A NEW BOWING MACHINE

J.E.McLennan

SUMMARY

A new bowing machine, weighing 250 g, has been developed so that it can be attached to the violin and enable notes to be stopped with the left hand. It is supported on a wooden shoulder rest and permits the four necessary parameters; string selection, "bow position", "bow force" and "bow speed" to be changed.

The bowing machine enabled certain expected string behaviour e.g. the sympathetic excitation of harmonics on strings other than on the one being played, to be demonstrated.

A comparison between machine bowing and hand bowing used in a parallel study employing a modified Saunder Loudness Test, gave similar results.

INTRODUCTION

The mechanical bowing of string instruments is not new; the Hurdy Gurdy is an old example. Early this century the idea was introduced in violin research in an attempt to eliminate the subjective human influence on the sound produced so that a more objective evaluation of its qualities could be made. The comment by a player when asked to try out a violin for a friend "do you want me to play it for buying or selling" is particularly apt. Meinel (1937) and Rohloff (1940) used a continuously moving belt. Raman (1920) moved the violin to and fro beneath a bow, while Saunders (1937) used a motor driven celluloid disc. More recently, the bow has been mechanically driven back and forth on a stationary violin. Notes, other than the open strings, were obtained using a "mechanical finger" in some cases. There has been more recent use of mechanical bowing, (Schumacher (1994)), while hand bowing has been more carefully monitored, (Askenfelt (1986, 1989)).

A question arose about the validity of results obtained with a modified Saunders Loudness Test using hand bowing. This approach had been used to study the effect of soundpost stiffness and position on the output of the violin, McLennan (1996 unpublished work). It was considered to be an easily accessible way to discover trends in behaviour and might be generally useful. A bowing machine was developed so that comparisons could be made between Saunders Loudness Curves produced by mechanical and hand bowing. The S.L.T. was modified in that a constant bow force and bow speed near the maximum but below that demanded by the S.L.T. was adopted. As a result no prominent peaks were expected.

A new device has been developed which is mounted on the violin by being attached to the shoulder rest and allows notes to be stopped normally while the violin is held at the shoulder. It uses the celluloid wheel of Saunders and can be weighted to give a required "bow force". The wheel can be positioned on the string to give a desired "bow position", and the wheel rotation can be varied to give different "bow speeds".

DESCRIPTION OF THE BOWING MACHINE

A plywood (5 ply) bracket was attached to the G string end of a wooden shoulder rest and consisted of a vertical member to which was fitted a horizontal cross piece that could be raised and moved along the axis of the violin. To this member an arm was fixed to which the bowing machine was clamped so that it could be positioned to excite the string required.

The bowing machine was made from perspex to keep the weight to a minimum and consisted of a frame that carried two bosses each of which supported a shaft on which perspex pulleys, fitted with ball races, were mounted. A small (tape recorder) DC motor was mounted between them and drove one of them through a pulley that could be changed, attached to it. The other pulley was driven by the first and had the celluloid wheel attached to it. The celluloid wheel consisted of 19 thin (0.12 mm) discs clamped together giving a width of 4 mm in contact with the string. The edges of this contact surface were relieved (2 degrees) to avoid possible edge contact problems.

The frame was 3 mm perspex with a stiffening rib glued on to withstand the tension of the drive belts between the two pulleys. The boss carrying the pulley driven by the motor was spring loaded to tension the drive belts. The frame had a moveable pivot which allowed it to be balanced before weights were added. Putting the motor below the pivot aided the balancing step. The frame was pivoted on two old-style gramophone needles fitted in a clamp that adjusted the position of the frame on the bracket over the appropriate string. A friction damper was attached to this clamp to prevent vertical oscillation of the bowing machine when in use. The bowing machine weighed 250 g. The all up weight of this attachment to the violin was 400 g.

Photographs of the bracket and bowing machine together with it assembled on the violin are shown in Figures 1 and 2.

