AN INVESTIGATION OF EUPHONIUM VALVE SYSTEM DESIGN

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The four-valve automatic compensating system as developed by David James Blaikley has become an integral part of the professional euphonium in use today. While the Blaikley system was designed to allow a euphonium to play chromatically down to the fundamental pitch of the instrument, it was hardly the only design to do so. Using a historical analysis of euphonium valve systems, the case is made for why Blaikley's design has been widely adopted in the face of criticism about the four-valve automatic compensating system. The analysis also clarifies the viability of Blaikley's, as well as others', euphonium valve system designs based upon the four factors of intonation, range, intuitiveness of use, and weight. These factors are further explored in a rubric in order to quantify the results of the analysis.

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CHAPTER 1

THE MODERN EUPHONIUM

A Brief History of Euphonium Design

The euphonium was created in 1843 by Ferdinand Sommer, a bandmaster in Weimar, Germany.[1] The instrument was named as the sommerophone but patented as the 'Euphonion' by Franz Bock in 1844.[2] Like several brass instruments of the time, the euphonium was designed to take advantage of the emerging technology of the valve, which had been growing in popularity since its introduction in 1788.[3] Brass instruments operate on a series of pitches called the overtone series, the series of pitches that can be sounded using an open tube. In the case of brass instruments, the instruments are sounded by using air to vibrate the lips of the musician into a cup mouthpiece. Chromatic operation on a natural brass instrument meaning an instrument without any means of changing tube length is without manipulation or special technique, impossible.[4] To achieve chromatic operation on a brass instrument, it becomes necessary to develop or provide a means of adding or subtracting the tubing needed to lower the sounding pitch of the instrument.

Previous to the invention of the valve, there had been two means of changing notes chromatically on a brass instrument. The first was the operation of a long slide, which has developed into the modern trombone family of instruments. The second was the use of tone holes

[1] Michael B. O'Connor. "A Short History of the Euphonium and Baritone," In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 7.

[2] Ibid., 7.

[3] Eugene Walter Nash. "The Euphonium: Its History, Literature, and use in American Schools." (MM Thesis, University of Southern California, 1962), 40.

[4] Ibid.,36-39.

that when opened would vent causing a change in pitch.[5] These began with finger holes and can be observed on instruments like the serpent. Later, as manufacturing and development improved, tone holes became more exact. This had the added effect of changing the size of the tone holes which beforehand were limited to what the fingers could cover. Variable sizes of tone holes led to the application of key pads similar to the saxophone's means for covering tone holes.[6]

The valve had first been applied to brass instruments in 1788 by Charles Clagget, but manufacturing techniques and designs needed to be improved enough to provide a consistency of production and operation to mass apply the concept.[7] The first valves were rotor valves. Some of them being double-action valves like the Vienna valve where the action of depressing the valve activating two piston air passages with only one allowing air to pass when the valve is not engaged.[8] The next valve system, the Berliner pumpen, was a single-action piston improvement on the rotary system, but with a drastic angle difference of air passage within the valve.[9]

The application of valves ushered in a wave of creating new musical instruments, in which both the tuba and euphonium were two results of the design development and technological advancements. The euphonium, at the time the sommerophone, received honorable mentions in competitions and was even mentioned by Queen Victoria at the 1851 Great

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[5] Richard Demy. "The Automatic Compensating Euphonium as the Ideal Choice for Performing Music Composed Originally for Ophicleide" (DMA diss., University of North Texas, 2014), 6.

[6] Richard Demy. "The Automatic Compensating Euphonium as the Ideal Choice for Performing Music Composed Originally for Ophicleide" (DMA diss., University of North Texas, 2014), 6-7.

[7] Eugene Walter Nash. "The Euphonium: Its History, Literature, and use in American Schools." (MM Thesis, University of Southern California, 1962), 40.

[8] Michael B. O'Connor. "A Short History of the Euphonium and Baritone," In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 3.

[9] Eugene Walter Nash. "The Euphonium: Its History, Literature, and use in American Schools." (MM Thesis, University of Southern California, 1962), 44.

Exhibition where the instrument name was finally settled as the euphonium.[10] Sommer gave the instrument two possible names, sommerophone and euphonion, for which the public decided on euphonium. Euphonium, as it is called today, roughly translates to “well-sounding” horn which was deemed an appropriate name for the instrument.[11]

Over time, rotor valves would be improved upon in manufacturing due to harsh angles for the air passages within the valve itself. Using rotors in the early 1800s meant that there were marked pressure differences as valves were engaged.[12] Rotor valves operate by depressing a paddle tensioned with a spring that, through mechanical device or by string, turns a rotor which in turn reroutes air through separate tubing. Once the finger is lifted, the spring’s tension returns the paddle to the open position. There is also a spring in the rotor, which turns the rotor into its open position when the tension from the paddle is released. The valve type that replaced the rotor in euphonium design was the piston valve.

The piston valve, developed by Francois Perinet, is operated by depressing a metal button toward the valve cap.[13] A metal shaft connects the valve cap to the valve, which is held in an upwards position with a spring that is usually below the valve, and pushes the valve down. This movement depresses the spring, thereby increasing tension so that the valve can return to the top of the casing when the finger is lifted. This design favored less drastic angles in the tubing, meaning the change in air pressure, or back pressure, was less noticeable when the valve was depressed. It was this valve design which created the ability for systems like Pierre Gautrot’s

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[10] Michael B. O’Connor. “A Short History of the Euphonium and Baritone,” In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 7.

[11] Michael B. O’Connor. “A Short History of the Euphonium and Baritone,” In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 7.

[12] Eugene Walter Nash. "The Euphonium: Its History, Literature, and use in American Schools." (MM Thesis, University of Southern California, 1962), 44.

[13] Ibid., 44

systemme equitonique to exist. By using a piston valve, the manufacturer can create multiple pathways through the valve, meaning that it is possible to create a secondary loop from one valve, like the fourth valve, through the main valve cluster.[14] While this could be achieved using double-action rotary valves, the piston was a simpler, more effective design.

The wrap of the instrument also evolved over time to reflect the instrument we recognize today. The wrap refers to the design of the main tubing of the instrument after the tubing leaves the valve cluster. The euphonium is a conical instrument, meaning the instrument's tubing is increasing in bore size from lead pipe to bell, with the notable exception of the tubing related to the valve cluster. As the bore was gradually enlarged, so was the wrap of the instrument. This eventually became the wrap for the nine feet of tubing in the modern B-flat euphonium.[15]

Euphonium and Bands

While the euphonium has enjoyed prominence in most bands in the United States, the euphonium is perhaps best known for its inclusion in brass bands in the United Kingdom. Brass bands and military bands began as a byproduct of the industrial revolution, with the tradition starting in the 1830s, and brass-specific ensembles forming in the 1850s.[16] The nature of these industrial townships, mostly in the north, meant that there were very few activities outside of work, and would lead ultimately to companies sponsoring competitive brass and military bands in their communities.[17] The interest in brass bands and military bands created a large culture of ensemble competition in Great Britain that still lives in the brass band world. Today, community

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[14] Arnold Myers. "Brasswind Innovation and Output of Boosey & Co. in the Blaikley Era." *Historic Brass Society Journal* 1, no. 14 (2002): 403.

[15]Carl Kleinstuber. "An Argument in Favor of the Saxhorn Basse (French Tuba) in the Modern Symphony Orchestra."(DMA diss., University of North Texas, 2017), 10.

[16] Michael Arthur Mamminga. "British Brass Bands." (Ph.D. Diss., Florida State University, 1973), 3-9.

[17] Ibid., 3.

brass bands commonly participate in competitions. Community, in this case, is somewhat disingenuous, as these were factory and mining towns, and in most cases, the bandsmen were paid by these corporations to compete.[18] Each competition commissioned composers to write test pieces for ensembles to play, which has added a large amount of work to the brass band repertoire.[19]

The brass band eventually came to include B-flat and E-flat cornets, flugelhorn, E-flat alto horns, baritone horns, euphoniums, trombone, and BB-flat and E-flat tubas. This instrumentation grew out of Adolph Sax’s family of brass instruments known as saxhorns.[20] These instruments were patented in 1845, just one year after the euphonium.[21] One of the notable points of Adolphe Sax’s saxhorn family was alternating between B-flat and E-flat tuned instruments.[22] The military band, in contrast, is a mixture of brass and woodwinds almost analogous to the modern concert band.

Another hold-over from Adolphe Sax is the transposing treble clef tradition of the brass band. All brass instruments involved in brass bands, including traditionally non-transposing bass clef instruments like tuba, play in either B-flat or E-flat treble clef.[23] This tradition is perpetuated through the methods in which the bands operate. Having started as community ensembles, illnesses as well as other reasons to be absent from rehearsals cannot be avoided all the time. The simplicity of a transposing clef system means that another brass instrumentalist from the

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[18] Arnold Myers. "A New Introduction." In *Talks with Bandsmen: A Popular Handbook for Brass Instrumentalists* (London: Tony Bingham) 5.

[19] Ibid., 5.

[20] Trevor Herbert and Margaret Sarkissian. "Victorian Bands and their Dissemination in the Colonies." *Popular Music* 16, no. 2 (May, 1997): 167-168.

[21] Ibid., 167.

[22] Michael Arthur Mamminga. "British Brass Bands." (Ph.D. Diss., Florida State University, 1973), 12-13.

[23] Ibid., 22-23.

ensemble can cover another brass instrument if need be during rehearsal since the C4 written pitch will always be the basic open note of whichever instrument needs to be covered. This also takes for granted the normal sequence of brass instrument valve combinations descending from the overtone series. The aggregate of the chosen solutions means there is a written, not sounding, valve combination parity between instruments of the British brass band.

The competitive nature of the band environment also meant that contest pieces increased in difficulty. While the brass band tradition in the north of England is seen as the apex of the brass band tradition, more brass band literature came from London.[24] With works demanding higher and higher skill set, the need for higher quality instruments increased.[25] This meant that ensembles were constantly looking for instruments with better intonation, increased range, and easy operability. These ensembles were funded by industrial corporations, and musical instrument companies would sell sets of instruments at a time. These bands would be registered with the instrument companies, with companies like Besson & Company having 10,000 bands registered at times.[26] While Besson's numbers appear substantial, and to some degree they are, there were 40,000 brass bands in operation in the late 1890s.[27] Keeping track of and selling instrument sets was especially easy to do, as the maximum number of musicians was twenty-five, and the instrumentation within that number was codified since the ensemble type revolved

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[24] Arnold Myers. "A New Introduction." In *Talks with Bandsmen: A Popular Handbook for Brass Instrumentalists* (London: Tony Bingham) 5.

[25] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*. (Gloucester, England: Wright and Round LTD., [19??]), 46.

