A REVIEW OF AN EXPERIMENT ON THE PRESSURE BUILD-UP IN THE FEET OF FLUE ORGAN PIPES ORIGINALLY CARRIED OUT BY NOEL BONAVIA-HUNT

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1 INTRODUCTION

The Reverend Noel Aubrey Bonavia-Hunt was an Anglican priest who lived from Dec 25th 1882 to Aug 6th 1965.

He was very highly regarded as both a flue and reed organ pipe voicer and he published many papers on the subject in the journal “The Organ”, which, at the time, was the main vehicle for serious articles on the subject. He authored several books apart from the one cited here, for example “The Modern British Organ”[1].

In 1923 he published his book “Modern Organ Stops”[2], which is still available as a reprint[3]. In this book, under the heading “Diapason” (the pipe that gives the characteristic tone of the organ), he describes some experiments on the pressure build-up in the feet of flue pipes. He concluded that if a note was repeated rapidly, the pressure in the foot of the pipe, and thus directly causing the pipe to speak, never reached the pressure in the foot when the pipe was sounded continuously.

This did not appear to accord with empirical tests on the effect of varying the wind pressure and it was decided to try to repeat the experiment as a student project using modern equipment.

2 BONAVIA-HUNT’S ORIGINAL WORK

2.1 Extract from “Modern Organ Stops”

The following is an extract from “Modern Organ Stops”.

“On 3in. [pallet or groove pressure], with a 1/2in. foot-hole this pipe speaks on a pressure of 2.4in. [water] at the flue. But instead of holding down the key for a sustained note, let us try the effect of a series of taps on the key at the rate of four per second, and the actual pressure in the foot will now be reduced to 1.5in. Thus it will be seen that the attacking or repetition pressure, is much less than that of the sustained note. Placing the pipe with a 5/16in. bore on 6in. pallet pressure, we get a sustained speaking pressure in the foot of 2.4in., but the attacking pressure is only .9in.! Here then we see the real difference between the two kinds of discharge: the high pressure pipe fills up at a slower rate per second than the low pressure one under the same conditions, and this is an important factor that the high pressure diapason voicer has to reckon with.”[4]

Bonavia-Hunt states that the wind-gauge is fitted to a hole bored in the pipe. He does not state what type of gauge he used or give any detail as to how it was fitted. It is also not clear what he means by “tapping” the key. He does not state the area of the flue or the volume of the foot.

2.2 Review

If the pipe foot hole is smaller than the flue, then it would be expected that the steady state pressure in the foot will be less than the pressure in the groove. The pipe would automatically be voiced on the foot pressure. There are two reasons to question Bonavia-Hunt's conclusion about the reduced pressure with the repeated notes:

In general, when notes are repeated the pipes speak properly. If the steady state pressure is reduced to the levels suggested, the pipe will not reach stable speech.

Measurements of the pressure in the groove, pallet pressure, (as opposed to the foot) indicated that the pressure rose in around 35ms. This suggests that the pressure in the foot might also rise sufficiently quickly to question the results.

3 CONSTRUCTION OF ORGAN PIPES

Figure 1 shows the nomenclature of the parts of a metal organ pipe (Norman)[5]. Figure 2 shows the mouth of a typical pipe and Figure 3 shows the toe hole. If the foot hole area is greater than the flue area the volume is controlled by adjusting the flue. This is known as open toe voicing.

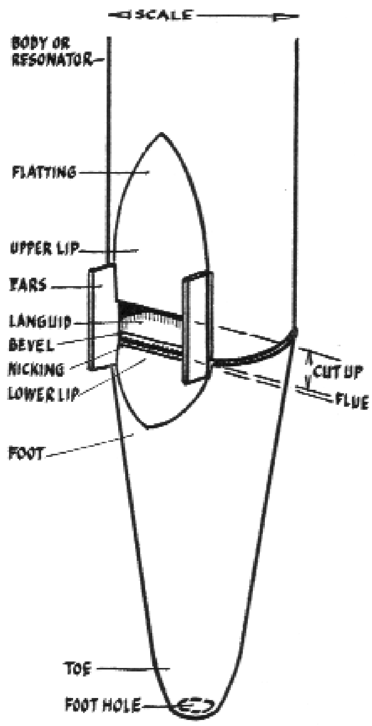


Figure 1 Nomenclature of a metal organ pipe (Norman)[4]

