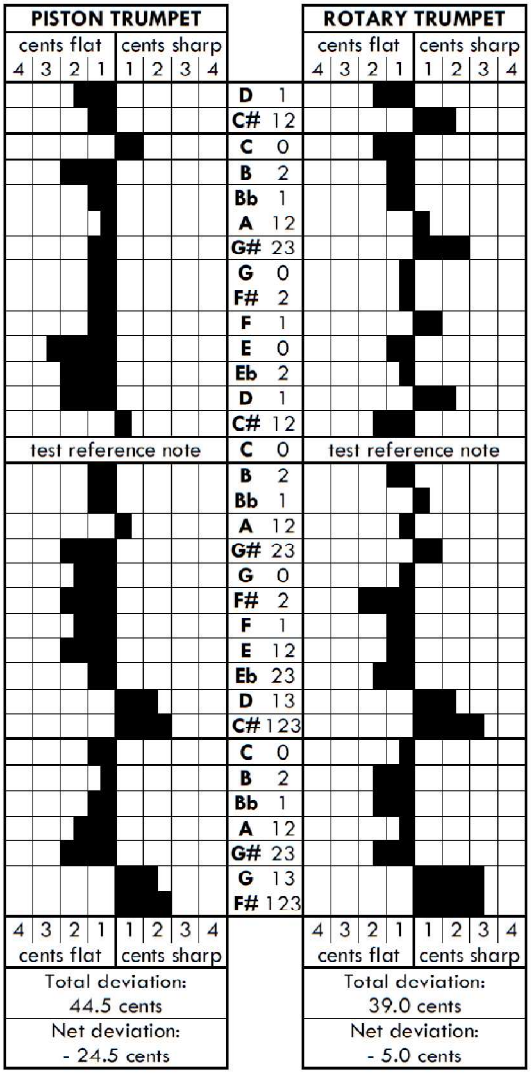


Figure 5: Pitch accuracy profiles for the tested piston (left) and rotary (right) trumpets in C.

Tone and the Wiener Klangstil

Tone is affected by bore generally, but also how early in the air column conicity starts and its profile particularly towards the bell, by materials[32] and bracing, by the quality of construction but *above all* by the player. Perhaps most critical to tone is the early position of the valve cluster on the rotary trumpet which allows conicity to start much earlier in the tube length and thus take a more gradual journey to a bell that has a distinctively earlier flare and a wider neck. A piston trumpet starts effective conicity after exiting the valve cluster, further along the air column.

> **Jack Hall**: *"The closer a valve section is added toward the mouthpiece, the darker the sound... This is the main reason for the characteristic dark sound of the rotary valve trumpet."*[33]

> The traditional garland to the bell may contribute to the distinctive rotary tone. It has been described as *"a metal ring that prevents the sound from becoming too brassy or 'edging out' at higher volumes."*[34]

The timbre of the rotary trumpet has long been associated with Vienna and is also known as a Vienna trumpet. The Wiener Klangstil (Vienna sound style) is an institutional initiative[35] to identify and protect a distinctive Viennese sound and style, defined for brass instruments as

> *"A generally righter timbre...of horn, trombone and tuba...*
> *The characteristic timbre of...trumpet, on the other hand, is considerably darker (fewer overtones)..."*[36]

Playing Posture

Posture is pedagogically under-represented. *"While brass pedagogy has traditionally focussed on sound output, the importance of bodily posture to both short-term performance and longer-term injury prevention is now widely recognized."*[37]

Correct posture extends stamina, reduces stress, improves breathing, confidence, alertness, and tone, and leads to better performance and health. A mouthpiece maker who recognises this even provides with each mouthpiece advice on posture and even on how best to place one's feet.[38] Rotary and piston trumpets by their configurations encourage different postures, in turn affecting the player's physiology and performance. Differences between 'rotary posture' compared to 'piston posture'(Figure 6) are:

(1) Because the rotary trumpet is a lateral rather than a vertical instrument, the arms naturally cantilever slightly outwards so that the chest and shoulders are more open and symmetrical, promoting relaxation and effective breathing without the hunching and spinal slouching often seen in piston trumpeters where the instrument is held vertically with one hand and played with the other.

(2) Cantilevering the arms outwards also encourages a more open, balanced stance, promoting more effective breathing and lessening postural stress, especially when standing.

(3) The rotary trumpeter's right hand and wrist are less curved which, coupled with the rotary valve's much shorter travel distance makes playing less physically demanding especially for those even lightly troubled by common hand afflictions such as arthritis or Dupuytren's contracture.

