Mechanical and Other Considerations

by George Jameson

This article, a follow-up to one by Art Benade about the genesis and gestation of his NX clarinet (*The Clarinet,* Jan./Feb. 1994), discusses some of the more mundane details of the NX design, including some development details, its key mechanism, and tone hole placement.

Art's earlier acoustical study had disclosed a number of ways to coax a clarinet to behave more efficiently. He had identified misalignment of mode resonances and turbulence as villains, and had devised various means of minimizing their role in wasting energy. He had altered several "good" clarinets, markedly improving their performance.

Art had known the effectiveness of lining up mode frequencies prior to starting work on the NX. The many instruments he refined were aligned as well as possible short of making radical alterations. Among other niceties, instruments properly aligned don't wander sharp in the low register on diminuendo. He also recognized the effects of the energy drain caused by turbulence. First-order turbulence was considerably reduced in his altered instruments, which contributed to a noticeably increased dynamic range. The combination of good alignment and reduced turbulence also increased carrying power.

Benade realized that implementation of the three elements listed in the previous article (register vent system, minimized second-order effects and bell profile) would carry the project beyond what could be done by normal means to alter an existing instrument, so he decided he would need to make a clarinet. For raw material, I supplied a "lamp-grade" clarinet-like object that I dredged from my junk box along with a certain amount of key stock. Major alteration was judged more time-efficient than starting with a few hunks of wood and metal. Art was a capable machinist and had access to the equipment necessary to make major body grafts, plug and redrill tone holes, and machine the bell. He could also construct usable key work.

Availing himself of the new register vent, Art altered the bore profile to permit lining up mode frequency ratios within about 10 cents. The alteration is most visible on the lower joint, where the flaring of the bore is considerably reduced. He computed and made a new bell profile and eliminated two of the three E♭-B♭ holes. (The LH2 ring hole is included here as a B♭ hole since this is its primary function.) The hole emitting B♮ is now a single hole rather than two.

Removal of the normal hole under LH2 gave rise to the model designation NX for this clarinet. Art gave cryptic letter names to his designs. The flute he mentioned in the previous NX article is called the BCB, **B**aroque **C**onical **B**oehm, to denote some of its characteristics. NX translates as **N**on-Boehm e**X**perimental, which calls attention to the lack of an easily contrived means of producing the Boehm second-register B♭ fingering — much admired by players of the French clarinet.

The rationale for elimination of the E♭-B♭ holes is discussed in Art's *Fundamentals of Musical Acoustics* (pp. 448-9). The volume of the closed holes in the tone hole lattice acts in effect as an overall bore enlargement in the tone hole area. This is a factor in bore design. The E♭-B♭ holes, being in about the same north-south position on the tube, produce a closed-holes bulging of the bore. This extra perturbation upsets the fairly smooth characteristics of the overall closed-holes bore enlargement and can't be properly dealt with by designers.

Note that the bore toward the top of the tone hole lattice (where the volume of the holes is small) and also above the lattice (where no closed-holes enlargement exists) must be enlarged to preserve mode frequency ratios. Art even added one tone hole to the top of the scale to extend the lattice. A similar enlargement at the south end of the tone hole lattice is needed because the holes in this area are fewer and farther apart, which results in less bore enlargement from the closed holes.

Art dealt with second-order effects by moving holes farther apart where possible, and pad opening was increased beyond what is common. Where cutoff frequency allowed, chimneys were made taller toward the south end of the body. The reduced bore flare (permitted by the small register vent) helped by leaving the tube wall thicker in this area.

By 1981 the acoustical design was in place, and it was good enough that the two instruments Art built on existing pieces of junk clarinets (the NX-811 in B♭, and the NX-861 in A) became the instruments he preferred for his personal music making. Though the bodies at this point had been extensively revised, Art couldn't fully implement all his ideas because he utilized much of the existing machinery. However, these instruments indicated that it would be worthwhile to make an NX from scratch. This project has fallen to me.

Carrying out the acoustical design more fully involves primarily the minimizing of the effects of the Lighthill term (part of the theoretical equation that deals with convective turbulence effects). To attack Lighthill-related effects, tone holes should be distanced from one another by at least one tone hole diameter where the holes enter the bore. To minimize padded-key effects, pads ought to rise one tone hole diameter above their holes.

