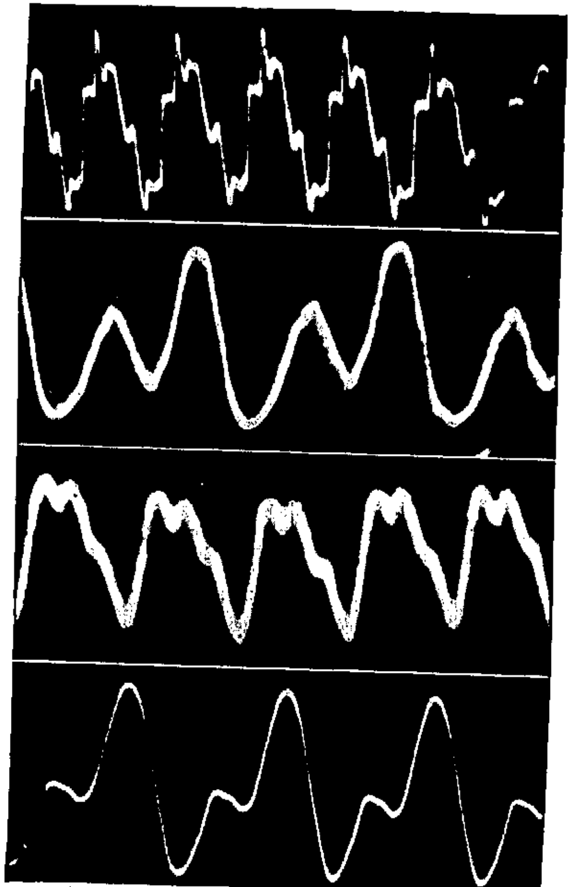


FIG. 13–7. Waveforms of organ pipes. *Reading down:* clarinet, A 220; viole, A 220; harmonic flute, A 440; diapason, A 220. Heaviness of trace not significant.

vibration; hence the wavelength is four times the length of the pipe; (2) The air in the resonating pipe is mechanically closely coupled with the reed. This latter fact means that the "speaking" frequency of a reed pipe is determined by the joint effect of both the generator (the reed) and the resonator. It has been determined by careful experimentation that, generally, the speaking frequency of a reed pipe is lower than that of either the reed itself or its associated pipe. If the reed is too stiff, the generator may impose its natural frequency on the pipe, but in the case of organ pipes

From Charles Culver, Musical Acoustics (1956)



the reed is of thin metal, thus bringing about a condition of reciprocal influence. In practice the reed and pipe are arranged to have nearly the same frequency; this condition makes for a more satisfactory tone, and a "quick speaking" pipe assembly.

From (1) above it would appear that a reed pipe might be considered to be a closed pipe, with a node at the reed end. Actually