[26] Algernon S. Rose. *Talks with Bandsmen: A Popular Handbook for Brass Instrumentalists*. (London: Tony Bingham, 1895), 125.

[27] Arnold Myers. "A New Introduction." In *Talks with Bandsmen: A Popular Handbook for Brass Instrumentalists* (London: Tony Bingham) 5.

around several competitions.[28] The competitive nature, and the sets of instruments, would lead to marketing campaigns looking to sell more instrument sets featuring bands who placed well in these competitions.[29] It was in this competitive ensemble environment for which David James Blaikley of Boosey & Company, and his contemporaries at Besson & Company, Joseph Higham's factory, and Hawkes & Son were competing for more instrument sales.

The Blaikley Four-Valve Automatic Compensating System

The direct predecessor to the modern euphonium, the *systemme equitonique*, was created in France by Pierre Gautrot in 1865.[30] This euphonium has four valves and employs a means of porting the air through a second set of passages within the valve assembly. A version of the instrument was brought to the Boosey & Company factory where instrument designer David James Blaikley took interest in the design in the early 1870s. Blaikley set out to improve upon the *systemme equitonique*, eliminating one of six air passages within the valve assembly.[31] The original Blaikley automatic compensating euphonium had four valves and five passage ways within the valve assembly.[32] Gautrot's *systemme equitonique* and the four-valve automatic compensating euphonium by Blaikley were designed for specific issues related to range and intonation. The fourth valve on both instruments allows for chromatic playing down to the fundamental pitch of the euphonium which is B-flat when depressed. The design also allows for

[28] Michael Arthur Mamminga. "British Brass Bands." (Ph.D. Diss., Florida State University, 1973), 1.

[29] "Wright and Round's Brass Band News." *Wright and Round's Brass Band News,* September 1, 1914, 396, http://www.salford.ac.uk/__data/assets/xml_file/0004/530869/RoyNewsome.xml (accessed September 16, 2019) 1.

[30] Arnold Myers. "Brasswind Innovation and Output of Boosey & Co. in the Blaikley Era." *Historic Brass Society Journal.* Vol. 1, No 14 (2002): 403-404.

[31] Ibid., 403-404.

[32] Ibid., 404.

a replacement of the 1-3 and 1-2-3 valve combinations, or low C, B, F, and E on any b-flat brass instrument. These notes are notoriously sharp on any three-valve B-flat brass instrument.

Blaikley took the design of an automatic compensating system one-step further, applying the same principle to the three-valve euphonium, creating and patenting the three-valve automatic compensating euphonium in 1878.[33] The instrument provided the tubing necessary to play 1-3 in-tune but added nothing to the range. While this was the second instrument created by Blaikley with this principle, it was the only one patented. The three-valve automatic compensating euphonium by Blaikley was also the first of the compensating designs brought to market through Boosey & Company. The four-valve automatic compensating euphonium was eventually sold as a "perfected" compensating system.[34] These instruments, sold by Boosey & Company, would be the first of many instrument designs in Great Britain jockeying for a place in both competitive and professional bands.

Boosey & Company bought Hawkes & Son in 1930, becoming Boosey & Hawkes.[35] This meant the elimination of some competition in the musical instrument market and gives an idea to the popularity of Boosey & Co.'s instruments over its competitors. This, along with purchasing Besson in 1948, further solidified the market for the Blaikley four-valve automatic compensating euphonium.[36] The British brass band market was not the only market to be affected by rising popularity of Blaikley's design. In 1939, a British naval vessel docked in port near Washington

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[33] David James Blaikley. US216595A. *Improvements in Cornets*. United States, 1879.

[34] Arnold Myers. "Brasswind Innovation and Output of Boosey & Co. in the Blaikley Era." *Historic Brass Society Journal.* Vol. 1, No 14 (2002): 403-404.

[35] Michael B. O'Connor. "A Short History of the Euphonium and Baritone," In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 15.

[36] Ibid., 15.

D.C. swapped out their old instruments for new American-made instruments.[37] This was a routine custom for ships in port. It was there that Harold T. Brasch, a euphoniumist with the United States Navy Band, became aware of Boosey & Hawkes's four-valve automatic compensating euphonium. The euphonium eventually became popularized by Brasch, spreading to the rest of the United States' premier military bands.[38]

The popular euphonium design used in the United States military bands before the introduction of Blaikley's four-valve automatic compensating euphonium was the double-bell euphonium. This instrument, as its name suggests, has two bells. The bells can be in a few different configurations, with a larger bell next to the lead pipe and a smaller bell on the opposite side of the instrument. Depending on the manufacturer, either the smaller bell would be facing forward, or both would. The valve system employed by this instrument is typically a three- or four-valve non-compensating system. If the double-bell euphonium has four valves, it is a three-valve non-compensating system with the fourth valve switching between bells. If the instrument has five valves, it is a four-valve non-compensating system with the fifth valve switching between bells. The double-bell euphonium, while important in other aspects of euphonium history, especially the United States military bands, is not important in its valve design because of the scope of issues discussed in this dissertation. The valve system used for this instrument is the same as any three- or four-valve non-compensating instrument and does not solve any intonation or range issues.

[37] Edward Keith Mallett. "The Double Bell Euphonium: Design and Literature Past and Present - Volume 1." (DMA diss., Michigan State University, 1996), 17.

[38] Edward Keith Mallett. "The Double Bell Euphonium: Design and Literature Past and Present - Volume 1." (DMA diss., Michigan State University, 1996), 1.

The four-valve automatic compensating euphonium developed by David James Blaikley gained popularity outside of the military bands slowly. The four-valve design was adopted *en masse* by instrument manufacturers once the patent for Blaikley's three-valve automatic compensating euphonium expired in the 1978.[39] The design is now so widely applied by different instrument manufacturers that Blaikley's four-valve automatic compensating euphonium is regarded as the professional standard for the modern euphonium across the world, with a version of it being manufactured by just about every brass instrument manufacturer and played by most, if not all, euphonium soloists.

Critics of the Blaikley Four-Valve Automatic Compensating Euphonium

The four-valve automatic compensating system developed by David James Blaikley is the most well-known and widely used automatic compensating system for the euphonium, however, it is not without its critics. This mainly comes in the form of mathematical analysis, claiming that while the compensating system addresses intonation issues in the low range to some extent, it still does not account for tuning discrepancies of multiple valve usage. The point is disputed in terms of its validity, but the claim about this discrepancy is the same about multiple valve combinations in the low register in general. It is argued that the increased amount of valves per note causes pitches to run sharp to the point where playing in the low range with this system is impractical.[40] These intonation arguments about the Blaikley four-valve automatic compensating euphonium by Matthew McCready and others are incorporated into the Analysis of euphonium valve systems rubric in Appendix A. There are two major suggestions made by

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[39] Michael B. O'Connor. "A Short History of the Euphonium and Baritone," In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 7.

[40] Matthew A. McCready. "Compensating Systems: A Mathematical Comparison." *T.U.B.A. Journal* 12, no. 3 (February, 1985): 11-13.

these critics, one is the addition of sliding mechanisms to adjust slides on the main valve cluster, the other being to use an added fifth valve to a four-valve non-compensating euphonium.

One proposed method for fixing these issues is to use a mechanism for easier operation of valve slides, specifically the first valve slide.[41] The mechanism, amounting to a metal rod braced on the slide and valve tubing, would allow for easier adjustment of the slide. This, in turn, would allow easier access to a variable amount of tubing configurations to assist in improving intonation in the low register. The main issue, however, is that the first valve slide is not conducive to such operation due to the wrap of the instrument. The tubing faces away and downward from the musician, requiring the left hand to leave fourth valve operation to adjust any valve tuning slide mechanism.

Another proposed solution is abandoning the use of the four-valve automatic compensating euphonium altogether. This solution favors using an additive flat whole-step fifth-valve with a non-compensating four-valve euphonium, mainly the YEP-321 made by Yamaha.[42] The fifth valve would be dependent upon usage of the fourth, meaning that independent operation of the valve would be impossible. However, the valve is meant to specifically add more tubing in the low register, and making it an additive valve system where the valve can be added and taken away as needed creates a certain versatility that some might find appealing.

While not specifically for the low register of the instrument, some manufacturers have added a trigger mechanism placed in-between the tubing of the third valve to allow for easier main tuning-slide operation. This would suggest that intonation on low notes can be an issue on four-valve automatic compensating euphoniums, and as such, not beyond reason that using the

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[41] Peggy Heinkel and Dan Vinson. "The Obvious Solution." *T.U.B.A. Journal* 10, no. 2 (Fall, 1982): 4.

[42] Matthew A. McCready. "Compensating Systems: A Mathematical Comparison." *T.U.B.A. Journal* 12, no. 3 (February, 1985): 13-14.

main tuning slide might be a better solution than either additive valves or devices meant to manipulate smaller slides in impractical places. However, the need for such a tuning mechanism might be overstated.

Mathematical tubing optimization has been rigorously discussed for most of the modern valve combinations of tubas and euphoniums with articles by Matthew McCready and Frederick J. Young in academic journals.[43] The culmination of this research does, in fact, show deficiencies in the tubing length for the four-valve automatic compensating euphonium as designed by Blaikley. The mathematic discussion of tube lengths and physics has generally left out the player's experience from the conversation. In response to the mathematical critique, the counterpoint to this has been to make use of the small slides on the back of the valve cluster that route the air through Blaikley's compensating system.[44] It should be noted that on most euphoniums, the amount these slides can be adjusted is minimal, though it has been claimed to be of use when considering the intonation challenges inherent in playing in the low register.

Other solutions in early euphonium manufacturing have been to create a wrap where the tubing drastically changes bore size so the tubing is significantly larger after the fourth valve, allowing for larger manipulation possibilities for adjusting pitch with just the embouchure, colloquially referred to as "lipping" notes up or down.[45] The inclusion of such a sudden bore size change was seen as a workable solution to the issue, but in turn creates other issues. Sudden pressure changes can cause problems like stopping lip vibration, drifting flat due to unsupported

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[43] Frederick J. Young. "The Optimal Design and Fair Comparison of Valve Systems for Brass Instruments: Part I." *T.U.B.A. Journal* 13, no. 4 (May, 1986): 30-33

[44] David Werden. "The Blaikley Compensating System: A Player's Perspective." *T.U.B.A. Journal* 13, no. 1 (August, 1985): 17-18.

