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Director of Public Relations

Note to Editors and Reporters: The A.I.P. will not conduct a Press Room for the 72nd meeting of the Acoustical Society of America. Press inquiries will be handled by Dr. William J. Galloway who will be available in the Headquarters hotel, Statler Hilton, Dallas Room, to set up interviews if desired. Telephone: (213) 629-4321

RELEASED FOR THURSDAY AFTERNOON, November 3, 1966

Authors' Popular Version of Paper 3C5:

"WORKING THEORY OF TRUMPET AIR-COLUMN DESIGN"

Presented by W. T. Cardwell, Jr.
Chevron Research Company
La Habra, California 90631

Working Theory of Trumpet Air-Column Design

W. T. Cardwell, Jr.

Trumpets have been made and played for literally thousands of years, and the shapes of the air columns inside modern trumpets have resulted from centuries of trial and error. We are now learning the scientific reasons for some of the shape features, and we may be at the point where we can not only explain functions of the old shapes, but can design new shapes that will work better than the old.

The shape of the air column inside a trumpet determines the pitches, or vibrational frequencies, of the notes that the trumpet will play. The difficulty of the problem of finding a proper shape may be appreciated by comparing the trumpet with a pipe organ. In the pipe organ, each of the pipes contains a vibrating air column that is responsible for just one note of the scale. In contrast, the trumpet contains just a single vibrating air column that must be responsible for many notes. Some of the note changes on a modern trumpet are produced by the valves; but the large changes are made by the air column itself changing its kind of vibration. The so-called bugle notes that a trumpeter can blow without moving his valves represent the various kinds of vibration of the trumpet air column. There are at least six of these bugle notes that should be usable for every valve setting. So, whereas an organ pipe must be able to play only one note in tune, a trumpet must be able to play at least six notes, over a range of two octaves, without valve motion, and all of these six notes must be in proper musical tune with each other.

By shaping the trumpet air column correctly, it is possible to make the trumpet notes in tune with each other, or, at least, it is possible to make them so little out of tune that the trumpeter himself can do the rest of the tuning job very quickly with his lips.

Various attempts have been made to calculate theoretically what kind of air column shape should be needed to produce proper relative tuning between the bugle notes of a trumpet. Those investigators who have also made experiments to test their theoretical calculations have encountered unexplained difficulties.

New experimental data, and some reinterpreted old data, indicate that previous theories may have overemphasized the importance of the bell of the trumpet. The trumpet mouthpiece also is important. It is not merely an adapter for the lips. Its peculiar internal passageway, which starts out large, contracts to a small orifice, and then expands again to the main tubing size of the trumpet, has a significant part in the proper relative tuning of the various notes of the trumpet.

If full account is taken of the help that the mouthpiece gives to the bell, it then becomes possible to calculate mathematically the bell shape that is needed for a trumpet; and the calculated results agree with experimental results.

Using the theory, a new trumpet has been designed and built to play classical trumpet parts in high E-flat and F.

THURSDAY, 3 NOVEMBER 1966 LOS ANGELES ROOM AT 9:00 A.M.

Session 3C. Musical Acoustics

JOHN BACKUS, *Chairman*

Contributed Papers

3C1. Corrected String Lengths to Compensate for Tension and Damping. O. J. BURCHETT (nonmember) AND R. R. EATON (nonmember), *School of Mechanical Engineering, Oklahoma State University, Stillwater, Oklahoma.*—The fact that the diatonic scale cannot be used on a fretted instrument is shown. The derivation of the chromatic scale is also shown and the results are compared to the diatonic scale. A testing device that simulates the stretching of a string when fretted was used to obtain the necessary string lengths to produce the desired vibration frequencies. The desired vibration frequencies are determined by the chromatic scale. Nylon guitar, steel guitar, and banjo strings were tested. [*15 min.*]

3C2. Effect of Warping of the Reed Tip on Clarinet Tone. JOHN BACKUS, *University of Southern California, Los Angeles, California 90007.*—In a previous paper [J. Acoust. Soc. Am. 39, 1220 (A) (1966)], there were described several parameters associated with the clarinet reed that influence the harmonic structure of the tone produced. In addition to these, another important effect has been found. The aperture between reed and mouthpiece does not actually close completely during this part of the cycle that the reed is in contact with the mouthpiece, due to a certain amount of warping usually present. That part of the reed not in contact with the mouthpiece can then still oscillate with a small amplitude at a high frequency. A harmonic of the internal standing wave near this frequency can then be produced at a relatively high amplitude by the same regenerative mechanism that produces the fundamental frequency with the entire reed. The magnitude of this effect will be unpredictable for cane reeds. [*15 min.*]

