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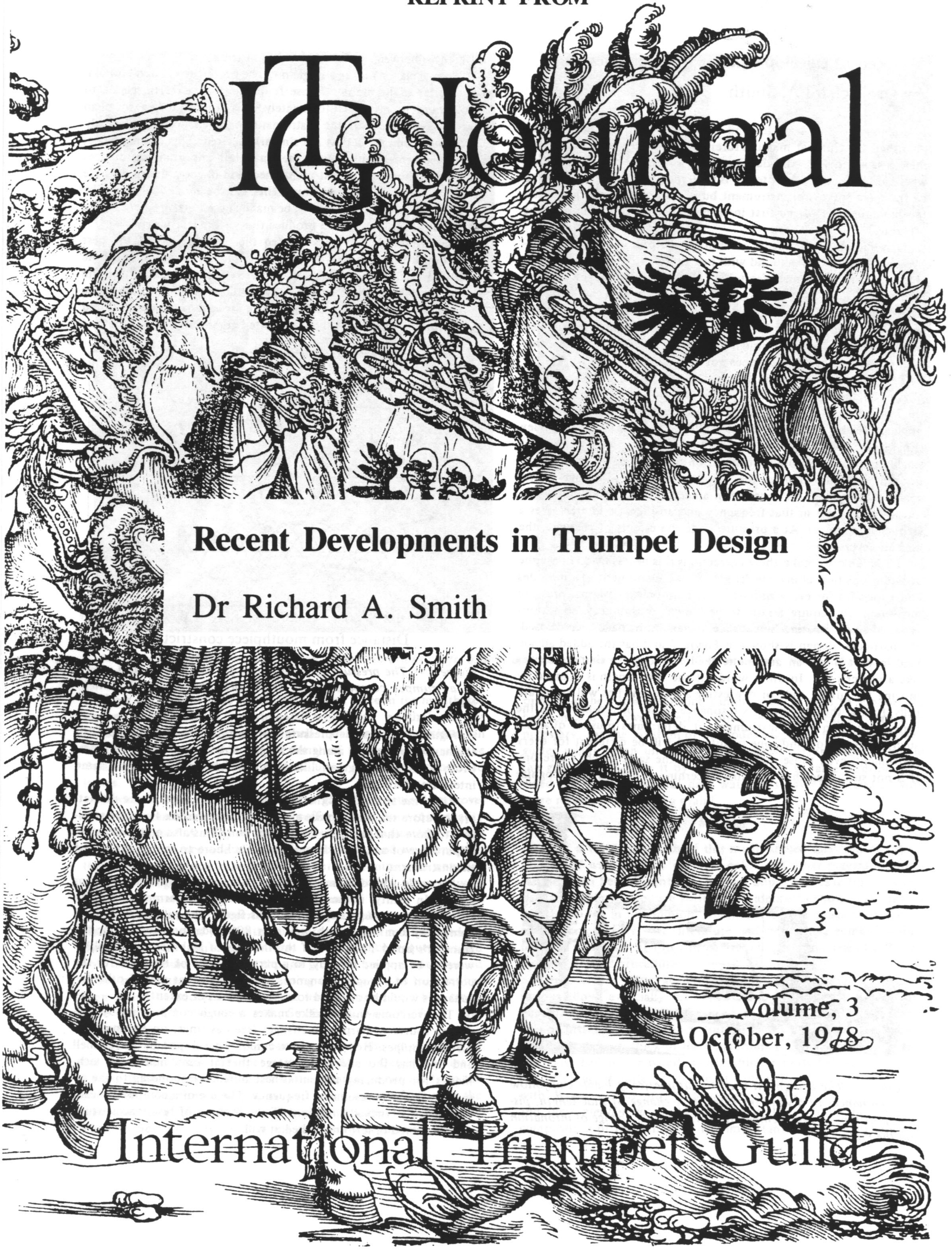

Recent Developments in Trumpet Design

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Recent Developments in Trumpet Design

by Dr. Richard A. Smith

Judging by the quantity and quality of technical information published by trumpet manufacturers, one may readily assume that their instruments are still developed by a form of natural selection where an instrument built today is patterned after what is judged to be the most successful instrument built yesterday, in the hope that the best qualities of the first instrument will be reproduced in the offspring.

