



A NEW AIR FLOWMETER DESIGN FOR THE INVESTIGATION OF SPEECH PRODUCTION

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ABSTRACT

The study and development of an air flowmeter for the simultaneous study of oral and nasal airflow during speech are described. The specific functions of this device are used for the investigation of speech production and as an aid for diagnosing velum and larynx disorders and their therapeutic control.

Keywords: Measurement instrumentation, aerodynamic parameters, speech production.

1. INTRODUCTION

The measure of aerodynamic parameters in the study of the articulatory mechanisms of speech production poses a problem that has always been solved by compromises. In order to measure airflow, a certain number of specific conditions must be met, as follows. (1) The flowmeter must be bidirectional. (2) The thermodynamic conditions of the gas (temperature, composition, humidity, and viscosity) must not have an effect. (3) Likewise, gas vortices (which depend on the type of consonant) must not have an impact, in particular on oral airflow. (4) The dead volume of the air flowmeter must be small, due to the wide frequency bandwidth required for accurate airflow description (especially oral airflow). (5) Above all, the flowmeter must be correctly adapted to the speaker to enable proper articulation, while taking the above conditions into account.

In instrumentation engineering it is rare to find devices which can satisfy so many difficult and contradictory conditions. Some of these conditions are also found in the study of respiration, and the measuring devices developed therein have long been used in speech research. Moreover, some of these conditions are specific to speech production and therefore require specially designed equipment.

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Speech physiologists have long used P.T.G.'s in conjunction with anesthetic masks. The air flowmeters are composed of a fine mesh grid which generates, in the flow path, a pressure drop measured by a sensitive pressure transducer [1]. This device is known to have more advantages than the original Fleisch P.T.G. Many studies have been conducted using this device [2].

To solve the problem of the airflow capturing mask, attempts have been made to measure airflow by means of anemometric speed transducers (hot wire) without a mask, but they have not given satisfactory results [3]. To increase the measuring speed of grid P.T.G.'s while decreasing their dead volume, Rothemberg [4] developed a facial mask with an incorporated grid. A few years ago, a new airflow measuring principle was proposed in respiratory studies [5]. It is an ultrasonic air flowmeter with good linear properties and without excess pressure in the vocal tract. However, its dead volume is still too high and it is too sensitive to gas vortices at the buccal exit.

2. DESCRIPTION OF THE AIR FLOWMETER

A. Oral Air Flowmeter

The oral air flowmeter is based on the grid flowmeter principle, but must be designed and built with particular care to optimize its response time, sensitivity, and linearity in all articulatory contexts. It is composed of a measuring tube 30 mm in diameter and 20 mm in length which contains a stainless steel grid with 200- μ m wires and a mesh of 225 μ m. The airflow resistance of this mesh leads to a pressure drop of 10 Pa for an airflow rate of 1 l/s, i.e. for the normal airflow rate in speech with a mean intra-oral pressure of 5 hPa. Under these normal conditions, the excess pressure in the vocal tract is lower than 1/100 of the intra-oral pressure. This characteristic is important in the study of disphonia. For this purpose, highly sensitive pressure transducers must be utilized.