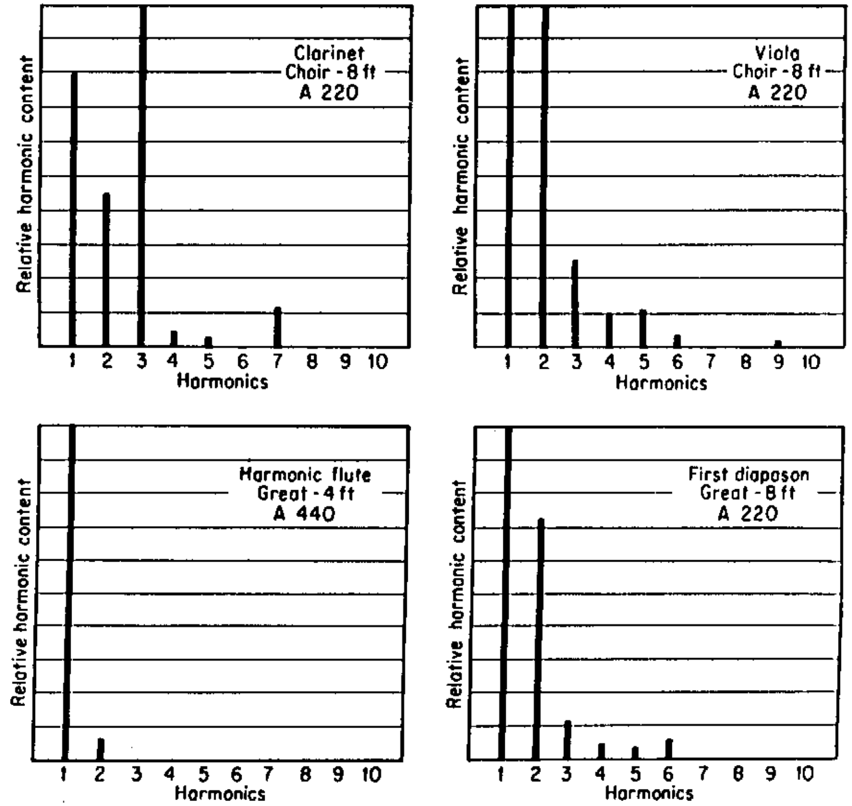



FIG. 13–8. Spectra of organ tones shown in Fig. 13–7.

such a pipe does not function as a closed pipe, as will be evident from the sound spectrum (Fig. 13–8) of a clarinet pipe. In practice both orchestral and chorus reeds (discussed below) show even as well as odd overtones.

A reed pipe is tuned by altering the natural period of the reed, rather than by altering the length of the pipe. The lower end of wire *W* (Fig. 13–5) presses against the reed, and when moved up

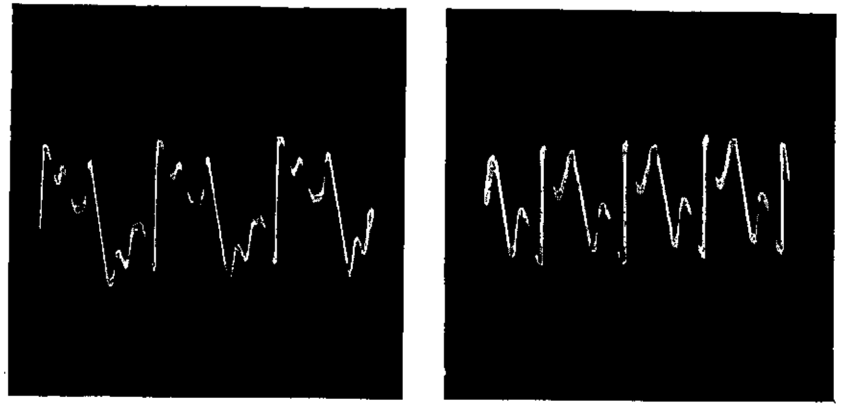


FIG. 13–17. Waveforms of clarinet tones: *left*, $G_3$; *right*, $D_4$.

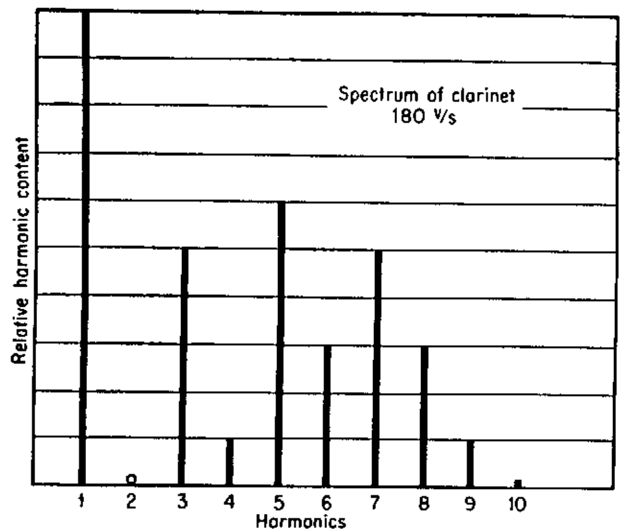



FIG. 13–18

The reed is then compelled to yield notes corresponding to those which are natural to those of the air column. The result of this is that the instrument emits tones which are considerably lower, and much more stable, than those natural to the generator itself. The sound spectrum of a lower note (Fig. 13–18) shows the presence of strong upper partials, the second, fourth, and sixth being particularly prominent. These overtones give the clarinet its characteristic



tone color. It is possible to control the intensity of the clarinet tone more effectively than that of other wind instruments.

When used in military and concert bands, the clarinets take the place of the violins in orchestral instrumentation. Indeed, symphonic music is sometimes rendered by largely substituting reeds for strings.

