3.11.3.5: Pipe Organs and Other Reed Instruments

Although technically a keyboard instrument, pipe organs are based on tubes. Instead of changing the length of a single pipe (with holes or other mechanisms) to get different frequencies there is a large collection of pipes of different lengths and a mechanism to blow air through them. The sound generating part may be either a fipple or a reed and some organs have different pipes with each type. The tubes may be made of wood or metal, may be open or closed on the end and have various shapes, as shown below. A variety of methods are used to tune an individual pipe by slightly changing its length or modifying the end of the pipe. As in the case of reed instruments different pipe shapes lead to different overtones that change the timbre of the note being played. Because a large number of pipes can be employed (the Wanamaker Pipe Organ has $28,604$ pipes), pipe organs can produce a wide variety of sounds. The longest pipes may be as long as 19.5 m which makes an 8 Hz pitch.

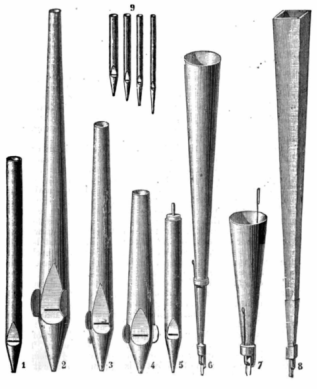

Figure 3.11.3.5.1

A final class of instruments that use reeds but not tubes are called ***free reed aerophones***. These include harmonicas, accordions, bandoleóns and similar instruments. In these instruments a reed vibrates as air is forced over it, so they are blown open reeds, unlike clarinet or saxophone reeds. There is a reed with different tension to produce each note. The mouth and cupped hands form the resonating bodies for harmonicas. In accordions and similar instruments a set of bellows are used to force air over the reed and the air box forms the resonating cavity.

Video/audio examples:

- Wikipedia on free reed aerophones.
- A web site about harmonicas and other mouth blown, free reed instruments with sound samples.
- Performance of the Wanamaker Organ.
- Slow motion of harmonica reeds.
- One of many YouTube video of a didgeridoo. The didgeridoo is an instrument used by the aboriginal peoples of Australia and consists of a long tube of wood. The lips are buzzed to make a sound but the voice is also used. Because of the large diameter and length there are many interesting resonances that can be excited while playing the instrument.

Summary

As is the case for all instruments, tube instruments start with a vibrating sound source and use resonance to amplify the desired frequencies. For woodwind instruments a single or double reed vibrates. For flutes a fipple turns a smooth air flow into an oscillating flow which becomes the initial vibration. Woodwind instruments use holes to change the effective length of the tube to get different fundamental frequencies. Keys activated by springs and levers extend the reach of the human hand in opening and closing holes in the instrument. The cross sectional shape of the tube changes the overtone frequencies, giving the particular instrument its timbre. Brass instruments start with a pair of buzzing lips. The length of the tube is changed by either a sliding tube arrangement or a valve that shunts the air through tubes of different lengths. The impedance matching provided by the bell of a brass instruments enables them to produce more sound and also shift their overtone frequencies to give them their unique timbre.

Questions on Tubes:

1. How are the modes of vibration of a string similar to the modes of vibration (fundamental and overtones) of air in a tube and how are they different?

2. How are the modes of vibration of air in a tube that is closed at one end different than those of one open at both ends?
3. How is the length of a tube related to the fundamental frequency of vibration of air inside a tube open at both ends?
4. How is the length of a tube related to the fundamental frequency of vibration of air inside a tube open at only one end?
5. What is the difference between pressure nodes and displacement nodes in a tube instrument?
6. What are pressure anti-nodes and where are they located in a tube open on both ends for the fundamental and the first three harmonics?
7. How can the fundamental frequency of a tube instrument be changed?
8. Why does introducing finger holes in a flute affect the frequency played?
9. Holes on a tube instrument change the frequencies being played. List some problems with using holes for this purpose.
10. What is the general definition of impedance?
11. Why is some impedance necessary for tube instruments?
12. In a tube instrument, how are standing waves established in the tube?
13. What vibrates to produce the initial sound in each of the following instruments: Oboe, clarinet, flute, pipe organ, trumpet, trombone.
14. What is embouchure and why is it important?
15. Explain how a flute works without a reed to vibrate.
16. What is an edge tone?
17. Brass instruments are generally louder than woodwind instruments because they have bigger bells. Why does a bigger bell make the instrument sound louder (Hint: Think about impedance.)?
18. What other effect does a large bell have on a brass instrument besides making it sound louder?
19. Clarinets and trumpets are both tube instruments which can play the same note (same fundamental frequency) but they have very different timbre. What are some factors that cause the timbre to be different?
20. How do the following instruments change the pitch they are playing: Slide trombone, trumpet, flute, French horn, clarinet, saxophone, flute, pipe organ.
21. A didgeridoo is a long lube of wood, an instrument used by Aboriginals in Australia. How is the sound produce? Is there any impedance? Explain your answers.
22. Harmonicas, accordions, and bandoleóns all belong to what type of non-tube instrument? How do they work?