Manufacturers' catalogues are not too helpful with their qualitative description; they abound with pseudo-scientific jargon, presumably reflecting the manufacturers' idea of their market requirements.

However, it is encouraging that a few makers, Renold Schilke and Boosey and Hawkes, for example, give some indication of their developmental methods through published material in the hope that essential design information does not die with the skilled worker.

Schilke and Boosey and Hawkes (Smith, R.A. & Daniell, G.J., *Nature 262*, p. 761-765, 1976.) have developed techniques where the intonation of a trumpet can be improved. Both are based on the original work attributed to Mahillon (Belgium) and Blaikley (England) towards the end of the 19th century, who found that small changes in the bore cross section near a pressure node (zero) or antinode (maximum) of the standing wave would change the resonance frequency. (A decrease in area at a pressure antinode produces an increase in that frequency and an increase in area gives a frequency decrease. At a pressure node the effects of changing the area are reversed.)

To be able to make these corrections it is necessary to know the accurate position along the length of the instrument of the nodes and antinodes for every note (and its harmonics). Internal pressure measurements require a note to be blown continuously, so various types of self regulating 'lips' or sound generators have been devised. My particular design is shown in *Figure 1* and has the added advantage in that it has an automatic feedback loop, so that it behaves like a player's lips. In other words, if the tube length is changed by moving the tuning slide or depressing a valve, the lips will automatically follow the instrument's resonance. A set of resonances is the fingerprint of a wind instrument; it determines musical qualities such as intonation and tone quality and will be different for every instrument, even those manufactured in the same batch. Therefore, it is not surprising that the most discerning of players can recognize differences between so-called identical instruments.

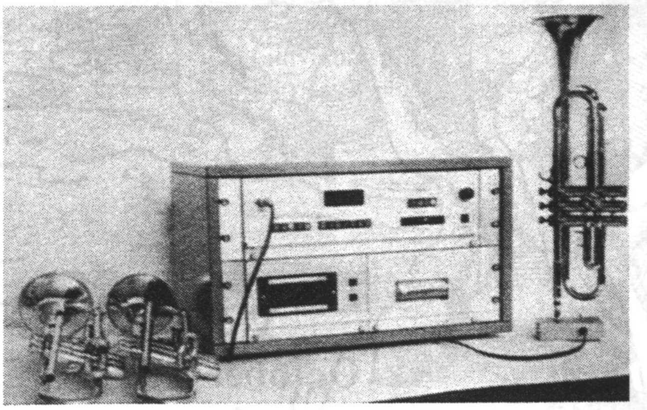

Figure 1 – The equipment used to automatically locate and follow the resonances of a wind instrument. A change of slide length, piston position, or even temperature will show a change of intonation on the meter.

When a player makes a single note, he produces a sound containing a series of harmonics whose frequencies are ***exactly*** related to whole number ratios. Unfortunately, this is often taken to mean that the resonances of the instrument (or open notes, incorrectly called the harmonic series) are similarly related. This cannot be so, as a) their irregularity causes the small but important differences between instruments as just mentioned, and b) acousticians are able to move them so that improvements can be made. It should be added that a compromise has to be made and no arrangement of the instrument's resonances will produce the *perfect* instrument.

The automatic tuner has assisted the development of the best compromise of resonance position to improve intonation and tone quality. Initially, the tuner was allowed to locate and excite the second resonance (note name: Low B-flat$_3$) while a microphone probe was pulled through the bore. The pressure response measured by the microphone could then be plotted graphically.

