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Saxophone Acoustics

The acoustics of any one instrument are a very complicated, yet are also a fascinating field to study. This study allows one to learn how not only that particular instrument produces the sound heard, but why it does as well. Without these studies, instruments could not have been constructed to produce the brilliant sounds that people all across the world enjoy today. An understanding of acoustics can lead to playing an instrument more effectively, and to a greater understanding of all aspects of music.

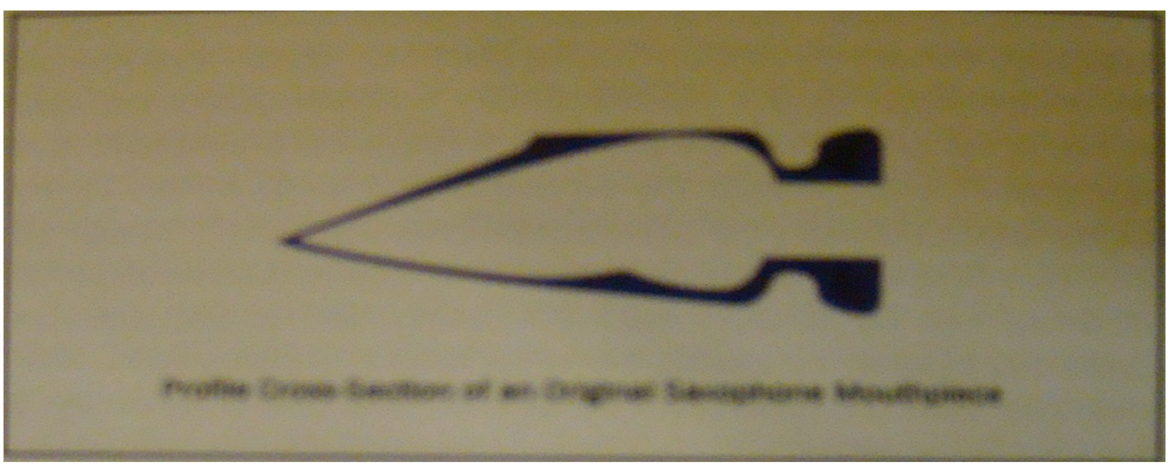
Every instrument displays certain acoustic properties within its construction to create acoustic resistance. This resistance is related to properties of aero and hydro dynamics. The study of these two fields has been essential to instrument makers throughout all periods of history. This allows them to study how air moves. One basic principle of these fields tells them that any object will continue to move indefinitely until met by another opposing force. John-Edward Kelly says, "Far from being the 'enemy' of movement, this resistance is actually the complementary force that gives the movement structure and form, i.e. gives it practical applicability" (Kelly 5).

We define the characteristic of any instrument's sound by the series of overtones that it produces when it vibrates to create sound. Different parts of every type of instrument produce these vibrations and the forces that resist and regulate them. On a stringed instrument this force comes from the tension of the string. The amount of tension is proportional to the amount of resistance contained in that string. On a percussion instrument, the mass of the vibrating portion of the instrument determines the amount of resistance that it contains to prolonged or excessive vibration. This resistance to excessive or prolonged vibrations has a few results in a change of temperance. This temperance regulates the proportions of overtones to create a consistency of sound quality through varying notes, dynamic ranges, and registers on an instrument. Contrary to modern belief, the material that an instrument is made of has almost no acoustic effect on its sound. (Kool 75-77)

The length of the vibrating portion of any instrument determines the pitch that it plays. Bass instruments are substantially longer than treble ones. Any instrument can play multiple notes on one fingering. This is comparable with a string player playing on an open string. These notes are part of the harmonic series available to the musician when dealing with that fingering. When a wind musician plays higher than the principle pitch of a fingering they are creating the same effect as a string player depressing a string at a certain point on the fingerboard to create a higher pitch. The wind musician has many different ways to alter the length of the vibrating airstream inside his/her instrument to control the pitch coming from it. With the brass family, this length change happens when the musician depresses a valve, which changes the length of the instrument by redirecting the air through a different length of tubing. This is the same principle of the panflute; the musician playing the instrument has complete control of which tube the column of air travels through. This conception allows the person playing the instrument to play on a different harmonic series. Modern valves direct air through longer portions of tubing when depressed. Trombone is the exception to this rule in the brass family. The length of the instrument is changed by moving the main slide which serves the same purpose as depressing valves on other instruments in the brass family. Woodwinds function slightly differently than brass instruments. Woodwind players alter the length of this airstream by the use of boring holes to shorten the length of their instrument. Boring each hole creates the same effect as completely chopping off the cylinder at that point. An important consideration to take while doing this is to take care that the holes being bored are not too small in relation to the diameter of the instrument. The size of the tone hole bored should allow the entire column of air inside the instrument to make contact with the air outside of the instrument. This means that the size of the tone holes must be proportional to the size of the body of the instrument into which they are bored. For these holes to produce the right effects, they need to be graduated in their distance from each other, meaning that the farther they progress down the length of the instrument, the farther apart they must be from one another. In a conical bore instrument such as flute or clarinet, the tone holes must also graduate in size as they progress down the instrument. This is because the bore gets larger in very small proportions as it moves towards the bottom.

