Dept. for Speech, Music and Hearing
Quarterly Progress and Status Report

The source spectrum of double-reed wood-wind instruments

Fransson, F.

journal: STL-QPSR
volume: 8
number: 1
year: 1967
pages: 025-027

III. MUSICAL ACOUSTICS

A. THE SOURCE SPECTRUM OF DOUBLE-REED WOOD-WIND INSTRUMENTS

F. Fransson

Part 2. The Oboe and the Cor Anglais

A synthetic source spectrum for the bassoon was derived in part 1 of the present work (STL-QPSR 4/1966, pp. 35-37). A synthesis of the source spectrum for two other representative members of the double-reed family is now attempted. Two oboes of different bores and one cor anglais were used in this experiment. Oboe No. 1 of the old system without marking, manufactured in Germany, has 13 keys; Oboe No. 2, manufactured in France and marked Cabart, is of the modern system; and the Cor Anglais No. 3 is of the old system with 13 keys and made by Bolland & Menz in Hannover.

Measurements

A mean spectrogram for tones within one octave covering a frequency range from 294 to 588 c/s was produced for the oboes by playing two series of tones. One serie was d_4, e_4, f_4, g_4, and a_4 and the other serie was g_4, a_4, b_4, c_5, and d_5. Both series were blown slurred ascending and descending in rapid succession, recorded and combined to a rather inharmonic duet on one loop. The spectrograms are shown in Fig. III-A-1 where No. 1 displays the spectrogram for the old system German oboe and No. 2 for the modern French oboe. Both oboes show a first maximum between 1200 and 1400 c/s. The second peak is at about 3600 c/s for the German oboe (No. 1) and at about 3200 c/s for the French oboe (No. 2).

A mean spectrum for the cor anglais (No. 3) was obtained by a slurred playing of seven tones sounding g_3, a_3, b_3, c_4, d_4, and e_4 in rapid succession ascending and descending and recorded on one loop. The frequency range was 185 to 349 c/s. The first spectrum peak for this instrument is about 1100 c/s, there may be a second peak at about 2000 c/s, and there is a third peak at about 4200 c/s, as shown in Fig. III-A-1 (No. 3). Meyer [4] has on page 43 shown the following approximate formant positions:

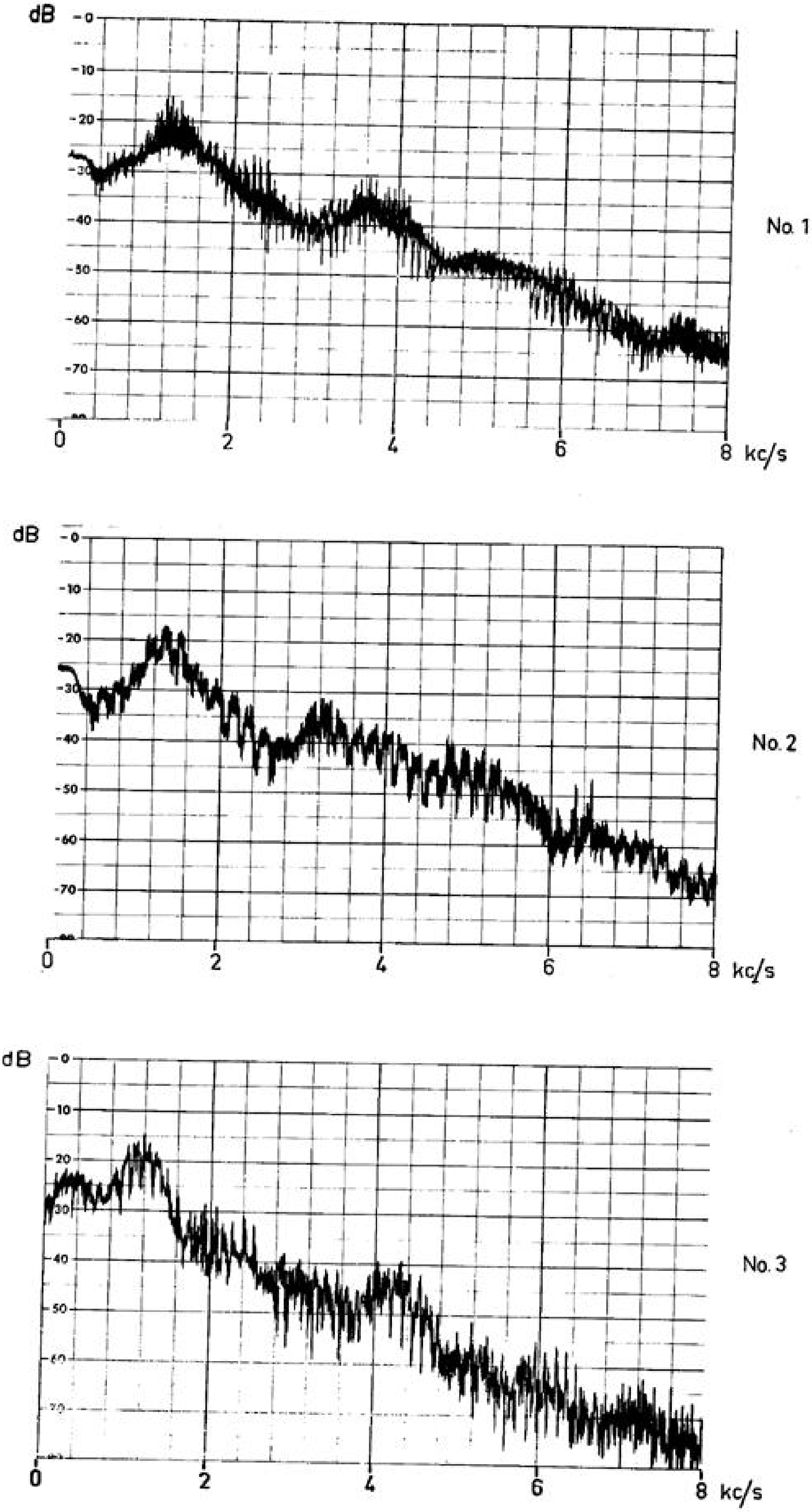

Fig. III-A-1. Spectrogram of tone series played in rapid ascending and descending succession on:
No. 1: Old system German oboe with 13 keys.
No. 2: Modern system French oboe marked Cabart.
No. 3: Old system cor anglais with 13 keys marked Bolland & Menz.

Bassoon: 500 and 1100 c/s.
Oboe: 1250 and 3000 c/s.
Cor Anglais: 950, 2200, and 3500 c/s.

An attempt was made to synthesize the source spectrum for the German oboe (No. 1) and the cor anglais (No. 3) by means of ionophone excitation. The procedure was similar to that used in the bassoon experiment III in part 1. The same container with the ionophone electrodes was used and applied either to the staple for the oboe reed or to the crook of the cor anglais. The ionophone was modulated by pulses as shown in Fig. III-A-2 (C). The modulation circuit consists of a pulse generator, a pulse shaping network, and an amplifier. The matching was accomplished by adjusting the pulse duration, frequency and bandwidth of the low-pass circuit and the cutoff frequency of the high-pass filter. Fig. III-A-2 (A) shows the spectrum of the blown and synthetic tone b_3 (247 c/s) for the oboe (No. 1) and Fig. III-A-2 (B) the spectrum of the blown and synthetic tone sounding e_3 (165 c/s) for the cor anglais (No. 3). The transfer function $H(\omega) = \frac{p_t}{u_i}$ for the oboe No. 1, shown in Fig. III-A-3 (A), was realized by sine wave excitation of the ionophone. (B) in the same figure shows the response for a sine wave sweep of the pulse forming circuit and (C) is the synthetic source spectrum. Corresponding functions for the cor anglais (No. 3) are shown in Fig. III-A-4 (A), (B), and (C).

The characteristic timbre of the double-reed wood-wind instruments depends to a great extent on the $\frac{\sin(\omega \cdot b/2)}{\omega \cdot b/2}$ pulse function of the reeds. The pulse duration time b is related to the effective mass and compliance of the reed and it was found that b remains fairly constant for normal reeds of good quality. The values of b for the tested instruments are:

The oboe	b = 0.40 msec.
The cor anglais	b = 0.48 " .
The bassoon	b = 1.20 " .

In the high register the pressure of the lips is increased somewhat and there is a certain change in the pulse duration [1].

The position and amplitude of the formants in the spectrum will depend primarily upon the reed and secondarily upon the lip pressure and the transfer function (Ref. [4], page 54) for the instrument.