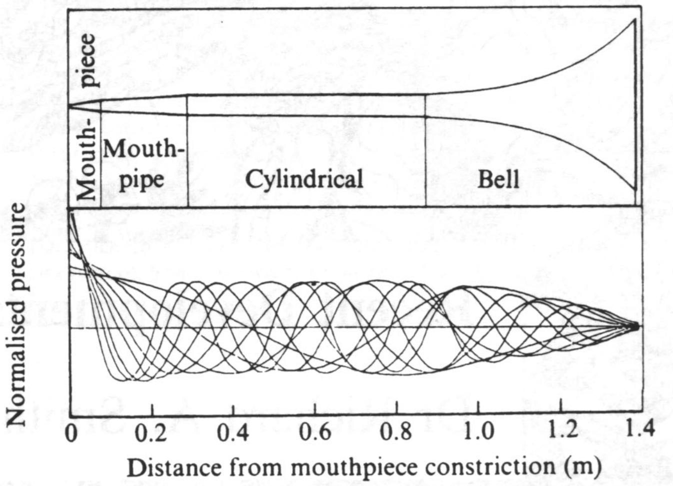

Figure 2 – The pressure standing waves for the 2nd to 10th modes of a trumpet compared with its physical shape. (Smith-Daniell/ Nature).

Figure 2 shows the pressure distribution (for the 2nd to 10th resonances) measured along the length of an 'open' B-flat trumpet. From a composite graph like this, one can readily deduce some interesting features.

First, the strength of the pressures depends on the bore diameter; therefore the mouthpiece and mouthpipe area are far more sensitive to bore changes than the bell section. This also emphasizes the importance of a suitable mouthpiece backbore to match the rest of the instrument.

Secondly, this diagram shows only nine of the pressure waves for clarity. In reality, if the patterns of all notes and harmonics used by the player were superimposed on this figure, the picture would become very confusing with well over 800 nodal positions along the trumpet's bore! Therefore, if the theories of Mahillon and Blaikley were to be applied directly to a particular part of the bore for the correction of a single resonance, it is obvious that several other resonances would be affected to a greater or lesser extent.

To overcome this, Schilke makes a rough compromise by producing fourteen sharp bore changes (seen as rings) on the inside of his mouthpipes. However, the technique developed by Dr. Daniell and me has the added advantage that it uses numerical techniques for producing the smoothest bore corresponding to the required change in resonance frequency. The use of a computer means that there is virtually no limit to the number of resonances which can be altered or left untouched at will.