(4) The lateral holding position of the shorter rotary trumpet with the centre of gravity closer to the body results in it being balanced on and held more lightly in the two thumb crooks, rather than gripped, while played.

(5) Depending on player preference and hand size, up to three middle fingers of the left hand wrap naturally and comfortably over the bell. This not only gives a pleasant sensory connection and physical feedback, but has an additional bracing effect on the bell.

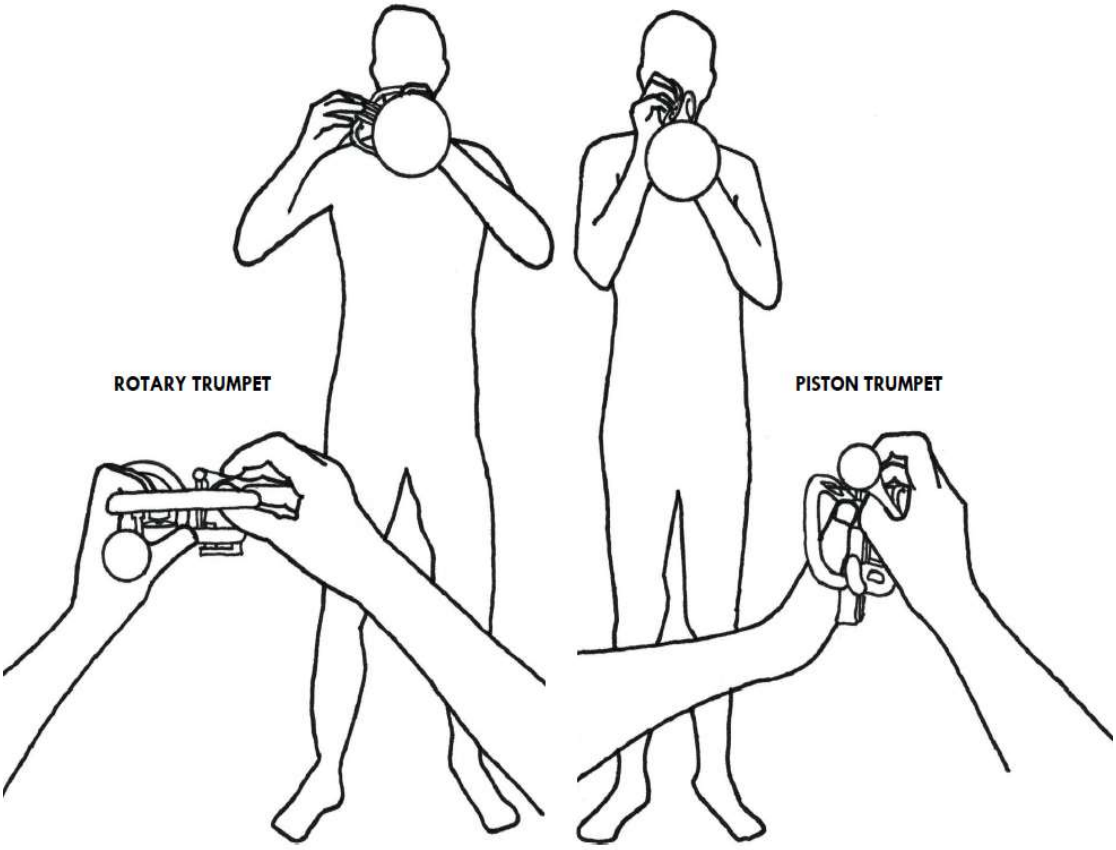


Figure 6: Typical postures of body and hands for rotary (left) and piston trumpeters (right).

Players alternating between rotary and piston trumpets generally use the same mouthpiece; the shank receivers are similar. Rotary trumpet mouthpieces in Europe (particularly in Austria) by tradition are different, usually with a more rounded rim and inner lip, a more funnelled bowl and throat, and a different back bore. *"The rotary trumpet has the same size shank as piston trumpets and are interchangeable. ... if the performer wishes to play on a rotary trumpet in order to get a different sound, color, or to match the sound of a German orchestra, then it is appropriate to have the rotary style mouthpiece. ... a rotary trumpet mouthpiece helps to improve intonation. Compared to a piston trumpet mouthpiece, a rotary mouthpiece has a rounder shape to the rim and softer bite. The* (survey) *respondents also believed there to be a difference with the shape of the backbore to account for the short leadpipe and smaller bore."*[39] For one player a specialist rotary mouthpiece *"...made a huge difference in pitch, articulation and slurring. I never play rotors without them."*[40]

Other Rotary Issues: Low F Natural, Mutes, and the TARV Trumpet

Rotary trumpet tuning slides do not always extend easily to play a low F natural. This is a traditional problem but some makers now provide extendable slides, or a conjoined extension mechanism for the first and third valve slides.

