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Vessel flute

A **vessel flute** is a type of flute with a body which acts as a Helmholtz resonator. The body is vessel-shaped, not tube- or cone-shaped.

Most flutes have cylindrical or conical bore (examples: concert flute, shawm). Vessel flutes have more spherical hollow bodies.

The air in the body of a vessel flute resonates as one, with air moving alternately in and out of the vessel, and the pressure inside the vessel increasing and decreasing. This is unlike the resonance of a tube or cone of air, where air moves back and forth along the tube, with pressure increasing in part of the tube while it decreases in another.

Blowing across the opening of empty bottle produces a basic edge-blown vessel flute. Multi-note vessel flutes include the ocarina.

Vessel flutes

Ocarinas on display at a shop in Taiwan

Blowing across the opening of empty bottle produces a basic edge-blown vessel flute.

A Helmholtz resonator is unusually selective in amplifying only one frequency. Most resonators also amplify more overtones.[1] As a result, vessel flutes have a distinctive overtoneless sound.

Contents

Types

Fipple vessel flutes

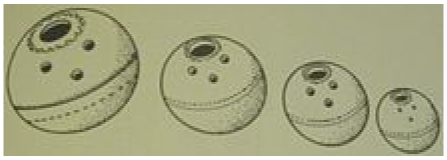
These flutes have a fipple to direct the air at an edge.

- Gemshorn
  - Pifana
- Ocarina
  - Molinukai
  - Tonette
- Niwawu

A referee's whistle is technically a fipple vessel flute, although it only plays one note.

Edge-blown vessel flutes

These flutes are edge-blown. They have no fipple and rely on the player's mouth to direct the air at an edge.



Borrindos, vessel flutes made of clay, often by children.

- Xun
  - Hun
- Borrindo
- Hand flute
- Kōauau ponga ihu (a Māori gourd vessel flute played with the nose)
- Ipu ho kio kio (a similar instrument from Hawai'i)

Other

The shepherd's whistle is an unusual vessel flute; the fipple consists of two consecutive holes, and the player's mouth acts as a tunable vessel resonator. A nose whistle also uses the mouth as a resonating cavity, and can therefore vary its pitch.

Acoustics

Sound production

Sound is generated by oscillations in an airstream passing an edge, just as in other flutes. The airstream alternates quickly between the inner and outer side of the edge.

Some vessel flutes have a fipple to direct the air onto the labium edge, like a recorder. Others rely on the player's lips to direct the air against the edge, like a concert flute. Fippleless flutes are called edge-blown flutes.

The pitch of a vessel flute is affected by how hard the player blows. Breath force can change the pitch by three semitones.[2] This is why vessel flutes generally have no tuning mechanism, and why it is hard to learn to play a vessel flute in tune.

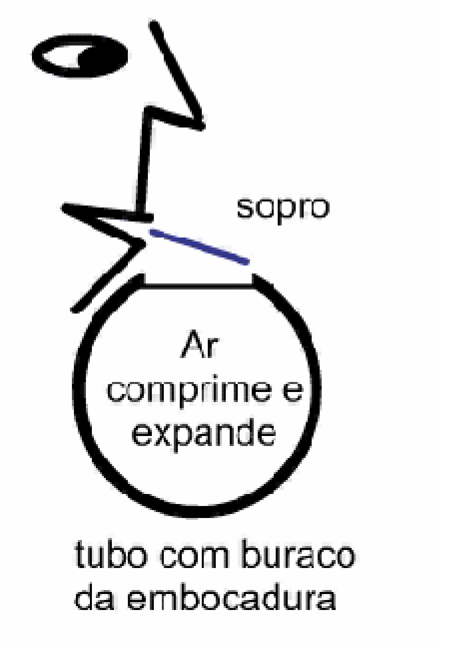
Fingering holes and fingers that are too close to the labium disrupt the oscillation of the airstream and hurt the tone.

Amplification

At first the sound is a broad-spectrum "noise" (i.e. "chiff"), but those frequencies that match the resonant frequency of the resonating chamber are selectively amplified. The resonant frequency is the pitch of the note that is heard. Vessel flutes use the air in a vessel for amplification; the vessel acts as a Helmholtz resonator.

