The Four-Valve Compensating System

by
David Werden

All brass instruments share some common characteristics. They are all essentially tubes, at one end of which is found a musician vibrating his lips in order to produce a tone. Played in this way, any tube (even a length of garden hose) will produce a series of widely spaced notes, known as the "partial series." With no other means of pitch adjustment, the musician could play only melodies as simple as bugle calls (a standard bugle is, in fact, just that simple an instrument).

In order to fill in between these notes, brass instruments employ either a series of valves or a fully movable slide (as on the trombone). This discussion deals with valve systems.

The valve is a device which, when depressed, detours the sound waves through an extra length of tubing. This action (which has the same effect as extending a trombone's slide) causes the working length of the instrument to become longer, thereby lowering the pitch. The valves of virtually all instruments in use today are set up in the same way: the 2nd valve lowers the pitch 1/2 step, the 1st valve lowers the pitch 1 step (2 half steps), and the 3rd valve lowers the pitch 1-1/2 steps (3 half steps). If there is a 4th valve it will lower the pitch by 2-1/2 steps (5 half steps).

Usually unnoticed by the musician, a great deal of mathematics is going on under his fingertips. Based on acoustical theory, each time the player wishes to lower the pitch by 1/2 step, he must increase the working length of the instrument by approximately 6%. For the sake of mathematical convenience, imagine an instrument with a basic length of 100" when no valves are depressed (this is only slightly longer than a Bb euphonium). If the 2nd valve is to lower the pitch by 1/2 step, its tubing would then have to be 6" long (6% x 100"). The total working length is now 106". To lower the pitch another 1/2 step below this level, the instrument needs an additional 6.36" of tubing (6% x 106" = 6.36"). Therefore, in order for the 1st valve to be capable of lowering the pitch of the basic instrument by 1 step, its tubing should be 12.36" long (6" + 6.36"). With just the 1st valve depressed, the total working length is now 112.36". For another 1/2 step below this level, an additional 6.74" of tubing (6% x 112.36") is necessary. Therefore, the 3rd valve's tubing should be 19.1 " long (12.36 + 6.74) in order to produce the desired 1-1/2 step change.

As seen in the preceding paragraph, changes of 1/2 step, 1 whole step, and 1-1/2 steps, require adding 6%, 12.36%, and 19.1% respectively to the working length of the instrument. While each of the 3 valves can be designed to provide exactly the length needed when it is used alone, a conflict arises when 2 or 3 valves are used at the same time. Using the example of a 100" instrument, the working length with the 3rd valve depressed would be 119.1". To lower the pitch by 1 step from this point, 12.36% must be added to its length, which in this case would be 14.7" (12.36% x 119.1 " = 14.7"). Since the 1st valve's tubing is only 12.36" long, the 1 & 3 combination will be quite sharp. Because of similar discrepancies, 2 & 3 will be slightly sharp and 1, 2 & 3 will be a full 1/4 step sharp.

The problem becomes more severe with 4-valve instruments. The 4th valve alone is used in place of 1 & 3, and can be designed to provide the 33.8" (in the case of a 100" instrument) necessary to lower the pitch a perfect fourth (5 half steps). Also, the 2nd and 4th valves can be used together as a satisfactory substitute for the troublesome 1, 2 & 3 combination. However, below this pitch level the problems become severe. For example, with the 4th valve depressed the instrument's working length is 133.8". To lower the pitch another whole step, an additional 16.5" (12.36% x 133.8") would have to be added, but the 1st valve can provide only 12.36", leaving the pitch quite sharp. However, 1 & 2 together would add 18.36", making the pitch somewhat flat. With just the 4th valve depressed, lowering the pitch by a diminished fifth (6 half steps) would require the addition of 55.9" (41.8% x 133.8"). Unfortunately, the 1st, 2nd & 3rd valves together only add up to 37.46", and can produce slightly less than 5 half steps of pitch change below the 4th valve alone. On a Bb instrument such as the euphonium, all 4 valves together produce a slightly sharp C, leaving a low B unavailable. Consequently, a full chromatic scale between the 1st and 2nd partials is not possible.