[45] 4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 46. (Gloucester, England: Wright and Round LTD., [19??]), 45-46.

air flow, and other challenges that are not advantageous to playing a brass instrument. Some instruments, like the Willson 2900 euphonium, have scaled back this difference in bore size, favoring better response than a wider range to "lip" notes into tune.[46]

Many of these arguments brought up in articles seem to be primarily concerned with selling the particular solution the authors have come up with. While this is hardly an unbiased viewpoint of the issue, the issues surrounding Blaikley's four-valve automatic compensating system are apparent in other research on ideal tube length.[47] One article that seems ignored in the conversation is, perhaps, the argument that matters the most: that of the practical experience of the musician playing the euphonium by David Werden.[48] The reason this account matters is possibly for the most obvious reason: it provides an account that downplays the faults of the Blaikley four-valve automatic compensating euphonium. David Werden also adds information about a five-valve euphonium in production at the time that was omitted by McCready's article in favor of the additive fifth valve, further complicating the argument McCready was trying to make. This *T.U.B.A.* [49] *Journal* tete-a-tete, while interesting in its own right, is not enough to cover the discussion of these issues, relying on the comprehensive four-part article by Dr. Frederick J. Young to confirm the tubing length deficiencies.[50]

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[46] Sharon Huff. "The Life and Career Contributions of Brian L. Bowman through 1991." (University of Illinois at Urbana-Champaign, 1994), 172.

[47] Frederick J. Young. "The Optimal Design and Fair Comparison of Valve Systems for Brass Instruments: Part II." *T.U.B.A. Journal* 14, no. 1 (August, 1986): 35-39.

[48] David Werden. "The Blaikley Compensating System: A Player's Perspective." *T.U.B.A. Journal* 13, no. 1 (August, 1985): 17-18.

[49] Tuba Universal Brotherhood Association, now ITEA or International Tuba Euphonium Association

[50] Frederick J. Young. "The Optimal Design and Fair Comparison of Valve Systems for Brass Instruments: Part II." *T.U.B.A. Journal* 14, no. 1 (August, 1986): 35-39.

CHAPTER 2

DEFINING OPERATING ISSUES

Brass Instrument Operating Methods

Brass instruments are based upon pitches sounded by buzzing into a cupped mouthpiece through a tube. The pitches created by a static tube are not diatonic or chromatic, instead relying upon the overtone series. The overtone series is the aggregate of frequency distances for which an open tube will produce pitches when they are buzzed into. The lowest pitch is referred to as the fundamental where the pitch or key of the instrument is derived. The intervals diminish in size the higher the pitches in the overtone series, starting from an octave from the fundamental, then a fifth, then fourth, third, etc. This means that before the application of slides, tone-holes, keys, or valves, brass instruments were not chromatic or diatonic, with the exception of the highest registers of the instruments. Playing in the upper registers where diatonic operation was possible often was not practical due to the extreme nature of range, taxing and increasing the level of fatigue for the musician. The problems with intonation, while manipulated more easily in the upper registers, is somewhat analogous to operation in the lower registers, where pitches are often out of tune without a means of compensation.

One way of solving the issue of creating chromatic pitches on a brass instrument is to manually lengthen and shorten the instrument based upon a slide system.[51] The current trombone family of instruments is the latest set of instruments to use this method. The slide operates along a set of positions to which the slide is extended based upon the pitch relative to the overtone series. As the range increases, the distance between the positions decreases. This occurs to the

[51] Michael Arthur Mamminga. "British Brass Bands." (Ph.D. diss., Florida State University, 1973), 5-6.

point where notes like G4 generally use less tubing and different slide postions than their lower octave counterparts.

The use of tone-holes, which eventually led to using vented keys, is another method of creating chromaticism in a brass instrument.[52] Tone holes are placed on the tube at specific lengths to lower pitch relative to the overtone series. The serpent and ophicleide are popular brass instrument examples of this, as the serpent is a bass-voiced instrument which is played by using six tone holes that are generally operated by using fingers to cover the tone holes. The ophicleide is a family of instruments that operate similar to a saxophone in its use of keys to mechanically vent tone holes along the length of the instrument.

Another method of creating chromaticism in brass instruments, and one that has replaced keyed brass instruments entirely, is the use of valves to add pre-determined yet adjustable lengths of tubing to a brass instrument relative to the overtone series. As valves are depressed, tubing is added to the instrument, lowering pitch by a pre-determined amount. Much like the decrease in slide positions with slide instruments, the higher the pitch, the less valves are needed for adequate operation. The addition of valves eventually was codified into the system currently used on most brass instruments, where the first valve lowers the pitch by a full step, the second valve by a half step, and the third valve by one and one-half steps.[53]

Definition of Intonation Issues

The use of valves has become the standard operation of most brass instruments. Valves have simplified and streamlined brass instrument operation due to its simplicity of use as

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[52] Richard Demy. "The Automatic Compensating Euphonium as the Ideal Choice for Performing Music Composed Originally for Ophicleide" (DMA diss., University of North Texas, 2014), 6.

[53] Mark Hindsley. "Valve-Brass Intonation Difficulties." In *Brass Anthology.* (Northfield, Illinois: The Instrumentalist Publishing Company, 1991), 98.

opposed to a myriad of keys and its effectiveness as a system of instrument operation. The system is not perfect, though, as there are a few issues to consider in regard to intonation. Valves are meant to be depressed both singularly and in combination to achieve chromatic pitches along the overtone series. Since brass instruments use "just intonation," the lower the register is, the farther the distance between chromatic pitches. The aggregate of the overtone series and "just intonation" creates a need for more tubing in the lower register to account for the extra distance between pitches.

The result is a general trend of sharp intonation the lower an instrument plays, especially when using the 1-3 and 1-2-3 valve combinations.[54] Trumpets have developed rings and metal slots to facilitate manual adjustment of the first and third valve slides using the right thumb and ring fingers. When using the 1-3 valve combination, a trumpet player will extend both first valve and third valve slides to account for the need for more tubing. With the size of the euphonium, this is impractical as the first and third valve slides are far away from where the instrument is held while playing. This means there is no pragmatic way to account for this tubing deficiency manually.

To bypass this issue, manufacturers have developed a four-valve non-compensating euphonium.[55] The fourth valve lowers the pitch by a fourth, therefore eliminating the need for the 1-3 valve combination. Adding a fourth valve also assists in bringing pitches typically played on a three-valve euphonium via the 1-2-3 combination closer into tune by using the 2-4 valve combination. The addition of the fourth valve adds the potential to play pitches lower than E2,

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[54] Mark Hindsley. "Valve-Brass Intonation Difficulties." In *Brass Anthology.* (Northfield, Illinois: The Instrumentalist Publishing Company, 1991), 98.

[55] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. Gloucester, (England: Wright and Round LTD., [19??]) 45.

the lowest note on a three-valve B-flat euphonium as well. Four-valve non-compensating euphoniums were not originally designed for range, as the distances between pitches below E2 are large enough that even on a four-valve euphonium, the need for more tubing makes playing in this range impractical without a compensating system.[56] Instrument manufacturers have also made five-valve non-compensating euphoniums to grant more access to the low register of the euphonium, but the issues with the five-valve instrument are similar to the four-valve non-compensating instruments, except one or two notes lower.

Definition of Range Issues

With band literature evolving both through major works and contest works, the development of euphoniums with increased range and better intonation was crucial to the brass band and wind band fields. This desire was due to a competitive brass band and wind or military band culture developing among communities, most notably in Great Britain.[57] By having three valves on a euphonium, it is sufficient for some chromatic operation of the instrument within a limited range. The issue becomes apparent when the music approaches the fundamental pitch of the instrument, B-flat1. The overtone series' first interval is the largest, that of one octave. Most B-flat tuned instruments begin at the octave up from the fundamental which is B-flat2 in the case of the euphonium. The instrument does not have the tubing necessary to play chromatically after E2 while approaching the fundamental. This is, of course, ignores the previously mentioned intonation issues of 1-3 and 1-2-3 valve combinations.

[56] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. Gloucester, (England: Wright and Round LTD., [19??]) 46.

[57]Ibid., 46.

The four-valve non-compensating euphonium has more tubing than its three-valve counterpart but is still insufficient in its amount of tubing, meaning it can play chromatically down to C2. This point also ignores the aforementioned intonation and practicality issues in the low register.[58] The common wisdom is that one can adjust by using valve combinations for a half-step below the intended pitch.[59] This is not truly a fully chromatic solution as this method renders B1 unplayable. While only having one note as unplayable is an improvement, it is not full chromatic operation down to the fundamental. In addition to the chromatic issues, there are the practicality concerns of dealing with a system that is a compromised solution operating past the intended functionality of the instrument with the fourth valve as a substitute for 1-3 valve combinations, meaning the pitches still have marked intonation issues.

Instrument manufacturers also created five-valve euphoniums to attempt to provide the tubing adequate for chromatic operation as well. The fifth valve provided for E2 or E-flat2 in later models like the Stauffer valve.[60] Yet another tuning for the fifth valve was D-flat2 in the case of the Miraphone 56-5.[61] These different options for the fifth valve allows for the instrument to be played in tune but still has issues in the lower register. This problem led to the creation of various valve systems referred to as *compensating systems*.[62]

[58] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. Gloucester, (England: Wright and Round LTD., [19??]), 46.

[59] Ibid., 47.

[60] Matthew A. McCready. "Compensating Systems: A Mathematical Comparison." *T.U.B.A. Journal* 12, no. 3 (February, 1985): 11.

[61] David Werden. "The Blaikley Compensating System: A Player's Perspective." *T.U.B.A. Journal* 13, no. 1 (August, 1985): 17.

[62] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46.

A compensating system is a valve system that is designed specifically to address the issues of range and intonation in the lower registers of an instrument. Applied to the euphonium, this means the inclusion of extra tubing to allow for in-tune chromatic operation down to the fundamental. Compensating euphoniums, in general, are four-valve instruments capable of playing chromatically down to the fundamental, B-flat1. The designs of these instruments would eventually lead to the Blaikley four-valve automatic compensating euphonium becoming the modern professional euphonium.

CHAPTER 3

THREE-VALVE SYSTEMS

Three-Valve Non-Compensating Systems

The three-valve euphonium is commonly used as a starting instrument for young musicians. The valves are arranged in an upright configuration, with the first valve lowering pitch a full-step, second valve a half-step, and the third valve one and one-half steps. The lowest note playable is E2. As mentioned before, 1-3 and 1-2-3 valve combinations are typically sharp due to tubing length requirements in the low register. This means that E2 and F2 are typically sharp and require adjustment either through “lipping,” the process of using embouchure to adjust pitch up and down, or through some mechanical addition to the instrument. The act of “lipping” pitches up or down is a very limited function in playing a brass instrument. Any pitch played on a brass instrument can only be adjusted so far in either direction before it begins to lose the characteristic tone quality of the instrument. It is also impractical for fast passages as such pitch manipulations for a few notes can affect accuracy of intonation at best and of the note itself at worst.

