Rudall Carte and E.A. Couturier Conical-bore Instruments Compared

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In the 1995 volume of this *Journal*, the late Frank Tomes and I described Rudall Carte's "Patent Conical Bore" (PCB) instruments, including "Webster Trumpets."[1] These were covered by a British patent of 1903,[2] were marketed from 1903, and exhibited in the Fishmongers Hall exhibition of 1904.[3] The present author has since gained access to examples of Rudall Carte & Co and E. A. Couturier conical-bore instruments including French horns in F and E♭, allowing comparisons of the respective designs.

The principle employed by both Rudall Carte & Co and E. A. Couturier in their conical-bore instruments was to minimize the length of cylindrical tubing. The narrower sections including the leadpipe and the passage through the valves were not all strictly conical, but included steps; the wider parts such as the bell were flared as usual, so the term "conical-bore" should not be taken literally. Nevertheless, a rough approximation to a cone was achieved for parts of the bore. The bore increased between valves and within valves: the two legs of the valve tuning slides were of wider bore in the distal leg (nearer the bell) than the proximal leg (nearer the mouthpiece). The main tuning slides similarly were of wider bore in the distal leg than the proximal leg. The expansion of the bore through the valve section was particularly effective in approximating to a conical profile when one or more valves were operated (in conventional instruments operating valves introduces significant lengths of cylindrical tubing).[4]

Rudall Carte's instruments were designed so that the leadpipe connected the mouthpiece receiver to the second valve, which was then connected to the first valve and finally to the third valve, then to the bell. E. A. Couturier further minimized the proportion of cylindrical tubing in some instruments by doing away with tuning slides in the valve loops altogether; the main tuning slide had to be retained but the length of the sliding part was very short.

It is not known if Ernst Couturier was aware of Rudall Carte's "Patent Conical Bore" designs when he introduced his own ten years later. Couturier was a brilliant cornet player,[5] but no acoustician. His understanding of sound-wave propagation in a brass instrument was "A sound wave, started in the mouthpiece of any Couturier instrument, with the slightest vibration of the lips, gathers speed and volume as it travels through the expanded tubing, emerging from the bell a pure tone of unmatched musical beauty."[6] In fact the majority of the energy in sound waves reaching the bell is reflected back towards the mouthpiece, forming a standing wave. The existence of standing waves in the air columns of wind instruments was well established in acoustical theory (and had been elegantly demonstrated by D. J. Blaikley).[7] It is however true that the frequencies of the natural notes in an approximately conical instrument are

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closer to a harmonic series than in a more cylindrical instrument, so the marketing promise of easier intonation[8] may have been fulfilled to some small extent.

Cornets

The traditional cornet design places the valve cluster approximately halfway along the instrument, between an approximately conical leadpipe and a flaring bellpipe. Rudall Carte and E. A. Couturier conical-bore cornets do not significantly differ from each other, and only differ from conventional cornets in having the progressively widening bore through the valves. The earliest surviving PCB instrument, a small-bore cornet (serial number 5074) in the author's collection, has bores in the valve tuning slides of 10.5 and 10.9 (second valve), 11.05 and 11.3 (first valve), 11.5 and 11.7 (third valve), all in millimeters. The Couturier small-bore cornet is not very different. Both firms also offered large-bore cornets.

As with cornets, conical-bore saxhorns and tubas did not require a radical departure from conventional designs. The placement of valves in the windway of saxhorns and tubas is much closer to the mouthpiece receiver than in cornets. The E.A. Couturier Band Instrument Company offered an alternative "Direct Mouthpipe Model" of cornet in which the valves were close to the mouthpiece receiver (as in a flugelhorn) and thus of narrower bores and shorter piston travel than the more numerous cornets with mid-length valve placement.[9]

Trumpets

The convergence of trumpets and cornets was already in progress at the start of the twentieth century,[10] but "conical-bore" trumpets are still further removed from the earlier conventional, predominantly cylindrical trumpets. The tapered leadpipes of both Rudall Carte and E. A. Couturier conical-bore trumpets require a narrow mouthpiece receiver, fitting a cornet mouthpiece. Both firms produced fairly shallow-cupped mouthpieces specifically for these instruments. Although patented and marketed as trumpets, there is little to distinguish them from the long-model cornets that were popular in the first half of the twentieth century.