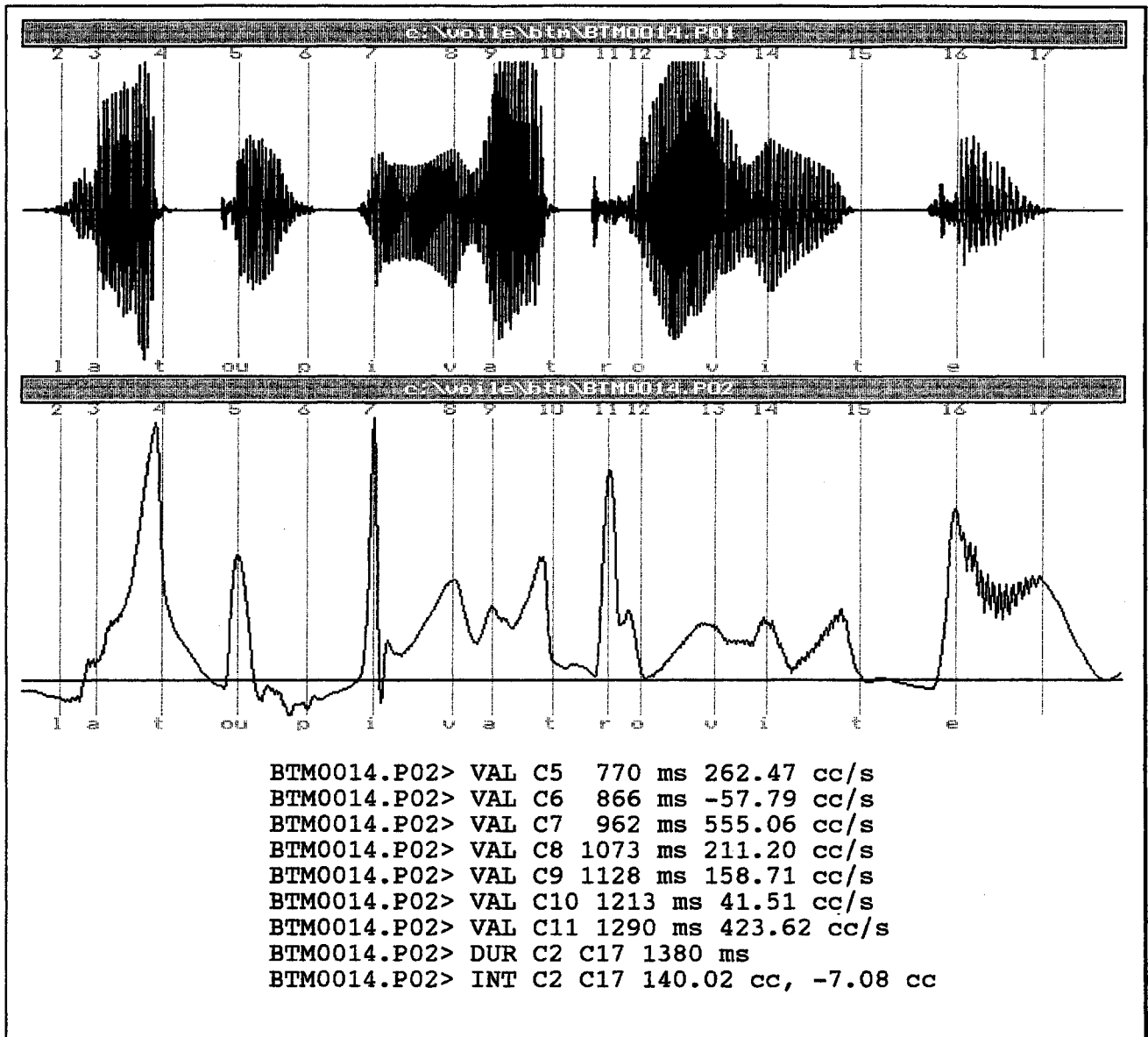


figure 1

French sentence: *La toupie va trop vite* (male speaker).
 Oral airflow recorded with a 1 liter per second scale, and a low pass filter of 50 Hz.
 Different measurements are realized on cursors:
 VAL for value, DUR for duration and INT for integration

We use integrated SENSYS SCXL004DN piezo-resistive sensors with a 10 hectoPa pressure range. Each flowmeter is equipped with 2 sensors wired in parallel. Due to individual sensor power supplies, enhanced instrumentation amplifiers, and symmetrical sensor mounting, the device is capable of generating an output level of 10 volts for an airflow rate of 0.2 l/m. The noise level is 30 mv RMS. It is possible to

measure a rate as small as 2 cm³/s.

The flowmeter has six measuring ranges: 0-10, 0-5, 0-2, 0-1, 0-0.5, 0-0.2 l/s. The linearity of this transducer is better than 0.98 for the 0-2, 0-1, and 0-0.5 l/s ranges. For the 0-10 and 0-5 l/s ranges, a linearization device is used to attain the same linearity. The parallel wiring of the 2 sensors gives 8 pressure pickups distributed symmetrically around