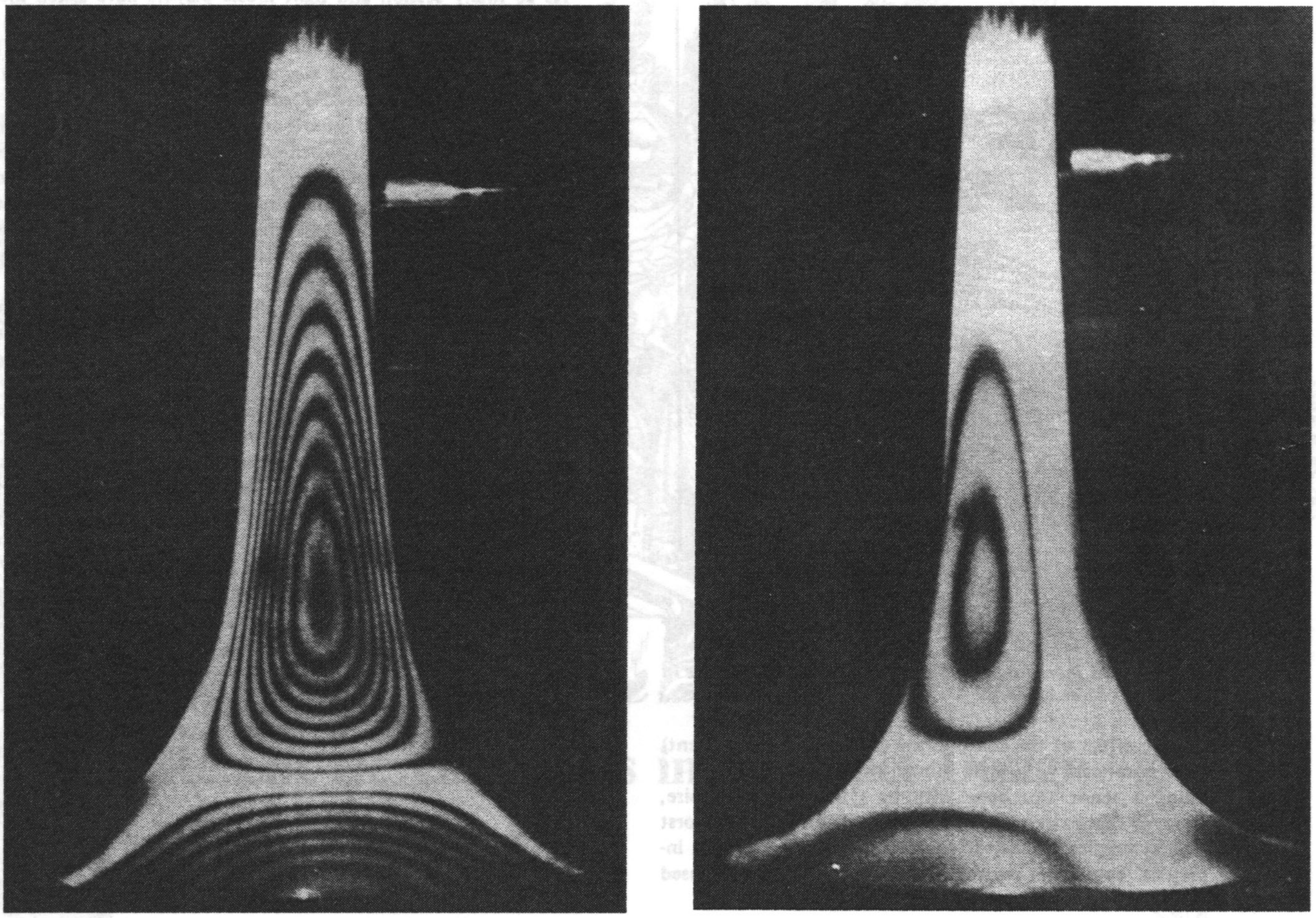

Figure 3 — Holographic reconstruction of bell vibrations. Left: 0.3mm approx. wall thickness. Right: 0.4mm approx. wall thickness. (Crown Copyright, N.P.L.)

Bore corrections have traditionally taken place in the mouthpipe region, partly because experimental mouthpipe mandrels are far easier and cheaper to produce than bell mandrels. Our technique can be applied to any section (or sections) of the instrument and the data can be converted into mandrels using numerically controlled lathes.

Earlier trials with perturbed bores gave the required improvement in intonation but a few notes suffered from poor tone quality and "stuffiness." A study of their tonal spectrum indicated a change in harmonic balance due to these perturbations, and we found that the resonances which support the higher harmonics were now out of tune through neglect. By extending our frequency range we were able to accommodate for the higher resonances.

The technique just described is used for making changes to the resonance pattern of an existing instrument, and is not intended for the design of an instrument *in toto*. The resonance frequencies and bore shape should be known, though great accuracy is not required as the information we have concerning the bore of one trumpet has been scaled up successfully to make improvements to a bass trombone (Pratt, R.L. Bowsher, J.M., Smith, R.A. *Nature 271*, p. 146-147, 1978).

More recently, I have been concerned with the development of the Sovereign *Studio* trumpet with the help of Derek Watkins, a leading British session player. An earlier prototype derived from the Sovereign *Symphony* trumpet showed an intonation fault with the high concert *g'* (G_6 1568Hz). This note uses the 13th resonance which is not normally used in the symphony repertoire. (Being a prime number, this resonance cannot even be used to support the harmonics of a lower note.) In this case no great calculations were necessary, for the position of the nodes suggested that the waterkey gutter might be an unwanted or misplaced perturbation. Filling in the gutter, or moving it by 7mm to a more suitable position, provided the cure. Since that day, waterkeys have been treated with more reverence than just a drain!

Material

Only a brief discussion of this much argued question of the influence of wall material on tone color and other playing qualities can be given here. Essentially, it is an impossible task for the scientist to be able to produce sufficient evidence to show that a player may be wrong in his opinion, whether it be for or against the argument. Superficially, the literature indicates disagreement among research workers, but this can be attributed to the use of different instruments and procedures.