OPERATION OF THE BOWING MACHINE

For the measurement of the physical parameters, the violin was supported in a violin case so that the plane of the instrument was 25 degrees to the horizontal laterally and the neck was supported on a block of foam plastic so that the strings were lying horizontally to simulate the playing position. The shoulder rest and bracket attached had already been mounted on the instrument so that the bracket was parallel to the bridge. The bowing machine was clamped to the bracket over the desired string and the position of the bracket adjusted to place the celluloid disc at the desired "bow position" with the surface of the disc parallel to the string. The bowing machine was balanced on its pivot (the lead from the motor was supported on the bracket) by adjusting the position of the pivot point (the pivot was clamped in place with the assembly screws) prior to weights being placed on a small platform over the celluloid disc to obtain the required bow force. The weights were kept in place with double sided sticky tape. With the appropriate weight added, the position of the damper was adjusted. This could only be done when the celluloid disc was in contact with the string. Because of the different tilt of the machine on each string, the "bow force" was measured directly. This was done with a small spring balance attached by a thread to one of the clamping screws on the celluloid disc so that the line of action of the spring balance passed through the axis of the disc and the line of the violin string in contact with it. The "bow force" did not always agree with the value of the weights added. In other words, for the same total weight the effective "bow force" became less in going from the G string to the E string due to the increasing tilt of the machine from the horizontal.

The "bow speed" was set by the choice of drive pulley and had a lower limit of 0.3 m/s set by the design of the machine i.e. the drive pulley of largest diameter, 88 mm, that could be fitted. The celluloid disc had a diameter of 60 mm. The "bow speed" was affected by the "bow force" applied because of the small motor, but not to any significant extent for the force needed to excite the string. The "bow speed" was determined by timing a number of circuits (say 10) of the drive belt and from the geometry of the pulleys the surface speed of the celluloid disc i.e. the "bow speed", was found.

The motor was started with the celluloid disc held off the string and after rosin was applied to the surface, it was lowered onto the string. At low bow forces the second, third and fourth harmonics of the string were easily observed. A full exploration of this effect has not been done on all strings but it was observed on the G string because of the larger amplitudes. It was also shown that the open string above the same note stopped on the next lower string was strongly excited by the bowing machine e.g. D on the G string and open D. Likewise, A3 on the G string would excite the open A string. Similarly, G4 on the D string would excite the octave on the G string. The thing of note about this behaviour was that it ocurred more easily than with hand bowing and that it could be sustained indefinitely. This illustrates how the bridge excited by a note on one string will in turn excite at least the low harmonics of that note on other strings which are then acting sympathetically. The amplitude of the excited harmonic is usually less than the bowed note but in the case of exciting the open string the amplitudes were significant.

A COMPARISON WITH HAND BOWING

This bowing machine was developed to make a comparison with hand bowing by taking out the subjective element in the bowing process. Hand bowing for test purposes relies on maintaining as uniform and constant a technique as possible. While the bow position is possibly the easiest parameter to maintain reasonably constant, bow speed and bow force are more difficult and cannot be measured easily. This raises the question whether the bow force, during hand bowing, normally decreases as one moves to a higher string as it did using the same weights on the bowing machine because of the tilt of the violin. The natural playing position allows the weight of the bow to be taken off as one shifts to a higher string. A lower bow force would be needed for lighter strings. The actual string weights for the string length of 324 mm, were; G 0.68 g, D 0.958 g, A 0.175 g, E 0.125 g. The three lower strings had gut cores.

To obtain any comparison with hand bowing, this uncertainty makes the choice of values for these parameters a matter of guesswork. For this initial trial, similar trends in the results from the two forms of bowing were looked for rather than comparison of actual sound levels. The choice of "bow force" for a given "bow speed" with mechanical bowing was that force needed to maintain a steady fundamental. Since the "bow position" was constant the natural tendency in hand bowing to increase the bow force as the bow moves closer to the bridge for the higher notes on each string, was not a problem. With hand bowing, the bow position had to be maintained and the desire to move closer to the bridge resisted.

The comparison was made by carrying out the modified Saunders Loudness Tests for the same violin setup with both machine and hand bowing. The hand bowing tests had previously been done as part of another investigation. It was thought that if similar trends in behaviour were found the validity of hand bowing would be verified. This would not mean that the problems associated with hand bowing were removed but that comparable results could be obtained with both methods.