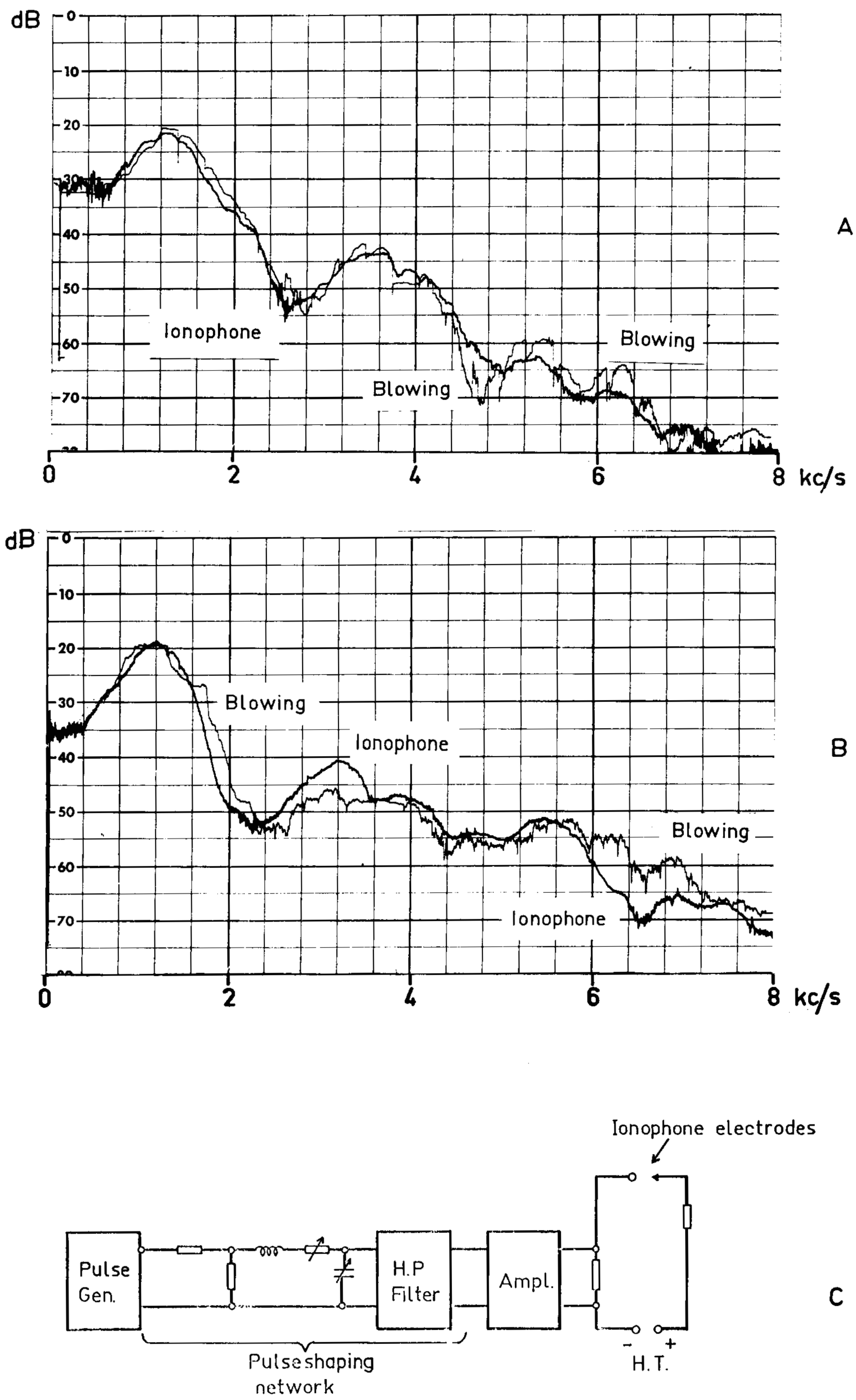

Fig. III-A-2. (A) Spectrogram of tone b_3 (247 c/s) produced from oboe No. 1 by regular blowing and ionophone excitation.
(B) Corresponding spectrogram of the tone sounding e_3 (165 c/s) produced from the cor anglais No. 3.
(C) The modulation circuit for the synthetic ionophone tone.