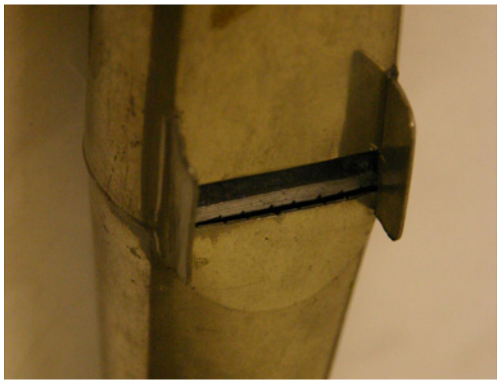


Figure 2. Mouth of metal organ pipe

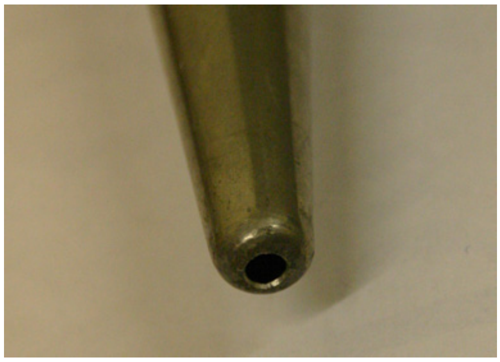


Figure 3. Foot hole of metal organ pipe

Figures 4 to 7 illustrate the details of the two wooden pipes used in this experiment. They are both approximately the same speaking length, but the stopped pipe will sound an octave lower than an open pipe of the same length. It can be seen from Figure 7 that the airflow into the open pipe is very much reduced relative to the stopped pipe due to the wedges inserted by the voicer. The cut up (mouth height) of the stopped pipe is much greater to allow for the greater airflow. Figure 6 shows the mouth of the stopped pipe – note the diagonal nicking, which is always done this way but it is not clear why. The "inverted" mouth of the open pipe is not significant in this exercise. An open metal principal pipe was also used. The pipes were chosen from the best speaking pipes in the laboratory and were not revoiced for the experiment. They had varying flue area to toe hole area ratios. These pipes cannot be directly compared with Bonavia-Hunt's examples because of his lack of detail.

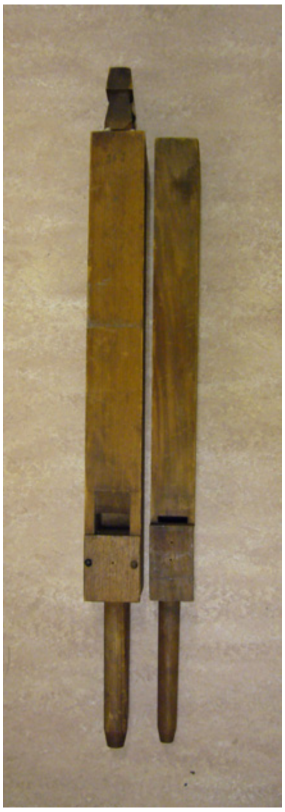


Figure 4. The Stopped Wood (left) and the Open Wood pipe

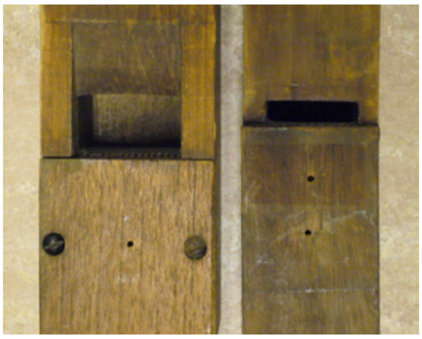


Figure 5. The mouths of the two pipes in Figure 4. The open pipe (right) has a lower cut up to offset the lower speaking pressure, and an inverted mouth. The holes for the pressure sensor are visible.

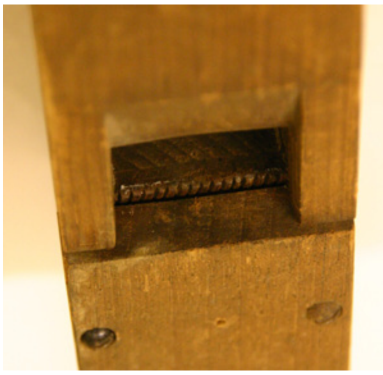


Figure 6. The flue of the stopped pipe. Note the diagonal nicking.