The S.L.T. was carried out by mechanical bowing and repeated a series of tests in which the soundpost position was altered and results obtained by hand bowing. A "bow position" of 30 mm was set. A " bow speed" of 0.4 m/s was chosen which requira "bow force" of about 1.5 N to be certain of exciting the fundamental. This actual force varied approximately from 1.7 N for the G string to 1.3 N for the E string for the same total weight of 120 g used. From the photographs it can be seen that the weights which were placed on an "outrigger" led to a lever advantage.

The S.L.T. was conducted in exactly the same way as the previous hand bowing test. It was carried out in the same position in the same partially reverberant room. The Sound Level Meter was placed 1 m horizontally from the violin and read by an assistant who sat at rightangles to this line. The S.L.M. was set at fast response and A weighting. The dB readings were quite steady with this kind of bowing.

The results are shown in Figure 3 and summarised in Table 1. The same soundposts were used and the position carefully reproduced with the post vertical as before. It can be seen in figure 3 that the loudness of the open string note was in 7 instances higher than the same note played on the next lower string, 3 were lower and 2 were the same. Also prominent in these figures are some peaks that appear in more than one plot, namely at 290-300 Hz (A0), 470 Hz (B1-), 1200 Hz and 1900-2000 Hz.

Table 1 Summary of results from mechanical bowing S.L.T's. with decreasing bow force. Results in Figure 3.

Bow position 30 mm

Weight used 120 g

G string Ag on gut (0.8 mm) D string gut (0.98 mm)

A string gut (0.73 mm) E string steel (0.25 mm)

S/post Pos^{n}.*	Bow force (N)				Bow speed (m/s)				Average Loudness (dB)		
	G	D	A	E	G	D	A	E	<600 Hz	>600 Hz	Diff
None	1.7	1.6	1.5	1.3	0.38	0.42	0.44	0.44	80.4	85.3	4.9
5/25	1.7	1.6	1.5	1.3	0.36	0.42	0.44	0.44	81.2	84.8	3.6
5/20	1.7	1.6	1.5	1.3	0.38	0.42	0.44	0.44	81.6	84.7	3.1
5/15	1.7	1.6	1.5	1.3	0.38	0.42	0.44	0.44	83.25	87.0	3.75

* see Appendix

A second S.L.T. was carried out keeping the "bow force" constant and at a value necessary to excite the finger stopped notes. The value arrived at was 1.4 N for the G string and 1.0 N for the other three. The results are shown in Figure 4 and set out in Table 2.

Table 2. Summary of results from mechanical bowing S.L.T's. with constant bow force. Results in Figure 4.

Bow position 30 mm

Bow speed 0.44 m/s

S/post Position	Bow force (N)				Average Loudness (dB)		
	G	D	A	E	<600 Hz	>600 Hz	Diff.
None	1.4	1.0	1.05	1.05	80.2	85.6	5.4
5/25	1.4	1.0	1.05	1.05	80.0	86.1	6.1
5/20	1.4	1.0	1.05	1.05	81.3	85.8	4.5
5/15	1.4	1.0	1.05	0.95	83.3	86.0	2.7

In general, the average loudness above 600 Hz was greater than that below 600 Hz, the difference in the last column of Table 1 and Table 2 showing a trend to smaller values for a soundpost position outboard of the bridge foot compared to inboard of the bridge foot for the violin used. This result agrees with that obtained with hand bowing.

In the first series of S.L.T's, a wolf note was found in the no soundpost condition. In the second series of S.L.T's, wolf notes were experienced at B and C on the A string (the position of the main body resonances) with no soundpost and one at 5/25. Evidence for the influence of A0 at $C_4^{\#}$ was apparent when the soundpost was present.

For comparison the results for hand bowing from the earlier work are shown in Figure 5 and summarised Table 3. It can be seen that the trend with change in soundpost position is similar to that obtained with machine bowing.

Table 3. Summary of results for S.L.T's with hand bowing for 3 positions of the soundpost across the violin.