The clarinet has been used extensively in operatic and symphonic renditions since about 1770, one of the themes frequently being carried by this instrument. Wagner gives a prominent part to the A clarinet in the *Tannhäuser* overture. Mozart makes effective use of the clarinet in his *Quintet in A major*.

In addition to the instrument just described and sometimes referred to as the soprano clarinet, a **bass clarinet** is frequently used in orchestral work. As is to be seen in Fig. 13–19, it resembles somewhat the saxophone in appearance, being crooked at the upper part and having a turned-up metal bell. This instrument is made in both A and B♭ types, though the latter form is more commonly used. The bass clarinet is tuned an octave below the corresponding soprano instrument, and has a range extending from $D_2$ to $E\flat_5$. Having this range it can compass the higher notes of the bassoon and the lower notes of the flute. Because of its musical flexibility and rich tonal quality, it is used by many composers to carry solo and theme parts. Wagner for instance uses it for important passages in several of his compositions, notably in *Tannhäuser* and in *Die Valkyrie*.

In passing, it is interesting to note that some musicians contend that an A clarinet, for instance, will yield a different tone color than that produced by a B♭ instrument. Objective tests show that few, if any, composers or conductors can actually detect any

FIG. 13–19. Bass clarinet. (Carl Fischer Musical Instrument Co.)

fundamental; the third and fifth harmonics are also relatively strong. This complement of harmonics gives the oboe its characteristic tone color, a penetrating, "reedy" sound resembling in some respects the human voice. Overblowing gives the octave rather than the third partial, as in the case of the clarinet. This fact simplifies somewhat the note-hole arrangement as compared with that of the clarinet.

The range of the oboe is from $B\flat_3$ to $F_6$ inclusive.

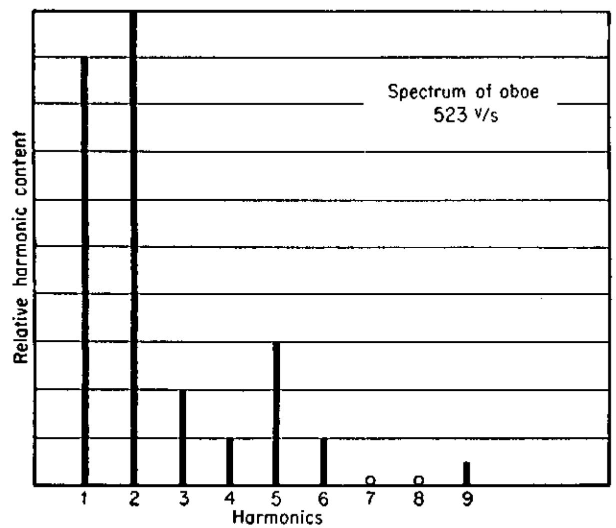



FIG. 13–26

The oboe has long been used effectively as an orchestral instrument—from the time of Bach and Handel down to the works of Sibelius. A beautiful oboe obbligato appears in the chorale *Jesu, Joy of Man's Desiring*. A notable solo passage for the oboe occurs in the first movement of Beethoven's *Fifth Symphony*.

## 13–11. *The English Horn*

This instrument, a picture of which is shown in Fig. 13–27, is the alto member of the double-reed family. While somewhat similar in appearance to the oboe, this reed instrument has a curved mouthpipe, is somewhat larger than the oboe, and terminates in a globular-shaped bell. Acoustically, the English horn develops both



odd- and even-numbered partials, but its complement of overtones is somewhat different from the oboe, as may be seen by comparing the sound spectra shown in Figs. 13–26 and 13–29. Its waveform is indicated in Fig. 13–28. The English horn is pitched a fifth lower than the oboe, and like most lower pitched instruments has a relatively extensive complement of upper partials, as shown in Fig. 13–29. Its tone is, accordingly, richer and somewhat

FIG. 13–27. English horn. (C. G. Conn, Ltd.)

more somber than that of the oboe, the tone character resembling, to some extent, the tone of the human voice. The instrument is sometimes used in orchestral compositions to express grief and anguish, sometimes tenderness or a dreamy mood. The English horn is built in the key of F, and has a pitch range of two and a half octaves, its lowest note being E below middle C. The keying arrangement and the fingering are the same as those of the oboe. In its modern form, the English horn was first