Some journal articles have discussed the idea of a mechanical device to adjust the first and third valve slides in these cases.[63] This is due to the upright configuration of the valves, where the first and third valve slides are inaccessible in any meaningful way while playing since they are angled down. The solution for such an intonation issue could possibly be a tuning trigger for the main tuning slide, as on many professional euphoniums today. The use of the three-valve non-compensating euphonium as a beginning student instrument might be why such

[63] Mark Hindsley. "Valve-Brass Intonation Difficulties." In *Brass Anthology: A Collection of Brass Articles Published in the Instrumentalist Magazine from 1946 to 1990, Ninth Edition*, 97-99. (Northfield, Illinois: The Instrumentalist Publishing Company, 1991), 99.

systems of manual adjustment are not incorporated into the three-valve non-compensating euphoniums at present. This would make sense when using the instrument as a beginning student model, since a gradual introduction to the complexities of the skill set required for playing a brass instrument might be preferable to starting with a more expensive four-valve intermediate or professional model euphonium.

The Blaikley Three-Valve Compensating Euphonium

The three-valve automatic compensating euphonium was patented by David James Blaikley in 1878.[64] David James Blaikley was the head instrument designer of the Boosey & Company factory in Great Britain at the time and had patented many improvements upon brass instruments.[65] Blaikley developed this instrument as an improvement upon Pierre Gautrot's *systemme equitonique* euphonium, fully eliminating an air pathway, which brought the air passages from six to five.[66] Boosey & Company would eventually sell the four-valve design that Blaikley originally developed, referring to it as a "perfected" compensating system as well. The *systemme equitonique* was a four-valve euphonium, but Blaikley's patent application presents his improved compensating system as applied to a three-valve euphonium.

The instrument itself adheres to the general layout of modern euphoniums, three top-action valves inside of the wrap of the instrument but without a fourth valve. There is, however, a notable difference. The instrument was not intended to extend range but uses the Blaikley system as a method of compensation only to apply extra tubing to the problematic valve combinations of 1-3 and 1-2-3. Activated by the third valve, the air is routed back through the

[64] David James Blaikley. *Improvements in Cornets*. United States, 1879.

[65] Arnold Myers. "Brasswind Innovation and Output of Boosey & Co. in the Blaikley Era." *Historic Brass Society Journal* 1, no. 14 (2002): 392.

[66] Ibid., 403-404.

valve casing and another, smaller set of tubing. This smaller set of tubing allows the euphoniumist to play pitches like E2 approximately more in tune.

Three-valve automatic compensating euphoniums are generally rare, if existing at all, in the United States, where the non-compensating variety of instruments is more favored instead. When developing the brass playing skill set, it would seem logical to use instruments like the one developed by Blaikley, as the intonation issues are less of a concern and it will familiarize the user with compensating systems. While the three-valve automatic compensating euphonium developed by David James Blaikley does much to correct the issue of intonation, it still leaves the consideration of range. The instrument still has a low range only able to sound chromatically down to E2, meaning the chromatic pitches from E2 to B-flat1 are unplayable with this design.

CHAPTER 4

FOUR-VALVE SYSTEMS

Four-Valve Non-Compensating Systems

Figure 1: Yamaha YEP-321 Four-Valve Non-Compensating Euphonium

The four-valve non-compensating euphonium generally has three different design layouts based upon valve configuration. The first configuration simply adds the fourth valve to the three-valve cluster. This is done to contain valve operation to one hand. The second configuration of the four-valve non-compensating euphonium is in a configuration referred to as 3+1, and the third is four rotary valves down the front of the instrument, similar to that of a tuba. This four-valve down the front of the euphonium configuration is not as common as the other two. The 3+1 valve configuration means that the initial three-valve cluster remains the same, with the fourth valve being added on the side opposite the bell of the euphonium. Without a compensation system in place, these instruments were only meant to use the fourth valve as a replacement to the 1-3 valve combination.[67] This meant that the appropriate tubing could be more closely approximated for C3 and F2. The addition of the fourth valve also created the option of using 2-4 instead of 1-2-3 as a means of better approximating the appropriate tube lengths for B2 and E2.

The lack of a compensating system on the four-valve non-compensating euphonium means that below E2, technical limitations prevent the instrument from effectively and practically playing chromatically down to the fundamental. As the range lowers, the spaces between notes increases, therefore creating a need for more tubing. This means that simply depressing the fourth valve and continuing with regular valve ordering is impractical. The way around this issue is using fingerings one-half step down from the note intended. Playing pitches this way is impractical for two reasons. The first reason is that while the fingerings make it easier to play lower pitches in tune, the improvement is marginal. Second, operating this way means that the instrument runs out of tubing before B1. This disrupts the chromatic range down to the fundamental of the euphonium, B-flat1.[68] All of these considerations can be viewed in rubric supplied in Appendix A.

The functionality of the four-valve non-compensating euphonium is typically as a student model within school band programs, often times supplanting the three-valve non-compensating euphonium as the beginning instrument of choice. While this particular type of euphonium is non-compensating, it allows for better intonation between B2 and E2, and allows students to prepare for a compensating euphonium by getting used to fourth valve operation.[69] The inherent downside is that, in general, many student models are designed with an in-line four-valve design.

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[67] 4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 46.

[68] Adam Carse. *Musical Wind Instruments: A History of the Wind Instruments used in European Orchestras and Wind-Bands from the Later Middle Ages Up to the Present Time*. (New York: Da Capo Press, 1965), 301.

[69] Harold T. Brasch. *The Euphonium and 4-Valve Brasses*. (Arlington, VA: 1971), 6.

This means that the fourth valve is operated by the same hand as the other three valves as opposed to the index finger on the left hand. It is possible, but ergonomically awkward to bring the left hand up toward the fourth valve to use the left index finger: this places extra strain on the right hand, which would now be bearing most of the weight of the instrument.

The Blaikley Four-Valve Automatic Compensating System

Figure 2: Boosey & Co. Four-Valve Compensating Euphonium

The four-valve automatic compensating euphonium as developed by David James Blaikley in 1874 is the first of four compensating systems reviewed in the chapter. Compensating systems refer to the means for which the instrument designers added the tubing necessary to fix intonation and range problems in brass instruments. The system of automatic compensation developed by David James Blaikley is an improvement upon the previously mentioned *systemme equitonique* created by Pierre Gautrot.[70] The instrument utilizes a 3+1 valve

[70] Arnold Myers. "Brasswind Innovation and Output of Boosey & Co. in the Blaikley Era." *Historic Brass Society Journal.* Vol. 1, No 14 (2002): 403-404.

layout in the design. The first three valves operate in the exact same way a non-compensating four-valve euphonium would with the same valve combinations. The fourth valve is also used to replace the 1-3 and 1-2-3 valve combinations with 4 and 2-4 respectively in lower register operation.[71] The difference between this euphonium and its non-compensating counterpart rests with what happens when the fourth valve is depressed.

Depressing the fourth valve on a four-valve automatic compensating euphonium re-routes the air back through a secondary set of tubing in the top valve cluster.[72] This re-routing adds full chromatic operation down to the fundamental, B-flat1, in the process.[73] The system was innovative for the fact that it added minimal tubing to the instrument to attain its design goals. The compensating euphoniums developed by David James Blaikley would be the first in a series of designs developed in Great Britain with the intention of solving the range and intonation issues of the euphonium.

David James Blaikley developed this system while working with Gautrot's *systemme equitonique* at the Boosey & Company factory as the head of instrument design.[74] When working with Gautrot's *systemme equitonique* euphonium, Blaikley had reduced the number of air pathways from six to five. The first of automatic compensating euphonium Blaikley built using this concept was the four-valve automatic compensating euphonium.[75] He then applied the same concept to three-valve instruments and patented the three-valve automatic compensating system

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[71] Harold T. Brasch. *The Euphonium and 4-Valve Brasses*. (Arlington, VA: 1971), 6.

[72] 4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 46.

[73] E. J. Robbins. "So You Play the Euphonium?" In *Brass Anthology: A Collection of Brass Articles Published in the Instrumentalist Magazine from 1946 to 1990, Ninth Edition* (Northfield, Illinois: The Instrumentalist Publishing Company, 1991), 274.

[74] Arnold Myers. "Brasswind Innovation and Output of Boosey & Co. in the Blaikley Era." *Historic Brass Society Journal* Vol. 1, No. 14 (2002): 392.

[75] Ibid., 403-404.

discussed in the aforementioned chapter. The four-valve automatic compensating euphonium was then sold later. Blaikley's design is the basis for most modern professional euphoniums in use in military and brass bands today.[76]

Victory Compensating Transpositor

Boosey & Company's entry of the four-valve automatic compensating euphoniums created a need among instrument manufacturers to develop similar systems. One of the instruments created in competition with Blaikley's compensating euphonium is Besson's Victory compensating transpositor, developed in 1890.[77] This euphonium is set up in a 3+1 fashion typical of compensating euphoniums and allows for full chromatic operation down to the fundamental of the instrument, B-flat1. The Victory compensating transpositor also accounts for the previously mentioned intonation issues via the fourth valve. However, there is a marked difference in how this particular euphonium achieves these goals.

The Victory compensating transpositor was developed by Besson & Company by employing what is referred to as the doubling principle.[78] The doubling principle is similar to a double French horn in the fact that the fourth valve switches to different full sets of tubing on the instrument. The difference being that, while the double French horn has an F and B-flat side, the Victory compensating transpositor has a B-flat and slightly longer set of B-flat tubing meant for operation in the low register. The slightly longer set of B-flat tubing was activated by the fourth

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[76] Michael B. O'Connor. "A Short History of the Euphonium and Baritone." In *Guide to the Euphonium Repertoire: The Euphonium Source Book*, edited by Lloyd E. Bone, Eric Paull and Winston R. Morris, 1-17. (Bloomington, IN: Indian University Press, 2007), 6.

[77] Niles Eldredge and Arnold Myers. "The Brasswind Production of Marthe Besson's London Factory." *The Galpin Society* 59, (May, 2006): 50-51.

[78] Arnold Myers. "British Forms of Valves and Valved Brass Instruments." *Valve.Brass. Music. 200 Jahre Ventilblasinstrumente* (December 6, 2013): 8-9, https://www.research.ed.ac.uk/portal/files/15519718/bpv3u.pdf.

valve, meaning that air needed to be routed through to the fourth valve before going through the main valve cluster. The aggregate of these design choices meant a much heavier euphonium with what amounts to nearly double the tubing of the non-compensating four-valve euphonium as well as almost doubling the number of slides adjustable on the instrument.[79] The Victory compensating transpositor's operational lifespan was relatively short, as weight was the largest concern with this euphonium. These concerns are further elucidated in the rubric in Appendix A. The Victory compensating transpositor lasted until around 1903, when Besson unveiled their next compensating model of euphonium.[80]

The Enharmonic System

Figure 3: Besson & Co. Four-Valve Enharmonic Euphonium

After the Victory compensating transpositor euphonium failed to become popular, Besson modified the instrument. Using the doubling principle to create essentially a double

[79] Michael B. O'Connor. "A Short History of the Euphonium and Baritone." In *Guide to the Euphonium Repertoire: The Euphonium Source Book*, edited by Lloyd E. Bone, Eric Paull and Winston R. Morris, 1-17. (Bloomington, IN: Indian University Press, 2007), 9.

