THE FUNCTION OF F-HOLES IN THE VIOLIN

The most noticeable thing apart from the difference in pitch, about the paper in the STRAD (April 2001,408) was the similarity between the plots for the harmonic content of the notes played on the G and E strings and measured on the instrument near the G and E strings respectively. This is not surprising since both sides of the central area of the top plate on which the bridge stands, are active; the centre of rotation is variable and not necessarily unique, somewhere between the two feet of the bridge and not exclusively at the right foot as many body and plate modes are activated simultaneously and to varying extents, by the fundamental and harmonics of the note being played.

The f-holes perform a function more complex which the paper attempted to point out, than the opening needed for the Helmholtz resonance.

To consider this function first. The frequency of the Helmoltz resonance depends on the volume of air in the body of the violin, the total area of any openings and the thickness of the edges of the openings. If the volume is increased the frequency goes down, 10% reduces it by about a semitone; if the f-hole area is enlarged the frequency goes up, 20% raises it about a semitone, and vice versa. So small variations in volume and hole area are not going to have a large effect. The area of an f-hole can be expressed in terms of an equivalent ellipse for the purpose of calculation (J.W.Strutt (Lord Rayleigh) The Theory of Sound, Dover, 1945, Vol 2, 176) as used by Helmholtz (On the Sensations of Tone, Dover 1954, 86).

To be more specific, the volume of air acts as a spring together with the walls of the body. If the walls are rigid, the air, only, provides the spring action. The body of the violin is always somewhat compliant and lowers the frequency of the Helmholtz resonance. Fitting the soundpost increases its stiffness, enough to raise the Helmholtz resonance about 4 semitones. Variation in soundpost stiffness would have an effect as would variation in body stiffness.

In addition to a spring element, for a resonance to occur there has to be a mass element, and in all real systems there is some damping. The mass element is provided by the plug of air situated in the f-holes. This is difficult to define and will extend a little beyond the two surfaces of the top plate. Thicker edges at the ff's will raise the mass and as a consequence lower the frequency. It is this "air plug" when vibrating that radiates sound and will require an energy input to maintain the vibration (and radiation) otherwise it would decay at a rate determined by the damping and the energy lost through radiation.

Damping will arise from the friction between the air and the sides of the ff's. If the damping is reduces by having very smooth surfaces and relieving the sharp edges of the ff's, the height of the peak will be raised and the width reduced. The width determines how many notes are enhanced by the resonance.

As for the other functions of the f-holes the most obvious one is that they detach the central region on which the bridge stands from the sides of the top plate attached to the centre bout. It has been long considered necessary for this region to be supported by the bassbar and the soundpost. A violin whose plates are not too thin is able to support the bridge when fitted up without the presence of the bassbar or the soundpost. So that while both these items help to support the forces, their major purpose may be otherwise; the bassbar to restore the stiffness (and tuning) lost on cutting the ff's and the soundpost to adjust the evenness of output across the strings.

The bridge has not always been located between the notches in the ff's as accepted to-day. It has been placed to varying distances below them in times past but the soundpost has remained near its present position although attempts had been made to move it with the bridge. The reasons for moving the bridge to these lower positions has been commented on briefly by David Boyden (The History of Violin Playing, O.U.P. 1975, 34) that by so doing, the longer string gave more space in the higher positions and a more viola like tone was obtained. If the higher pitches were to be maintained the longer string length would require a higher tension with greater demands placed on the gut strings of the time. It might have benefitted the G string of the day which was unwound.

The spacing of the ff's has been variable but not less than the width of the bridge feet. It is traditional for the bassbar to be placed under the foot of the bridge on the bass side so that the upper finial circle of the f-hole has to be outside the edge of the bassbar. The bassbar and soundpost would restrict the freedom of the central region created by cutting the f-holes. Their presence however appears necessary for stability and to limit the occurrence of Wolf notes. Any departure of the "sides" of the f-holes from being normal to the top plate surface will have an adverse effect on the function of the "air plug". Either it will be reduced in mass if the sides are tapered or its effective "length" will be altered which amounts to the same thing. Damping may also be increased. In the extreme, if the f-holes were so tapered to present an edge at the top plate surface, the "effective mass" would be greatly reduced which would raise the Helmholtz frequency, reduce the amplitude (strength) and greatly shorten the duration of the resonance.

The nodal lines and hence the vibration modes of the violin body do not seem to be radically affected by the presence of the f-holes. This may be due to their location in the centre bout and placement near the margins of the plate. Of the free top plate modes that are usually studied, #2 and #5 are modified but are returned to nearly the f-hole free shape by installing the bassbar. The bassbar also raises the stiffness along the plate which was reduced by cutting the f-holes. In fact this stiffness can be adjusted by trimming the bassbar. The stiffness across the plate is little affected.

A top plate glued to rigid sides showed some major changes in nodal patterns when the f-holes were cut (Jansson E. et al "Res;onances of a Violin Body Studied by Hologram Interferometry and Acoustical Methods" Physica Scripta, Vol 2, 1970, 243-256). The main difference was the immobilisation of the plate area between the f-hole and the plate edge at the C-bout. The margins of both plates are effectively clamped as the glue joint between the plates and the ribs must remain intact. Any flexing must occur in the plate margins away from the joint and in the ribs. The inner edge of the f-hole then becomes an effective "free" edge of the plate in this region.

Some body modes are modified in the vicinity of the f-holes. The soundpost creates an "island" at the treble f-hole in association with the Helmholtz resonance and nodal lines along the top tend to pass through the ff's.

The unique shape of the f-holes must allow the bridge the maximum freedom to function in transferring the string vibrations to the top plate with some latitude in bridge placement as seen in early paintings. Other shapes while allowing the Helmholtz resonance, would appear to be more restrictive. Crescent shapes both inward and outward facing have been used. Flame shape openings have also appeared. What has been lacking is the simultaneous inward projection at the upper end and the outward projection at the lower end.

An additional round sound hole placed under the fingerboard in some instruments would simply serve to enlarge the sound hole area in determining the Helmholtz resonance. Whether f-holes could be reduced to slits close to the C-bouts to enlarge the central area and the Helmholtz resonance opening be provided by a circular sound hole under the fingerboard is a development few would welcome.