While mechanical devices (such as lever-operated tuning slides) may be used on smaller instruments as a means of adjusting intonation, such cures are not practical for instruments the size of euphoniums or tubas.

The Four-Valve Compensating System

If a euphonium or tuba player wishes to be able to play a full chromatic scale in the lower register, a 4valve compensating system is the best answer. The 4th valve tubing routes back through the first 3 valves so that when the 4th valve is used in combination with any other(s), air can automatically be detoured through extra compensating loops.

Progressing downward from the open horn, the first five fingerings (2, 1, 3, 23, and 4) don't involve the compensating system as their intonation is satisfactory. However, the compensating loops are used for the next six fingerings (24, 14, 34, 234, 134, and 1234), since their pitch would otherwise vary from uncomfortable to unusable. Diagrams 1 through 4 (linked below) show some of these situations, in which the detours have provided for bringing down the pitch of these sharp fingerings.

The compensating system makes it possible to play a full chromatic scale between the 1st and 2nd partials. All four valves together will produce a usable B, l/2 step above the first partial. On a non-compensating instrument, this same fingering would only produce a sharp C, leaving the B unavailable.

The compensated instrument has the further advantage of being able to play in the lower octaves using conventional fingerings. For example, a euphonium player would use 23 for a middle-range Db. To play an octave lower he would simply add the 4th valve. On a non-compensating euphonium, he would have to use 134 to approximate the lower Db.

While the compensating system may seem complicated, remember that the player needn't be aware of all the mathematical theory behind it. He need only play the instrument and let tubing design resolve the inherent conflicts. In fact, simplicity is one of the benefits of the compensating system. As an illustration of this, consider the professional-grade non-compensating tubas on the market. Many of these employ 5 or 6 valves whose purpose is to allow for enough alternate fingerings to be able to play a full chromatic scale.

One of the most respected of modern texts dealing with the euphonium and tuba is The Tuba Family by Clifford Bevan. He begins his discussion of the compensating system by saying, " By the 1870's it was obvious that the most satisfactory method of compensation would be completely automatic (probably the player's lack of enthusiasm for extra valves, levers and keys was striking home). In fact the first completely automatic system turned out to be the best.'' (Clifford Bevan, The Tuba Family (New York: Charles Scribner's Sons, 1978); p. 82)

4th-Valve Placement: a "Side Issue"

While many manufacturers place the 4th valve immediately next to the 3rd, Hirsbrunner and Sterling-Perantucci place the 4th valve halfway down the right side of the instrument, intended to be played with the left hand. While this can be justified by simply noting the relative weakness of the 4th finger of the right hand, there is also a consideration relating to the compensating system.

Euphoniums are essentially conical-bore instruments. That is, their tubing is almost constantly expanding from the mouthpiece to the bell. The most notable exception to this is found within the 1st, 2nd & 3rd valves, where the bore size is constant. However, the separation between the 3rd and 4th valves allows the connecting tubing to expand gradually as it approaches and passes through the 4th valve's tubing, maintaining a more constant taper. For example, in the case of the Sterling-Perantucci euphonium the main bore (measured at the 2nd valve) is.592". At the compensating loops it has expanded to .630", and it expands to .670" within the remainder of the 4th valve tubing. By preserving a more conical bore through this area, freedom of response and consistency of tone are enhanced.