			Average Loudness (dB)		
S/post length (mm)	Impedance Z (kg/s) Calc.	Pos^n (mm)	<6oo Hz	>600 Hz	Diff.
No s/post	-	-	80.28	86.04	5.74
56.0	81.2	5/25	81.88	87.54	5.66
55.5	110.6	5/20	83.28	86.54	3.26
54.7	61.3	5/15	85.69	87.32	1.63

CONCLUSION

These limited experiments with machine bowing used in conducting a modified Saunders Loudness Test show the same behaviour as found when hand bowing. A more sophisticated approach to this type of test may reveal more useful information about the behaviour of the violin.

APPENDIX

To indicate the position of the soundpost in e.g. 5/20, the first number gives the distance (mm) between the rear face of the bridge and the nearest surface of the soundpost. The second number gives the distance (mm) between the inner edge of the treble f-hole and the nearer surface of the soundpost. These measurements applied to the top of the soundpost. In this work the soundpost has been kept vertical. Knowing the soundpost diameter allows the position of its centreline to be determined.

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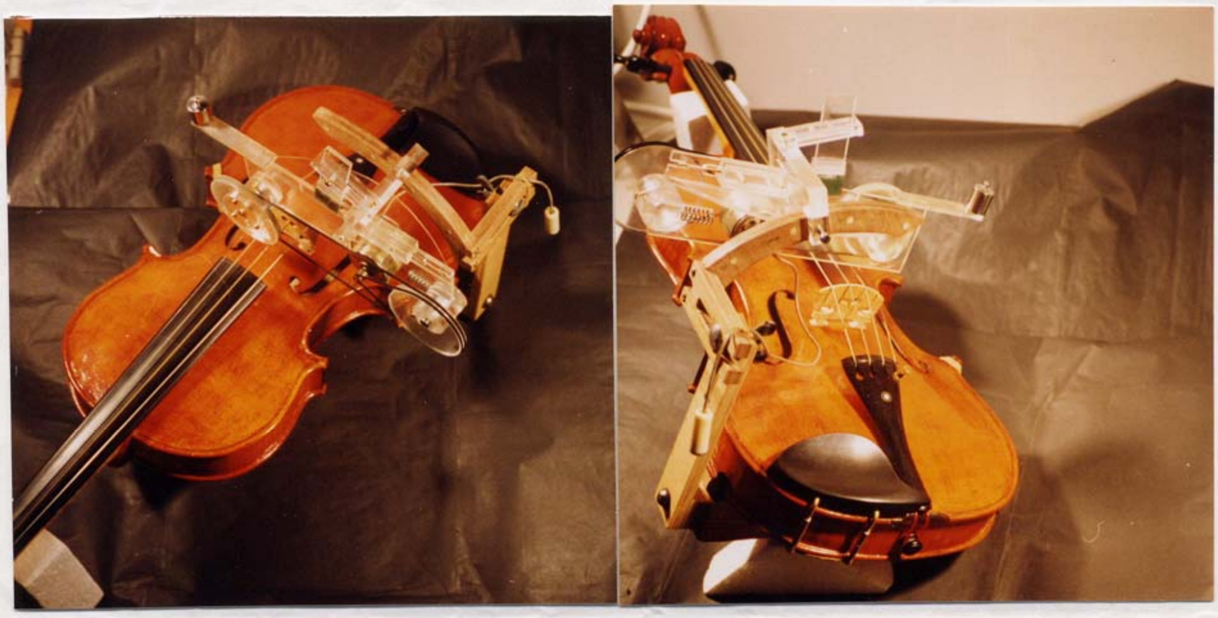

Figure 1. Bowing machine assembled on violin.