The Rudall Carte conical-bore trumpets from 1919 onwards were inscribed "WEBSTER TRUMPET" and had a much narrower and more highly flared bell than those of standard cornets and trumpets. This favored the preferential radiation of the high-frequency components of the sound energy and thus counteracted the mellowness introduced by the tapered leadpipe, and increased the support given by the instrument for high note playing.[11]

Trombones

A conical-bore slide trombone might seem like an impossibility, but the Couturier firm produced an ingenious model in which the bore of the inner slides was tapered while the exterior was conventionally cylindrical.[12] The descending slide had a fixed inner slide with a stocking at the bottom and a moving outer slide (as usual); the ascending slide had a moving inner slide with a stocking at the top and a fixed outer slide (opposite to the usual); both inner slides had a slightly expanding bore. The tuning-slide legs also had an expanding bore, although necessarily externally cylindrical.

In fact the conical-bore trombone was not as novel as Couturier claimed. In 1849 Nicholas Firmin Michaud of Paris patented a tenor trombone with conical bore inner slides and the ascending slide with moving inner and fixed outer slide.[13] George Case had anticipated the inner-outer trombone slide thirty years earlier,[14] and the tapered tuning-slide bore was also a feature of some Boosey & Co. trombones. The bell flare of the "Symphony" (wide-bore) model was very close to that of the Conn 8H trombone.

Attempts to classify instruments by the proportions of the sounding length composed of cylindrical and conical (or, more generally, expanding) tube fail, since they do not take into account the degree of expansion. Often it is not possible to determine where a cylindrical section finishes and an expanding section starts. In a cylindrical tube the traveling wavefronts are virtually plane, but in an expanding bore such as a conical section the shape of the wavefronts approximates to a portion of a sphere. The effect of the developing shape of the wavefront is significant in noticeably flaring sections of tubing, especially the bell flare (where it is a major factor in the reflection and radiation of sound). More generally, there is some reflection of sound waves from any point where the cross-sectional area changes. In a slide trombone the main reflections occur in the region of the bell end; there are also reflections at the abrupt changes of bore at foot of each inner slide, but the effect is negligible in gently expanding sections of tubing. In the main slides of a Couturier "conical bore" slide trombone the bore diameter expands by approximately 1 mm over a slide length of 675 mm, so the angle between the axis and the tube wall is only 0.04°. This is so close to cylindrical that this effect can be disregarded.

The spectral enrichment resulting from non-linear propagation (the brassiness effect) is less in wider tubing than in narrow. It is a cumulative effect over the whole sounding length of an instrument: long sections of narrow tubing brighten the sound while wide bore sections engender less enrichment. Other things being equal, slide trombones sound brighter than (say) euphoniums because much of the bore profile is narrower. In a "conical bore" trombone there is a slight expansion of the bore through the inner slides, but this expansion is irrelevant: the same spectral enrichment effect could equally well be achieved by conventional cylindrical dual bore trombone slides of appropriate diameters in which the descending slide from the mouthpiece is narrower than the ascending slide leading to the bell section.

French horns

The divergence between Rudall Carte PCB and E. A. Couturier designs was most marked with the French horn. The Rudall Carte (Figures 1a and 1b) is possibly the only survivor of the eight PCB French horns made. It does not depart radically from the conventional military model except to accommodate the longer windway through the valves, the crook required to put the instrument in F is the length of a standard

Figures 1a and 1b. French horn (military model, to be crooked in F or E♭), Patent Conical Bore. Rudall Carte & Co., London, 1907, serial number 5607. According to the firm's archives (stock books) held at the Horniman Museum, London, "French horn in F and E♭ combined"; entered in stock 18 December 1907; sold 26 August 1918 to "R.A.J. Sch Mus. £15/15/0". Author's collection; Edinburgh University Collection of Historic Musical Instruments (6390). Photograph: Raymond Parks. Views from above and from underneath.

crook for G; a crook of the usual length for F gives E♭ (this is also the case with French ascending-third-valve horns, but here the valves are all descending). The E. A. Couturier & Co. horn (Figure 2) is the "Direct Mouthpipe" model with the entry to the valves only 233 mm from the mouthpiece receiver.[15]

The bore profiles are shown in Figures 3 and 4 (excluding the terminal bell flares).