Diagrams of Compensating Action

Diagram 1: The sound passes through the 1st valve tuning slide and no others

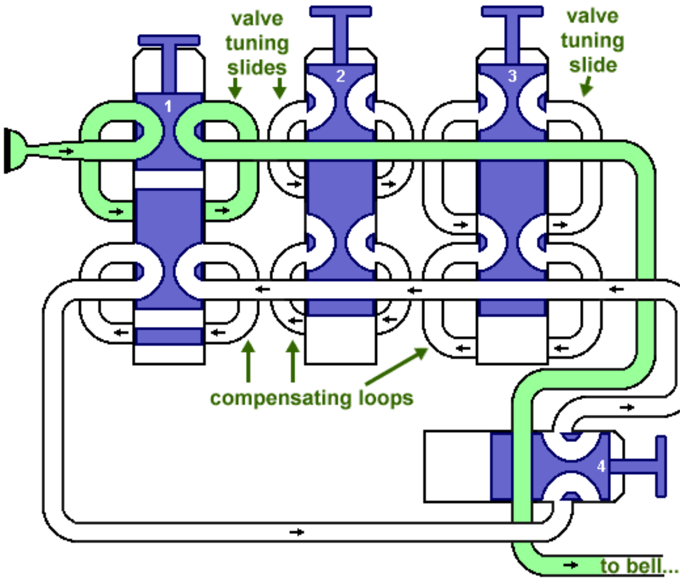


Diagram 2: The sound passes through the 4th valve tuning slide and no others

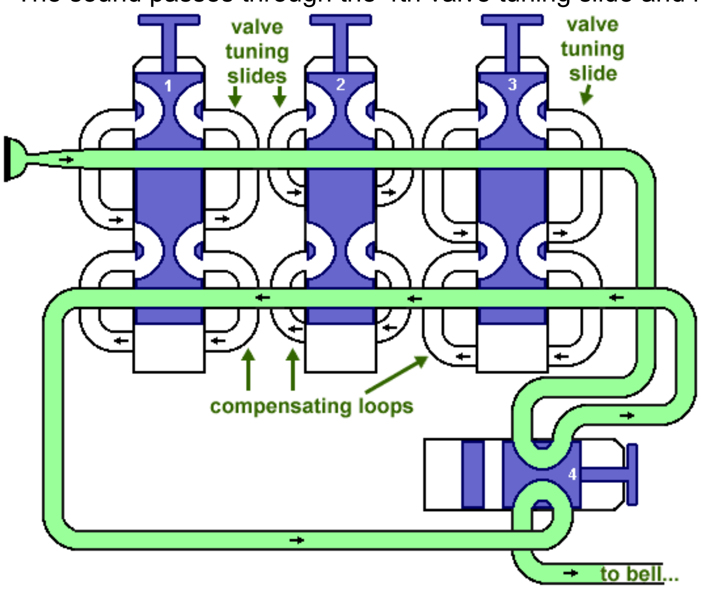


Diagram 3: The air passes through the 1st valve tuning slide, the 4th valve tuning slide, and the 1st valve compensating loop