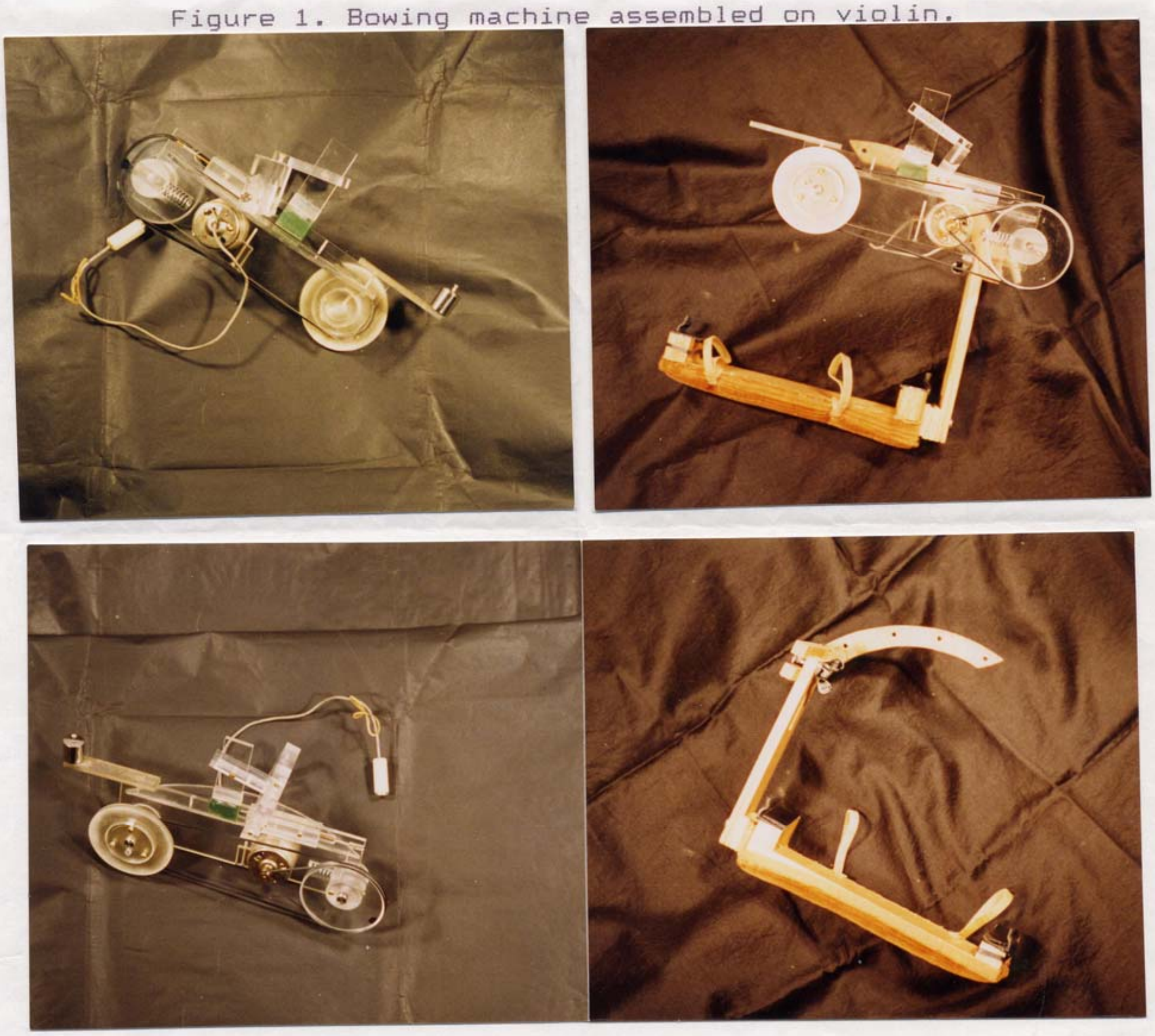

Figure 2. Bowing machine and shoulder rest bracket.

