Stopped Horn Arcana

Christopher Earnest

Stopping a horn effectively cuts off about 9 inches of the pipe (the length of a stopping valve slide). This raises the pitch of an F horn about a half step (that is, however one gets there, the harmonic series of a stopped F horn is half a step higher than that of an open F horn). As is well known, stopping the Bb horn raises the pitch 2/3 of a step (not ¾; see below). What about all the horns in other keys – those obtained by pressing the valves? On horns shorter than the F horn, stopping raises the pitch more than half a step, on longer horns, less:

	Fingering			Steps higher when stopped	
	High F	Bb	F	Fractional	Decimal
High F horn	***0***			***1***	***1.00***
High E horn	2			15/16	0.94
High Eb horn	1			8/9	0.89
high D horn	1,2			5/6	0.83
high C# horn	2,3			4/5	0.80
high C horn	1,3			3/4	0.75
high B horn	1,2,3			45/64	0.70
Bb horn		***0***		***2/3***	***0.67***
A horn		2		5/8	0.63
Ab horn		1		3/5	0.60
G horn		1,2		9/16	0.56
F# horn		2,3		8/15	0.53
F horn		***1,3***	***0***	***1/2***	***0.50***
E horn		1,2,3	2	15/32	0.47
Eb horn			1	4/9	0.44
D horn			1,2	5/12	0.42
C# horn			2,3	2/5	0.40
C horn			1,3	3/8	0.38
B horn			1,2,3	45/128	0.35

These are concert pitches. The chart ignores the innate sharpness of valve combinations, so for example it is assumed that valves 1,3 together lower the pitch a perfect fourth. The rest of the paper uses correct (approximate) valve slide lengths, but it is really only a guide. Different individual horns and hand positions will no doubt give somewhat different results.

On the Bb horn, the valve slide lengths are multiples not of 9 inches, but of about 6.75 inches, so one cannot use the valves to add back on the 9 inches cut off by stopping. This is why a (9

inch) stopping valve is needed for stopping on the Bb horn. While it is true that a Bb horn with valves 1 and 3 depressed is again in the key of F, without a stopping valve there is no available way to lengthen the pipe 9 inches.

On the F horns, the fingering combinations work out pretty well, although in some cases stopping and fingering a half step lower does cause some small pitch changes. Pressing the 2nd valve of the F horn (or the first valve of a high F horn) adds back on just the 9 inches cut off by stopping. So when the next lower semitone can be reached in that fashion, the pitch stays the same. Examples, using F horn pitches: 0 –> 2 (C -> B or E -> D# or G -> F# or D -> C#), 1 –> 12 (Bb -> A or F –> E), 3 –> 23 (A -> Ab), 13 -> 123 (D -> Db).

Other cases where the harmonic does not change are 2 -> 1 (B -> Bb or F# -> F or D# -> D), 12 -> 23 (A –> G# or E -> D# or even C# -> C), and 23 -> 13 (Eb -> D or maybe Ab -> G or even C -> B). These essentially substitute one valve for another just slightly over a half step lower. So either 2 -> 1 or 23 -> 13 substitutes 1 minus 2 (the stopping amount) for 2, an increase of only about half an inch, lowering the pitch by just 6 cents. Similarly, 12 -> 23 substitutes 3 minus 2 (the stopping amount) for 1, an increase of about an inch, lowering the pitch by 11 cents.

The cases where the harmonic changes also cause some pitch changes. They are 2 -> 0 (C# -> C or D# -> D), 1 -> 0 (F -> E), 12 -> 0 or 3 -> 0 (C# -> C), 23 -> 0 (G# -> G), and 123 -> 0 (C# -> C). 2 -> 0 (C# -> C) changes the 9th harmonic on the E horn to the 8th harmonic on the F# horn, lowering the pitch by about 9 cents. 2 -> 0 (D# -> D) changes the 10th harmonic on the E horn to the 9th on the F# horn, raising the pitch by almost an eighth of a tone (23 cents). (Compared to equal temperament notes, the 5th and 10th harmonics are about 14 cents flat, so for that scale, the F# horn note is actually better in tune than the original E horn note). 1 -> 0 changes the 6th harmonic on the Eb horn to the 5th harmonic on the F# horn (or the 12th to the 10th), lowering the pitch by 9 cents. 12->0 changes the 5th harmonic on the D horn to the 4th harmonic on the F# horn (the stopped F horn)(or the 10th to the 8th), raising the pitch by about 9 cents. 3->0 (the same C# -> C, and the same harmonics) raises the pitch by some 19 cents. 23 -> 0 changes the 8th harmonic on the Db horn to the 6th harmonic on the F# horn (or the 4th to the 3rd, or the 16th to the 12th), raising the pitch by about 7 cents. 123 -> 0 (!) changes the 3rd harmonic on the B horn to the 2nd harmonic on the F# horn, lowering the pitch from the very sharp 123 fingering by almost a quarter of a tone, making it extremely close to in tune (in other words, the famous Tchaikovsky 6th low stopped C# should theoretically be in tune when played with no valves depressed).

It may be a bit puzzling that stopping a C# horn (valves 23) raises the pitch just 2/5 of a step (see above) to a flat D horn, then changing to 13 lowers the pitch back by just about that much,

instead of a half step as it does normally. The reason is that the valve slides for the F horn are shorter than D horn slides would need to be, so they don't lower the pitch as much on a D horn. In more detail: the valve slides for an F horn are 5/6 as long as those for a D horn. Moreover, here we're dealing with what I'll a D-minus horn – one just 4/10 of a step (not 5/10) above a C# horn For that horn, the valve slides would need to be (6/5)(1 + 1/10), or 33/25 times as long as those for the F horn. So using a fingering that lowers an F horn a half step lowers a D-minus horn by only (1/2)(25/33), or 25/66 of a step. This is just about 2/100 greater than 2/5.

Note that with suitable routing of the pipes, the same stopping valve could apply to not just the Bb horn, but to the F horn and even (on a descant or a triple) to the high F horn as well. With any valve combination, on a horn in any key, the stopping valve adds back on just the 9 inches cut off by stopping.

Derivation of the chart above:

It is clear that cutting the length of the horn in half raises its fundamental frequency by the reciprocal of ½ (i.e., 2) times the original fundamental frequency. Length and pitch are inversely related. So, as stopping raises the pitch of the F horn by ½ step, it raises the pitch of the high F horn by twice that much – that is the reciprocal of ½ (i.e., 2) times a half step, or 1 step. Similarly, for the Bb horn, which is ¾ the length of the F horn, stopping raises the pitch by the reciprocal of ¾ (i.e., 4/3) times a half step, that is (4/3)(½) or 2/3 of a step. One more example: the D horn is a minor third lower than the F horn. In a harmonic series, the interval between the 5^{th} and 6^{th} harmonics is a minor third, so the ratio of the fundamental frequencies of the D and F horns is 5/6, and the D horn is 6/5 as long as the F horn. So, as stopping raises the pitch of the F horn by ½ step, it raises the pitch of a D horn by 5/6 (½), or 5/12 of a step. Other numbers are derived in a similar way.