



**ELECTROMAGNETIC SOURCE** for projecting acoustic waves into a test instrument was devised by John W. Coltman. The excitatory piston is directly coupled to the voice coil of a loudspeaker. The coil in turn drives the piston with an amplitude that is ultimately determined by a voltage induced in a pickup coil that is mounted on the same shaft. The mechanism is used in an overall system similar to that used with the Merhaut impedance head. The pressure response in the mouthpiece cup is detected by a miniature microphone.

that led him to a correct theory for the effect of a compliant structure (the reed or, in our case, the player's lips) on the input impedance of a column of air. This effect of the yielding closure of the mouthpiece cup provided by the lips is quite separate from the lips' functioning as a valve. Hermann von Helmholtz provided the next advance. In 1877 he added an appendix to the fourth German edition of his classic work *Sensations of Tone* that gives a brief but complete analysis of the basic mechanisms by which a pressure-controlled reed valve collaborates with a single impedance maximum. He found that for a given pressure-control sensitivity (what an engineer today calls the transconductance) a certain minimum impedance value is required. Oscillating systems of the type analyzed by Helmholtz are found around us everywhere. The pendulum clock is

nonlinearity in the control characteristics gives rise to additional frequencies at double, triple and quadruple the frequency of the basic oscillation. The net generation of oscillatory energy from the player's steady muscular effort, however, is still almost exclusively at the frequency of the impedance maximum; energy diverted in the process to other frequencies is dissipated in various ways to the outside world.

We must now try to explain how oscillations in a wind instrument can take place at not just the tallest impedance maximum but at any one of several maxima belonging to an actual air column. According to the Helmholtz theory, a wind instrument should show a strong preference for oscillations that take place at the tallest of the impedance maxima. Thus the question arises of how the bugle player finds it possible to play the