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FUNDAMENTALS OF ACOUSTICAL DESIGN OF THE SOPRANO CLARINET

BY LEE GIBSON

■ After nearly three hundred years of empirical development, the determining factors of the clarinet's acoustical performance remain imperfectly articulated and preserved as the secrets of instrument manufacturers. How badly the clarinet has needed its own Theobald Boehm, and how needlessly the clarinetist has tolerated malformations of this most exacting of all wind instruments! Apparently, the law is that nothing regarding these principles can ever be committed to print, lest it fall into the hands of a competitor. This view is myopic and benefits no one. (We are treated even now to retrogressions in the output of important factories, as they once again cover features of design that were discarded as inadequate a half century ago.) Regardless of what in past centuries may have been justifiable in such an attitude, ours is a century in which scientific knowledge belongs to the world and is disseminated accordingly.

Without question, the clarinet maker's first goal must be the achievement of the greatest perfection of intonation in all registers. This paper will be limited to the implementation of that goal. Two papers by A. H. Benade¹ should

¹A. H. Benade, "Woodwind Instrument Bores," *Journal of the American Acoustical Society*, No. 31 (1959), pp. 137-146; "On the Mathematical Theory of Woodwind Finger Holes," *idem*, No. 32 (1960), pp. 1591-1608.

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preface study of the subject, regardless of one's mathematical competence.

The dimensional factors summarized here have been listed in the approximate order of their importance. The further complexities of reed, temperature, humidity, and the like will be avoided in this presentation.

SIZE OF CYLINDRICAL BORE

The primary determinant of the relationships of pitches emitted in the different harmonic modes or registers of the clarinet is the size of its cylindrical bore. The soprano clarinet is currently available in the United States in basic cylindrical sizes (at the smallest point of the cylinder) of between 14.5+ mm. (.571") and 15 mm. (.590"). Anthony Baines² mentions clarinets with bores as large as 15.5 mm. (.610"), but it must be assumed that this figure refers to the bore at its largest and least characteristic point, the top of the barrel or thereabouts. This writer has never measured a professionally tolerable B-flat clarinet that had a cylindrical diameter of more than 15 mm. in its smallest portion.

The important criterion of a clarinet's cylindrical bore is the mean size of the twelfth produced by identical fingerings in the chalumeau and clarinet registers, particu-

²Anthony Baines, *Woodwind Instruments and Their History* (New York, W. W. Norton & Co., 1957), p. 123.

larly those of the finger holes of the right hand. The imperfectly vented B/F-sharp of the Boehm clarinet presently poses an inviolable limit upon the largeness of its cylinder. There has been increasing recognition of, and retreat from, a bore of 15 mm. (.590") as an extreme size for the cylindrical one-third to one-half of the bore of the B-flat instrument. At the other extreme, B-flat clarinets with satisfactory intonation can be built with bores as small as possibly 14 mm. (.551"), but this remains a quite unlikely event in view of consistent preferences for darker and broader tones from clarinets.

REVERSED CONICAL ENLARGEMENT OF LEFT-HAND JOINT AND BARREL

Within the limits imposed by the basic size of the cylinder, the chief means of adjustment of pitch relationships between registers lies in subtle control of enlargements of this cylinder in the left-hand joint and barrel. In the first of the aforementioned of Benade's studies, he states:

... a tube whose cross section decreases away from the closed end has a lower fundamental frequency than a uniform pipe, and its normal mode frequencies are spaced more widely than the 1, 3, 5 . . . sequence of a uniform pipe. The reverse is true for a pipe which increases in cross section away from the closed end.

Actually, as Benade and others have noted, the constantly enlarging tone holes of the clarinet make an effective conical enlargement of the bore that normally should be counterbalanced by a reversed cone. In practice, the smaller the bore for a clarinet in a given pitch, the more strictly cylindrical it may be; the larger the bore, the greater the need for the enlargement of the reversed cone. Thus, in the A clarinet with the same cylinder as the B-flat, one normally encounters slightly less enlargement of the reversed cone, with considerably smaller tone holes helping to maintain pitch relationships similar to those of the B-flat. The E-flat clarinet, having an oversized bore to minimize stridency of tone, needs a very considerable enlargement of its reversed cone.