Pitch and fingering

The resonant frequency of a vessel flute is given by this formula: (heavily simplified, see simplifications)[3]



Air pressure oscillating in the body of a vessel flute with no fipple. These are sounded by blowing across a hole, just like blowing across the opening of an empty bottle. In this case, the labium is the edge of the far side of the hole. Just as in a fipple flute, the airstream alternates quickly between the inner and outer side of the labium; another diagram, with fipple (https://commons.wikimedia.org/wiki/F

$$pitch\ of\ the\ note = (a\ constant) \times \frac{total\ surface\ area\ of\ open\ holes}{total\ volume\ enclosed\ by\ the\ instrument}$$

From this, one can see that smaller instruments are higher-pitched. It also means that, in theory, opening a specific hole on an instrument always raises the pitch by the same amount. It doesn't matter how many other holes are open; opening the hole always increases the total area of the open holes by the same amount.

A vessel flute with two fingering holes of the same size can sound three notes (both closed, one open, both open). An vessel flute with two fingering holes of different sizes can sound four notes (both closed, only the smaller hole open, only the bigger hole open, both open). The number of notes increases with the number of holes:

Number of holes	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Number of notes	1	2	4	8	16	32	64	128	256	512	1024
Powers of two	2^{0}	2^{1}	2^{2}	2^{3}	2^{4}	2^{5}	2^{6}	2^{7}	2^{8}	2^{9}	2^{10}

In theory, if the smallest hole were just big enough to raise the pitch by a semitone, and each successive hole was twice as big as the last, then a vessel flute could play a scale of 1024 fully-chromatic notes. Fingering would be equivalent to counting in finger binary.

In practice, the pitch of a vessel flute is also affected by how hard the player blows. If more holes are open, it is necessary to blow harder, which raises the pitch. The high notes tend to go sharp; the low notes, flat.[2] To compensate, fingering charts soon diverge from the plain binary progression.

The exact shape of the vessel is also not critical, as long as the cavity resonates as a Helmholtz resonator. This is why vessel flutes come in a variety of shapes.

Overtones

The resonator in the ocarina can create overtones, but because of the common "egg" shape, these overtones are many octaves above the keynote scale.[1] In similar instruments with a narrow cone shape, like the Gemshorn or Tonette, some partial overtones are available. Overblowing to get a range of higher pitched notes is possible on the ocarina, but not widely done, because the resulting notes are not "clean" enough.

Multiple resonant chambers

Some ocarinas are double- or triple-chambered, often with the chambers tuned an octave or a tenth apart. This allows the player to play chords, but it also allows an increased range.

Double-chambered ocarina, for playing chords and extending range.

Physics simplifications

A **less**-simplified formula for the resonant frequency of a Helmholtz resonator is: [3]

$$f = \frac{v}{2\pi}\frac{A}{V}$$

Where ***f*** is the resonant frequency, ***v*** is the speed of sound, ***A*** is the total area of openings in the vessel, and ***V*** is the volume of air enclosed in the vessel, and π is a geometric constant.

The pitch of a Helmholtz resonator is also affected by how far the air has to go to get in or out of the resonator; in other words, the thickness of the material the holes are cut in.

Variations in the speed of sound

The speed of sound, assumed to be constant above, is in fact somewhat variable.

The speed of sound in air varies with temperature, meaning that a vessel flute's pitch will change in hot or cold air. However, varying the playing airspeed can change the pitch by three semitones.[2] This is enough to cancel the expected pitch effects of any probable temperature change.

Air pressure variations do not affect pitch (the ratio of pressure to air density in an ideal gas is constant. Air pressure and density changes therefore cancel, and have no effect on the speed of sound; air is nearly an ideal gas, so there is nearly no effect).

Humidity has a comparatively small effect on the speed of sound. Going from zero to 100% relative humidity should change the frequency by less than a two-degree-Celsius change in room temperature.[4] As the player's breath has ~100% relative humidity, the humidity can't vary that much anyway.

See also

- End-blown flute
- Fipple flute
- Hand flute
- Nose flute
- Overtone flute
- Side-blown flute

References

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