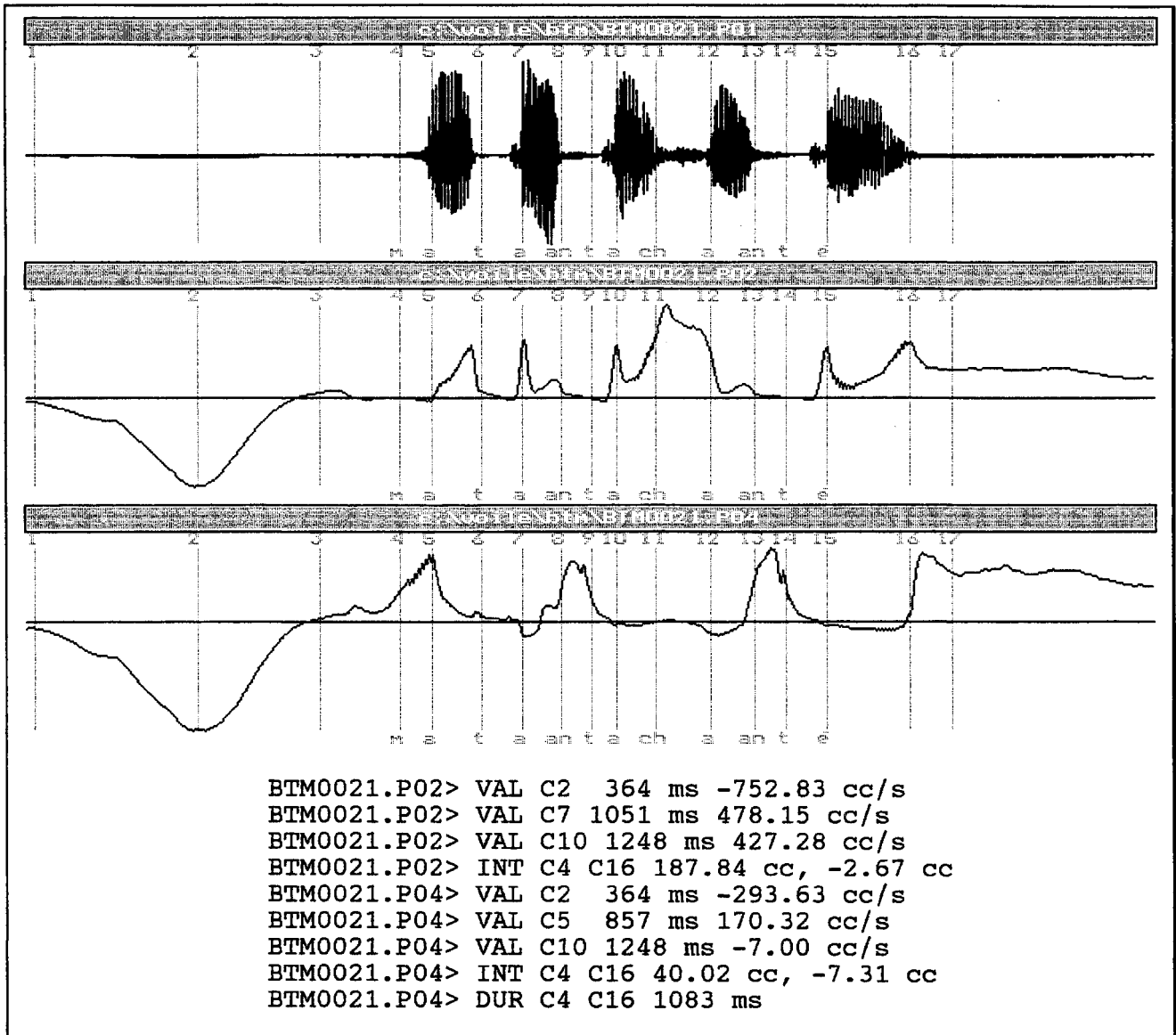


figure 2

French sentence: *Ma tante a chanté*, (male speaker).

Oral airflow with a 1 liter per second scale and nasal airflow with a 0.4 liter per second scale.

Same measurements on cursors as figure 1

the circumference of the tube. The measured pressure is the mean value of the pressure at the eight different locations of the tube. This feature decreases the non-linearity of the transducer caused by the gas vortices of the various consonants. To further decrease this non-linearity, a wider-meshed grid with a negligible pressure drop is used near the mouth. This grid reduces the airflow vortices in front of the pressure pickups. Finally, the high resonance frequency of the sensors, combined with the low dead volume of the tube (8 cm^3) and with the short length of the pressure probes makes it possible to attain response times as short as 1 ms.

When optimized for certain specific conditions of airflow in speech, perfect symmetry between inhaled airflow and exhaled airflow is not reached. This drawback is overcome by a specific linearization circuit which also takes thermodynamic differences between inhaled and exhaled airflow into account. The flowmeter is made of synthetic material (polycarbonate) with a very low thermal conductivity in order to decrease condensation phenomena without heating.

B. Nasal air flowmeter

The nasal air flowmeter is identical to the oral air flowmeter, except that the airflow vortex reduction grid is eliminated and the linearization circuit is different. The latter is necessary because the inhaled-exhaled airflow difference is greater than in the oral air flowmeter.

3. ADAPTATION OF THE AIR FLOWMETERS TO THE SPEAKER

A. Flowmeter placement

The oral air flowmeter is placed horizontally, directly in front of the lips. It is connected to the speaker's face by means of a mouthpiece. The nasal air flowmeter is placed vertically under the buccal opening so that the nasal airflow captured at the nostrils by tubes flows naturally into the flowmeter without generating vortices due to changes in airflow direction.

B. Mouthpiece

The mouthpieces are made of flexible, soft silicone rubber. The cross-section is conical. A triangular section of the cone is removed to release the area around the base of the nose and the nostrils.

The speaker can press the flexible mouthpiece against the face without hindering articulatory movements. The dead volume between the mask and the speaker's face, which causes the muffling and distortion of the produced sound, is thus reduced.

C. Nosepiece

Nostril air intake is done through silicone tubes which link the nostrils to the nasal flowmeter. The tube length is 12 cm. Their dead volume is greater than for the oral flowmeter, but this has little effect on nasal airflow since its frequency bandwidth is much smaller. The tubes are adapted to the nostrils via silicone tips molded to imitate overall nostril shape. The tips are placed firmly in the nostrils without hindering the speaker or allowing for nasal airflow leakage.

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