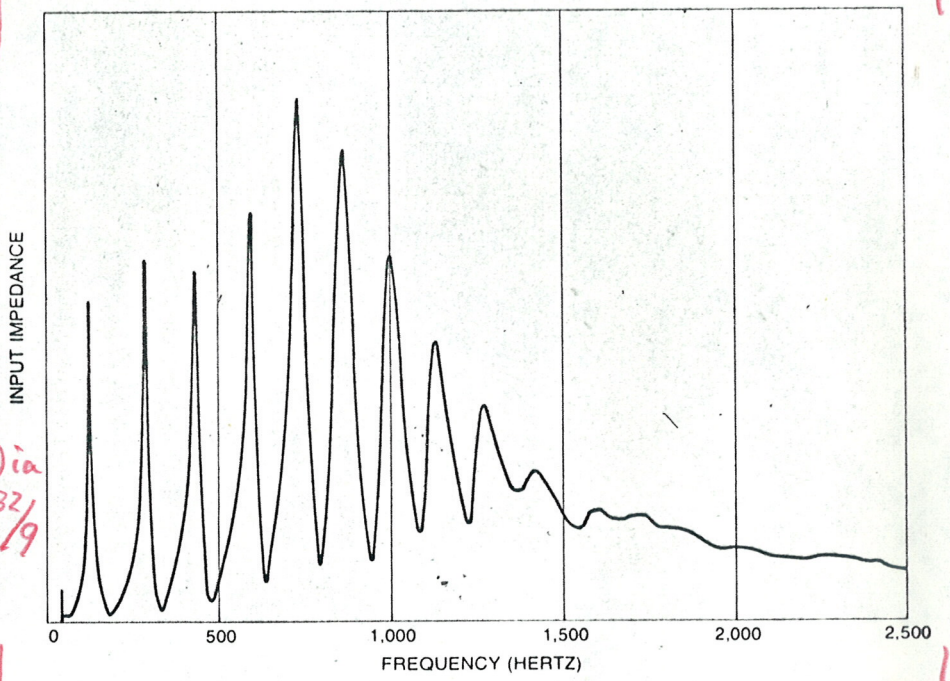

IMPEDANCE PATTERN OF A 19TH-CENTURY CORNET is typical of most of the trumpet and trombone family. The peaks grow progressively and then fall away sharply. The cornet was made in 1865 by Henry Distin. The third and fourth impedance peaks do not quite follow the smoothly rising pattern required for a genuinely fine instrument. The shortcoming is due chiefly to slight constrictions and misalignments in the valve pistons.

The reader may be wondering what happens when the valves on a brass instrument are depressed. Does anything radically new happen? The answer is no. The bell, the mouthpipe and the mouthpiece dominate the "envelope," or overall pattern, of the resonance curve; the pattern of peaks for a trumpet rises steadily as one goes from low frequencies to about 850 hertz and then falls away and disappears at high frequencies. When a valve is depressed, thereby increasing the length of cylindrical tubing in the middle of the horn, it merely shifts the entire family of resonance peaks to lower frequencies but leaves them fitting pretty much the same envelope.

In addition to working out the details of the regimes of oscillation in wind instruments, Worman's striking result is that when the player blows very softly, there is essentially no other component present in the vibration as it is measured in the mouthpiece, and that as he plays louder the amplitude of the second harmonic grows in such a way that for every doubling of the strength of the fundamental as the player blows harder, the strength of the second harmonic quadruples. Furthermore, the strength of this component proves to be approximately proportional to the impedance of the air column at the frequency of the second harmonic. Similarly, the third harmonic has a strength that is proportional to the impedance at the third-harmonic frequency, and from an even tinier beginning it grows eightfold for every doubling of the strength of the fundamental component.