Figure 7. The foot holes of the pipes in Figure 4. The stopped pipe has a larger bore and no restriction. The open pipe has wedges inserted to reduce the airflow.

4 CURRENT EXPERIMENT

4.1 Measurements with an electronic sensor

Bonavia-Hunt's experiment was repeated using a model organ based in the School of Physics at the University of Edinburgh. The three pipes used had varying ratios of foot hole to flue. Initial tests indicated that the position of the measurement hole was not critical.

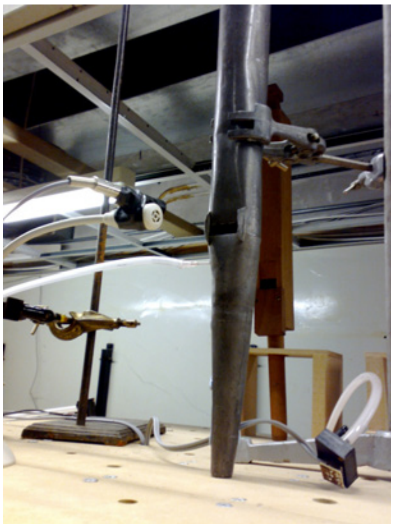
Pressure readings were taken using Sensortechnics HCXM020D6 sensors. These have a linear output between 0.5V and 4.5V with an upper pressure limit of 20mb. Signal processing was undertaken with an Iotech Wavebook 512 data acquisition box and Waveview v7.14.16 software. The tubing was attached to a blunt hypodermic needle which was inserted into the hole in the pipe and sealed with "blu tac". Microsoft Excel was used for analysis.

The experiment was carried out in two stages. The first one measured the pressures in the foot using the electronic pressure gauge. The second one attempted to ascertain how Bonavia–Hunt had reached his original conclusion by using the standard form of pressure gauge used by organ builders.

Having established that the position of the hole in the pipe foot was not critical by comparing the result from a number of holes drilled in one pipe, the test results on the metal pipe were obtained by drilling a small hole at the back of the pipe near the top of the foot. The wooden pipes had a hole drilled through the front of the cap (Figure 5).

The results are presented along with measurements of the pipes in the following diagrams.

All tests were carried out using a windchest pressure of 7.5mb (75 mm water).



Principal:

- Called principal because it represents the most important and characteristic sound of the organ.
- Metal pipe generally made from a slightly tin-rich lead-tin alloy, "spotted metal".
- Pitch c^2, an octave above middle C
- Foot hole area = 13.01mm²
- Flue area = 16.00mm²
- Ratio foot hole to flue area 0.81:1
- Speaking length approx. 26cm
- Scale 2.9cm
- Mouth width 1.7cm
- Cut up 0.45cm
- Foot pressure 4.2mb

Figure 8. Photograph of the metal Principal pipe with measured details

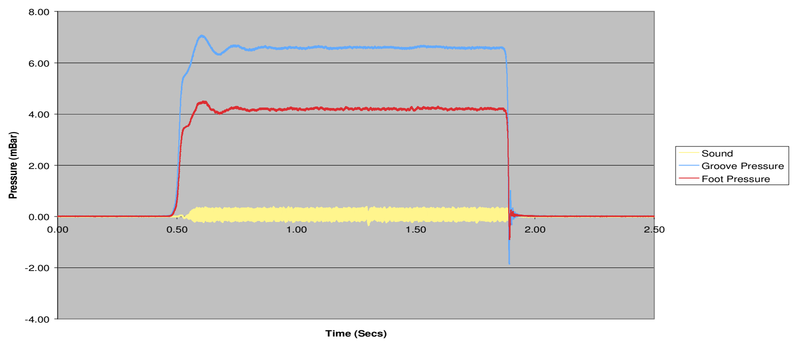


Figure 9. Graph showing groove pressure, foot pressure and sound recording for a sustained note on the metal Principal