Art's construction notes also specified devising a means to reinstate the Boehm B♭ fingering. To do this, I pursued two ideas — well, actually I built something that seemed promising, didn't like the resulting note, hatched another gadget, abandoned it because of mechanical complications which were potentially undependable, and finally modified the original so that it works rather well. This mechanism adorns my prototype, dubbed the NX-931J.

My efforts in spreading tone holes apart and increasing pad opening resulted in most pads being levered to their spatules rather than being hooked up directly. Thus, excessive spatule (finger) travel attendant on increasing the pad opening of a direct key was largely avoided. Key opening, finger travel and effort to move a key were played off against one another.

This was an effort to make something a player might live with comfortably — though it would not duplicate the feel of his favorite instrument.

From a repairman's perspective, indirect keys eliminate some chancey pad covering prevalent in longish keys and those where pad seats aren't in a plane parallel to the plane of the hinge axis (e.g., trill keys). All padded keys on the new NX are on tubular hinges to minimize wobble. (My thoughts on minor end play are not a part of this article.)

While the instrument appears to bristle with machinery, it weighs about 2 oz. more than an R-13. This excess is reducible. The NX-931J is a prototype. Its keys are built from likely looking bits of key scrap from my junk box. Having established the essential shapes of many key parts, one can then be concerned with elegance and weight reduction.

As a doubler who has sat in cold theater pits playing parts written by piano players, I stuck in a few of my own nice-to-have features. Where possible, I moved tone holes farther away from the bottom of the tube. This may help the "spit in the G♯ hole" situation. I made German-type spatules for the little fingers to promote ease in making the two legal and five illegal slides needed to get over some music that says "Clarinet" at the top of the page. Also, while making ways to play the second-register B♭, I added the saxophone *bis* fingering and the flute A♯ lever. I have found these to be severely nifty on both clarinet and sax. The standard forked fingering is also provided.

A couple of optional "bells and whistles" are fairly easy to incorporate. For those who worship the German projection from the C♯-G♯ key (which I don't like on the French clarinet), provision is made to put a sliver key between RH1 and RH2 for trills involving C♯ and G♯. A LH A♭-E♭ is in place, the spatule for which can be put in a number of locations for real sliding freaks.

Art's NX clarinet design has elucidated the physics basis for two and one-half centuries of often enlightened empirical development. The NX has also attacked weak spots in the acoustics of the current instrument by identifying the physics basis of said weaknesses.

My NX-931J has carried some of Art's discoveries further than was possible on his two prototype instruments. It is an attempt to bring the design into the area of practical instruments. However, this latest incarnation should not be looked upon as a commercial, production-type instrument. Perhaps elements of the design will ultimately surface in regularly available instruments.

The NX's insistence on being played "its way" attracts some and puts off others. "Its way" refers to the fact that a woodwind air column pretty much controls the instrument. If a player experiments with embouchure settings, the instrument will disclose the pitch at which it will yield its fullest tone. With the NX, this coincides closely with the tempered scale at A-440. The NX has enough flexibility to allow fine adjustments of pitch without sacrificing tone and response.

The reduced vent size and altered bore of the NX (described in the previous article) permit more accurate alignment of mode frequencies than was previously possible. Discovery and reduction of second-order, Lighthill-related turbulence augments the effects of previous turbulence-abatement work. With all the known "fixes" in place, we have an attractive instrument. It works like a clarinet with its bad habits minimized or eliminated.

A number of Art's friends have played his originals in private, and the NX-811 has been used successfully in public performance. The original and newer versions of the NX design will be demonstrated at Clarinetfest '94 in Chicago this coming July.

Reference: Arthur H. Benade, *Fundamentals of Musical Acoustics,* reprint edition with corrections (New York: Dover, 1990) of a book originally published by Oxford University Press, New York, 1976.

About the Author...

George Jameson, Mus.Ed.B., Oberlin, studied clarinet with George Waln. After completing a course in instrument repair at the Conn Vocational School, he tested woodwinds for the Conn Company. The next 30 years he spent in Wisconsin working on the bench at G. Leblanc, repairing woodwinds with R.W. MacGibbon, teaching and building an occasional instrument. In 1968 he met Arthur Benade at the I.C.S. convention in Denver. Their collaboration continued until Dr. Benade's death in 1987.

Since 1985 he has built several of Benade's BCB flutes and, most recently, two NX clarinets.