By 1810 the popularity of the C clarinet was declining; makers increasingly turned to larger bores

more suitable for the B-flat and A. A collection owned by the University of Colorado includes a thirteen-keyed B-flat clarinet of cocuswood, made about 1840 by W. H. Wilde, Sheffield, England, that has interior dimensions typical of many made 125 years later. In its control of the cone of the mouthpiece, the reversed cone of the upper joint, the parabola of the lower joint, and fraising (the undercutting of a tone hole by chamfering or beveling the interior junction of the tone hole with the bore) appropriate to the size of the affected tone hole, it represents concepts that have only recently achieved wide acceptance. To the present day, however, some makers have preferred to limit the reversed cone to only the barrel, further correction of twelfths being accomplished by a lower placement of a larger register vent.³

PARABOLA OF THE RIGHT-HAND JOINT AND BELL

The primary reason for the bell of the clarinet is to improve the sounds of the lowest tones of both the chalumeau and clarion registers, as any student soon learns when he plays without a bell. In the very early clarinet, which had a bell placed at the end of a slightly fraised cylinder, it became evident that a drastic improvement in the pitch relationships of these tones nearest the bell occurred when a parabolic taper was begun some distance up the tube. For an instru-

³Both Baines (*op. cit.*, p. 123) and Rendall (F. Geoffrey Rendall, *The Clarinet*, New York, the Philosophical Library, 1954, pp. 42 ff.) have permitted themselves undue simplification in their descriptions of clarinet bores. The clarinets of Boosey & Hawkes, which they have described as strictly cylindrical down to the parabolic cone of the lower joint, have in every case known to me, shown a reversed conical diminution of the upper joint, as have those of H. & A. Selmer. The clarinets of G. Leblanc have ordinarily confined the reversed cone to the barrel joint, further equalization being accomplished by a somewhat larger register vent which is placed correspondingly lower. A most sophisticated version of the reversed cone is that developed by Buffet-Crampon & Co. c. 1950 for the purpose of improving the relationships of the twelfths of the critical upper portion of the right-hand joint. This is a cylindrical enlargement from the center of the left-hand joint upwards to the point of a further reversed conical enlargement at the top of this joint. The third register (fifth partial mode) of the clarinet is brought downwards in pitch, this being beneficial on the ordinarily sharp high C-sharp and E, and quite the contrary on the possibly flat high E-flat, F, and F-sharp. However, this cross is borne rather lightly by most orchestral clarinetists, overjoyed by the virtual elimination of the clarinet's traditional sharpness in its lower chalumeau notes.

ment of small bore, this parabola needs to be slightly longer in order to reduce properly the size of the three lowest twelfths; for a larger bore these will be correctly sized with a shorter parabola. If the clarinet has fraised tone holes it will need fraising for the bell tones, this normally being accomplished by a slightly accelerated flare at the bottom of the lower joint and an offsetting diminution of the bore of the bell. A clarinet with more than minimal fraising will not favor a bell having a straight-walled cone, whereas something near to this will do best on the clarinet without fraising.

MOUTHPIECE CONE AND WINDWAY

The clarinet mouthpiece, being the nearest and dearest part of a player's equipment, has been more frequently and thoroughly studied by clarinetists than has the instrument as a whole.⁴ A generalization relevant to our subject is that the cross-sectional area enclosed within the mouthpiece as a whole determines (a) the overall sharpness or

⁴Cf. Walter L. Wehner, "The Effect of Interior Shape and Size of Clarinet Mouthpieces," *Journal of Research in Music Education*, No. 11 (1963), pp. 131-136.



flatness of pitch, and (b) the final pitch relationships of the registers. As Benade's equations have corroborated,⁵ a mouthpiece having a larger and/or longer cone will not only produce a lower overall pitch, but will also markedly increase the spacing of the frequencies of the chalumeau and clarion registers. (This effect diminishes as more tubing is used for the lower tones.) Less obvious, but of real importance, will be the lowering of the tones near the bell in both registers. Conversely, a mouthpiece having a smaller and/or shorter cone will markedly decrease the spacing of the frequencies of the chalumeau and clarion registers and raise the pitch of the tones near the bell in both registers, in addition to producing a higher pitch overall.