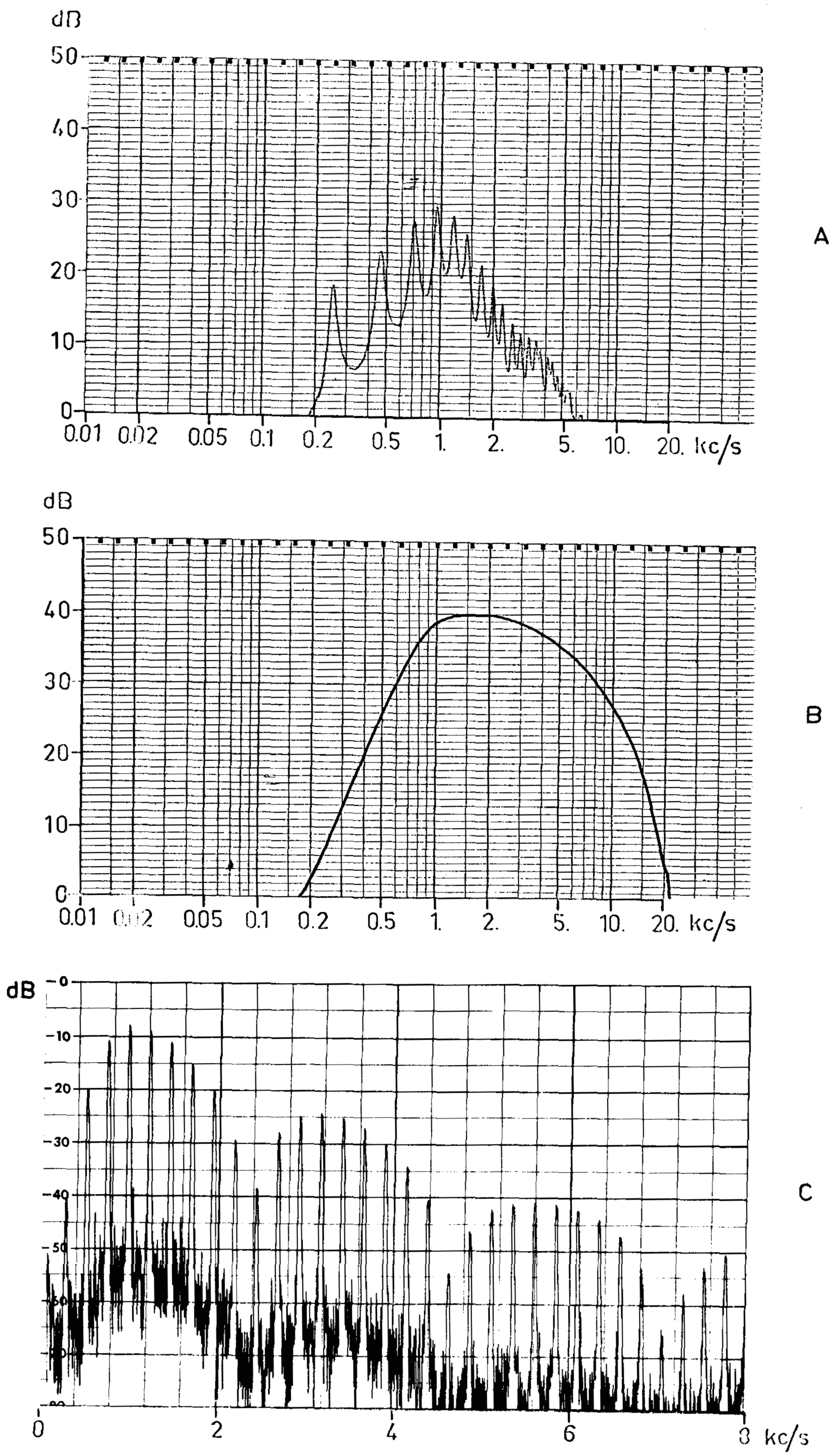

Fig. III-A-3. (A) Transfer function $H(\omega) = \frac{p_t}{u_i}$ for oboe No. 1.
(B) Response for sine wave sweep of the pulse forming circuit for oboe No. 1.
(C) Source spectrum for oboe No. 1 produced by ionophone excitation.