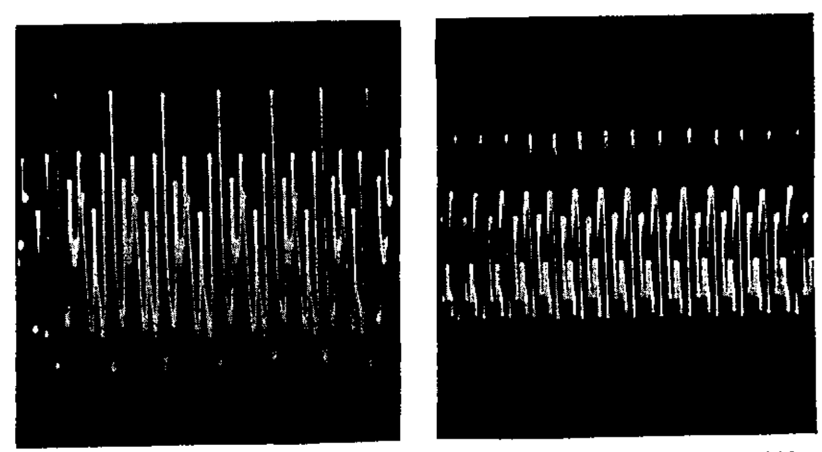


FIG. 13–28. Waveforms of English horn, sounding A 220 and A 440.

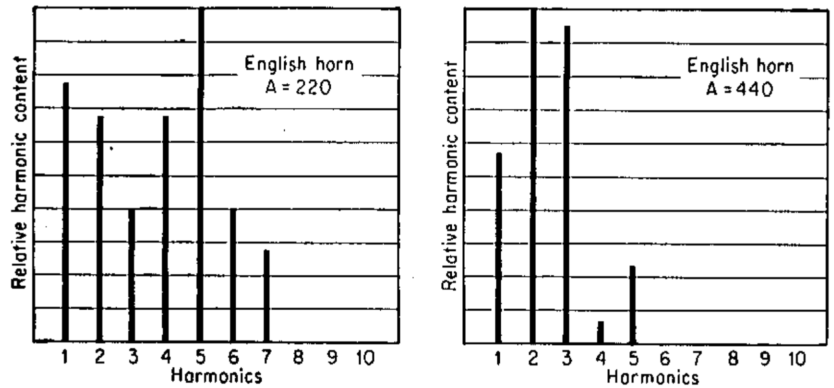
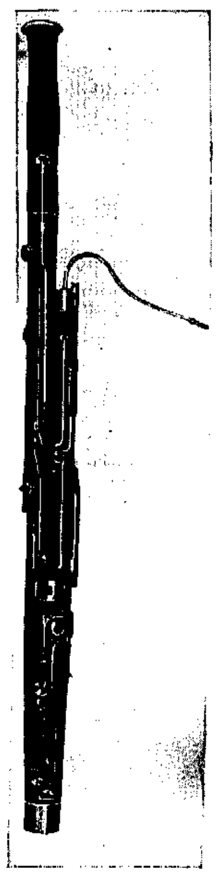



Fig. 13–29



used by Rossini in *William Tell* (1829) and by Meyerbeer in *Roberto* in 1831. Commonly only one English horn is used in orchestral instrumentation.

## 13–12. *The Bassoon*

Like the oboe, the bassoon is a double-reed instrument, and it functions, essentially, as an alto oboe. It consists of a conical tube 93 in. in length, measuring 1¾ in. in diameter at the flared end, and 3⁄16 in. at the reed end. A short metal crook connects the reed assembly to the wooded tube. The double reed is larger than that used on the oboe. Because of its relatively great length it is doubled back on itself (Fig. 13–30), the actual length of the instrument being only 4 ft. The acoustical length of the bassoon is controlled by seven holes and 16 or 17 keys. Owing to the length of the instrument the

Fig. 13–30. Bassoon. (Carl Fischer Musical Instrument Co.)