3C3. Rôle of Jet-Edge Asymmetry in Pipe Voicing. S. A. ELDER, *United States Naval Academy, Annapolis, Maryland.*—Observations were made, using schlieren optics with stroboscopic illumination, of jet motion in mouth region of open diapason-voiced and flute-voiced pipes. For diapason, the jet-edge system is strongly asymmetrical, the jet spending only about $\frac{1}{4}$ of a period in pipe each cycle. Resulting "Class C" driving generates strong second-harmonic content evident even in the motion of the jet itself. Direct-current flow through pipe, into open end and out of the mouth, caused by Bernoulli pressure associated with average external jet flow, purges the pipe of all but about 14% of jet fluid in normal operation, making it possible to drive the pipe on CO_2 with very little pitch change. Jet-edge configuration is more nearly symmetrical for flute-voicing, with even harmonics consequently weak. Driving pulse for flute-pipe lags phase of standing-wave velocity maximum only slightly, in qualitative agreement with Bechert–Cremer model. For diapason voicing, in contrast, driving pulse is very nearly in phase with pressure. This effect causes essentially the entire fundamental component of jet influx to be used in overcoming acoustic losses in diapason pipes. [Work supported by the U. S. Office of Naval Research.] [*15 min.*]

3C4. Open Tones of Musical Horns. FREDERICK J. YOUNG, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania.*—A computer program is presented that calculates the frequencies of the open tones of musical horns from the dimensions of the horns. The program also allows for the consideration of the additional tubing added by the valve slides. The calculations are executed for several different horns. For a given bell and untapered portion of the horn diameters, the ratio of the length of the untapered portion to the total length of the horn is varied and the resonant frequency is calculated. In these calculations, the tapered portion of the horn varies as $r(x)/r(o)=(1+x)^{-\alpha}$, where r is the radius, x the distance from the mouth of the bell, and α the taper constant. The effect of varying the taper is investigated by letting $r(x)/r(o)=(1+x^p)^{-\alpha}$, where p is varied but the bell diameter and the length of the cylindrical tubing is held constant. The effect of temperature upon intonation is evaluated in several cases. [*15 min.*]

3C5. Working Theory of Trumpet Air-Column Design. W. T. CARDWELL, JR., *Chevron Research Company, La Habra, California 90631.*—The boundary conditions for waves in a trumpet are not simply a pressure antinode at the mouthpiece end and a pressure node at the bell end. The mouthpiece acts approximately as an infinite impedance closure at the lip plane, but viewed from its trumpet end, the mouthpiece acts as a Helmholtz resonator, and the imaginary component of its impedance moves from a high value down through zero, as the trumpet frequencies rise through their useful range. The function usually ascribed to the bell, of shifting the frequencies of the vibrational modes from those of a closed-open pipe to the musically useful modes of an open–open pipe, is significantly handled by the bell only in the lower playing modes. The necessary shifts in the upper modes of a modern trumpet are handled by the resonator action of the mouthpiece, and by an actual shortening of the over-all tube below the simple-theoretical length. Experimental resonance data are given to support the theory. The conclusions have been embodied in a playing trumpet designed for high register work in E♭ and F. [*15 min.*]

3C6. Graphical Language for the Scores of Computer-Generated Sounds. M. MATHEWS AND LAWRENCE ROSLER (nonmember), *Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.*—Conventional musical scores are an insufficient and inconvenient way of describing sound sequences to computers. A procedure is described for drawing scores as graphical functions of time, using a light pen on a cathode-ray tube attached to a small computer. The information is transmited digitally to a larger computer, which synthesizes the sound and reproduces it immediately with a loudspeaker. Typically, functions for amplitude, frequency, and duration of a sequence of notes are drawn. An algebra allows combining functions by addition and multiplication. In this way, certain compositional processes may be performed by the computer. For example, the time-varying weighted average between two melodic or rhythmic sequences may be synthesized. The graphical programs provide great flexibility for drawing, copying, erasing. and altering functions. Thus it is easy to develop a sound sequence by a succession of trials. Microfilm and punched-card versions of the score are automatically provided. In addition to being compositional tools, the graphical scores are effective representations of the sound to a listener. In many ways, they are easier to follow than conventional scores. [*15 min.*]