Figure 2. French horn (with tuning slides for F and E♭), Continuous Conical Bore, "Direct Mouthpipe" model. E. A. Couturier & Co., La Porte, Indiana, 1922–23, serial number 6170. Author's collection; Edinburgh University Collection of Historic Musical Instruments (6216). Photograph: Raymond Parks.

There are obvious differences with or without valves being operated. The bore profile influences timbre: instruments with more narrow tubing (relative to the initial bore) produce markedly brighter sounds at high dynamic levels where the sound becomes "brassy"—but the effect also influences the timbre at moderate dynamics. A measure of this effect, the "Brassiness Potential Parameter" which depends entirely on the geometry of the bore and lies between zero and one has been devised.[16] The Brassiness Potential for the Rudall Carte horn (with E♭ crook and no valves operated) is 0.57, whereas the Couturier horn (with E♭ slide and no valves operated) is 0.47. For a given dynamic, the Rudall Carte will sound brighter than the Couturier. An alternative interpretation

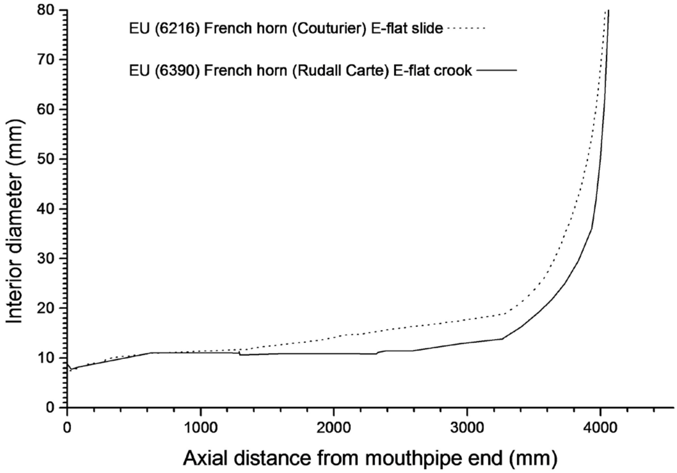

Figure 3. The overall bore profiles of conical-bore French horns by Rudall Carte (London, 1907) with E♭ crook and by Couturier (La Porte, Indiana, 1922–23) with tuning slide for E♭, no valves operated, omitting final bell flares. The main tuning slide of the Rudall Carte horn extends from 1586 mm to 2098 mm, the valves from 2174 mm to 2549 mm; the valves of the Couturier horn extend from 233 mm to 303 mm, the main tuning slide from 619 mm to 1378 mm.

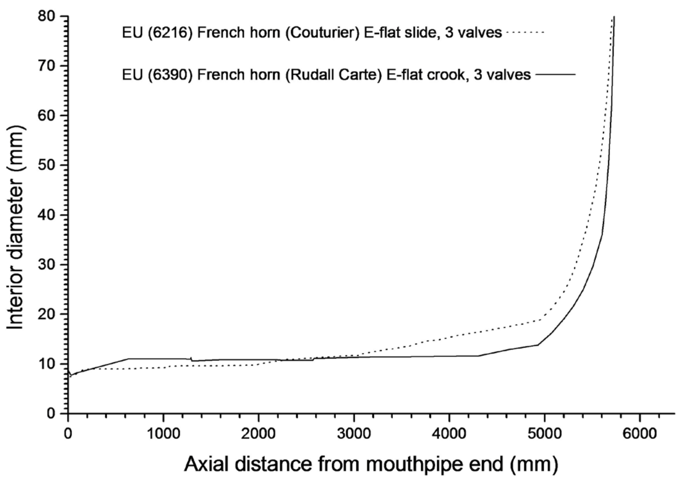

Figure 4. The overall bore profiles of conical-bore French horns by Rudall Carte (London, 1907) with E♭ crook and by Couturier (La Porte, Indiana, 1922–23) with tuning slide for E♭, with all three valves operated, omitting final bell flares.