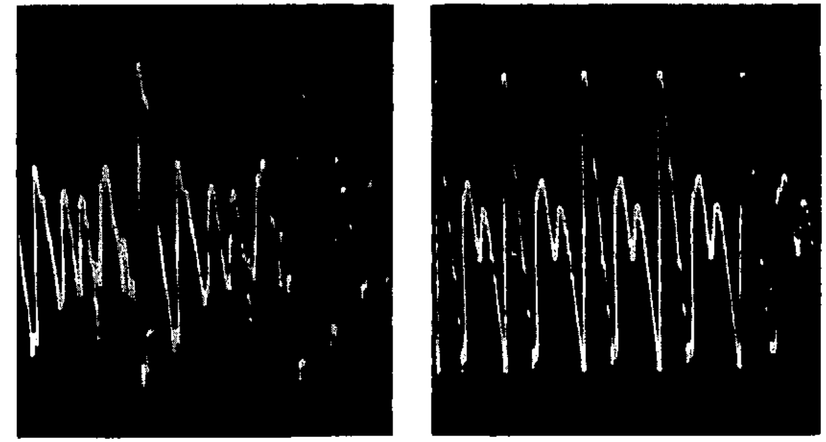


Fig. 13–31. Waveforms of the bassoon in the low and middle register.

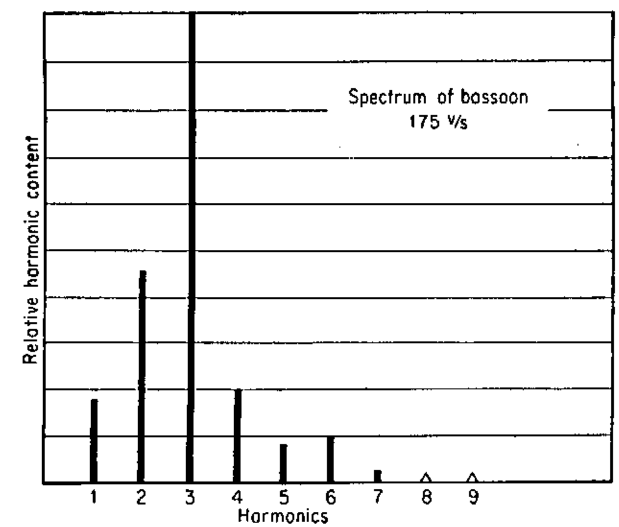



Fig. 13–32

holes pass obliquely through the tube wall, thus bringing the actual apertures within the compass of the fingers. Representative waveforms emitted by the bassoon are shown in Fig. 13–31, and in Fig. 13–32 may be seen the spectrum of the middle register. The instrument yields the full harmonic series and has a range of more than three octaves, extending from $B\flat_1$ to $E\flat_5$. It will be noted that the strongest component is the third harmonic, the fundamental being of relatively low-frequency components, and the other involving a group of relatively high-frequency partials. In general, such a grouping is characteristic of vowel sounds. The details of each