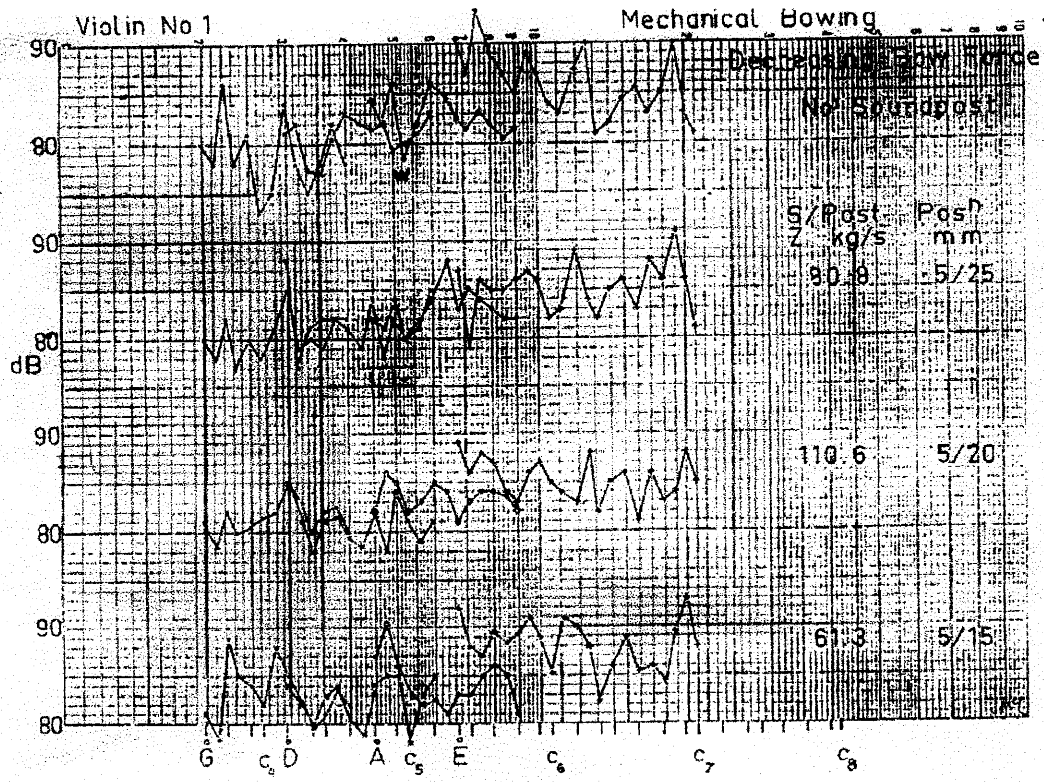

Figure 3. Saunders Loudness Tests at different bow forces on each string for 4 soundpost positions.