PLACEMENT AND SIZING OF TONE HOLES

Early woodwind instruments, without mechanisms enabling acoustically proper positioning of holes and needing small holes easily covered by fingers, almost invariably had holes that were too small and too heavily fraised for the production of satisfactory intonation in all registers. The old clarinet was designed to be played in its clarion register, as anyone playing it soon discovers. In this register, it had a soft, mellow beauty unmatched by any instrument used in the twentieth century. But the chalumeau register was disastrous, a nightmare of uneven stuffiness and sharpness. (In all truth, the instrument played in symphony orchestras until only a few years ago was still a prime example of this noble tone wedded to an unfortunately confining intonation.) The requirements of mellow tone in the clarion register with good intonation in the chalumeau have always been and still are antithetical. The larger the tone hole, the greater the size of the twelfths and the more strident the tone. This truth applies most critically to the placement and sizing of the register vent but is relevant in every case.

FRAISING OF TONE HOLES

The first clarinets were recorders fitted with mouthpiece and reed; their fraised tone holes were already time-honored. Henri Selmer's

⁵Benade, "Woodwind Instrument Bores," *JASAS*, No. 31 (1959), p. 139.

clarinets of about 1905 were among the first to dispense with fraising. Today the only woodwind manufactured in two basically different designs is the clarinet. Boehm conclusively discarded fraising in his new cylindrical flute; Triébert and Lorée as conclusively reinforced fraising for the fine oboe; and the Heckel bassoon, which might profitably use more fraising on the large-octaved F-sharp and G tone holes, apparently makes little use of it. Fraising slows the passage of wind through the tube, making necessary a smaller bore than that for an unfraised tube, so that for a given bore only an appropriate amount of fraising—no more, no less—should be applied. Furthermore, since most tone holes are not ideally located and sized, and since venting below the open hole varies, the amount of fraising appropriate to each hole may vary. What should not be overlooked is that the fraised tone hole produces a smaller twelfth than does an unfraised opening of the same displacement. Only recently have makers recognized the need for such correlations, and these are as yet only imperfectly executed in some instances. Although fraising is done to (a) produce a darker or mellow tone and/or (b) achieve greater flexibility, it is now recognized that with the bores in common usage today, fraising should be minimal on the clarinet.

Adjustment of the opening of a pad produces effects that are, for the most part, well known to the clarinetist. The fact that these parallel but do not duplicate the phenomena of fraising should be noted. Such adjustments may be used in a limited correction of faults of pitch, resistance, wind noise, and brilliance or dullness, but should be considered as expedients, since correction of one fault may produce others. Again, the relationships between pitches emitted from one tone hole in various registers will be affected by changes in clearances of pads.

■ Antithetical specifications for achieving the best intonation and the best tone in one clarinet have been responsible for the failure of the development of a single, definitive model which would merit the universal acceptance of Boehm's



flute. It can hardly be doubted that within the next quarter century such a truly definitive clarinet will appear. The instrument of the twenty-first century may have the following characteristics:

(a) A cylinder of between 14.5 and 14.7 mm. (.571" to .579").

(b) A reversed cone effectively compromising the long straight-walled cone and the stair-stepped cylinder now most frequently used.

(c) Very minimal fraising of tone holes, which will include C-sharp/G-sharp/high-F vent placed as far down the tube as the center joint will allow.

(d) A revival of the extended liner of the barrel joint for improved adjustability of pitch.

(e) A somewhat extended lower joint, with an uncovered E-B vent providing better control of these pitches (as in the Lorée extended model oboe bell with additional venting on the low B-flat). ▮