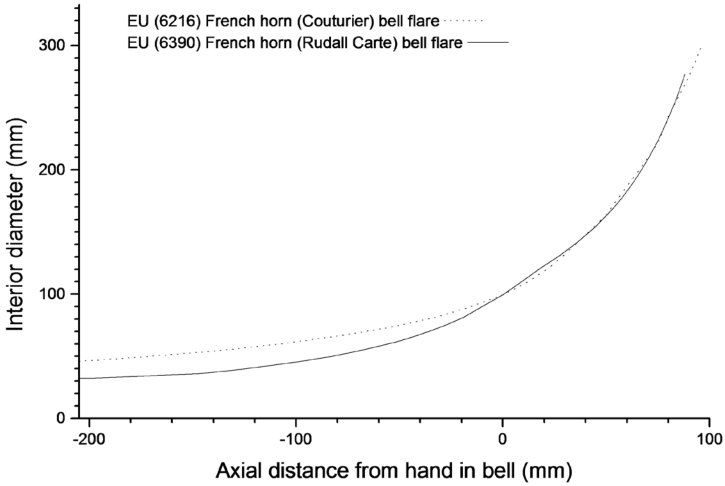

Figure 5. The bell flare bore profiles of conical-bore French horns by Rudall Carte (London, 1907) and by Couturier (La Porte, Indiana, 1922–23), axial distance measurements taken from the point where the internal diameter is 100 mm, a typical placement for the hand in the bell.

is that for a similar degree of brassy (*cuivré*) timbre, the Couturier horn will be playing at a greater volume than the Rudall Carte.

There is also a distinct difference in the bell flares, as shown in Figure 5. In 2004 the acoustician Robert Pyle investigated horns with narrow and with wide bell throats (typical of French and German models respectively) and found (confirming players' experience) that narrow bells are more sensitive to hand-stopping in that less hand movement is needed to achieve a given lowering of pitch.[17] A player's hand is placed in the bell at a depth where the diameter is approximately 100 mm, so a useful measure of bell throat is given by the angle of the bell wall at the point where the diameter is 100 mm. Measurements of a large number of French horn bells[18] have found that this angle ranges from around 20° to around 30°. The Rudall Carte horn has a bell wall angle of 28° (offering the player scope for hand-in-bell technique), while the Couturier has a bell wall angle of only 20.5° (suggesting that hand technique was less important to its intended players).

Conclusions

The two instrument-making firms attempting to improve instrument design by means of bore-profile engineering and specifically by reducing the proportion of cylindrical bore, Rudall Carte and E. A. Couturier, produced generally similar models of cornet and trumpet, of which the trumpets differed more from regular trumpets of the period.

Couturier alone attempted a conical-bore slide trombone. The most significant difference between the firms' models was in the French horns, with the Rudall Carte model being close to the piston-valve horn with crooks used in Britain while the Couturier, although having piston valves, was of original design suited for a more modern (louder) performing style.

Surviving Instruments

The extant Rudall Carte "Patent Conical-bore" instruments known to the author are listed with brief details on the Galpin Society website, URL: http://www.galpinsociety.org/reference.htm; the author would be glad to hear of other extant instruments.

Extant Couturier instruments are listed by Mike Keller in "Detailed Record of Couturier-Related Instruments" with brief details on the Horn-u-Copia website, URL http://www.horn-u-copia.net/Docs/Couturier%20db.htm

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Notes

1 Arnold Myers and Frank Tomes, "Rudall Carte's Patent Conical-bore Brasswind and Webster Trumpets." *Historic Brass Society Journal* 7 (1995): 107–22. This article also reviews earlier conical-bore models.