The complicated acoustics of the saxophone can be understood after one has a conventional knowledge of the broader field of acoustics. Though the saxophone looks similar and functions similarly to other instruments in the woodwind family, it is very different at the same time. It does use the concept of bored tone holes to change the length of the column of vibrating air inside it, but in a slightly more complicated way. The acoustic resistance of the saxophone appears in a different place than that of the flute or clarinet. One needs only to study the design of this instrument to understand these differences.

Adolphe Sax designed the saxophone in such a way to produce a very specific sound. He designed every aspect of this instrument to beget the sound that he wanted to hear. The mouthpiece designed by Sax produced the acoustic resistance of the instrument.



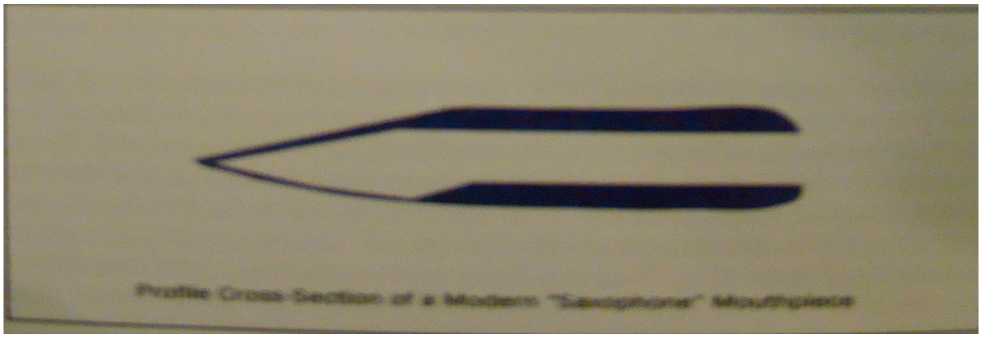
Profile Cross-Section of an Original Saxophone Mouthpiece

This occurred because of a very large chamber of air inside it. The air contained in the mouthpiece was then channeled into the much smaller bore of the neck of the saxophone. This channeling effect of the air creates resistance because it has to enter the bore of the instrument a little at a time. To understand the bore prescribed to the saxophone by Adolphe Sax, one must first have a basic knowledge of the physics behind an airplane wing. John-Edward Kelly states this principle best in his text called *The Acoustics of the Saxophone from a Phenomenological Perspective*.

> As a wing passes through an air-mass, the later is parted by the wing passing through it, but at the same time, the stability of its mass resists disturbance. Consequently, the air is not simply pushed out of the way, but attempts as much as possible to remain stationary. Without this resistance to change, the fundamental dynamic qualities of the earth would be entirely different, and many of the things we take for granted would be extremely difficult, if not impossible: flight, swimming, even the communication of music via sound-waves. Due to the shape of the airfoil – a quasi-parabolic arch towards the leading-edge on the upper surface, a relatively flat surface beneath – the air over the top surface effectively travels a greater distance than the air beneath, hence the speed of the airfoil relative to the surrounding air is greater on the top of the wing than on the bottom. In accordance with Bernoulli's Law, the relatively faster air above the wing therefore exerts less pressure upon the wing surface than the slower air below. This difference in pressure between the upper and lower surfaces generates lift, perhaps the most indispensable single element of winged flight. (14-15)

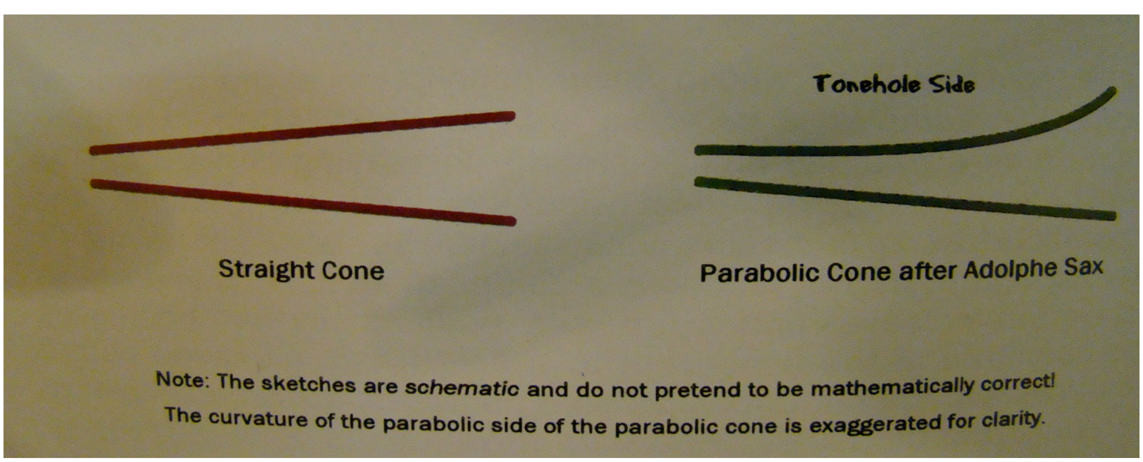
Adolphe Sax very simply designed the saxophone bore as an inversion of the design of the airplane wing. This causes a quasi-parabolic curve on the tone hole side of the bore of the saxophone. This curve serves a very important purpose in the design intended by Sax. It creates a longer and shorter side of the bore in which the longer side promotes less static pressure on the parabolic (longer) side of the bore and greater static pressure on the straight (shorter) side. Within this kind of pressure in the bore, an unstable environment is created that promotes free vibration of the entire length of the bore of the instrument. This causes a very great amount of resonance in the instrument. This resonance is caused by the unstable environment in the bore of the saxophone. Put simply, the saxophone as prescribed by Adolphe Sax creates resistance in the mouthpiece and promotes free vibration of air in the instrument itself. (Kelly 15-16)