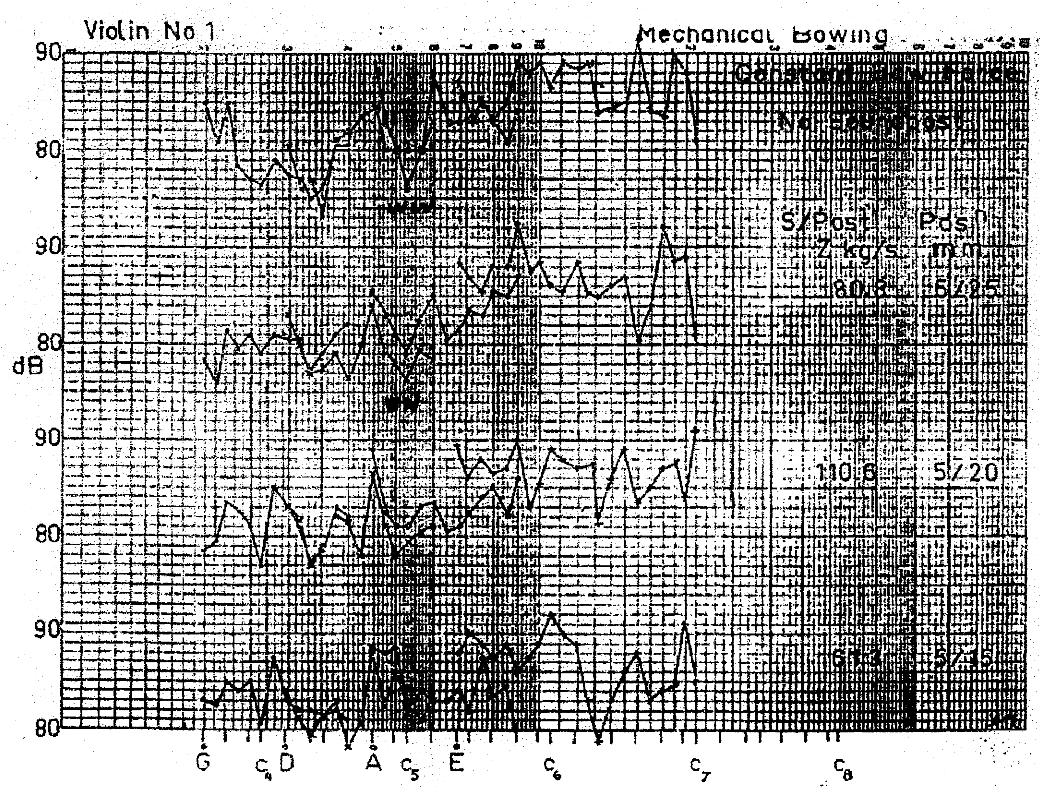

Figure 4. Saunders Loudness Tests at a constant bow force on each string for 4 soundpost positions.

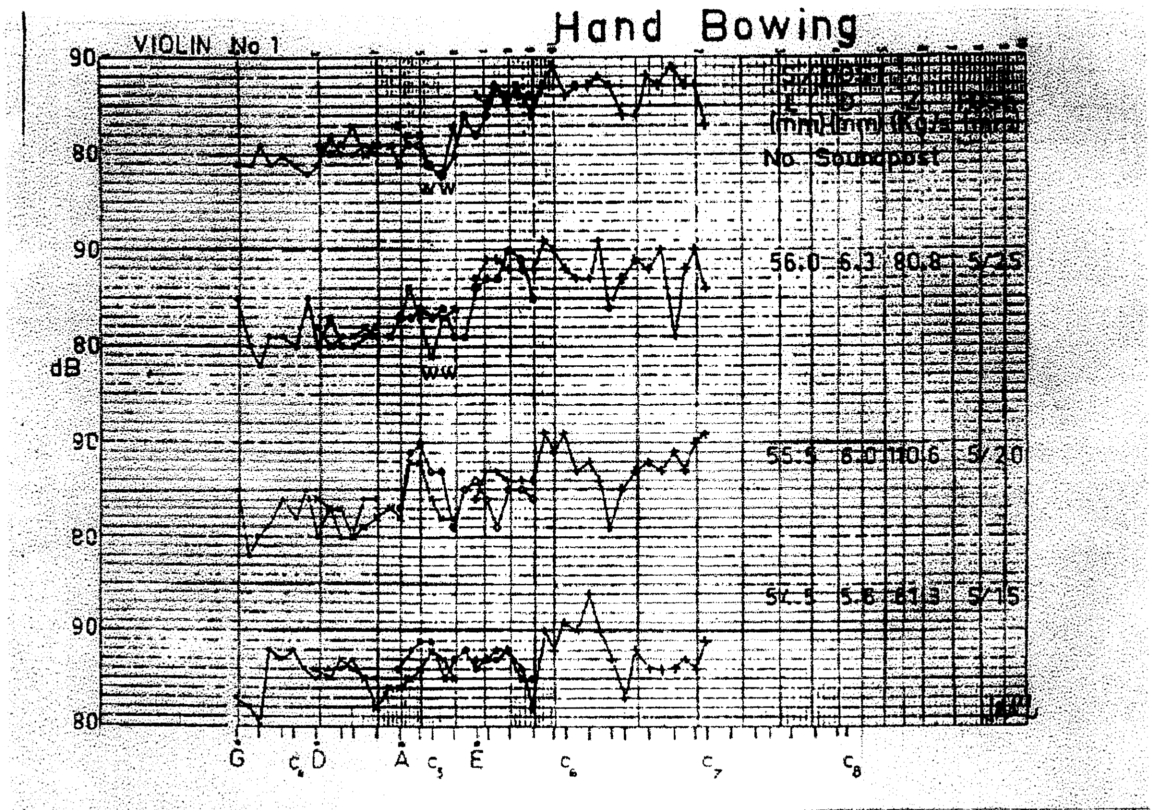

Figure 5. Saunders Loudness Tests with hand bowing for 4 soundpost positions.