A quick mute change is a challenge on a rotary trumpet. Whereas a piston trumpet can be held and played with the right while changing a mute with the left, this is unrealistic on a traditional rotary trumpet where both hands are required to balance it in a playing position.

The TARV (top action rotary valve trumpet) allows mute changing while playing a rotary trumpet. The TARV is configured vertically rather than laterally but with the rotary valves activated by an added mechanism such that the player has the feel of a piston action and some of the playing characteristics of a rotary trumpet with the ability to change mutes while playing. TARV trumpets originated in the early 19th century[41], were popular in central and eastern Europe and have recently gained popularity particularly in Europe in the jazz sector.[42] The TARV configuration is almost as old as rotary and piston trumpets; in 1857 Joseph Higham of Manchester, England patented a TARV and a TARV cornet was made by Carl August Müller (1804 - 1870) in Switzerland.

Wrapping Up

The quality, consistency and reliability of trumpets have improved. Trumpets now cost less, can more confidently be bought untested, and last longer. Between 1935 and 2020 the cost of a trumpet as a percentage of income reduced from 11.1% to 5.1%[43] while trumpeters are living longer to enjoy them.[44] Globalism, competition, precision manufacture and a player-led approach means that choice focusses on narrower discernments. Rotary trumpets are made more by smaller ateliers and can thus be more easily customised. Just as there are traditional differences between USA and European piston trumpets, so too have Austrian rotary trumpets traditionally had a lighter and brighter quality than their German counterparts, but most makers now offer rotary trumpets of universal character, although the spectrum of variance is less nuanced than between piston trumpets.[45]

The rotary trumpet in this millennium is increasingly becoming the instrument of choice particularly for the orchestral classical and romantic Austro-German repertoires. There is also a recognised reciprocal benefit of developing a regime of symbiotic practice and performance between both types, articulated earlier here by Chris Martin and by Adolph Herseth.

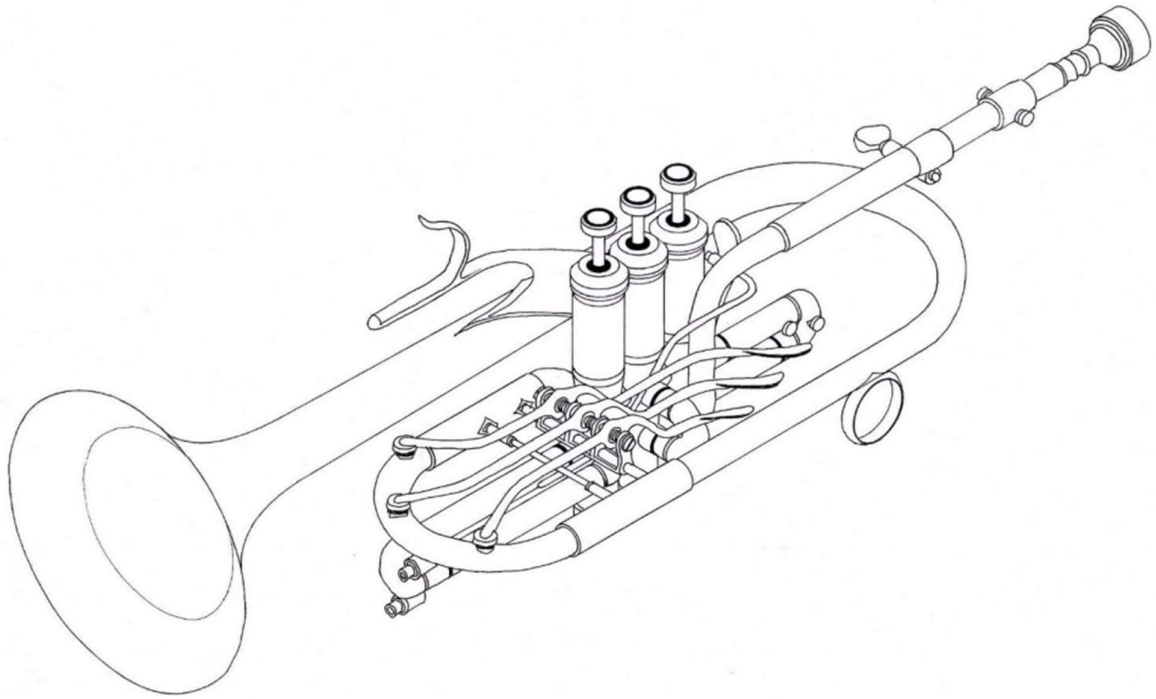
The key differences in configuration and playing quality between the two types have been set out here, illustrating how they affect performance. Successful orchestral players will need to develop flexibility and adeptness between the two types, with the potential of reciprocal improvement in performance and musical satisfaction on both.