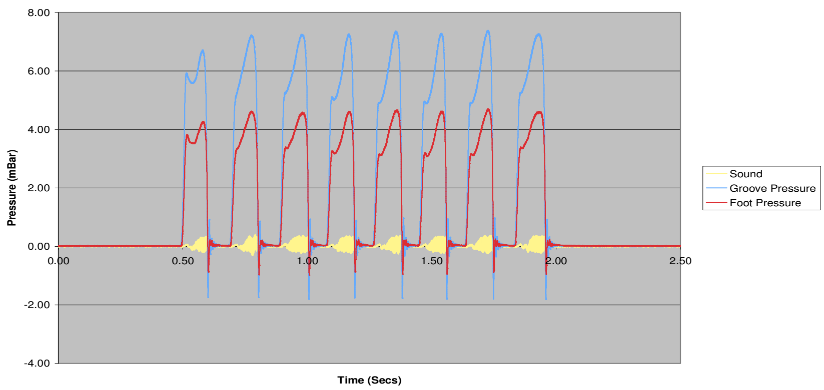
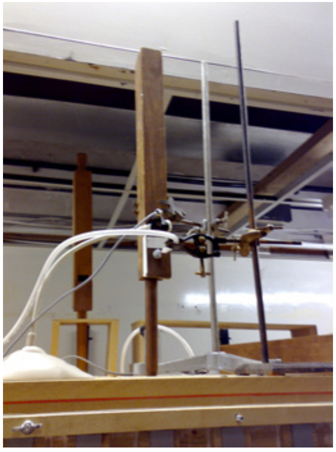


Figure 10. Graph showing groove pressure, foot pressure and sound recording for repeated note on the metal Principal

Figures 8 to 10 show the results from the metal Principal pipe which had the nearest flue and foot hole areas of the pipes tested. The foot hole to flue area was measured at 0.81:1. The foot pressure to groove (pallet) pressure was 0.63:1 and is the same for the repeated notes.



Open Wood Flute:

- Wooden rectangular pipe
- This example has an inverted mouth.
- Pitch f#[1]
- Foot hole area = 13.73 mm^2
- Flue area = 27.74 mm^2
- Ratio 0.49:1
- Speaking length approx. 36.2cm
- Scale 3.8cm deep x 2.8cm wide
- Mouth width 2.8cm
- Cut up 0.75cm
- Foot pressure 0.9mb

Figure 11. Photograph of the open wood pipe with measured details

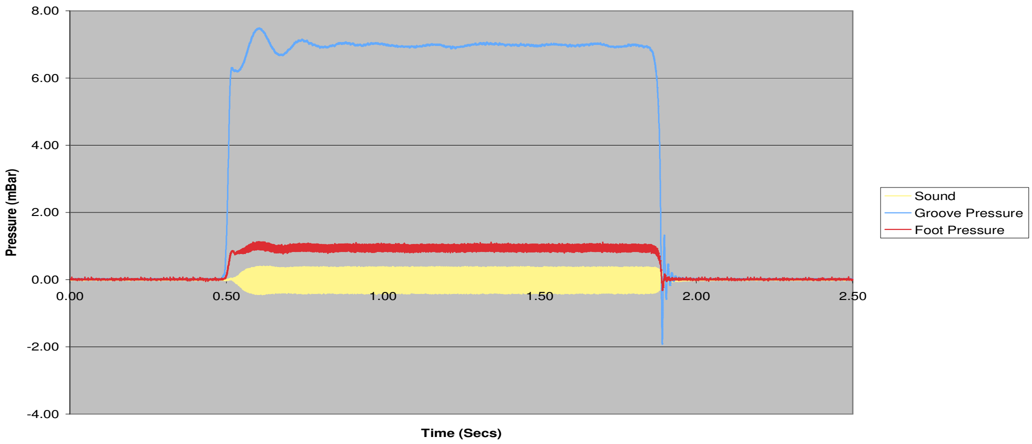


Figure 12. Graph showing groove pressure, foot pressure and sound recording for a sustained note on the open wood.