During the 1930's and 1940's more and more young saxophonists began to play a clarinet style mouthpiece on the saxophone.



This was a saxophone mouthpiece designed with a narrow bore in which the expanding inner chamber of the mouthpiece is the same size as the beginning of the neck of the instrument. This type of set up creates absolutely no acoustic resistance. This creates an acoustic environment in the saxophone that requires little effort to develop a large dynamic range. Other musicians accept the fact that developing this takes many years of dedicated study. This can also create a situation for the saxophonist in which playing becomes difficult due to the fact that there is much less resistance to regulate the overtones that are being produced by his/her instrument.

The mouthpiece is not the sole change that took place with the saxophone in the early twentieth century. The essential shape of the bore that was prescribed for the saxophone was altered. One of the hardest things for instrument makers and saxophone players alike to understand is the difference between a parabolic cone and a straight cone.



The original bore shape that Sax designed has been altered by more modern instrument makers. The parabolic cone has become a straight cone on contemporary saxophones. As it has already been discussed, the straight cone creates within itself a static environment for the movement of air. This does not allow the bore of the instrument to vibrate beyond the lowest tone hole that is closed. This causes less resonance in the tone produced by the instrument when it is being played.

> When a straight cone is “shortened” by opening a tonehole, a different mixture of overtones results, almost as if the player had “changed instruments”. This would not be a problem if the unneeded length of cone were simply “cut off”, but by opening toneholes, the unused cone remains attached, disrupting the balance of overtones differently and to a various extent for each tonehole opened or closed. (Anyone familiar with the conical brass instruments will readily grasp that this is not an issue when valves are used instead of toneholes. In this case, one does not “shorten” the cone by opening or closing valves, but rather creates an entirely different cone.)” (Kelly 13)

This shows one principle difference between the way the conical bore functions in the saxophone and the way it functions in other instruments in the brass family. The differences in the straight cone of the saxophone and other conical woodwinds should also be addressed. This problem is greatly reduced in other woodwinds because one property of wood is its ability to absorb more upper overtones than metal can. This greatly reduces the tone holed problem on a conical instrument. Some oboes use a “stepped cone” according to John Kelly. This produces a series of successive cones that would be a problem with brass.

The acoustical differences in the parabolic saxophone and the conical saxophone each have advantages and disadvantages. Whichever works better really depends upon the person playing it. Each is still a saxophone, just in slightly different forms. Adolphe Sax envisioned a sound that was produced with a parabolic bore in the saxophone. When asked about this, Dr. Richard Scruggs said,

> With 6.8 billion people in the world, there are those who can make just about anything sound

> like just about anything else, considering facial structure, lip size, throat cavity shape and size, tongue shape & size, not to mention the vast array of mouthpieces, reeds, and varying saxophone bores/tapers/etc. ... parabolic or conical, or even maybe something else.

The physical build of the saxophone player will play a substantial role in determining which type of saxophone works the best for him/her. Saxophone players should try both types of bore to discover which is best for him/her. There is also the mental aspect for some players that want to achieve the sound that Sax envisioned. These players enjoy playing on the parabolic bore. Dr. Richard Scruggs stated,

> I have to believe in a mind-over-matter aspect, too. The parabolic bore, and appropriate mouthpieces, in my view, provide the basis of a situation in which there is a possibility of getting closer to an ideal sought by Adolphe Sax, one in which we can choose to take part, or not. There are beautiful sounds made by non-parabolic instruments and players, but they are not taking part in the possibilities of the saxophone in its most pure physical form.

Each type of saxophone can make beautiful sounds, depending on the musician playing it.

Even though it has been quite some time since the last parabolic saxophone was built, quality saxophones are still being built today that work for a great deal of saxophonists all over the world. The brilliant sounds produced by this beautiful instrument are becoming more popular in the modern world every day. This instrument is relatively young in the musical world but has changed a lot in that time. It is sure, however, to have a wonderful future in music.

Works Cited

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