[80] Ibid., 11.

euphonium added weight concerns and operational complication for the user. Instead, keeping the 3+1 valve layout, Besson decided to partially abandon the doubling principle, opting for only a couple of valves having a slightly longer set of tubing instead of direct parity across the whole system.[81] Besson patented this new design, calling it the Enharmonic euphonium, in 1904.[82] The first and second valves had a slightly longer set of tubing, and the fourth valve's secondary tubing was slightly shorter than its regular counterpart. The secondary tubing for the Enharmonic euphonium was activated by depressing the third valve of the instrument.[83]

While the Enharmonic valve system still provided intonation solutions and chromatic range down to the fundamental B-flat, it was much more complicated than the Victory compensating transpositor. The compensating transpositor had direct parity of instrument tubing on each "side" of the instrument. This is what is meant by the "double principle." Creating a double instrument is relatively simple by comparison, as only one pivot point needs to be considered. By removing a full double system, the practical concerns about how to access the secondary tubing needs to be addressed. Besson's solution was to use the third valve as a means of activating the secondary sets of tubing attached to the valves, creating a complex series of tubes routing air through the instrument by comparison to the relative simplicity of the compensating transpositor. A solution that was more complex than the Victory compensating transpositor, the aggregate of the changes, is explored further in Appendix A. This was a marked

[81] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46.

[82] Arnold Myers. "British Forms of Valves and Valved Brass Instruments." *Valve.Brass. Music. 200 Jahre Ventilblasinstrumente* (December 6, 2013): 9-11, https://www.research.ed.ac.uk/portal/files/15519718/bpv3u.pdf.

[83] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46.

reduction in overall tubing, which is not difficult to imagine since Besson's previous compensating system was a double euphonium.[84] With all of the improvements Besson made from the Victory compensating transpositor to the Enharmonic system, weight was still a primary concern with the instrument.

The Synchrotonic System

Besson and Boosey & Company were not the only two to manufacture compensating systems. Joseph Higham's factory would create a system which boasted a tuning slide for every possible valve combination called Synchrotonic valves.[85] This four-valve, 3+1, compensating system appears in the early 1910s and includes two tubes specifically for valve combinations in the top valve cluster with the fourth valve operating with the functionality of a non-compensating fourth valve.[86] The operation of these tubes manually provides for the amount of tubing necessary for all valve combinations, but considering the tubing lengths required, it is unlikely the Synchrotonic system would provide chromatic operation down to the fundamental B-flat1. Operation down to the fundamental would conceivably require a readjustment of all slides to account for the pitch discrepancies. This adjustment, by definition, would not be automatic as in the systems developed by Boosey & Company or at Besson. The manual adjustment would likely mean that the euphoniumist would have to stop playing the instrument to apply the necessary changes without some sort of mechanical aid. The fourth valve would also need to be

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[84] Arnold Myers. "British Forms of Valves and Valved Brass Instruments." *Valve.Brass. Music. 200 Jahre Ventilblasinstrumente* (December 6, 2013): 11, https://www.research.ed.ac.uk/portal/files/15519718/bpv3u.pdf.

[85] "Wright and Round's Brass Band News." *Wright and Round's Brass Band News*, September 1, 1914, 396, http://www.salford.ac.uk/__data/assets/xml_file/0004/530869/RoyNewsome.xml (accessed September 16, 2019), 1.

[86] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46-47.

depressed beyond F2, but such operation is similar to other valve systems. While this instrument was definitely advertised and discussed, the popularity would seem to have been short-lived as very little information remains.

The Dictor System

Figure 4: Hawkes & Son Dictor Euphonium[87]

The development of so many euphonium valve systems grew out of the competitive nature of wanting instruments with better intonation, wider range etc. Some manufacturers had decided to create essentially partial double-euphoniums, some manufactured double-euphoniums, other manufacturers developed intricate means of connecting valves to tune all possible note combinations. Oliver Hawkes and Poupin Francis Maurice of Hawkes & Son had

[87] Charlie Brighton. http://www.euphoniumcollective.co.uk/neweuph5a.jpg (accessed January 21st, 2020).

still another means of adding chromatic operation down to the fundamental. Their design would become known as the Dictor euphonium and was patented in 1910.[88] The Dictor system is differentiated from other means of compensation in the fact that it changes the fundamental organizational pattern of the valve cluster.

The instrument still conforms to the 3+1 standard for four-valve compensating euphoniums, however, the fourth valve is lengthened to accommodate more tubing attached to the valve casing. This added series of tubing comes into play twice in the “wrap,” or how the main tubing is arranged around a brass instrument, through the fourth valve of the euphonium.[89] This additional connection to the wrap with more tubing is why the fourth valve was extended. The aggregate of these design decision drops pitch by an augmented fourth instead of the perfect fourth typically associated with fourth valve operation. While this does provide for chromatic operation down to the fundamental, and without the additional weight of systems like the Victory compensating transpositor, it also complicates valve combinations in the low register. The Dictor euphonium requires a separate set of valve combinations below G-flat2 that are one half-step above the expectation for each note. To the average competitive brass band, this would be perhaps too much of a complication to make things practical, as most things in the brass band world are designed to allow for musicians to switch instruments without having to learn a new system.[90] This design factor is further qualified in Appendix A. The Dictor model of euphonium

[88] Oliver Hawkes and Poupin Francis Maurice. GB191029613 (A). *Improvements in and Relating to Euphoniums and the Like.* Vol. GBD191029613 19101220. England, 1911.

[89] Ibid., 4.

[90] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46-47.

lasted until Boosey & Company bought Hawkes & Son, becoming Boosey & Hawkes, in 1930.[91]

[91] Michael B. O'Connor. "A Short History of the Euphonium and Baritone." In *Guide to the Euphonium Repertoire: The Euphonium Source Book*, edited by Lloyd E. Bone, Eric Paull and Winston R. Morris, 1-17. (Bloomington, IN: Indian University Press, 2007), 15.

CHAPTER 5

FIVE-VALVE SYSTEMS

Five-Valve Non-Compensating Systems

Figure 5: Boosey & Co. Five-Valve Non-Compensating Euphonium

The five-valve non-compensating euphonium has been manufactured by several companies throughout its history. There are three different valve system layouts for five-valve non-compensating euphoniums. The keisereuphonium has a valve layout of 4+1 with four front-action rotor valves operated by the left hand and the fifth valve toward the upper side of the wrap opposite the bell of the instrument.[92] Other five-valve non-compensating euphoniums use a 3+2 organizational layout, with the fourth and fifth valves toward the middle of the instrument opposite the bell. There are also means for which to convert four-valve non-compensating

[92] O'Connor, Michael B. "A Short History of the Euphonium and Baritone." In *Guide to the Euphonium Repertoire: The Euphonium Source Book*, edited by Lloyd E. Bone, Eric Paull and Winston R. Morris, 1-17. (Bloomington, IN: Indian University Press, 2007), 2.

euphoniums to a 4+1, which is classified as an additive five-valve system with the fifth valve being a rotary in the middle of the instrument inserted as a crook to the fourth valve slide.[93]

Five-valve euphoniums generally do not have a means of compensation. Instead, the fifth valve provides tubing for limited operation in the low register. The five-valve non-compensating euphonium's valves generally follow the design of the saxhorn or French C tuba, meaning that the first valve lowers the pitch by a whole step, second valve a half-step, third valve a step-and-a-half, and the fourth valve a perfect fourth.[94] The fifth valve deviates into three different options for operation. The first option, the option that aligns with saxhorn valve ordering, is a flat half-step to be used in combination with the fourth valve for E2.[95] The second option is a flat whole step to be used in combination with the fourth valve for E-flat2. The third option is a fifth valve that is a flat two and a half steps. This third option is exemplified in the Miraphone 56-5 five-valve non-compensating euphonium.[96] The fifth valve also conceivably assists in chromatic operation down to the fundamental by virtue of adding more tubing to the potential valve combinations. It should be noted that none of the other valves are designed to provide enough tubing in the low register. In this case, the fifth valve can provide more tubing as the instrument descends in pitch, but this is an imperfect option.

The fifth valve as E2 would adjust the valve combinations by a half-step assuming that the logical combination after 4-5 (E2) is 2-4-5 (E-flat2). This is due to the fact that the fifth valve has the appropriate amount of tubing to play E2 in tune with the fourth valve but requires an

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93 "Stauffer Brass Fifth Rotary Valve for Yamaha 321 Euphonium." https://www.hornguys.com/products/stauffer-brass-fifth-rotary-valve-for-yamaha-321-euphonium (accessed September 7th, 2019).

94 Earle L. Louder. "An Historical Lineage of the Modern Baritone Horn and Euphonium." DMA Diss., (Florida State University, 1976), 28-29.

95 Ibid., 28-29.

96 David Werden. "The Blaikley Compensating System: A Player's Perspective." *T.U.B.A. Journal* 13, no. 1 (August, 1985): 17.

extra half-step to play E-flat2. With the fifth valve set for E-flat2, the valve combinations would be offset by a whole step, meaning that D-flat2 would be 2-4-5. The same concept also applies where the fifth valve is tuned so that 4-5 is D-flat2, where 2-4-5 would be C2. Beyond E2, E-flat2, and D-flat2, respectively, the valve combinations bear little resemblance to what we would consider common practice for B-flat brass instruments. There is also the consideration that the first, second, and third valves do not have a lowered set of tubing for the lower register of the instrument, so the tendency that lower pitches would become sharp are offset by either a half or whole step. This practicality is briefly explored in Table 1 (pg. 47), rather than being dealt with in a definitive manner.

Additive Five-Valve Systems – The Stauffer Valve

While the kaisereuphonium is the only euphonium designed to embrace a 4+1 valve setup, it was not the only five-valve option in the euphonium's history to have such a valve layout.[97] Some euphoniumists and instrument manufacturers thought it could be pragmatic to add a fifth valve to an otherwise four-valve non-compensating euphonium.[98] The thought would harken back to the time in brass instrument history where crooks would be inserted into brass instruments to change the keys of the instrument. Although this insert would not be nearly as drastic, it would add functionality in the low register that was lacking for what is a very common and popular four-valve non-compensating euphonium.