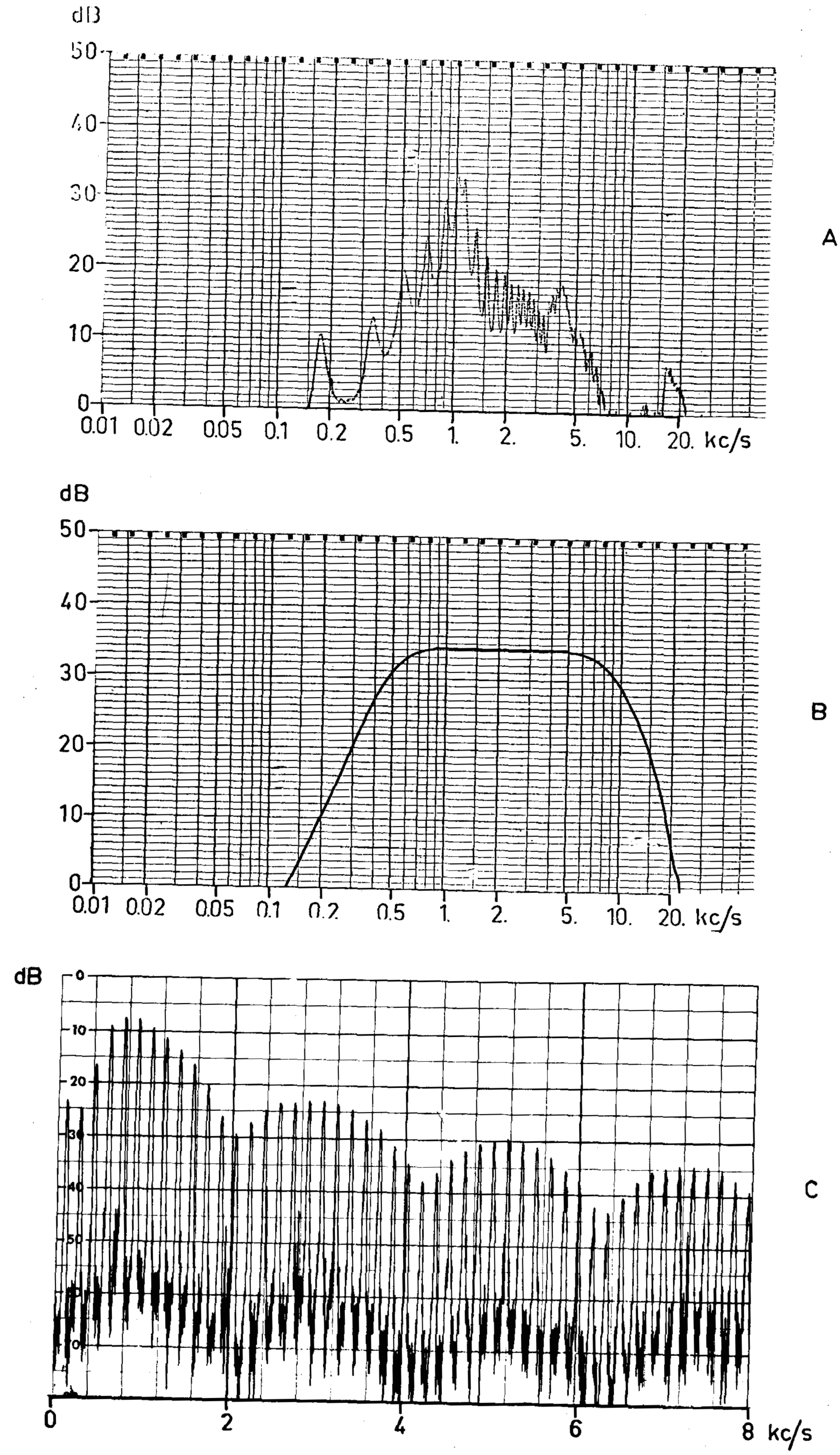

Fig. III-A-4. (A) Transfer function $H(\omega) = \frac{Pt}{u_i}$ for cor anglais No. 3.
(B) Response for sine wave sweep of the pulse forming circuit for cor anglais No. 3.
(C) Source spectrum for cor anglais No. 3 produced by ionophone excitation.

Conclusions

The double-reed wood-wind instrument group is to a certain extent characterized by a vowellike timbre due to the appearance of some fairly broad peaks in the output spectrum. These peaks are practically independent of the fundamental frequency of the note played at least up to the very highest register.

The origin of these spectral peaks or "instrument formants" has, as far as I know, not been investigated earlier (Ref. [2], page 34). The object of this study has been to show that the instrument formants are a property of the source pulse shape and are only to a less extent influenced by the transfer function.

The frequency positions of the instrument formants are mainly determined by the effective mass and compliance of the reed, but the transfer function may have an influence on the exact amplitude and frequency positions of those formants.

The reaction between transfer function and source, as well as the conditions for a proper selection and adjustment of the reed to the frequency range and transfer functions of these instruments, remains to be investigated.

References:

(1) Backus, J.: "Small-Vibration Theory of the Clarinet", J.Acoust. Soc.Am. 35 (1963), pp. 305-313.

(2) Baines, A.: Wood Wind Instruments and Their History (London, 1962).

(3) Benade, A.H.: Horns, Strings and Harmony (Graden City, N.Y., 1960).

(4) Meyer, J.: Akustik der Holzblasinstrumente in Einzeldarstellungen (Frankfurt am Main, 1966).

(5) Olson, H.F.: Musical Engineering (New York, 1952).

(6) Young, R.W.: "A Decade of Musical Acoustics", Proc. of the Fourth Int. Congr. on Acoustics, Copenhagen 1962.