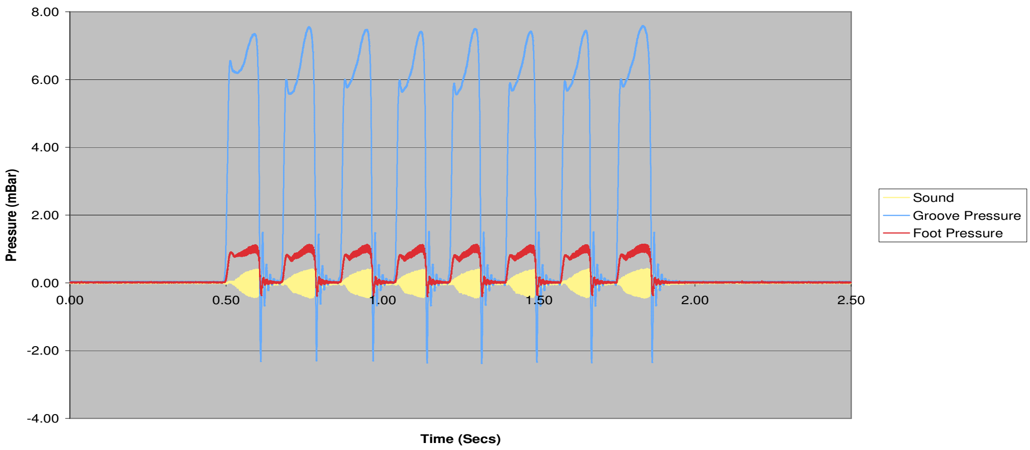


Figure 13. Graph showing groove pressure, foot pressure and sound recording for repeated notes on the open wood.

Figures 11 to 13 show the results from the open wood pipe. The foot hole to flue area was measured at 0.49:1. The foot pressure to groove (pallet) pressure was 0.13:1 and is the same for the repeated notes.

Stopped Wood:

- Wooden rectangular pipe with a stopper in the end. Produces flute tone.
- Pitch a^1
- Foot hole area = 139.35 mm^2
- Flue area = 47.70 mm^2
- Ratio 2.92:1
- Speaking length approx 31cm
- Scale 3.7cm deep x 3.3cm wide
- Mouth width 3.3cm
- Cut up 2cm
- Foot pressure approx 6.25mb

Figure 14. Photograph of the stopped wood pipe with measured details

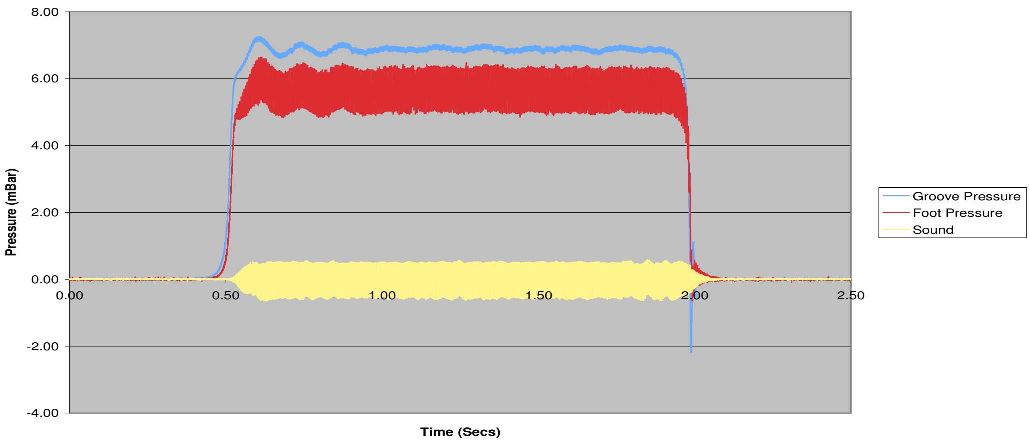


Figure 15. Graph showing groove pressure, foot pressure and sound recording for a sustained note on the stopped wood.

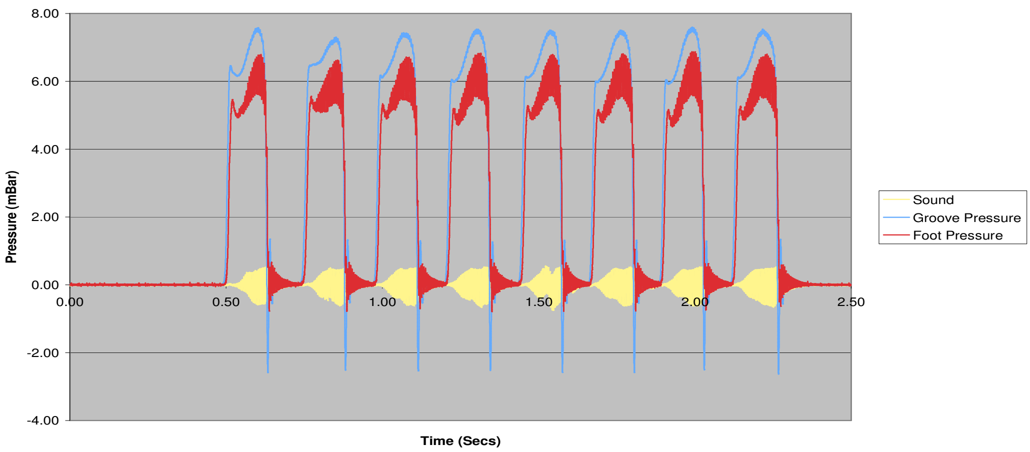


Figure16. Graph showing groove pressure, foot pressure and sound recording for repeated notes on the stopped wood pipe.