The Stauffer valve is unique in its design in that it adds a fifth valve to an otherwise four-

[97] Michael B. O'Connor. "A Short History of the Euphonium and Baritone." In *Guide to the Euphonium Repertoire: The Euphonium Source Book*, edited by Lloyd E. Bone, Eric Paull and Winston R. Morris, 1-17. (Bloomington, IN: Indian University Press, 2007), 2.

[98] Matthew A. McCready. "Compensating Systems: A Mathematical Comparison." *T.U.B.A. Journal* 12, no. 3 (February, 1985): 11-12.

valve non-compensating euphonium.[99] The Stauffer valve was developed to fit into the fourth valve slide of a Yamaha YEP-321, which is a four-valve non-compensating euphonium with all four valves in the main valve cluster. The added valve lowers pitch by a flat whole step, meaning that depressing both fourth and fifth valves sounds E-flat1.[100] The intended purpose of this valve is to add extra low range only when necessary. Since playing in the low register on euphonium is not always required, the valve could be removed, making the instrument lighter to hold.[101] This is especially important to consider since the soloist tradition of the euphoniumist is to stand whether during a recital or being featured in front of an ensemble.

A Yamaha YEP-321 with the Stauffer valve added operates just like a five-valve non-compensating euphonium where the fifth valve lowers pitch a flat whole step, with the added complication that it is dependent upon depressing the fourth valve in order to operate. Much like the aforementioned five-valve euphoniums, this adds chromatic operation down to the fundamental but introduces the complication of having to manually adjusted for range, deviating from expected valve combinations for B-flat instruments. The aggregate of these changes is an instrument with increased chromatic range and the potential for better intonation in the low register with an entirely separate set of valve combinations for the lower range that would have to be learned to operate effectively.[102]

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[99] "Stauffer Brass Fifth Rotary Valve for Yamaha 321 Euphonium." https://www.hornguys.com/products/stauffer-brass-fifth-rotary-valve-for-yamaha-321-euphonium (accessed September 7th, 2019).

[100] "Stauffer Brass Fifth Rotary Valve for Yamaha 321 Euphonium." https://www.hornguys.com/products/stauffer-brass-fifth-rotary-valve-for-yamaha-321-euphonium (accessed September 7th, 2019).

[101] Matthew A. McCready. "Compensating Systems: A Mathematical Comparison." *T.U.B.A. Journal* 12, no. 3 (February, 1985): 13.

[102] Ibid., 13.

CHAPTER 6

ANALYSIS

This chapter is organized with the first four sub-sections listed as one of the four individual parameters for which each valve system is analyzed: Intonation, Range, Intuitiveness of Use, and Weight. Each sub-section is based upon a review of the literature and the research brought to bear in the previous chapters. These four subsections are then expressed as a numerical value as explained in the final sub-section Quantifying the Results. The results can be viewed in table format in Appendix A.

Intonation

Intonation is a factor that has always plagued instrument manufacturers. Whether pitch is derived through venting tone holes, moving a slide, or depressing valves, approximation of pitch is paramount to functional operation in any ensemble. In the realm of valve-operated brass instruments the complication is, as previously noted, that when used in combination, valves tend not to add enough tubing for in-tune operation in the low registers.[103] On an instruments like tuba, with certain wraps and orientation, intonation issues can be solved by simply moving the first valve slide.[104] Many other instruments have rings or u-shaped slots placing the thumb and ring finger, allowing the user to move slides as necessary. Navigating intonation issues on a euphonium without a compensating system, however, is not as simple a task.

Three-valve non-compensating euphoniums are not manufactured in the configuration of a bugle, where the instrument is held in front of the face with the tubing and bell facing outward

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[103] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46.

[104] Peggy Heinkel and Dan Vinson. "The Obvious Solution." *T.U.B.A. Journal* 10, no. 2 (Fall, 1982): 4.

from the player. Instead, the instrument is built to be held in a vertical orientation, with the bell pointed upwards and the tubing parallel to the body of the euphoniumist except the lead pipe. The first, second, and third valves generally have the tubing extending downward, parallel to the valve casing. This means that holding the instrument correctly does not comport with adjusting slides quickly and freely. The natural intonation of the instrument leaves much to be desired when using 1-3 and 1-2-3 valve combinations. Without a means of adjusting during operation, the three-valve non-compensating euphonium is the least in-tune instrument of euphonium types.

Four-valve non-compensating euphoniums also succumb to similar issues. The four-valve non-compensating euphonium is generally more in-tune because of the additional fourth valve replacing the 1-3 and 1-2-3 valve combinations with 4 and 2-4 respectively.[105] The intonation issues are merely shifted downward, as the lower range afforded by a fourth valve means that the instrument contends with the fact that it takes more and more tubing to play in the lower registers. The practical considerations mean that by E-flat2, or the 1-2-4 valve combination, the dye is already cast for the tubing being inadequate. With the previously mentioned three-valve non-compensating instruments, this is where the story would end. Out-of-tune notes with no means of correctly or accurately accommodating discrepancies in time for the issue. Its four-valve counterpart, however, can employ a strategy to approximate tubing length so that it is closer to the correct length.[106] This strategy would account for the intonation discrepancy by using valve combinations a half-step down from the regular B-flat instrument valve

[105] Matthew A. McCready. "Compensating Systems: A Mathematical Comparison." *T.U.B.A. Journal* 12, no. 3 (February, 1985): 11.

[106] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46.

combinations.[107] This method is not without flaws: primarily that the instrument was not manufactured for operation in the low register, and the tubing lengths are still not an adequate enough solution for successful in-tune operation.

The trend of marginally displacing intonation issues continues in the five-valve non-compensating euphoniums. While the fourth valve operates to replace the 1-3 valve combination, the 4-5 valve combination can replace either 2-4,1-4, or 2-3-4 depending on the intervallic drop of the fifth valve. If the fifth valve is a flat half-step, then E2, or 2-4 is replaced with 4-5; if the fifth valve is a flat whole-step, then E-flat2 or 1-4 is replaced by 4-5. This is also true for a five-valve instrument where the fifth valve is tuned to a flat two-and-a-half step configuration, except C2, or 2-3-4 is replaced by 4-5. At the surface level of operation, this would seem to be a simple solution to intonation issues; however, the addition of the fifth valve further complicates intonation in the lower register by creating multiple, yet compromised, solutions. One could depress both the fourth and fifth valve beyond E2 if the fifth valve is set for a flat half-step, and use the first, second, and third valves with typical B-flat brass instrument valve patterns. If the fifth valve is a flat whole-step, then the valve combinations have to account for the extra tubing in the fifth valve. This would create valve combinations that might not be idiomatic for practical operation. All three fifth valve tuning options are still flawed in the fact that it is only a closer approximation of the tubing necessary, not a system designed specifically to operate in these ranges.[108]

Hawkes & Son’s Dictor euphonium, by using the fourth valve to drop pitch by an

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[107] Ibid., 47.

[108] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46.

augmented fourth, also merely shifts issues lower. This solution is jeopardized by the fact that it does nothing to address the 1-3 valve combination issue of sharpness for C3 and F2. Instead, the fourth valve replaces the 1-2-3 valve combination for B2 and E2.

Other compensating instruments were designed specifically to solve these issues. The three-valve automatic compensating euphonium developed by David James Blaikley accounts for the intonation issues associated with 1-3 and 1-2-3 valve combinations by routing the air back through a secondary set of tubing in the valve casing activated by the third valve. The four-valve version designed by Blaikley uses the fourth valve to resolve these intonation issues, with the added benefit of adjusting intonation in the lower register.

The Victory compensating transpositor is essentially a double euphonium, designed to incorporate a second set of tubing designed to resolve the intonation and range issues. This may have been too heavy-handed in Besson's solution but solving these issues in euphonium design was paramount.[109] Later instrument designs like the Enharmonic and Synchrotonic euphoniums created by Besson and Joseph Higham respectively would try to solve these issues with secondary tubing to be used with specific valve combinations.

Range

One of the main concerns with the advancement of euphonium repertoire is range. Works like Gustav Holst's *First Suite in E-flat for Military Band*, Op. 28, No. 1, is a prime example of this increase in the demands placed on the euphonium. The first movement, "Chaconne," contains a section for which a large portion of notes are below F2. There is also an inversion of the melody that requires the euphonium to play C2. With chromatic range expansion down to the

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[109] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46.

fundamental, three-valve euphoniums simply do not have the tubing to operate in this register whether or not a compensating system is present.

Four-valve non-compensating euphoniums fare better than their three-valve counterparts but still have issues in operation.[110] As previously mentioned, the distance between pitches increases with the lower range. The intonation issues present on the four-valve non-compensating euphoniums necessitate that the operator uses valve combinations a half-step lower than the pitch they would like sound, in order to play lower notes with better intonation.[111] This adjustment rules out B1 as a possible note due to C2 using the 1-2-3-4 valve combination. From a purely operational standpoint, the four-valve non-compensating euphonium is designed to solve a different problem and is not designed to operate in such a range. As such, the solution mentioned above is compromised by the previously mentioned intonation issues.

Five-valve non-compensating euphoniums have similar issues, but have more flexibility based on the amount of tubing added by the fifth valve. In the instance of the addition of a flat whole-step when depressing the fifth valve, the functionality suffices as the tubing would adjust valve combinations in ways that allow for chromatic operation down to B-flat1.[112] In both instances of the fifth valve intervallic possibilities, it is possible to play chromatically down to the fundamental, as there is enough tubing to sound B1. The Dictor euphonium from Hawkes & Son, which is a four-valve compensating horn, allows for chromatic operation down to the

[110] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46.

[111] Ibid., 47.

[112] Matthew A. McCready. "Compensating Systems: A Mathematical Comparison." *T.U.B.A. Journal* 12, no. 3 (February, 1985): 13.

fundamental in a similar fashion due to the fourth valve lowering the pitch by an augmented fourth.[113]

Compensating systems were, for the most part, designed with the low range of the euphonium in mind. The four-valve automatic compensating euphonium created by David James Blaikley uses a system which briefly routes the air through a second air passage in the top valve cluster in order to reach chromatic operation in the low register.[114] Another example of a similar concept is the Victory compensating transpositor, where the second half of the euphonium is built specifically for operating in the lower register. Other compensating systems like the Enharmonic or Synchrotonic models by Besson's and Higham's factories use secondary tubing that is valve combination dependent as a means of operating in the low register.

Intuitiveness of Use

In the British brass band tradition, all of the brass instruments involved use transposing treble clef.[115] This system is relatively easy to learn, as keys of instruments are lessened in their importance through a direct parity of valve combination through written pitch. The sounding pitch is of course different, but written C is always played open, written D4 is 1-3 or 4, etc. In this ensemble format the only instruments who have anything different are the trombones, but only because the instrument is operated by slide as well as the use of bass clef by the bass trombone.[116] One benefit of the system is that people can be moved from one instrument to

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113 "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46-47.