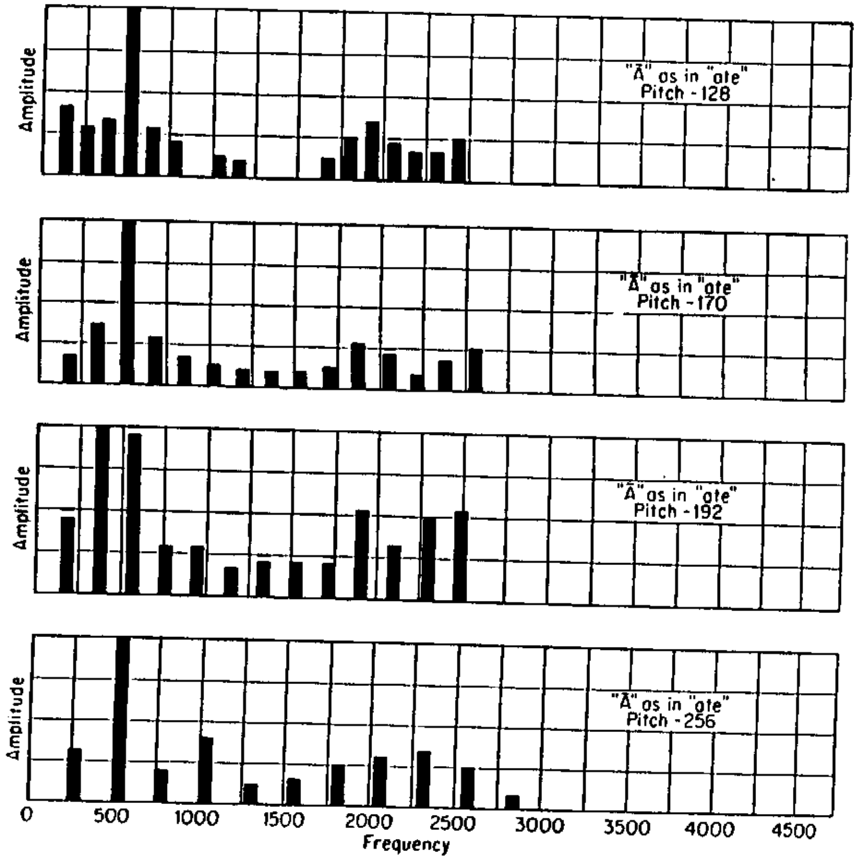



FIG. 13-53. Harmonic content of the vowel *ā* when vocalized at three different pitches. (Reprinted by permission from "*Speech and Hearing*" by H. Fletcher, published by D. Van Nostrand Co., Inc.)

formant, and the span of the formants in the scale, determine the voice characteristics of a particular person.

As a result of the extended research Dr. Fletcher found that the mean fundamental frequency of the male voice, when sounding the vowels, is about 124 cps, and for the female 244. The research also disclosed that the **low characteristic frequency** depends upon the particular vowel being uttered, the range being 296 to 955 for the



male voices and 332 to 1036 for the female voices in the cases studied. The corresponding values for the **high characteristic frequency** sounds are 1800 to 3000 and 2000 to 3266 respectively.

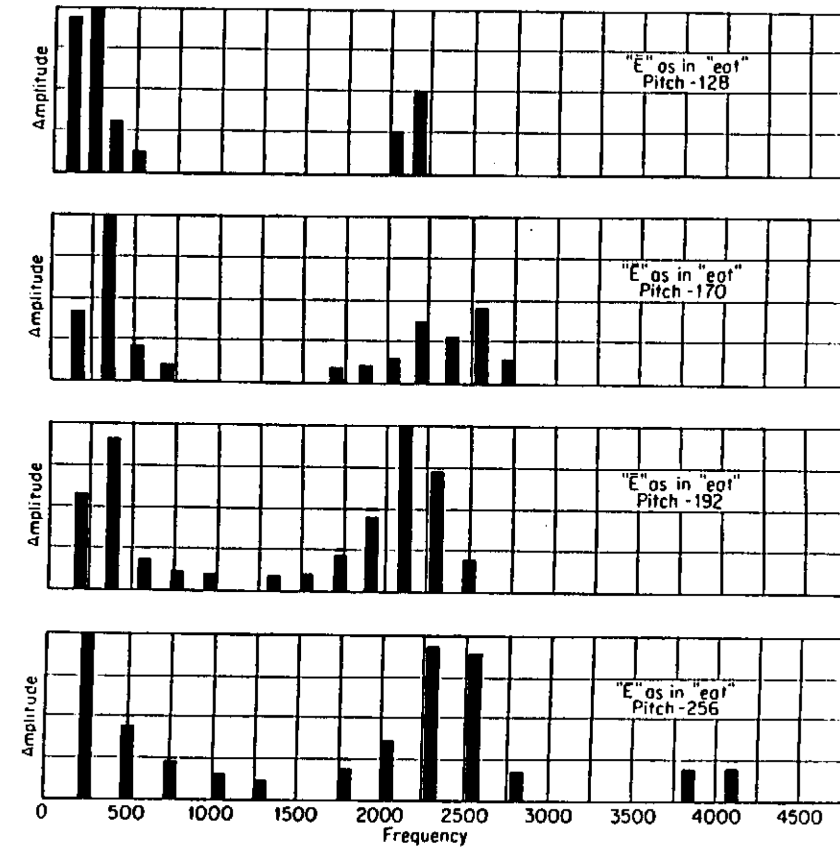



FIG. 13-54. Harmonic content of the vowel *ē* when vocalized at three different pitches. (Reprinted by permission from "Speech and Hearing" by H. Fletcher, published by D. Van Nostrand Co., Inc.)

**The high frequency characteristic components are essential to intelligibility.** It is possible to filter out all frequencies below 500 and still secure understandable speech.

In Fig. 13-55 may be seen the waveform of several vowel sounds as intoned by the same person at approximately the same pitch. While the details of a given vowel record will vary with the individual, the general waveform of each vowel is characteristic of