Post-Script: The Future …

Piston trumpets are generally favoured in the USA, and rotary trumpets in Europe even though the rotary valve was invented and patented in Massachusetts (1825), and the piston valve in Leipzig (1820). In the USA, orchestras and conductors increasingly call for rotary trumpets in classical and romantic works. There have only ever been five full innovations in the development of the trumpet, since Jericho:

1. the separate and transferrable mouthpiece and leadpipe,
2. the slide and clock-spring trumpet,
3. padded keys (Weidinger, Vienna, 1792),
4. piston valves (Sattler, Leipzig, 1820) and rotary valves (Adams, Massachusetts, 1825), and
5. the TARV mechanism (Belorgey, Paris, 1847).

The sixth true innovation will be the T6 trumpet, designed by Colin Bloch, which combines the virtues. This is the subject of a separate paper - 'The H7 Trumpet'. This drawing illustrates how it combines piston valves with a rotary valve cluster and conicity configuration.



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Dr Colin Bloch is a South African orchestral trumpeter, soloist and independent researcher who currently lives in Britain
He learned from **Georges Frans** (of the Paris school) and from **Chuck Few** (of the Chicago school). www.colinbloch.com

1 Jack Burt, *The Rotary Trumpet: An Introduction* (ITG Journal March 2004), 52.

2 Edward Tarr, *The Trumpet* (Batsford London 1988), 171. These were F. Besson (Paris) C piston trumpets.

3 Whitney Rose David, op. cit., 64.

4 David Bilger, *Rotary Trumpets - A Conversation with Dr Jack Burt* (ITG January 2017), 62.

5 David Bilger, op.cit., 63, quoting Dr Jack Burt.

6 Whitney Rose David, *Bb and C Rotary Trumpets in Orchestras of the United States: Perspectives from Professional Orchestral Trumpet Players on the Use, Audition Considerations, and Current Makes/Models* (Ohio State University, D.M.A. dissertation 2020), 26, 68, 69.

7 Gabriele Cassone, *The Trumpet Book* (Zecchini Editore, Varese, 2002/9), 191.

8 Jack Burt, op. cit., 53.

9 David Bilger, op.cit., 63, quoting Dr Jack Burt.

10 Maurice Faulkner, *The Rotary Valve Trumpet and the Vienna Style* (The Instrumentalist January 1972 in Brass Anthology (The Instrumentalist Company, Evanston, Illinois, 1976)), 600.

11 Jack Hall, *The Rotary Valve Trumpet - An American Revival* (The Instrumentalist in Brass Anthology *op.cit.* January 1972), 601, citing Vincent Bach, *Bach Means Quality* (Vincent Bach, New York, 1961).

12 Lucien Calliet, *The Flügelhorn* (The Instrumentalist in Brass Anthology *op.cit.* December 1961), 306.

13 Edward Tarr, *The Romantic Trumpet* (www.historic.brass.org), 213 et seq.

14 Edward Tarr, *The Romantic Trumpet, op. cit*., 230 states that the patent was not for a type of valve but for the principle of adding valves to brass instruments. Philip Bate op. cit., 146 states that the valve was the subject of the patent.

15 Philip Bate, *The Trumpet and Trombone* (Ernest Benn Limited, London 1972), 146

16 Philip Bate, op. cit., 159.

17 Edward Tarr, *The Trumpet,* op.cit., 161. Bate op. cit.& Tarr have 1839 as the Périnet patent date:Cassone op.cit. has 1838.

18 Robert J Eliason, *Early American Valves for Brass Instruments* (The Galpin Society Journal Vol. 23 Aug., 1970), 86-96 is authoritative and thorough. The trumpet by Adams is at the USS Constitution Museum in Boston, Mass., USA and is one survivor of two that he made. The other is lost, as is the 1824 cornet.