114 David Werden. "The Three- and Four-Valve Compensating System." www.dwerden.com/eu-articles-comp.cfm (accessed September 4th, 2019).

115 Michael Arthur Mamminga. "British Brass Bands." PhD. Diss. (Florida State University, 1973) 22-23.

116 Ibid., 22-25.

another, with the possible exception of trombone because of the slide operation, with minimal preparation since the clef reads the same in regard to the alignment of written notes and valve combinations.

The emphasis around brass instrumentation and clef reading in the brass and military band culture of Great Britain built a certain set of expectations into design. The culture was built around a consensus of the three-valve non-compensating valve system where the first valve drops pitch by a whole step, second valve by a half-step, and third valve by a step and a half. In this regard the simplest instrument to use within such a system are the three-valve euphoniums.

Instruments whose operation are marginally more complex would be the four-valve automatic compensating euphonium, Victory compensating transpositor, Enharmonic, and Synchrotonic euphoniums. These euphoniums utilize all the same valve combinations when playing in the low register. Each system operates below F2 with the fourth valve continually depressed until B-flat1. Aside from the constant use of the fourth valve, valve combinations are exactly as they would be an octave above. The operation of these types of euphoniums conform to the expected norm established in the band culture with minimal complication and maximizing the functionality of the euphonium.

Next in order of complexity is the four-valve non-compensating euphonium. As iterated previously, below F2, this euphonium has issues which adequate tubing. The adjustment for this has been to use valve combinations one half-step lower. Not only does this disrupt chromatic operation down to the fundamental, but in doing so, it disrupts the previously established valve combination patterns for B-flat instruments. This means that B-flat treble clef would not align with the previous notion of valve combinations. The Dictor euphonium is similar in this regard;

however, the augmented fourth interval established by the fourth valve allows for chromatic operation down to the fundamental pitch of the instrument.

Five-valve euphoniums are perhaps the most complex in terms of valve combinations in the low register. The inclusion of a fifth valve means that anyone switching to euphonium from another brass instrument, or even a three- or four-valve euphonium, has a new, specialized valve to deal with. This specialized valve could be in a flat half step, flat whole step, or a flat two-and-a-half step configuration. This means that, beginning at E2, E-flat2, or D-flat2, depending on the fifth valve configuration, the valve combinations would need to be adjusted either by a half or whole step. While providing chromatic operation down to the fundamental, like the *Dictor* and four-valve non-compensating euphonium, these designs eliminate the possibility of maintaining any resemblance to the B-flat valve combinations in the lower register when the fourth valve is added.

Weight

The euphonium has enjoyed a rich history of being featured among brass and concert bands as a solo instrument. The soloist tradition for the euphonium is to stand in front of the ensemble while being featured. This tradition means that instruments should be light enough to be easily balanced and held by the soloist, who would rest a considerable portion of that weight on their left arm.

Three-valve euphoniums are the lightest of the valve systems on virtue that they have the least amount of tubing. Other euphoniums, like the four-valve non-compensating euphonium, four-valve automatic compensating euphonium, synchrotonic, Dictor, and all three five-valve euphoniums tend to have no mention of weight being an issue in their operation, and based on how this functionality is achieved, it is reasonable to conclude that the weight differences between these instruments are marginal.

The Victory compensating transpositor has almost twice as much tubing as a four-valve non-compensating euphonium due to its use of the double-principle.[117] Weight was a complication with this model of euphonium, causing Besson to rethink their design and later patent the Enharmonic euphonium.[118] This system, a more complex compensating system using less tubing, was still markedly heavier than the other euphoniums being produced by Boosey & Company, Hawkes & Son, Joseph Higham, or even Besson's own five-valve non-compensating euphoniums. The inclusion of weight as a functional factor is difficult to comport with the other issues of intonation, range, and intuitiveness, but weight of an instrument can create issues with operation due to the nature of how the instrument is held while standing or sitting, as well as increased risk of damage to the instrument.[119]

Quantifying the Results

The eleven previously mentioned valve systems have thus far been compared along the categories of intonation, range, intuitiveness of use, and weight. However, to further elucidate the strengths and weaknesses of each valve system, it becomes necessary to develop a means of quantification of the analysis of said systems. A rubric designed with this purpose in mind appears in Appendix A. As in the previous sections of this chapter, each instrument is given a

[117] Niles Eldredge and Arnold Myers. "The Brasswind Production of Marthe Besson's London Factory." *The Galpin Society* 59, (May, 2006): 51.

[118] Ibid., 51.

[119] Arnold Myers. "British Forms of Valves and Valved Brass Instruments;" *Valve. Brass. Music. 200 Jahre Ventilblasinstrumente* (December 6, 2013): 9, https://www.research.ed.ac.uk/portal/files/15519718/bpv3u.pdf.

value along the lines of the aforementioned categories of intonation, range, intuitiveness of use, and weight. Each category is scored 1-4 along the following definitions:

1. Insufficient
2. Reasonably Close, but Still Insufficient
3. Sufficient, but Flawed
4. Completely Sufficient

These four numerical values are further qualified within the rubric to indicate the factors that mattered most in the assignment of its numerical value. The rubric takes as standard the ideal operation of a professional euphonium with full chromatic operation down to the fundamental B-flat1 and the intonation issues as well as valve issues inherent in this additional range. This accounts for the lowered score of both three-valve systems as they do not conform to this standard, regardless of how each system operates within the range it was designed for. The category of intuitiveness of use is informed not just by the valve operation itself, but also whether the additional tuning options with the added tubing would add unnecessary complication to using the specific euphonium valve system.

CHAPTER 7

CONCLUSIONS

The results in Appendix A would suggest that the Blaikley four-valve automatic compensating euphonium is perhaps one of the best valve system designs in existence once the aggregate of all four factors of intonation, range, intuitiveness of use, and weight are considered. From a mathematical perspective, the critics of the Blaikley four-valve automatic compensating system are correct in the fact that the system brings the low register closer into tune, but not fully. However, the efficacy of the system from a player's perspective would suggest a different experience, citing that intonation difficulties are minimal, and there are minor ways to affect pitch on the compensating side of the valve system.[120] Another item to consider is the design feature of the drastic bore-size change between the fourth valve and the main wrap of the instrument, which has been claimed to be incorporated specifically for euphoniumists to manipulate pitch easier.[121] These factors seem to nullify the argument for the need of a system which departs from the Blaikley four-valve automatic compensating euphonium. In all other factors, the instrument was shown to be the most functional with the least amount of complication either by adherence to typical B-flat brass valve combinations or weight.

The four-valve automatic compensating euphonium as developed by David James Blaikley and manufactured by Boosey & Company has been only marginally changed since the 1878 three-valve patent.[122] The instrument itself is a modification of the *systemme equitonique*

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[120] David Werden. "The Blaikley Compensating System: A Player's Perspective." *T.U.B.A. Journal* 13, no. 1 (August, 1985): 17-18.

[121] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 47.

[122] Michael B. O'Connor. "A Short History of the Euphonium and Baritone," In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 7.

developed by Pierre Gautrot, however, the elimination of an entire pathway from six to five was the largest change to be impressed upon the system and happened within the first twenty years of operation.[123] This means that for over a century the design has been relatively unchanged, especially when juxtaposed with Besson's Victory compensating transpositor being replaced by their Enharmonic system within twenty years.[124] Blaikley's modification is mere streamlining in comparison. The Enharmonic system also failed to come to prominence even though it had improved upon the lessons of the Victory compensating transpositor. The Dictor euphonium also did not catch on as well as the four-valve automatic compensating euphonium, although Boosey & Company had patented Blaikley's system almost thirty-five years before.

The culture around brass and military bands also played a role in the popularity of the four-valve automatic compensating euphonium. The combination of transposing treble clef and an instrument with only one additional valve meant someone could be switched to the instrument with relative ease. The minimal tubing meant there was less to adjust, causing intonation issues, but the practicality and weight of the design outweighed the intonation issues, which were considerably improved from their four-valve non-compensating counterparts.[125]

Boosey & Company, with the success of their musical instruments and Blaikley's compensating system, eventually bought Hawkes & Son in the 1930, putting a definitive end to the Dictor euphonium and expanding the business to become Boosey & Hawkes, and Besson

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[123] Arnold Myers. "Brasswind Innovation and Output of Boosey & Co. in the Blaikley Era." *Historic Brass Society Journal.* Vol. 1, No 14 (2002): 403-404.

[124] Niles Eldredge and Arnold Myers. "The Brasswind Production of Marthe Besson's London Factory." *The Galpin Society* 59, (May, 2006): 51.

[125] "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*, 45-48. (Gloucester, England: Wright and Round LTD., [19??]), 46.

was acquired by Boosey & Hawkes in 1948.[126] This left the four-valve automatic compensating euphonium developed by Blaikley as the modern professional euphonium in use in Great Britain. Around the same time, one of the Boosey & Hawkes euphoniums had made it into the hands of Harold T. Brasch, a euphoniumist with the United States Navy Band who popularized its use in the premier military bands in Washington D.C.[127]

Previous to the four-valve automatic compensating euphonium, the popular euphonium within the military bands of the Unites States was the double-bell euphonium.[128] This instrument, while not in the scope of valve systems discussed, operated with a double-bell design, wherein the fourth or fifth valve routed air to the next bell. The double-bell euphonium's exclusion from this investigation is due to the fact that, without the second bell, the euphonium is either a three- or four-valve non-compensating instrument depending upon the model, meaning the fourth or fifth valve is only responsible for switching the bell and has no significant properties in range or intonation. It should also be noted that the four-valve automatic compensating euphonium is lighter than the double bell due to its lack of a secondary bell and bell-switching valves. Popularization of the four-valve automatic compensating euphonium continued until the patent for the three-valve automatic compensating euphonium by David James Blaikley expired in 1978.[129]

Various manufacturers have also developed five-valve non-compensating instruments in order to provide the same chromatic operation to the fundamental as a compensating system.

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[126] Michael B. O'Connor. "A Short History of the Euphonium and Baritone," In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 15.

[127] Edward Keith Mallett. "The Double Bell Euphonium: Design and Literature Past and Present - Volume 1." DMA Diss. (Michigan State University, 1996), 17-18.

[128] Ibid., 11.

[129] Michael B. O'Connor. "A Short History of the Euphonium and Baritone," In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 7.

However, the lack of standardization in fifth valve tuning, mainly whether or not to follow the tuning style of the saxhorn, tuba, or bass trombone's dual-trigger mechanism, and a lack of tubing to add to the original valve cluster, makes the five-valve non-compensating euphonium problematic to use. The idea that someone could switch instruments in a brass band to a five-valve euphonium using one of these designs effectively is flawed, as the range requirements of the work could lead to confusion in operating the euphonium.