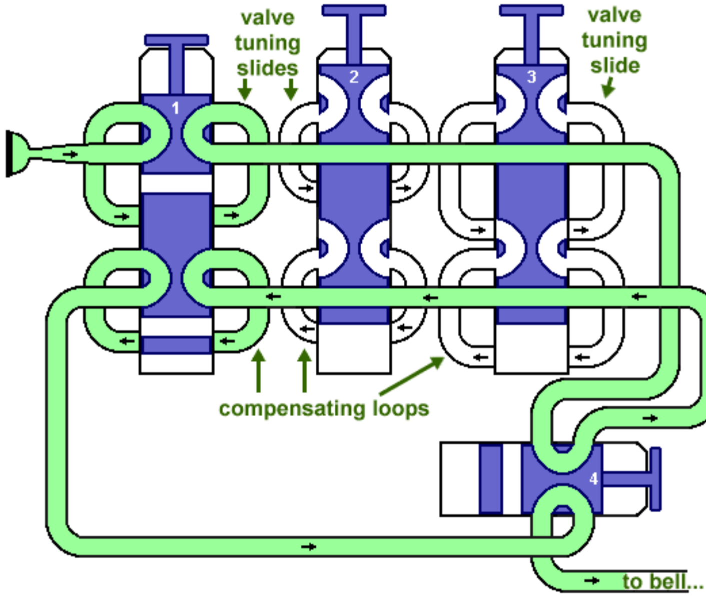
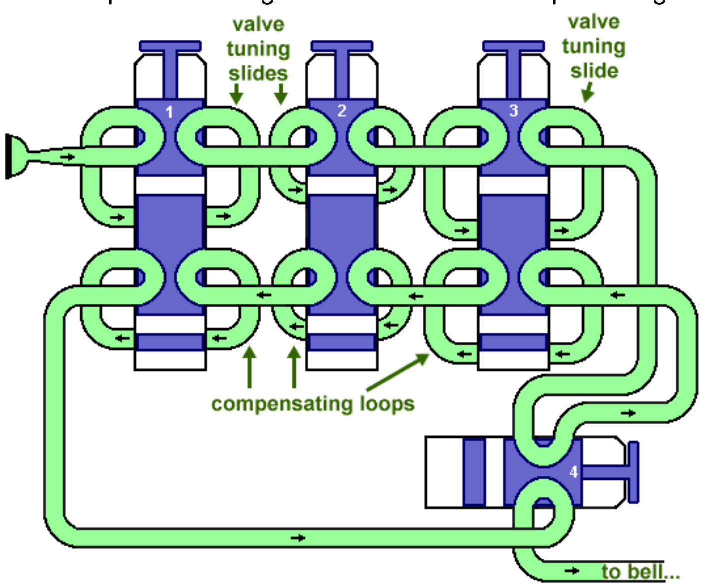


Diagram 4: The air passes through all valves and all compensating loops



David Werden

A graduate of The University of Iowa, Mr. Werden was the euphonium soloist with The United States Coast Guard Band for more than 20 years. He has performed throughout the United States, as well as in Canada, England, Japan, and the former Soviet Union. Through FM and TV broadcasts, his solos have been heard in dozens of countries around the world. He is a recitalist and clinician, and has performed at local, national, and international symposiums. He was a member of The USCG Band Euphonium/Tuba Quartet, the Atlantic Tuba Quartet, and the Classic Brass Band. He previously taught at the University of Connecticut and is listed in the 1996 edition of Marquis' *Who's Who in American Education*.

His efforts to expand the role and recognition of the euphonium led the British magazine Sounding Brass in conjunction with the American publication Euphonia to name him "Euphonium Player of the Year" in 1980. He is the first American awarded this honor. In 1981 he was elected to the post of Euphonium Coordinator for the Tubists Universal Brotherhood Association (T.U.B.A). In 1987 he was appointed to the Board of Directors of T.U.B.A. His many solo performances and his efforts to expand the role of the euphonium in music earned him the prestigious Coast Guard Commendation Medal. He has also been awarded two Coast Guard Achievement Medals, the Coast Guard Special Operations ribbon, two Coast Guard Unit Commendations, and three Coast Guard Meritorious Unit Commendations.

He has published articles in *Euphonia* magazine, *The Instrumentalist* magazine and the *T.U.B.A. Journal*. He is the author of *The Blaikley Compensating System*, *Scoring for Euphonium*, and is co-author with Denis Winter of the *Euphonium Music Guide*. He compiled and edited a series of papers by Arthur Lehman into the book *The Brass Musician*. He has also published over three dozen arrangements for a variety of solo instruments and ensembles.

David Werden is currently living in Minnesota and working as a computer consultant. He continues to work with Custom Music Company and Sterling Musical Instruments to develop and improve the Sterling compensating euphonium. Since moving to Minnesota he has performed with the Sheldon Theater Brass Band and has appeared on A Prairie Home Companion. He is in constant demand as a guest artist and clinician.

© 2003 – David Werden
All rights reserved.