Figures 14 to 16 show the results from the stopped wood pipe. The foot hole to flue area was measured at 2.92:1. The foot pressure to groove (pallet) pressure was 0.91:1 and is the same for the repeated notes. The noise on the foot pressure recording may be due to acoustic feedback through the flue.

4.2 Measurement with water manometer

The traditional method of measuring wind pressure used by organ builders is the water manometer and this is presumably the method used by Bonavia-Hunt. In the absence of any details, a standard U-tube manometer measuring up to 100mm water (10mb) was used. In each case the indicated pressure, averaging the oscillations of the water column, was less than the steady state pressure – the smaller the foot hole to flue area ratio, the lower the pressure ratio. The results are summarized below in Figure 17. The ratios attributed to Bonavia-Hunt (Figure 17, column 7) are for pipes with the flue larger and smaller than the foot hole and are not directly comparable with the pipes in the current exercise.

Pipe	Principal	Open Wood	Stopped wood	B-H 1	B-H 2
Foot hole:flue area ratio	0.81:1	0.49:1	2.92:1	high	low
Groove (pallet) pressure mb	6.6	7.0	6.8	7.5	15.0
Elect. gauge foot press. steady mb	4.2	0.9	6.2		
Elect. gauge foot press. repeated mb	4.2	0.9	6.2		
Ratio foot pressure: groove pressure	0.63:1	0.13:1	0.91:1		
Water gauge foot press. steady mb	3.8	0.7	5.6	6.1	6.1
Water gauge foot press. repeated mb	3.0	0.3	2.8	3.8	2.3
Ratio water gauge steady:repeated	1.3:1	2.3:1	2:1	1.6:1	2.7:1

Figure 17. Tabulation of measured pressures from the three pipes used in this experiment. The two pipes used by Bonavia-Hunt are also included. B-H 1 is the first pipe mentioned in the extract in Section 2.1 and B-H 2 is the second pipe. It is assumed that he used a water manometer. The foot hole to flue area ratio is relative and assumed from the information available.

5 CONCLUSION

This experiment did not exactly replicate Bonavia-Hunt's conditions because he gave insufficient details and he voiced the pipes on a constant foot pressure rather than a constant groove (pallet) pressure, but the results clearly show that the pressure in the foot reaches the full steady state pressure even for rapidly repeated notes for all of the pipes tested including those with a foot hole area considerably smaller than the flue area. Measurements with a water manometer always gave a lower reading than the electronic gauge, but it was obvious that the water level could not keep up with the variations during the repeated notes. It would appear that Bonavia-Hunt incorrectly interpreted the results, presumably using a water manometer, by failing to realize that he was observing an average pressure. There is scope for further analysis of the wind pressure in the various parts of the wind chest, and the validity of only quoting the wind pressure in the pallet box, i.e. before the pallet that admits air to the groove that in turn admits air to the pipes, may give no indication of the pressure on which a pipe is actually speaking. More accurate measurements need to be taken in order to determine whether the pressure increase in the foot is significantly slower with a small toe hole – this does not appear to be the case from the above results. Bonavia-Hunt's basic conclusion that the pressure in the foot, and thus that on which the pipe speaks, reduces when a note is repeated is incorrect probably because he misinterpreted the results from a water manometer.

6 REFERENCES

1. N. Bonavia-Hunt. The Modern British Organ, A Weekes & Co (undaed)
2. N. Bonavia-Hunt. Modern Organ Stops, Musical Opinion (1923)
3. N. Bonavia-Hunt. Modern Organ Stops, Bardon Enterprises (1998)
4. N. Bonavia-Hunt. Modern Organ Stops, Bardon Enterprises, 25 (1998)
5. H. Norman, H.J. Norman. The Organ Today, Barrie and Rockliff, 113, (1966)