19 Edward Tarr, *The Trumpet,* op.cit.160 cites 1832 based on an inspection by Reine Dahlqvist (1945-2014) of the actual patent. Philip Bate op.cit. 153 also cites 1832. Cassone op. cit. 78 has the patent date probably incorrectly as 1835.

20 Brandon Norton, *A Piston Trumpeter's Guide To The Rotary Trumpet* (University of Colorado dissertation 2020), 6 et seq. citing Grego Wildholm, *Wiener Klangstil: Facts and Background Information on the Particular Sound of the Vienna Philharmonic* (Vienna: IWK), 20 et seq.

21 Rotary and piston valve sets have surface areas respectively of 12,666mm2 and 5,145mm2 approximately.

22 Maurice Faulkner, op. cit., 29.

23 Dr Renold Schilke in the 1970s promoted the benefits of an uninterrupted inner surface on his innovative tuning-bell trumpet as *"keeping the bore relatively free of gaps that may cause a disturbance in the nodal pattern of the sound wave."* (contemporary catalogue).

24 A rotary bell typically is 130mm (5.11") and a piston bell 122mm (4.80"). The wider bell may only have slight acoustic benefits. A natural trumpet's garland was required to reinforce thin and brittle hand hammered bells which later became traditional, some times ornamented, and remain so even though bell manufacturing techniques are improved.

25 Brandon Norton, op. cit., 9.

26 Figure 4 shows the last 550mm of the bells with a x5 vertical scale.

27 All rotary trumpets have at least the F/Bb key, which can be used as a water key although emptying is more quickly and completely achieved by inversion.

28 R Dale Olsen, *Brass Instrument Bore* (The Instrumentalist in Brass Anthology *op.cit.* January 1963), 329.

29 To calculate the average bore throughout or 'mean bore' two factors are required: the length of the air column (L in mm) and the internal volume (V in mm3). The formula for mean more is: 2 x the square root of [(V / L) divided by Pi)].

30 Colin Bloch, *The bell-tuning trumpet* (Brass Bulletin 26, 1979 ed. Jean-Pierre Mathez, Bulle, Switzerland), 45. Subsequently reprinted and distributed by Schilke Music Products, Inc., and maintained on www.everythingtrumpet.com.

31 There are 100 cents in a semitone.

32 Piston trumpets generally are of yellow brass; rotary trumpets are usually of gold brass with a slightly higher copper content.

33 Jack Hall, *The Rotary Valve Trumpet - An American Revival* (The Instrumentalist in Brass Anthology op.cit. January 1972), 601.

34 http://www.rjmartz.com

35 Department of Musical Acoustics Wiener Klangstil, University of Music and Performing Arts. Vienna www.mdw.ac.at.

36 en.wikipedia.org/wiki/Wiener_Klangstil.

37 Matt Dalgleish, Chris Payne, Steve Spencer *Postrum II: A Posture Aid For Trumpet Players* (University of Wolverhampton undated).

38 David G Monette Corp., Undated illustrated leaflet provided with a mouthpiece: "*Body Use and Breathing:…how to align yourself when playing so that you can play with less tension in your body. Playing in a more efficient, aligned and 'open' manner will help*

you to breathe in a more complete and effortless way. This in turn will immediately allow you to sound better and play easier".

39 Whitney Rose Davis, op. cit. 59 et seq.

40 David Bilger, op.cit., 64, quoting Dr Jack Burt.

41 www.brasspedia.com carries detailed information on TARV trumpets.

42 In Germany it is known as the Zylinder-Jazz-Trompete, Drehventil Jazz-trompete, Vertikaltrompete (rotary jazz trumpet, cylinder jazz trumpet, vertical trumpet).

43 Bach Stradivarius Bb trumpet silver plated (all data is USA): In 1935 the price was $142, or 11.1% of the median income of $1,269 (www.bachloyalist.com and www. libraryguides.missouri.edu). In 2019 the price was $3,499, or 5.1% of the median income of $68,703 (www.thebalance.com, www. thompsonmusic.com).

44 An additional 17 years in the USA. In 1935 average USA life expectancy was 61.9 (an average of 59.9 men and 63.9 women). www.u.demog.berkeley.edu. By 2020 it was 78.93 www.macrotrends.net

45 Jack Burt op. cit. 55 also refers to this.