2 Henry Ernest Klussman, Montagu Sidney George, and Julius James George Zambra, "Improvements relating to wind musical instruments made of brass or other metal." Great Britain Patent 21295, issued 31 December 1903.

3 John E. Borland, "The brass wind instruments," in: T.L. Southgate, ed., *English Music [1604 to 1904] being the lectures given at the Music Loan Exhibition of the Worshipful Company of Musicians held at Fishmongers' Hall, London Bridge, June-July 1904* (London, 1906), 445–77.

4 Myers and Tomes, "Rudall Carte's Patent Conical-bore Brasswind."

[5] H. M. Galloway, "Ernst Albert Couturier: American cornet virtuoso." *Journal of the International Trumpet Guild* 14, No. 4 (May 1990): 35–55.

[6] The E. A. Couturier Band Instrument Co., *Continuous Conical-bore Band Instruments* (La Porte, IN, ca. 1922) (trade catalogue describing and illustrating regular production models).

[7] David J. Blaikley, "On brass wind instruments as resonators." *Proceedings of the Physical Society of London* 2 (1875): 261–71; idem, "Communication respecting a point in the theory of brass instruments." *Proceedings of the Musical Association*, 4th Session (1877–78): 56–67.

[8] Ernst A. Couturier, "Cornet." United States Patent 1073593, issued 23 September 1913. Couturier subsequently took out patents for other conical-bore instruments.

[9] E. A. Couturier Band Instrument Co., Continuous Conical-bore Band Instruments.

[10] Arnold Myers, "How Different are Cornets and Trumpets?" *Historic Brass Society Journal* 24 (2012): 113–28.

[11] Ibid.

[12] Ernst A. Couturier, *Slide-Trombone*, U.S. Patent No. 1,385,202 of 19 July 1921 (application filed 25 June 1919).

[13] Michaud, *Trombone à coulisse*. Brevet d'invention de 15 ans No. 8014, deposé 26 Fev. 1849, delivré 27 Avr. 1849. There are examples of the Michaud conical-bore slide trombone in the Musikinstrumenten-Museum Markneukirchen (Inv. No. 145, formerly in the collection of Wilhelm Wieprecht) and in the Conservatoire National des Arts et Métiers, Paris (Inv no. 11015).

[14] See C. R. Day, *A Descriptive Catalogue of the Musical Instruments recently exhibited at the Royal Military Exhibition, London, 1890* (London: Eyre & Spottiswoode, 1891), item 377.

[15] E. A. Couturier conical-bore French horns were covered by U.S. Patent 1,438,363 granted to E. A. Couturier on 12 Dec 1922, which corresponds precisely to the example shown in Figure 2.

[16] Arnold Myers, Robert W. Pyle Jr., Joël Gilbert, D. Murray Campbell, Shona Logie, and John P. Chick, "Effects of nonlinear sound propagation on the characteristic timbres of brass instruments," *Journal of the Acoustical Society of America* 131, Issue 1 (2012): 678–88. For a simplified account of brassiness potential, see Arnold Myers and D. Murray Campbell, "Brassiness and the characterization of brass musical instrument designs," *Echoes: The Newsletter of the Acoustical Society of America* 18, no. 3 (Summer 2008) http://acousticalsociety.org/sites/default/files/docs/echoes/vol18no3.pdf

[17] Robert Pyle, "An Acoustical Comparison of Typical German and French hand horn," in Boje E. Hans Schmul and Monika Lustig, eds., *Jagd- und Waldhörner—Geschichte und musikalische Nutzung: Bericht über das 25 Musikinstrumentenbau-Symposium in Michaelstein, 8–10 Oktober 2004*, Michaelsteiner Konferenzberichte 70 (Augsburg: Wissner; Blankenburg, Harz: Stiftung Kloster Michaelstein, 2006), 391–410.

[18] Paul Lewis, Arnold Myers, and Raymond Parks, "French Horns and Cornophones," *Historic Musical Instruments in the Edinburgh University Collection: Catalogue of the Collection*, vol. 2, part H, fascicle vi (Edinburgh: Edinburgh University Collection of Historic Musical Instruments, 2006).