Great claims have been made for the acoustic properties of various alloys, especially the expensive ones! Tests that I have conducted suggest that an experienced panel of players and listeners cannot distinguish between a trumpet with a fiberglass bell and a brass bell (0.5mm thick of the same internal dimensions), but if this fiberglass bell is compared with a thinner brass bell (e.g. 0.3mm) the difference is quite noticeable. It would also appear, in agreement with Wogram (*Das Musikinstrument*, p. 1193-1194, Sept. 1977, and *Instrumentenbau*, p. 414-418, May, 1976), that the chemical composition of the bell is far less important than its thickness, and

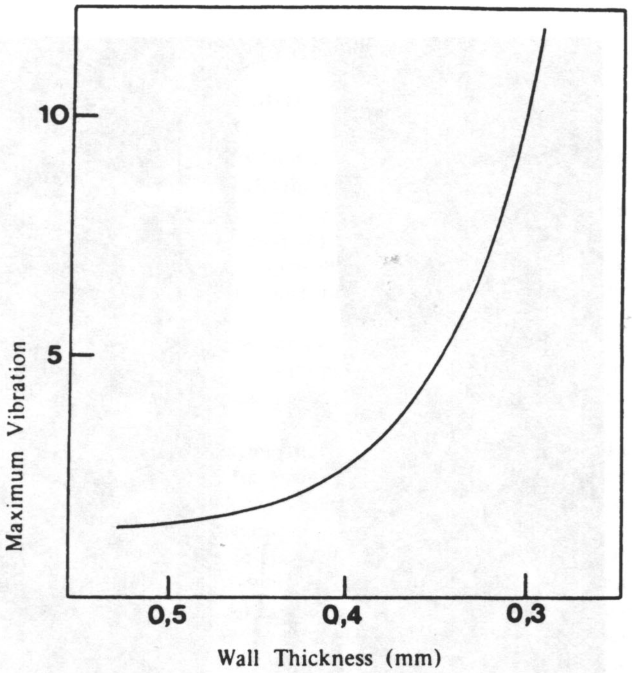

Figure 4 – The rapid increase of wall vibration with the decrease in wall thickness.

in my view, the effect of the composition (and any heat treatment) only becomes significant with these thinner gauges.

By testing a tenor trombone with its symphonic repertoire, Wogram "proved that extremely thin-walled bells turn out the worst response characteristics." This, of course, does not necessarily invalidate players' comments regarding trumpets or trombones used with other music.

As so many session and light music players have asked me to make thinner bells, it seemed that there should be a good reason for this request. Using a holographic technique (with lasers) at the National Physical Laboratory, I was able to observe the vibrations for bells of various thicknesses. *Figure 3* shows an example of the vibration of two bells, 0.3mm and 0.4mm thick. The number of rings (or contour lines) shows the degree of vibration. When several bells of different thicknesses are measured, it is possible to plot a graph (*Figure 4*) showing that the amount of vibration increases rapidly for only a small change in thickness. (Calculations agree with this curve, where the vibration is inversely proportional to the fourth power of material thickness.)

From a playing point of view, this material vibration appears to accentuate the higher frequencies and increase the responsiveness of the upper register. Further work is being undertaken to increase our understanding of this phenomenon.

Lastly, a few words on construction, for the ergonomics of trumpet playing rates highly in the players' requirements. In realizing that many of our customers hold their instruments to their lips for long periods, weight has been considered to be a very important factor. At 940 grams, the instruments are among the lightest B-flat trumpets available on the current market. Secondly, the distribution of weight is just as important, so the balance has been carefully adjusted. Great care has also been taken in the positioning of angled shunt rings, piston centers and the mechanical action. Small details maybe, but all aimed at helping the player forget his instrument and concentrate on producing beautiful music.

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The author of this article Dr. Richard Smith has research degrees in both woodwind and brass acoustical design, and was for 12 years the chief designer with Boosey and Hawkes Ltd. With his own company in London, he now applies this broad experience to the design of bespoke brass instruments for individual players. Dr. Smith is also a competent musician and regularly plays contra bassoon in London.

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