The four-valve automatic compensating euphonium's popularity, which played a role in Boosey & Company's corporate trajectory, was due to the instrument's design being the solution at the intersection of intonation, range, intuitiveness, and also did not considerably add to the weight of the instrument. Moving this design into the realm of public domain led to its proliferation further, being applied to professional euphoniums made by every major brass instrument manufacturer.[130] The growing popularity also saw the eventual decline of additive systems like the Stauffer Valve and most five-valve euphoniums, leaving Blaikley's four-valve automatic compensation euphonium as the professional standard for the modern euphonium today.

[130] Michael B. O'Connor. "A Short History of the Euphonium and Baritone," In *Guide to the Euphonium Repertoire*. ed. Lloyd E. Bone Jr., Eric Paull, and R. Winston Morris. (Bloomington, IN: Indiana University Press, 2007), 7.

APPENDIX A

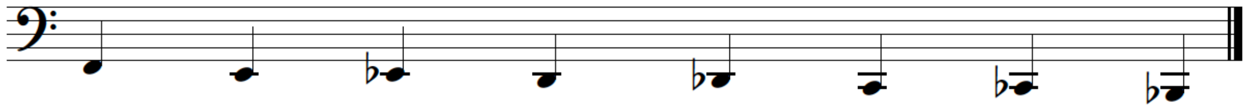
EUPHONIUM VALVE SYSTEMS ANALYSIS RUBRIC

Valve System	Intonation	Range	Intuitiveness of Use	Weight	Total
Three-valve non-compensating euphonium	1: 1-3, 1-2-3 valve combinations; sharp	1: Lowest possible note is E2	1: Conforms to three-valve B-flat brass instrument operation, does not provide for lower register	4: Least amount of tubing of listed instruments	7
Blaikley three-valve automatic compensating euphonium	2: Provides extra tubing for 1-2, 1-2-3 valve combinations; fails to provide intonation in the low register	1: Lowest possible note is E2	1: Conforms to three-valve B-flat brass instrument operation, does not provide for lower register	4: Second least amount of tubing of listed instruments	8
Four-valve non-compensating euphonium	1: Provides alternative to 1-2 and 1-2-3 valve combinations (4, 2-4); fails to provide for intonation in the low register	2: B1 is unplayable	2: Low register needs to be offset by ½ step to provide closer intonation	4: Less tubing than any of the compensating systems	9
Blaikley four-valve automatic compensating euphonium	3: Low register notes close, not fully in tune due to insufficient tube length in valves 1, 2, and 3	4: Provides chromatic operation down to the fundamental	4: Conforms to three-valve B-flat brass instrument operation, minimal tubing slides added	4: Least tubing of all compensating systems mentioned	15
Besson Victory compensating transpositor	4: Superior intonation due to separate tuning slides for each half of the euphonium	4: Provides chromatic operation down to the fundamental	3: Conforms to three-valve B-flat brass instrument operation, second set of valve tubing possibly confusing	1: Almost double the tubing of a regular euphonium, seen as prohibitively heavy	12
Besson Enharmonic euphonium	3: Reduction in tubing, reduced functionality from transpositor	4: Provides chromatic operation down to the fundamental	3; Conforms to three-valve B-flat brass instrument operation; incompete second set of valve tubing possibly confusing	3: Extra tubing adding weight but not prohibitively	13
Hawks & Son Dictor euphonium	2: No alternative for 1-3 valve combination; fourth valve descends; augmented 4th down	4: Provides chromatic operation down to the fundamental	2: Low register needs offset by ½ step of expected B-flat valve combinations	4: Minimal tubing added	12
Joseph Higham Synchrotonic euphonium	3: Incomplete second set of tubing	4: Provides chromatic operation down to the fundamental	3: Conforms to three-valve B-flat brass instrument operation; “tuning slide for each valve combination” possibly confusing	3: Incomplete second set of tubing	13
Five-valve non-compensating euphonium, 5th-valve flat half-step	3: Low register notes close, not fully in tune due to insufficient tube length in Valves 1, 2, and 3	4: Provides chromatic operation down to the fundamental	2: Low register offset by ½ step from B-flat brass with additional complication of fifth valve	4: Minimal tubing added for fifth valve	13
Five-valve non-compensating euphonium, 5th-valve flat whole-step	3: Low register notes close, not fully in tune due to insufficient tube length in Valves 1, 2, and 3	4: Provides chromatic operation down to the fundamental	2: Low register offset by whole-step from B-flat brass with additional complication of fifth valve	4: Minimal tubing added for fifth valve	13
Five-valve non-compensating euphonium, 5th valve flat, 2 and ½ steps	3: Low register notes close, not fully in tune due to insufficient tube length in Valves 1, 2, and 3	4: Provides chromatic operation down to the fundamental	1: Fifth valve operation not idiomatic to needs of low register operation	4: Minimal tubing added for fifth valve	12

APPENDIX B

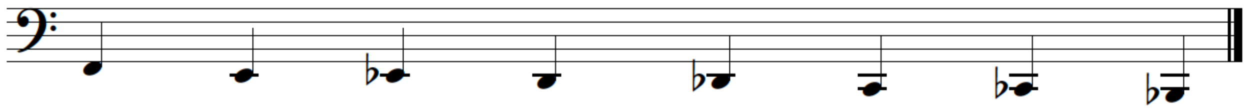
VALVE COMBINATION CHARTS

Four-Valve Non-Compensating Valve System Valve Combination Chart[131]



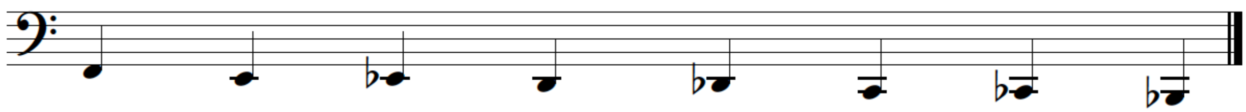
F2	E2	E-Flat2	D2	D-Flat/C#2	C2	C-Flat/B2	B-Flat2
4	2-4	1-2-4	2-3-4	1-3-4	1-2-3-4	N/A	0

Blaikley Four-Valve Automatic Compensating, Victory Compensating Transpositor Valve System Valve Combination Chart[132]



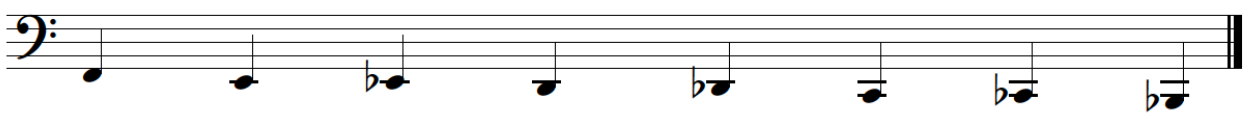
F2	E2	E-Flat2	D2	D-Flat/C#2	C2	C-Flat/B2	B-Flat2
4	2-4	1-4	1-2-4	2-3-4	1-3-4	1-2-3-4	0

Enharmonic Valve System Valve Combination Chart[133]



F2	E2	E-Flat2	D2	D-Flat/C#2	C2	C-Flat/B2	B-Flat2
4	2-4	1-2-4	3-4	2-3-4	1-3-4	1-2-3-4	0

Dictor Valve System Valve Combination Chart[134]*



F2	E2	E-Flat2	D2	D-Flat/C#2	C2	C-Flat/B2	B-Flat2
1-3	4	2-4	1-4	1-2-4	2-3-4	1-3-4	1-2-3-4/0

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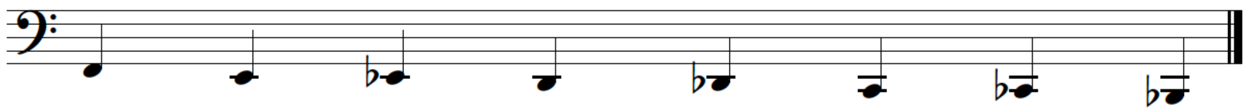
131 "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition*. (Gloucester, England: Wright and Round LTD., [19??]), 47.

132 Ibid., 47.

133 Ibid., 47.

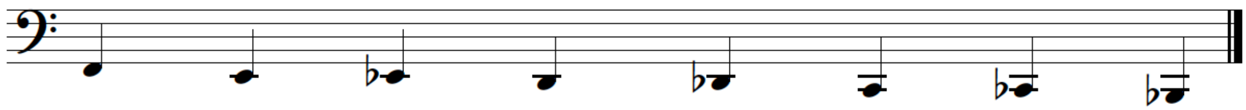
134 Ibid., 47.

Five-Valve Non-Compensating Valve System – 5th Valve Flat Half-Step Valve Combination Chart[135]



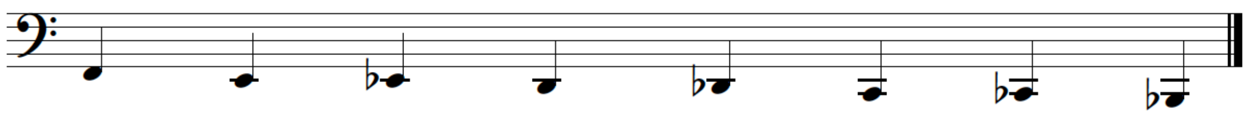
F2	E2	E-Flat2	D2	D-Flat/C#2	C2	C-Flat/B2	B-Flat2
4	4-5	2-4-5	1-4-5	1-2-4-5	2-3-4-5	1-3-4-5	1-2-3-4-5/0

Five-Valve Non-Compensating Valve System – 5th Valve Flat Whole-Step Valve Combination Chart[136]



F2	E2	E-Flat2	D2	D-Flat/C#2	C2	C-Flat/B2	B-Flat2
4	2-4	4-5	2-4-5	1-4-5	1-2-4-5 /3-4-5	2-3-4-5	1-3-4-5/0

Five-Valve Non-Compensating Valve System – 5th Valve Flat 2 ½ Steps*



F2	E2	E-Flat2	D2	D-Flat/C#2	C2	C-Flat/B2	B-Flat2
4	2-4	1-4	1-2-4	4-5	2-4-5	1-4-5	1-2-4-5/0 /3-4-5

*Valve Combinations Deduced via Valve Intervals

135 "4th and 5th Valves: Their Purpose and Use." In *Wright and Round's Amateur Band Teacher's Guide and Bandsman's Adviser: A Synthesis of the Systems on which Championship Bands are Taught, 60th Edition.* (Gloucester, England: Wright and Round LTD., [19??]), 47.

136 "Stauffer Brass Fifth Rotary Valve for Yamaha 321 Euphonium." https://www.hornguys.com/products/stauffer-brass-fifth-rotary-valve-for-yamaha-321-euphonium (accessed September 7th, 2019).

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